SESSA 2024

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SOUVENIR cum ABSTRACTS

NATIONAL SEMINAR on

SOIL ECOSYSTEM SERVICES FOR SUSTAINABLE AGRICULTURE (SESSA)

February 21-23, 2024, Nagpur

भाकृअनुप ICAR

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CONTENT

Preface

In the pursuit of a sustainable future, the significance of soil security and sustainability cannot be overstated. The groundwork laid by these principles is pivotal in achieving the ambitious targets set by the United Nations 2030 Sustainable Development Goals (SDGs), particularly in the realm of agricultural intensification. As we navigate through an era marked by population growth, technological advancements, and shifting consumption patterns, the strain on natural resources, notably soil, has escalated. This increasing demand for resources places soils at the forefront of the challenge, necessitating a thoughtful and strategic approach to their management. The longevity of food, fuel, and fiber production hinges upon our ability to enhance soil functions through sustainable practices. Soil, being intrinsic to all terrestrial ecosystems, plays a crucial role in catering to the escalating global population's need for food.

Recognizing the urgency and importance of addressing these challenges, the Indian Society of Soil Survey & Land Use Planning took the initiative to organize a seminar titled "***Soil Ecosystem Services for Sustainable Agriculture (SESSA-2024)."*** This forum aimed to explore and dissect the multifaceted dimensions of soil ecosystem services, with a focus on three overarching themes.

The first theme delves into ***"Land Resource Inventorization and its advancement in assessing soil ecosystem services"*** showcasing sixty-five research papers that contribute to the evolving understanding of soil dynamics. Theme two, ***"Soil Ecosystem Services for Sustainable Agriculture to Ensure Food and Nutritional Security"*** features fifty-five research papers, addressing the critical intersection of soil health and global food security. The third theme, ***"Soil ecosystem services, conservation, and management"*** encompasses forty-four papers that offer valuable insights into preserving and managing this precious resource.

This compilation reflects the collective effort to unravel the complexities surrounding soil sustainability and underscores the imperative of adopting conscientious approaches to soil management.

(***Dr. K. KARTHIKEYAN)***
Organizing Secretary
SESSA-2024

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MESSAGE

I am pleased to know that the Indian Society of Soil Survey and Land Use Planning (ISSLUP) is organizing a National Seminar on "Soil Ecosystem Services for Sustainable Agriculture (SESSA)" during 21-23 February 2024 at ICAR-NBSS&LUP, Nagpur. Climatic uncertainties have put a lot of stress on agriculture production systems, threatening food, water, and soil security. This calls for urgent measures to reduce the impact of climate change on soils and develop adaptation protocols for sustained ecosystem services.

I am sure the Seminar will explore important dimensions of soil ecosystem services in the context of changing climate. It will also provide an opportunity to look into the latest research findings and innovative approaches that preserve ecosystem integrity, ultimately leading to innovative and efficient ways of soil resource conservation and management. Hope this event will serve as a platform for meaningful dialogue, knowledge exchange, and effective collaboration, which can lead to implementable action plans.

I wish the Seminar all success.

Date : 21 February 2024
Place : Delhi

(Himanshu Pathak)

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उप महानिदेशक (प्राकृतिक संसाधन प्रबंधन)
Dr. Suresh Kumar Chaudhari
Deputy Director General (Natural Resources Management)

MESSAGE

Globally, the semi-arid tropical region occupies 11.6 million km^2 area, inhabited by more than 2 billion people who mostly depend on rainfed agriculture for their livelihood. India, which is a tropical country, supports 18% of the world's population with only 2.4% of the geographical area and 9% of arable land. Our country's vulnerability to the vagaries of climate change adds to the pressure on the crop production systems, which is compounded by soil and land degradation. Therefore, policymakers and other stakeholders need reliable data and tools to make informed decisions concerning possible actions to sustain the agriculture production and food security of the country.

It gives me immense pleasure to learn that the Indian Society of Soil Survey and Land Use Planning (ISSLUP), Nagpur, is bringing out the publication "Souvenir-cum-Abstracts" to commemorate the three-days National Seminar on "Soil Ecosystem Services for Sustainable Agriculture (SESSA)" during 21-23 February 2024 at Nagpur. It embodies the research efforts on various aspects of soil resource conservation and management. Good soil management practices considerably enhance the performance and resilience of key ecosystem services, preserve biodiversity, and ensure the well-being of humans. Seamless maintenance of soil ecosystem services requires concerted efforts in terms of appraisal, planning, and monitoring. The timing of the seminar is appropriate in the context of incessant pressure on soils to increase productivity, with minimal disturbance to the key soil functions.

I wish the Seminar a grand success!

Date : 21 February 2024

Place : Delhi

(Suresh Kumar Chaudhari)

कृषि वैज्ञानिक चयन मंडल
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Dr. B.S. Dwivedi
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Member (Natural Resource Management)
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MESSAGE

It is my immense pleasure that the Indian Society of Soil Survey and Land Use Planning, Nagpur in association with ICAR – National Bureau of Soil Survey and Land Use Planning, Nagpur is organizing a National Seminar on “Soil Ecosystem Services for Sustainable Agriculture (SESSA)” to discuss and deliberate the ways and means of soil ecosystem services in sustaining agricultural production.

Soils contribute to most of the regulating and supporting services of ecosystems. However, their importance is seldom recognized due to the pressure on soils to produce food and biomass. In recent times, there has been significant progress in the development of soil-centric integrated concepts such as conservation agriculture, land degradation neutrality, and regenerative agriculture. The Millennium Ecosystem Assessment aims to systemize and conceptualize the relationships between humans and nature under the approach of ecosystem services. As ecosystem services encompass human well-being or welfare, the contribution of soils to ecosystem services must be measured using biophysical indicators for improving food production. The SESSA-2024 aims to bring out the research developments in soil ecosystem services-related areas such as advancements in land resource inventory, soil and water management, land degradation, carbon sequestration, ecological restoration, agri-food systems, and soil health, and link them with the ultimate goal of sustainable agriculture.

I hope that deliberations during the seminar will help in identifying and implementing strategies and practices for utilizing the soil ecosystem services with scientific management of natural resources such as soil and water and pave the way for sustained and improved agricultural production in the country.

Date : 21 February 2024

Place : Nagpur

(Dr. B.S. Dwivedi)
President, ISSLUP

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THEME 3: Day 2- 22/02/2024
Soil Ecosystem Services, Conservation and Management

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Memorial lectures

The 9th Late S. V. Govindrajan Memorial Lecture

Climate Smart Soil Management Strategies for Sustainable Soil Health of Shrink-Swell Soils

A. L. PHARANDE

Former Dean (Faculty of Agriculture) and Director of Instructions
Mahatma Phule Krishi Vidyapeeth, Rahuri-413722 (Maharashtra)

Incipiently, I extend my sincere gratitude to the Indian Society of Soil Survey and Land Use Planning (ISSLUP), for giving me an opportunity to deliver the 9th Late S. V. Govindrajan Memorial Lecture at ICAR- National Bureau of Soil Survey and Land Use Planning, Nagpur. I am indulged and fortunate to pay a tribute by delivering this lecture in memory of Late S. V. Govindrajan a foremost scientist who initiated research on soil survey and soil fertility. His four decades dedicated work as a chief soil survey officer of All India Soil and Land Use Survey Organization is a memorable. He published a first soil map of India on 1:7 M scale in 1971.

Anne Glover once said that, it takes half of millennia to build two centimetres of living soil and only few seconds to destroy it. Soil is the real essence of life on earth. It serves as a natural medium for the plant growth that sustain human and animal life. Healthy soils provide a range of ecosystem services such as resisting erosion, receiving, filtering and storing water, retaining nutrients, promoting biodiversity, sequestering carbon and acting as an environmental buffer in the landscapes. Heathy soil is the foundation of production and sustainable agriculture Unfortunately, soils health has undergone implacable degradation at an alarming rate under climate change scenario.

The agricultural system in the world has been facing tremendous pressure on the use of resources largely due to climate change and environmental stresses. Increase of mean temperature, changes in rain fall patterns, increasing frequency and intensity of extreme events, sea level rise and salinization, perturbations in ecosystems are the clear indications of climate change and have profound impacts on agriculture (Thornton, 2012).

The concept of climate-smart soils put forth by Paustian et al. (2016). The key is that soils have the capacity to sequester carbon and remove it from the atmosphere, thus helping to fight against climate change. The management strategy of climate smart soils comprises of three focal areas, viz., soil carbon sequestration, soil management to reduce N_2O emissions and soil management to reduce CH_4 emission.

Soil Resource in India

Soil plays a central role for economic and social development by ensuring food, fodder, fibre, and renewable energy supplies to sustain human, animal and plant life. India is known as a land paradox due to diversity of soils. Diversity in geographical formation, diverse climate, topography and relief. The total geographical area consists of 328.7 Mha with seven taxonomical soil orders. For sustainable development at local, regional and country level and for efficient crop planning and transfer of technology, entire country has delineated in to 20 agro economical region (AER) and 60 agroecological subregion (AESRS) based on bioclimate, soil scape and length of growing period by NBSS & LUP (1999). The predominant soil orders in India are Inceptisol (39 %), Entisol (24 %), Alfisols (13 %) and Vertisols (9 %) are as shown in Fig. 1.

The Vertisol, Inceptisol and their intergrades soils are mainly localised in Peninsular India are shrink-swell soils, which occupies about 106 million hectare of land constituting about 35 % of total geographical area of the country. These group of soils are generally fertile with high production potential under rainfed as well as in irrigated agriculture and contributing significantly in increasing the food production in the country. The shrink–swell soils are generally medium to very deep, usually calcareous, alkaline in nature, dark in colour with low chroma, clayey with high smectatic clay minerals, low in organic matter with high CEC, base saturated and high shrink-swell potential with sticky and plastic consistency with poor drainage and low infiltration rate.

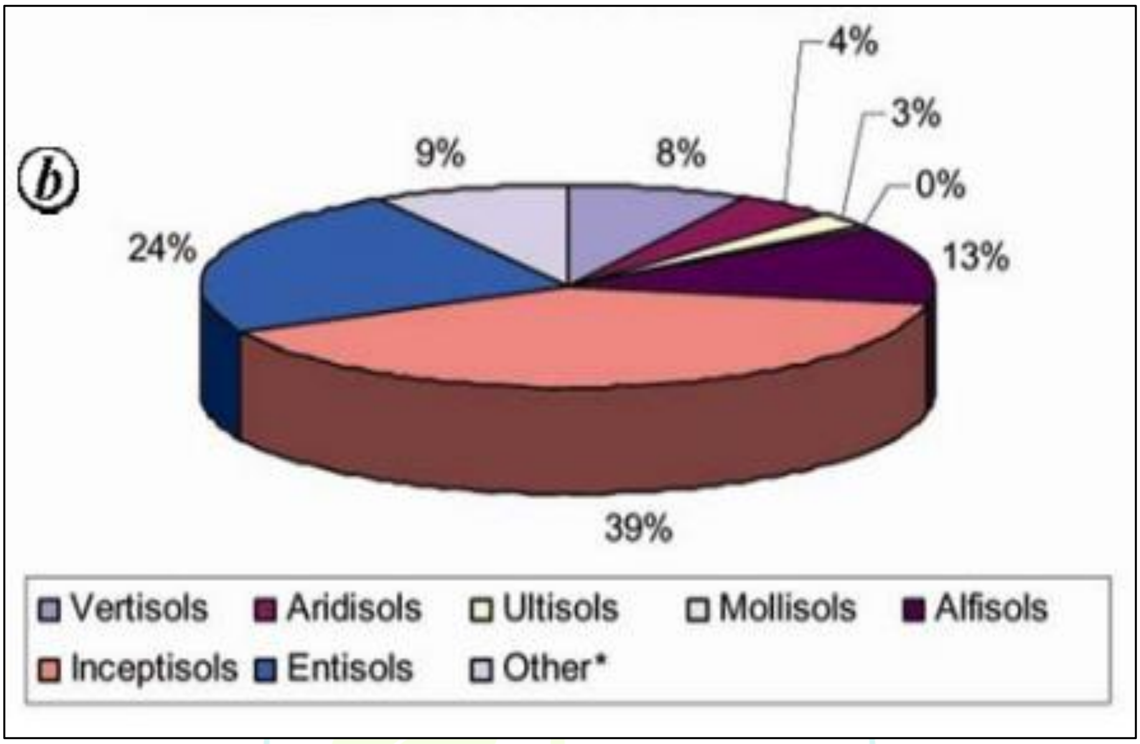

Fig 1: Various soil orders and their extent in India *Source*: Bhattacharyya *et al.,* (2013)

Soil Health

Heatly soil is the basis for food production and sustainability which has capacity to minimize the yield gap through soil health improvement. Seybold *et. al.* (1999) referred soil health as the capacity of soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental health and promote plant and animal health. Soil health refers to the biological, chemical, and physical features of soil that are essential to long-term, sustainable agricultural productivity with minimal environmental impact. Thus, soil health provides an overall picture of soil functionality. Although it cannot be measured directly, soil health can be inferred by measuring specific soil properties (e.g. organic matter content) and by observing soil status (e.g. fertility).

Soil Health Status of Indian Soils

In the semiarid tropics, poor soil health leading to sub-optimal crop yields (1to1.5tha^{-1}) and lower economic return in spite of existing potential (2.5 to 7.0 t ha^{-1}). Indian agriculture is a net negative balance of nutrients as every year there is a net deficit of about 10 million tonnes of nutrients added and extracted from the soil. Apart from major nutrients, the soils are now also showing the deficiency of secondary nutrients like sulphur and multi micro-nutrients. As per the DARE/ICAR Annual Report (2018-2019), the soil fertility maps of India showed about 59% of soils are low, 36% of soils medium and only 5% are high in available nitrogen. Similarly, about 49, 45 and 6% soils are low, medium and high, respectively in available phosphorus. With respect to potassium, about 52% soils are high, 39% of soils are medium and only 9% of soils are low. All India Coordinated Research Project on 'micro and secondary nutrients and pollutant elements in soils and plants' reported nearly 49, 15, 6, 8, 11 and 33% samples were found to be deficient in available zinc, iron, manganese, copper, molybdenum and boron, respectively, across the country and hence all contribute towards poor soil health. (Shukla *et al.,* 2012).

Climate and soil properties with special reference to soil inorganic carbon (SIC) related to soil quality and soil health. Formation of SIC is the major reason of chemical degradation resulting poor soil quality. The soils of semiarid tropics are favoured for formation of pedogenic calcium carbonate accentuating inorganic carbon sequestration has a deleterious effect on soil quality since it affects soil pH, ESP and hydraulic properties. (Bhattacharyya 2021a & b).

Organic carbon is an index of good soil health and application of organic manures helps in maintaining high organic carbon content of the soil. Shrink-swell soils have very low organic matter content. Therefore, without regular application of organic manures and recycling of crop residues, we cannot hope to maintain good soil health to sustain productivity and ensure high responses to fertilizers. For rejuvenating soil health, it is very essential to step forward to formulate soil centric programme *viz*., conservation of agriculture practices, INM and IPM, crop residue management, green manuring, cover crop and mulching, crop diversification with strong support of government policies.

Climate Change and its Impact on Agriculture Productivity

The Inter-Governmental Panel on Climate Change (IPCC), in its 5th Assessment Report, has warned that global climate has been changing and it would continue to happen in future (Field and Barros 2014). Scientific community stated that due to climate change the temperature will increase globally, and this will hamper agricultural productivity significantly. The Food and Agriculture Organization FAO (2018) report clearly indicated a continuous rise in world hunger due to climate change impacts on agriculture (State of Food Security and Nutrition in the World 2018).

Agriculture sector in India is climate-sensitive and highly vulnerable due to mansoonic climate, widespread poverty, dependence of about 58 per cent of its population on agriculture for livelihood. Among the 119 countries, India ranked 100 and was classified in the "serious category" with a score of 31.4 in the 2017 Global Hunger Index (Von Grebmer *et al.* 2017). Therefore, nations need to act sincerely towards achieving the Sustainable Development Goals (SDG) on food security and improved nutrition (State of Food Security and Nutrition in the World 2018).

Impact of Climate Change on Soil Health

Healthy soils are a natural source of essential plant nutrients and play a critical role in achieving higher agricultural productivity. Soils are formed by the complex interaction of many factors (*viz*., climate, relief, parent material, and organisms) over time. However, the climate factor is the most significant element that influences soil formation, substantially impacting soil development and management regarding structure, stability, water retention, fertility status, and erosion (Karmarkar *et al.,* 2016). Higher temperature and weather extremities viz., extreme rainfall, drought condition, frost situation, storms, and rise in sea level are the main predicted outcomes of climate change, which pose serious threats to the soil in terms of erosion, compactness, soil health and productivity (Lal, 2011). Higher CO_2, temperature and rainfall significantly impact diversity and distribution of microbes, soil erosion, runoff, infiltration, moisture storage and thus soil health and fertility. (Balasundram et. al., 2023) The expected consequences of climate change on various soil processes are enlisted in Fig. 2.

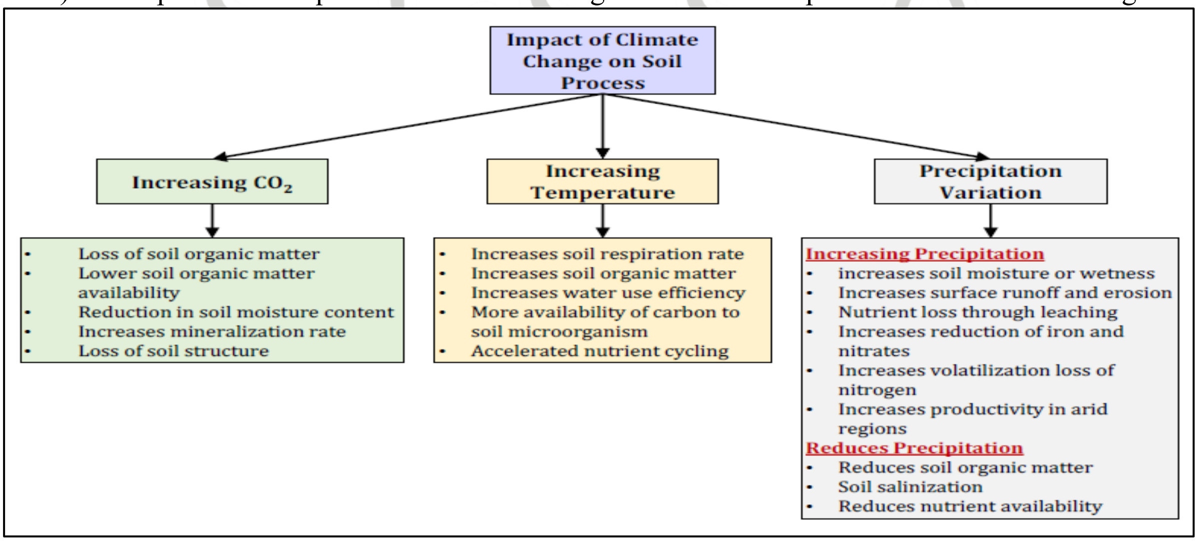

Fig 2: The Possible influence of climate change on soil activities

Source: Balasundram *et al.*, (2023)

Climate change will also have an impact on the soil, a vital element in agricultural ecosystem. Soil productivity and nutrient cycling are therefore, influenced by the amount and activity of soil organic carbon and micro-organisms activity.

Climate Smart Soils for Climate Smart Agriculture

The vital share of success of climate smart agriculture depends on climate smart soil management strategy which is smart approach for helping soil through enhanced carbon loading and curbing greenhouse gas emission and improving productivity under changing climatic situation.

Agriculture land contribute major share (37% as N_2O and CH_4) of agriculture emission. (Tubiello *et al*., 2013) While land has contributed 25% of total global anthropogenic GHG emission. (Smith *et al*., 2014).

Decreasing in GHG emission and sequestering carbon through improved soil management practices increases SOM content and tightened the nutrient cycle in the soil and helps to improve fertility, productivity, increase in biodiversity helps to develop resistance capacity against adverse effect of climate change. (Rakshit *et al*., 2021).

The SOM acts as a sink for atmospheric carbon which helps to improve soil structure as a stable aggregate, nutrient bio cycling and also impact on biological resilience of agroecosystem. During decomposition of SOM the multiplication of soil biota in soil food web releases essential plant nutrients and also form clay humas complex by enhancing soil CEC.

The French Govt. has suggested increase in carbon concentration of soil carbon in agricultural soil 0.4% per year, in accordance with the conference of parties to the UN framework convention on climate change (UNFCCC) negotiations in Dec.2015. This would lead to an increase in carbon sink of 1.2 petagram (Pg) of C per year. (Paustian *et al*., 2016).

The native ecosystem usually supports much higher soils carbon stock than agricultural counter parts and soils C loss ranged from 0.5 to grater that 2 t. per year of carbon by following land conversion to crop land. (West and Six, 2007).

Climate-smart agriculture (CSA) can be stated as a way of dealing with the challenges of climate change and food security for achieving SDGs (FAO, 2010). The CSA has three focal areas, *viz*., (1) agronomic and economic productivity, (2) adapting and building resilience to climate change, and (3) Climate change mitigation. (Palombi and Sessa, 2013). The key concept related to raising productivity is increasing food production sustainably from existing farmland while minimizing pressure on the environment. (Totin *et al.,* 2018).

There is need to implement climate smart management practices for enhancing carbon sequestration and mitigating agriculture soil GHGs emission. The Fig. 3 illustrate integrated research support and implementation platform with appropriate climate smart management practices.

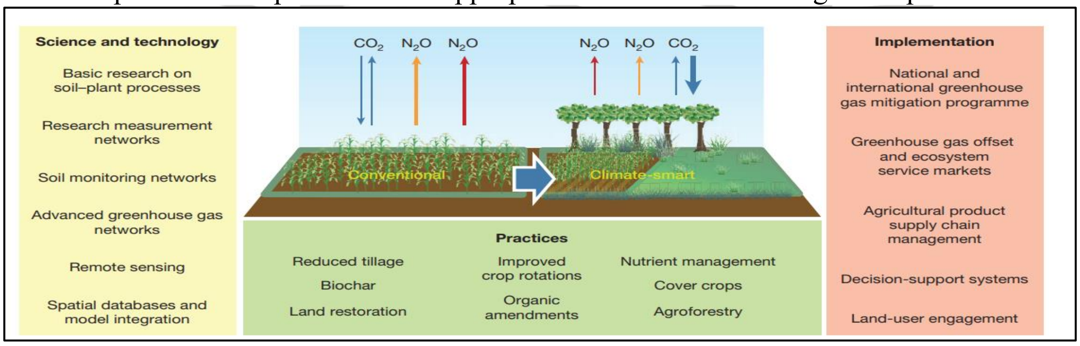

Fig 3. Climate Smart Soil Management Strategy and Implementation platform

Source: Paustian *et al.* (2016)

Management Strategies for Climate-Smart Soil

1. Conservation Agriculture:

Conservation Agriculture (CA), an approach based on the principles of minimum soil disturbance, retention of crop residues, or any other soil surface cover combined with appropriate crop rotation has emerged as an important management strategy to brings favourable changes in soil properties which affect the delivery of ecosystem services including climate regulation through carbon sequestration and greenhouse gas emissions. (Palm *et al.,* 2014). Zero tillage has been reported to increase soil organic carbon (SOC) by 270kg^{-1}ha^{-1}yr^{-1}. (Gangwar *et al.,* 2006) to as high as 501 kg^{-1}ha^{-1}yr^{-1} (Pandey *et al.,* 2012), whereas retention of crop residues has been reported to increase SOC by 90 kg^{-1}ha^{-1}yr^{-1} to 440 kg^{-1}ha^{-1}yr^{-1}. (Nayak *et al.,*2012). With these considerations, a long-term experiment was established in 2006 to evaluate the effect of various combinations of tillage, crop establishment methods, and crop residue management on crop productivity, economic profitability, and SOC changes in rice – wheat under maize-wheat-green gram cropping system. (Modak *et al*., 2019). Their results clearly indicated that conservation agriculture practices lead to 40% higher SOC sequestration in top layers. Deep soil layers accounted for 68 % of sequestered carbon. The SOC accumulation and sequestration rates were also enhanced significantly by conservation agricultural practices. SOC sequestered in aggregates significantly enhanced crop yields.

About 400 million tonnes of crop residue are produced in the country which has potential of supplying about 7.3 million tonnes of NPK. Sugarcane crop is one of the major cash crops grown in India. Sugarcane can add huge quantities of biomass in soil. After harvest of the sugarcane, 8-10 t trash ha^{-1} is generated. Burning of trash is common practice followed in sugarcane growing area which leads to great loss of precious organic matter and N loss through volatization. CSRS, Padegaon of MPKV, Rahuri recommended technology for the sugarcane trash management. Application of 1 kg decomposing culture, 8 kg urea and 10 kg single super phosphate per ton of sugarcane trash with 10 t ha^{-1} FYM is recommended to ratoon sugarcane for obtaining higher cane yield and maintaining soil fertility.

Reddy (2024) evaluated the impact of tillage, residue and nutrient management on soil organic carbon, biology and yield under multi ratooning sugarcane system in basaltic soils of semi-arid tropics and the results indicated that residue retention had 17 % higher total SOC with 63, 34 and 15 % higher labile, less labile and non-labile C pools, respectively than residue burning. Total SOC stock contribution of passive pools was higher 72-78 % than active pools. Reduced tillage coupled with residue retention and 50% RDF as basal and 50% through fertigation plots showed higher microbial and enzymatic activity reported highest net SOC enrichment of 5.23 Mg C ha^{-1}. In four season maximum average ratoon cane yield (153 t ha^{-1}) of was obtain in reduced tillage with residue retention. Whereas yields (137 t ha^{-1}) were reduced in residue burning treatment the corresponding values for conventional tillage were 113 and 95 t ha^{-1} respectively.

The results of 32-year long-term tillage and nutrient management practices on *rabi* sorghum grown on Vertisols in Dry farming research station, Solapur revealed that the TOC in minimum tillage (Table 1) at harvest was found to be significantly highest (0.92 and 0.85%) at 15-30 and 30-45cm soil depth over conventional tillage (0.81 and 0.75%) respectively. The higher TOC in LT and MT practices over CT might be because of lesser disturbances to the surface layer of the soil which might have led to sequestration and more conservation of organic carbon in soil. The depth wise C sequestration rate as influenced by tillage management practices under rainfed *rabi* sorghum was increased with increase in soil depth. At all the three depth the medium tillage practice was found to have the significant C sequestration rate over conventional tillage. Comparatively slow carbon sequestration rate was due to disruption of soil aggregate, incorporation of crop residue during tillage operation and enhanced SOC mineralisation as a result it increased aeration and drier condition caused reduction in SOC stock. (Kalbhor, 2019).

Tillage practices imparts significant effect on SOC pools intensive cultivation enhances oxidation rate, microbial activity through decomposition by increasing aeration and temperature and caused significant loss of SOC from surface layer. (Purkayastha *et al*., 2008).

Table 1: Effect of tillage on depth wise distribution of total organic carbon and soil carbon sequestration rate in dryland *rabi* sorghum

Treatment	TOC (%)			Soil respiration rate (mg CO_2-C 100 g^{-1} soil)			C seq. rate (kg ha^{-1} yr^{-1})		
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
LT	0.98	0.86	0.80	7.9	7.4	6.9	438.2	493.8	618.8
MT	1.00	0.92	0.85	8.6	8.0	7.5	535.1	690.9	749.9
CT	0.99	0.81	0.75	8.0	8.1	6.9	508.7	490.0	604.9
Mean	0.99	0.87	0.80	8.1	7.6	7.1	494.0	531.9	657.2
CD (p= 0.05)	NS	0.02	0.02	0.33	0.41	0.32	46.0	44.8	24.1

Low Tillage (LT) -Seed drill sowing + light harrowing after sowing (SSDH),
Medium Tillage (MT) - One harrowing + SSDH + One hoeing
Conventional Tillage (CT) - Ploughing once in 3 years + One harrowing + Ridges and furrows+ One harrowing + SSDH + three hoeing.

2. Cover Cropping and mulching

Planting cover crops during fallow periods or between cash crops helps in preventing erosion, compaction, improving soil fertility, reducing weed growth, promoting growth of beneficial soil organism enhancing carbon sequestration and this reducing the need of chemical fertilizers. Growing of leguminous as a cover crop can help to increase carbon pools and reduce C and N loss from soil (Singh *et al.,* 1998). Tonitto *et al.* (2006) found that, cover crops reduce nutrient losses, including nitrate that is otherwise converted to N_2O. Higashi *et al.* (2014) showed that, cover cropping with conservation tillage (mainly no tillage) in sandy clay loam soil increased SOC concentration up to 22%. Growing of cover crop in sandy clay loam soil gives stability to soil aggregates, which in turn gives protection to SOC from mineralization (Unger 1997).

Mulch plays a vital role in moisture conservation, water infiltration, maintaining temperature and stabilizing soil structure. Mulches modify hydrothermal regime, recycles plant nutrients, promote crop development and increase yields. Kadam (2022) studied the effect of different crop residue mulching on soil temperature, soil moisture and nutrient availability in *rabi* sorghum under *rainfed* condition and found that the treatment having wheat straw mulch recorded significantly higher sorghum grain yield (23.8 q ha^{-1}) and stover yield (54.9 q ha^{-1}) as well as soil organic carbon content (7.2g kg^{-1}) in rainfed *rabi* sorghum which was at par with pearl-millet straw mulch, glyricidia tendrils mulch and sorghum straw mulch. The moisture use efficiency (4.34 kg ha^{-1} mm) was found significantly higher in the treatment having wheat straw mulch in *rainfed rabi* sorghum followed by use of pearl-millet straw mulch.

3. Agroforestry:

Agroforestry is very important as a carbon sequestration strategy because of the carbon storage potential in its multiple plant species and soil and its applicability in agricultural lands and reforestation. Agroforestry can also indirectly benefit carbon sequestration when it helps to decrease pressure on natural forests, which are the largest sinks of terrestrial carbon. Forests play a major role in global terrestrial carbon cycling. On the one hand, forests, through photosynthesis, sequester carbon dioxide from the atmosphere and accumulate biomass (including trunks, branches, leaves and roots) as well as contributing to organic carbon in soils. Though forests account for only 38% of terrestrial lands on the earth, they store 893 Pg C or 45.70% of the terrestrial carbon stocks (Yoda, 1993). The ability of bamboo to sequester high amount of C per unit time can make the bamboo-based agroforestry system a possible prototype for Clean Development Mechanism (CDM) type projects.

Integrating trees with crops or livestock on the same piece of land helps in improving soil fertility, enhancing biodiversity, providing shade, and sequestering carbon. A long-term field experiment on different species of bamboo was conducted by Gaikwad *et al.,* (2022) at NARP, Dryland Sub-Centre (Agroforestry), Mahatma Phule Krishi Vidyapeeth, Rahuri. The results concluded that, the highest soil carbon sequestration rate (Table 2) was found in the soil under the treatment of *Bambusa nutans* (27.31 t C ha^{-1}) followed by treatments of *Bambusa tulda* (25.75 t C ha^{-1} yr^{-1}). Whereas, the carbon sequestration rate in different bamboo specie varies from 11.95 - 27.31 t C ha^{-1} $year^{-1}$.

Table 2: Effect of different bamboo species on total carbon stock and carbon sequestration rate

Treatment	Total plant biomass carbon stock (t C ha^{-1})	Total soil carbon stock (t C ha^{-1})	Total carbon stock (Plant + soil) (t C ha^{-1})	Bamboo carbon sequestration rate (t C $ha^{-1}year^{-1}$)
D.brandisii	16.46	19.50	35.96	17.98
B.nutans	27.83	26.79	54.62	27.31
B.balcooa	9.16	20.60	29.76	14.88
D.strictus	11.90	24.47	36.37	18.19
B.tulda	26.68	24.82	51.50	25.75
B.bamboos	8.57	15.34	23.91	11.95
D.asper	11.33	16.22	27.55	13.78
SEm±	0.22	0.10	--	--
CD @5%	0.67	0.29	--	--

Source: Gaikwad *et al.*, (2022)

4. Crop Rotation and Diversification:

Alternating different crops in a given field within specific time can helps in reducing soil erosion nutrient depletion, breaking pest and disease cycles, improving soil structure, and nutrient cycling. Diversification can also enhance resilience to climate extremes.

A farming system model encompassing crops, trees and livestock is the best option against climate change, recurrent droughts, loss of biodiversity and land degradation. Three farming system models were evaluated during 2008–09 and 2009–10 at MPKV., Rahuri, Maharashtra, to study their effect on the economic returns, water productivity, employment generation, energy balance and soil health improvement. The integrated farming system (IFS) involving field crops, horticulture, dairy, poultry and fishery proved promising and remunerative to soybean–wheat cropping system with higher net returns, water productivity, employment generation and energy output. On-station and on-farm IFS models were found more remunerative than the on-station cropping sequence model, showing maximum net returns of Rs. 1,99,848 water productivity (991ha^{-1}cm), employment generation (1,275man days ha^{-1} $year^{-1}$) and energy balance (4,11,949 MJ ha^{-1}), while the on-farm IFS model resulted Rs. 48,477, 406 ha^{-1}cm, 657 man-days $year^{-1}$ and 3,25,528 MJ ha^{-1} values of these parameters respectively (Surve *et al*, 2021).

5. Organic Farming

Organic farming plays an essential role in improvement of soil physical, chemical, and biological processes and that of soil organic carbon (SOC) is one of the most important indicators of soil quality and health. It helps to enhance soil fertility and crop productivity. Therefore, maintaining or increasing SOM is critical. Soil is a component of terrestrial carbon (C) cycle and can be either source or sink of atmospheric carbon dioxide. So, their judicious management has a significant potential for mitigation of CO_2 and other GHGs emissions (Ghosh *et al.* 2012).

The use of synthetic nutrients is banned on organic farms, so organic farmers must rely on naturally-occurring fertilizers such as compost and manure for enhancing nutrient content in soils. The use of organic amendments has been shown to increase soil carbon sequestration, which may help to mitigate climate change by locking away carbon that could otherwise act as a greenhouse gas in the atmosphere. However, organic soil amendments can vary dramatically in nutrient content, carbon to nitrogen ratios, and timing of nutrient release, which has led to variability in the impacts of organic soil amendments on soil health.

6. Integrated Nutrient Management and Site-Specific Nutrient Management:

Using organic sources of nutrients like compost, manure, biofertilizers, and incorporating them with inorganic fertilizers helps in maintaining soil fertility while reducing the environmental impact. Site specific nutrient management (SSNM) results in higher use efficiency, higher productivity and profitability besides positive environmental benefits.

A field experiment of soil test based targeted yield approach for balance fertilization to Bt. cotton in Inceptisol was conducted at MPKV, Rahuri during 2009-10 to 2013-14. Application of fertilizer nutrient as per 40 qha^{-1} yield target of *Bt.* cotton along with 10 t FYM ha^{-1} (Table 3) recorded the highest yield (42.62 q ha^{-1}), B:C ratio and maintain the soil fertility in Inceptisols. (Kadlag *et al*, 2016).

Table 3. Effect of fertilizer application to Bt cotton based on targeted approach on yield, economics, nutrient uptake and residual fertility status (pooled data of 5 years)

Treatments	Cotton Yield (qha-1)	Nutrient Uptake (kg ha^{-1})			Residual soil fertility status				B:C ratio
		N	P	K	OC (%)	Av. Nutrient (kg ha^{-1}) N	P	K	
Absolute Control	20.86	77.06	30.66	45.01	0.58	166.4	15.0	485	1.86
GRDF	32.19	128.55	48.94	72.79	0.61	187.2	18.0	530	2.20
AST	31.45	121.82	45.45	70.59	0.59	188.1	17.7	521	2.62
STCR target 40 qha^{-1}	38.49	153.72	56.79	83.34	0.59	186.3	19.0	562	2.68
STCRC target 40 q/ha+10 t/ha FYM	42.62	167.95	66.08	89.22	0.62	192.1	20.9	570	2.69
Only FYM	26.42	97.62	39.30	53.99	0.68	181.5	16.8	554	1.53
CD (p = 0.05)	2.17	17.02	6.28	8.64	0.035	8.88	1.36	54.74	

7. Soil and water Conservation Measures:

The problem of conserving soil and moisture is very great importance in the extensive region of low and uncertain rainfall areas. Agriculture land in the major part of the country suffers from erosion. Apart from reducing the yield through the loss of SOM and nutrients, erosion destroys the soil resources itself every year. Agronomic practices for soil and water conservation help to intercept rain drops and reduce the splash effects, help to obtain a better intake of water by the soil. The contour cultivation, mulches, dense growing crops, strip cropping and mixed cropping are the some of the majors practices for improving soil quality. The impact of *in situ* water conservation measures on different crop yields on different locations of India were summarised by Srinivasarao *et al.,* (2016) and given in Table:4.

Table 4: Impact of *in situ* soil and water conservation measures on crop yields

Practice	Crop	District/Location	Yield improvement over farmers' practice (%)
Regions receiving <500mm rainfall			
Bunding & Levelling	Sorghum	Kutch	30
	Cotton	Kutch	61
	Sesame	Kutch	18
	Castor	Kutch	61
Conservation furrow	Soybean, Pearl millet	Ahmednagar	15
Land levelling	Paddy, cotton, cluster bean	Sirsa	11-33
Regions receiving 500–1000 mm rainfall			

Compartmental bunding	Rabi sorghum	Baramati	45
	Pearl millet	Agra	35
	Pearl millet	S K Nagar	26
Mulching	Okra	Jehenabad	51
	Chilli	Bengaluru	75
	Cotton	Rajkot	12
Conservation Furrow	Castor	Kurnool	8
	Cotton, pigeon pea	Nalgonda	5-8
	Cotton	Aurangabad	10
	Pigeon pea	Aurangabad	15
	Cotton	Rajkot	18
	Groundnut	Anantapur	8
	Soybean	Akola	17
	Soybean, Pigeon pea, Cotton	Parbhani	35-40
Trench cum bunding	Finger millet, maize, horse gram, groundnut	Davanagere	22–24
Bunding	Paddy	Jehanabad	45
	Soybean	Amravati	32
Land levelling	Paddy	Jehanabad	35
	Pearl Millet	Baramati	23
Sowing across slope	Soybean	Amravati	29
Ridge & Furrow	Cotton	Amravati	58
	Black gram, maize, pigeonpea, green gram, soybean, mustard	Morena	8-10
	Castor	Kurnool	18
	Maize, Soybean	Nandurbar	15
	Rabi Sorghum	Solapur	22
Regions receiving >1000 mm rainfall			
Ridge and furrow	Wheat, chick pea, lentil	Uttarkashi	50
	Cotton	Khammam	11
	Tomato	Cooch Behar	74
Mulching	Cucumber	Cooch Behar	10
	Mustard, Toria	East Sikkim	70-82
	Chilli	Khammam	12
	Turmeric, Ginger	East Singhbhum	12-15
	Potato, Tomato	Biswanath Chariali	75
Hoeing & Weeding	Paddy, maize, pigeon pea, groundnut, sesame	Phulbani	16-22
Summer ploughing	Maize	Ballowal Saunkhri	14
Sowing across slope	Maize	Ballowal Saunkhri	
Set Furrows	Pearl millet, Pigeon Pea	Vijayapur	11-14

Source: Srinivasarao *et al.,* (2016)

in situ water harvesting with simple technologies enables greater water infiltration, improve soil porosity, prolongs the availability of moisture to the crop and enable crop to survive under variable rainfall conditions. (Srinivasarao *et al.,* 2016).

8. Smart Irrigation Practices:

Employing efficient irrigation methods such as drip or sprinkler irrigation reduces water wastage, maintains soil moisture, and supports sustainable agriculture.

The MPKV, Rahuri has been contributing a lot in precision irrigation water management including development of mobile and web-based applications, IoT and sensor-based application such as Phule irrigation scheduler (PIS) which is mobile and web-based application. The Phule Jal mobile app is also developed for estimation of evapotranspiration rate (ETR). Similarly in the mobile app (Spatial IWR) is also developed for estimation of location specific, real time irrigation water requirement for different crops.

Kale *et.al.,* (2018) studied the effect of fertigation on yield and nutrient use efficiency of ratoon banana (*var*. Grand naine) cultivated in medium deep soils of Western Maharashtra. The study indicated that 80% recommended dose of water-soluble fertilizer (9:5:33) application through fertigation (18 fortnight splits) increased the ratoon banana crop yields (79.66 t ha^{-1}) with concomitant increase in their nutrient use efficiency (20.19 kg kg^{-1}).

9. Restoration of Degraded Land

a. Restoration of Eroded Soil

The tank silt application in agricultural land is a traditional activity to benefit better crop growth. The tank sediment deposited over the years contains all the nutrients required for plant growth and can amend the very eroded soil when recycled improved soil fertility (Padmaja *et al*., 2003; Osman *et al.,* 2009). The addition of tank silt to cultivated land also enhances the physical properties, which results in good crop growth and higher yield (Vaidya and Dhawan, 2011). Most of the soils of Osmanabad district in Maharashtra State are very shallow in depth, poor in fertility and moisture-holding capacity and a study was carried out to understand the morphological, physical and chemical behaviour of these hybridized soil when amended with tank silt and its impact on yield of soybean crop. The field results showed that the maximum yield of soybean (31.44 q ha^{-1}) was recorded with 1500 m^3 ha^{-1} of silt application corresponding to 15 cm depth, which was three-fold higher over no application (9.6 q ha^{-1}). Application of tank silt has increased yield by 47 per cent in *rabi* sorghum and income increase by Rs.10000/- per ha. It has improved soil fertility and moisture holding capacity as well as enhanced moisture use efficiency up to 50 per cent. (Vaidya and Dhawan, 2015)

b. Salt affected soil

Inorganic carbon in soil of semi-arid tropics is one of the major reasons of chemical degradation resulting in poor soil quality and modifying chemical and physical properties in to less productive. The drier climate is the primary actor responsible of depletion of Ca^{2+} ion from soil solution due to formation of $CaCO_3$ (Bhattacharyya, 2021 a&b). This suggest that the source of Ca^{2+} for formation of pedogenic carbonates is soil exchange complex (Pal *et al*., 2000), which leads to concomitant increase in exchange Na that is formation of sodic soil. The most of the soil properties are influence by soil modifiers the positive modifiers are calcium zeolite and gypsum whereas negative modifiers are pedogenic carbonates and palygorskite minerals from Indian soils may degrade physical, chemical and biological properties of soil and thus retard crop growth and productivity. (Bhattacharyya, 2021a).

The effect of irrigation induced soil salinity and sodicity on soil minerology of shrink-swell soils was studied by using random powder bulk soil mineralogy by using spray drying techniques, XRD, SEM and TEM studies. These mineralogical studies of fine clays of normal rainfed shrink-swell soils indicated that predominance of smectite 99 % with negligible quantity of kaolinite, whereas, irrigation induced saline sodic soils showed association of pedogenic palygorskite (1-10 %) with smectite (88-99 %). Bulk soil minerology showed association of pedogenic palygorskite (3-18 %) with smectite in saline sodic soils, which is absent in rainfed normal soils. These results indicated saline sodic Pedo environment favors the formation of pedogenic palygorskite. (Hiller and Pharande, 2008).

c. Reclamation of Salt Affected Soil

Soil salinity and soil alkalinity are the primary land degradation processes in agricultural lands and both adversely affect the crop's yield. Injudicious and inefficient irrigation water management leads to waterlogging and development of soil salinity/alkalinity. Integrated soil management of such soils includes reclamation through subsurface drainage (SSD), use of a chemical amendment; salt leaching; improved agronomic practices, irrigation water and nutrient practices; alternate land uses; and use of salt-tolerant varieties etc, has profound effect on productivity. Subsurface drainage and mole drainage helps to improve physical and chemical properties. subsurface drainage (SSD) with corrugated perforated pipe at 1.32 m depth and 25 m lateral spacing (Table 5) showed significantly decline in water table, increases drain discharge, hydraulic conductivity after 3 years of installation in Vertisol (Rathod *et al.,* 2008).

Table 5: Effect of SSD on soil physical and chemical properties in Vertisol at ARS, K. Digraj

Soil properties	Hydraulic conductivity (m day^{-1})	Drain Discharge (L Day^{-1})	Water table (cm)	Soil pH	Soil EC (dS m^{-1})
Initial	0.0236	-	26.50	8.47	9.25
After 1 year	0.0297	5669.76	120.00	8.11	8.11
After 2nd year	0.0421	8138.67	122.86	7.63	5.75
After 3rd year	0.0575	9813.37	126.40	7.59	3.60

Source: Rathod *et al*., (2008)

Results of RKVY Farmer First Project

The subsurface drainage (SSD) technology was demonstrated at 10 different locations on farmers field of Sangli district of Maharashtra on saline sodic Vertisol. The soil pH, EC and ESP were continuously decreased (Table: 6) and improved physical and chemical properties within three years.

Table 6: Effect of subsurface drainage (SSD) on soil properties in saline sodic Vertisol on farmers field of Sangli district

Period	Soil properties		
	pH (1:2.5)	EC (dS m^{-1})	ESP
Before SSD	8.40	15.80	15.30
1 year after SSD	8.17	11.80	11.73
2 years after SSD	7.67	6.32	5.72
3 years after SSD	7.66	4.40	5.12

Source: RKVY Farmer First Project Report, (2015)

Results of Community Based Subsurface Drainage Project

The Datta Co-operative Sugar Factory, Shirol, Dist. Kolhapur, Maharashtra implemented community-based SSD technology on 7000-acre area of adjoining 19 village of Shirol tahsil. Development of subsurface drainage has increased the productivity (Table 7) of land appreciably to the tune of 96 per cent and has provided a source of regular income of Rs. 142533 ha^{-1} from sugarcane to resource-poor farmers. The B: C ratio of sugarcane production under irrigation induced soil degradation analyzed through budgeting technique before drainage and after installation of SSD was 0.87 and 1.59, respectively. The increase in yield is due to drastic decrease in soil salinity. The initial electric conductivity of the soils was ranged between 7.20-28.00 dS m^{-1} whereas, electric conductivity of the soils after one year of installation of sub surface drainage were in the range of 0.60 - 5.74 dS m^{-1}. The overall reduction in the soil electric conductivity was 95 percent within one year after installation of sub surface drainage technology (Patil, 2022).

Table 7: Impact of SSDS on yield of sugarcane on community based SSDS project, Tal. Shirol, Dist. Kolhapur, Maharashtra.

Sr. No.	Name of Farmer	Yield of sugarcane before SSD (t ha^{-1})	Yield of sugarcane after SSD (t ha^{-1})	Increase in yield (t ha^{-1})	Percent increase in yield
1.	Shri. Mallapa Ainapure	51.38	117.85	66.47	129.37
2.	Shri. Ramgonda Ainapure	84.35	122.88	38.53	45.68
3.	Shri. Baburao Maraje	58.68	129.37	70.69	120.47
4.	Shri. Baburao Maraje	73.98	139.44	65.46	88.48
	Average	**67.10**	**127.39**	**60.29**	**96.00**

Source: Patil, (2022)

Futuristic Farming: Precision Farming Tool for Climate Smart Agriculture

Precision Agriculture is a management strategy that gathers, processes and analyse temporal, spatial and individual data and combine it with other information to support management decision according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agriculture production. It involves precise management of resources like soil, water, fertilisers, seeds and pesticides using tools of GPS, satellite imagery, remote sensing, sensors, IoTs and data analytics. Through these tools, precision agriculture can significantly contribute in combating climate change by reducing greenhouse gas emission, persevering natural resource and promoting sustainable practices. The key component and methods are soil moisture resources, weather data, automated irrigation system variable rate irrigation/ applicator, crop sensors, remote sensing imaginary, irrigation scheduling software, precision fertigation for nutrient management. The tools requirement for precision agriculture are GPS, GIS, remote sensing, grid soil sampling, variable rate applicator, soil spectroscopy, information management, yield monitoring and mapping IoT etc. (Lenka *et al*., 2023) .Some of the precision agriculture strategies for combating climate change include site specific resource management for irrigation and nutrient management, precision seeding, weed management etc. The primary goal is to enhance crop yield by minimising agricultural input wastage, energy consumption and environmental impact (Kumar *et al*., 2021)

Indian Council of Agriculture research (ICAR) and National Agriculture Higher Education Project (NAHEP) sanctioned world bank aided project entitled Centre for Advance Agril. Sci. and Technology for Climate Smart Agriculture and Water management to M.P.K.V., Rahuri to develop climate smart technology on water management and strengthen Post graduate and Doctoral level programme and Postgraduate diploma in respective field. The various climate smart solution was developed with advance technologies such as application of robotics, drones, IoTs, Geo informatics, precision machineries for climate smart precision and efficient farming activities. The outcome of this project is the development of different tools/systems *viz*., Auto Phule irrigation Schedular, Agriculture spraying and seeding drone, Smart weather stations, Phule soil moisture sensor-based irrigation scheduling system, Smart Phule irrigation schedular and Phule Robo for spraying. Therefore, there is need to create awareness among students, researcher and farmers about climate smart precision agriculture technology and to identify the research studies to make these techniques available to small and marginal farmers for its effective use.

Conclusions

The vital share of the success of climate-smart agriculture depends on climate smart soil management strategy which is a smart approach for keeping soil healthy and sustainable through enhanced carbon loading and thereby curbing greenhouse gas emission and improving crop production under changing climatic situations. Climate Smart Soil is very pertinent for mitigation and building resilience of agriculture system along with increasing or sustaining production in climate change scenario. The climate smart soil management practices such as conservation agriculture, implementation of integrated farming system, improving soil biodiversity, organic farming, reduction in soil degradation processes and precise water and nutrient management practices should be adopted based on the farmers economic condition and availability of resources. Development of climate smart soil-water nutrient efficient and precise management technologies is the need of hour for sustainable soil health. It is crucial to ensure this benefit there should be good linkage between researchers, students, farmers and policymaker for achieving sustainable soil health and productivity.

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A Comparative Analysis of Soil Taxonomy (2022) and WRB (2022) Classifications for Categorizing Selected Soils in parts of South India

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Abstract

The USDA soil taxonomy and WRB for soil classification have been used for analysis and classification of the Vedavathi River basin in Chitradurga district and the Pennar river basin in Kadapa district. Seven unique soil types with distinct textures have been found in the Vedavathi basin. Soil Taxonomy (ST) classifies the soils from the Kannivimaramma series—dissected buried plains—as Typic Natrustalfs. The world reference base (WRB), on the other hand, classifies these soils as Abrupt-cutanic solonetz, with cutanic, colluvic, and hypernatric qualifiers as supplements. The upland soils of the Vedavathi basin are categorised as Typic Rhodustalfs (Ambalkere, P4 and Bidarkere, P7), Lamellic Haplustalfs (Gudunoorhalli, P5), and Typic Paleustalfs (Kandikere, P6) at the subgroup level of soil taxonomy. In WRB classification, these soils are classified as Luvisols with rhodic qualities (P4&P7), Abruptic/Lamellic (P5), and Cutanic/Colluvic (P6). Six soils in the Penneru transect are classified as Ustic or Lithic Torriorthents on summits (Kottala-P1 & Mallambhavi-P2), Sodic or Fluventic Haplocambids on the back slope (Kondapuram-P3 & Kanneleru-P4), and Sodic Haplusterts on the foot slopes (Seshareddiplaai-P5 & Peddapasupula-P6). Interestingly, both the WRB and ST systems classify foot slope soils as Sodic Haplusterts. To enhance our understanding of sustainable soil management techniques in agriculture and conservation initiatives, it is crucial to gather and categorize soil resource data that aligns with soil taxonomy and the WRB system.

Key words: Semiarid region, Soil classification, South India, Texturally contrast soils, Transect

Abbreviations: ST=Soil Taxonomy, WRB=World reference base for soils, FAO=Food and Agriculture Organisation, USDA=United States Department of AgricultureESP: Exchangeable sodium percentage, CEC=Cation Exchange Capacity

Introduction

Soil classification involves visually observing and analyzing the physicochemical characteristics of each soil layer. It is important for understanding soil characteristics and managing soil effectively. Different countries have their own classification systems, but the most widely used ones are Soil Taxonomy (ST) and the World Reference Base for Soil Resources (WRB). ST, developed by the USDA, categorizes soil into 12 orders based on physical, chemical, and biological characteristics. WRB, developed by FAO, classifies soil into 32 reference soil groups based on environmental and formation processes. These systems help classify soil based on its characteristics at different depths. However, implementing mutual studies between ST and WRB can be challenging due to differences in criteria, horizons, and naming. WRB is known for its flexibility in demonstrating soil conditions like depth limitation for plant growth, salinity, and contamination.
The National Bureau of Soil Survey and Land Use Planning, which operates under the Indian Council of Agricultural Research, serves as a leading institution for soil surveying. In order to facilitate agricultural land use planning, theBureau has adopted the U.S. Soil Taxonomy (USST) as a means to categorize Indian soils. The soil resource mapping programme conducted in India from 1986 to 1996 resulted in the creation of a comprehensive land resource database with systematic soil classification under seven distinct soil orders using the United States Soil Taxonomy (USST) system. The findings from soil resource mapping in India have highlighted the need for certain adjustments in the ST system.

To address this, a well-structured proposal has been put forward, supported by valuable insights derived from field data sets.

Contribution of soil survey to soil taxonomy

The shrink-swell soils in India cover 76.4 Mhawith prominent clay illuviation to designate sub soils as “B” instead of A1 and also observed "mollic" epipedon in benchmark soils in central India. In a study conducted by Sehgal and Bhattacharjee in 1988, they examined Vertisols in India and Iraq and proposed a rationale for grouping them into great groups based on soil taxonomy. They compared the genetic processes that result in homogeneity and weak horizonation, as well as well-developed profiles with B horizons. Due to the significant difference in available moisture during crop growth under rainfed conditions, the authors suggested subdividing the "ustic" moisture regime into "aridic," "typic," and "udic" to define subgroups. The Vertisols found in Gujarat state later exhibited thick layers with carbonate content surpassing 15 cm. These layers also demonstrated a high electrical conductivity in the saturation extract (ECe). Following ICOMERT guidelines, these Calciusterts were classified as Halic (due to high ECe) and Sodic (due to high ESP) at the subgroup level.

Identifying clay skins in highly weathered soils is a serious challenge in the field. As a result, the kandic horizon was frequently used to classify highly weathered humid subtropical soils in northeastern India. The "kandi" group, consisting of Alfisols and Ultisols, is widespread in India. The inclusion of the subsurface diagnostic horizon and the "kanhapl" intergrade helped group many low-activity clay Inceptisols into either Alfisols (with >35% base saturation) or Ultisols (with <35% base saturation). However, there is ongoing debate regarding the formation and existence of Oxisols. The kandic horizon serves as a basis for distinguishing soils with clay accumulation in the subsoils. The micaceous soils found in the IGP of northwestern India often exhibit sodic characteristics and have a clay-enriched B horizon. Some of these soils, classified as Alfisols, do not have easily identifiable clay skins, which results in their placement in the Inceptisol order. To confirm clay illuviation when clay skins are difficult to identify in the field, the decrease in clay mica (<2 mm) with depth in the soil profile is considered. A recent study conducted in the Shillong Plateau, Meghalaya, India highlighted that soils supporting pine forests have a high content of extractable Al^{+3} (>50%) in the Bt horizon, leading to the proposal of a new subgroup called Alumic Hapludults. Additionally, the concept of a Modic subgroup in Ultisols

In India, around 40% of soils are classified as Inceptisols. This is higher than the global average of 15.2%. In India, the Inceptisols consist of red soils with mixed/kaolinitic mineralogy and black soils with smectites. The pH of these soils can range from strongly acidic to slightly alkaline. The introduction of the kandic horizon has led to the classification of some red and hilly soils as Alfisols and/or Ultisols. However, the benefits of introducing the kandic horizon can only be realized when information on bases obtained from $BaCl_2$-TEA of the acid soils is used for US soil taxonomy. In India, the black (shrink-swell) soils are known for their dark color, low chroma, and low organic matter. These soils are typically shallow (<50 cm) and are classified as Inceptisols, mainly under vertic subgroups. The classification of these soils has undergone several changes over time. Srivastava proposed grouping shallow black soils, which is now included in the Vertisol order as Leptic Haplusterts. New subcategories, specifically Natric, have been proposed for the Inceptisols, Alfisols, and Aridisols orders to address the issue of sodium-saturated soils lacking Natric horizons. In order to address the challenges posed by high concentrations of salts in soils with high ESP, two additional subcategories, Salic and Salic Natric, have been suggested for the Aridisols and Alfisols orders. The relic Paleosols such as ferruginous soils found in southern Peninsular India, are characterized by the presence of kaolinite or dioctahedral smectites and are formed from the saprolites of metamorphic rocks. The prominent dark red beds in subsoils or brown Color with depth and ratios of various sand sizes have also been used to indicate the presence of paleosols in this region. The formation of these relict soils can be attributed to the shift from humid to drier conditions during the Plio-Pleistocene transition period. A series Vertisols in India under the ustic moisture regime have been transformed from Typic Haplusterts to Udic/Aridic/Sodic Haplusterts and finally to Sodic Calciusterts in a climosequence in Central India. Researchers in India, specifically in Andhra Pradesh, undertook an effort to categorize buried soils. These soils, which were formed by external sediment, were found to exhibit a dual profile. The proposed classification included a Thapto-Tropofluventic Haplustert and Ustropept/Haplustept. The Soil Survey Staff used the term "thapto" to represent buried Histosols or buried histic epipedons. In the case of AP soils, "thapto" was used to indicate any buried Entisol with fluvial characteristics in the tropical climate, as well as a Thapto-Haplustalfic subgroup for a buried Alfisols.

Taxonomic rationale of South Indian soils

The taxonomic justification of South Indian soils is a matter of utmost importance when considering the opulence and grandeur of this region's natural resources. Through a meticulous examination of the soil composition and classification, we can unravel the intricate tapestry of this land's fertility and potential. Such a comprehensive understanding allows us to appreciate the unique characteristics and diversity that South Indian soils possess, elevating them to a realm of sophistication and refinement. The present article utilizes the USDA Soil Taxonomy and an international scientific publication reference base to substantiate a discourse on soil classification in South India. The author recognizes the importance of providing readers with a holistic comprehension of the research conducted at the Regional Centre in Bangalore. To achieve this, the author heavily relies on the insights and observations of pedologists and geomorphologists who actively engage in soil resource inventory endeavors at different levels. This research paper explores two case studies that analyze soil taxonomy in southern India, specifically examining the methodologies utilized by the USDA and the FAO's WRB. Through the examination of these case studies, the objective is to provide insights into the similarities and differences between these two classification systems.

Case study-1 : Vedavathi basin of Chitradurga district, Karnataka

The village of Shidalaiahnakote is located between 13.950 N and 76.620E longitude. It is characterized by various types of rocks such as Archeans and Dharwars, including patches of closepet granite, granitoids, and schistose formations. The landforms in the area consist of denudational hills, dyke ridges, linear ridges, pediments, pediment inselberg complex, pediplains, residual hills, structural hills, and valleys. The study area falls under the agroecological region of southern Karnataka plateau, with a growing period of 90 to 120 days. The average rainfall is 562 mm ± 166 mm, with a coefficient of variation of 29%. The coefficient of variation for the pre-monsoon season is 58%, for the south-west monsoon is 43%, and for the north-east monsoon is 52%. The hottest months are March and April, while the night temperature in winter (November - February) can drop to 18°C. The analysis of twenty-eight years of monthly rainfall (1980 to 2010) shows an irregular rainfall distribution with marked seasonal rainfall and a long drier season. The dominant forest type is dry deciduous scrub, with trees such as Hardwickia binata (Kammara), Prosopis cineraria (Shami tree), Acacia sundra (Tharad or Kempu Khaira), Anogeissus latifolia (Dindiga), Ailanthus excels (Hebbevu), Pongamia pinnata (Honge), Tamarindus indica (Hunase), Cassia pistula (Kakke) and Albizia amara (Sujjalu).

In the study area, a soil landscape in granite-gneissic terrain and soil associations were depicted (Fig 1). We followed standard guidelines to record the elevation and coordinates of seven soil series, along with their morphological descriptions. These soils were classified according to the USDA Soil taxonomy and World Reference Base.

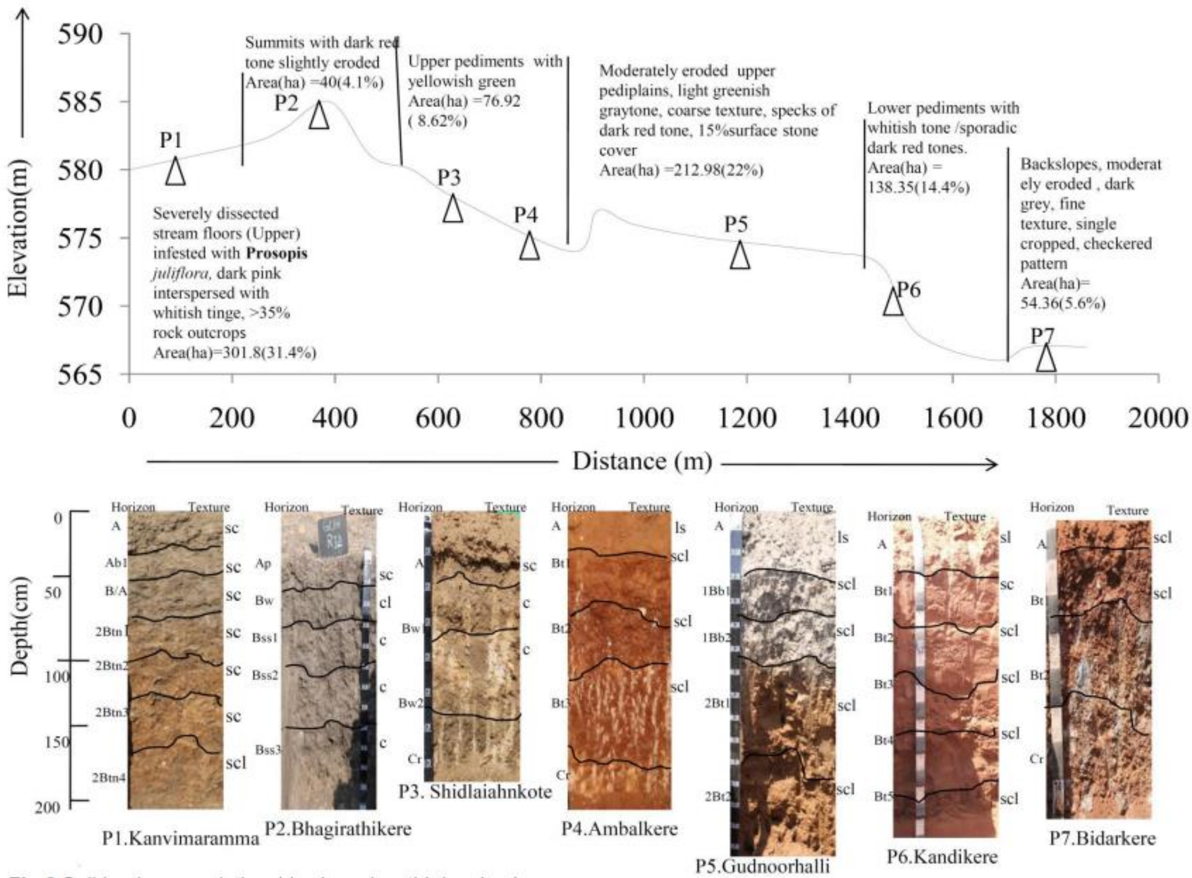


Fig.1. Soil landscape relationships in Vedavathi river basin

USDA Soil taxonomy

The Vedavathi soils are classified into subgroups of Alfisols, Vertisols, and Inceptisols based on their morphology, physical, and chemical properties. The Kanvi maramma series, found on severely dissected stream floors (P1), is classified at the subgroup level as Typic Natrustalfs. This classification is due to the presence of an illuvial natric horizon with an exchangeable sodium percentage greater than 40% and an increase in clay content of up to 1.2 times in the illuvial horizons under strongly alkaline conditions (pH greater than 9.4). On slightly eroded summits (P2), the Bhagirathikere soil is classified at the subgroup level as Sodic Haplusterts. This soil exhibits prominent slicken sides between 95 and 165cm with an exchangeable sodium percentage greater than 15% under strongly alkaline conditions (pH greater than 9.0). Additionally, this soil has a clay content exceeding 30% up to a depth of 18cm and experiences wide surface cracks that periodically open and close. The Shidlaiahnakote soil, found on upper pediments (P3), is classified as Typic Haplustepts. This soil features cambic horizons with a value of 3, chroma 2, and pressure faces on ped surfaces. It also contains a clay content exceeding 40% within 50cm and experiences a 1.15 times increase in clay content in the cambic horizons. The upper pediments (P4) of Ambalkere soil and the moderately eroded upper pediplains (P7) of Bidarkere soil exhibit clay-enriched argillic horizons with a hue of 2.5YR and a moist value of 3 or less. Additionally, the clay content in these horizons is 4.5 times higher than in other layers. As a result, these soils are classified as Typic Rhodustalfs. On the other hand, Gudunoorhalli soil, found on moderately eroded upper pediplains (P5), possesses a buried genetic horizon indicated by the suffix "b" in its horizon designations. This buried horizon contains twice as much clay as the eluvial horizon. The thick agrillic horizon in Gudunoorhalli soil exhibits broken clay skins on peds and a combination of lamellae with a clay content ranging from 20 to 25%. The surface Ap horizon of this soil contains 10.21% clay, with organic carbon and CEC irregularly distributed. This soil is classified as Lamellic Haplustalfs. Moving on to the lower pediments (P6), the Kandikere soil is characterized by its significant depth (>150cm) while maintaining a clay content below 20% of the clay maximum. The argillic horizons in this soil have a hue of 7.5YR and a chroma of 3 to 4. Furthermore, there is an abrupt textural change in the Bt horizons, leading to its classification as Typic Paleustalfs (Table 1).

World reference base for soils

The Vedavathi river in Hiriyur tehsil has soils with contrasting textures, which have been classified according to the World Reference Base for Soil Resources (FAO 2015). The Kanvi maramma series (P1) falls under the solonetz (SN) soil group, with a natric horizon starting below 100 cm from the soil surface. The principal qualifiers for this series are Abruptic-chromic, and there are supplementary qualifiers such as cutanic, colluvic, and hypernatric. Therefore, the final classification for Kanvi maramma series is Abruptic chromic Solonetz (cutanic, colluvic, hyper natric). Similarly, the Bhagirathekere soil (P2) is classified as Chromic Sodic Vertisols (VR), with supplementary qualifiers of ochric and mesotrophic. The Shidlaiahnakote soil (P3), which has a cambic horizon with vertic properties, is classified as Skelitic vertic cambisols (colluvic). The Ambalkere (P4) and Bidarkere soils (P7) have an argic horizon (illuvial clay) and are placed under the reference soil group of Luvisols. The principal qualifiers for these soils are Rhodic, and the supplementary qualifiers are cutanic and magnesic. On the other hand, Gudunoorhalli (P5) has an Abruptic/Lamellic horizon, and Kandikere soil (P6) has cutanic and colluvic properties (Table 1).

It is worth noting that the soils on basin floors (P1) and (P2) exhibit exchangeable sodium levels exceeding 15 in the subsoils, indicating the development of sodicity. Additionally, the presence of qualifiers such as cutanic (P4/P5/P6) and lamellic (P5) in certain argillic horizons, as well as the natric horizon in P1, suggests sodic conditions under WRB classification, which offers an advantage over USDA soil taxonomy. The classification of colluvial soils is particularly important in semiarid regions of India, as it allows for the mapping of these units and facilitates future correlation activities.

Table 1. Soil classification as per USDA soil taxonomy and WRB of Vedavathi basin

Pedons	Soil taxonomy USDA	WRB	Diagnostic characteristics	
			USDA	WRB
P1. Kanvimaramma	Typic Natrustalfs	Chromic /Haplic Solonetz (Cutanic, Colluvic, Raptic, Hyper natric)	Natric horizon with high exchangeable sodium and illuviation of clay	Same but having lithological discontinuities with Munsell color hue redder than 7.5YR and a chroma of > 4, both moist and dry
P2.Bhagirathikere	Sodic Haplusterts	Chromic/Sodic Vertisols (Ochric, Mesotrophic)	High exchangeable sodium , Clay >35% with shrink-swell properties	In addition , these soils have chroma >2 with strong, angular blocky aggregates and have moderate inherent fertility expressed as a ratio relating the major nutrient cations and poor in organic carbon
P3. Shidalaiahnakote	Vertic Haplustepts	Provertic Cambisols (Colluvic)	Cambic horizon with	≥ 30% clay, wedge-shaped soil aggregates,

			shrink-swell clays	thickness of >15cm, prsuure faces on ped surfaces
P4.Ambalkere	Typic Rhodustalfs	Rhodic Luvisols(Cutanic)	Argillic horizon throughout the depth in upper 100 cm with hue of 2.5YR	An argic horizon starting ≤ 100 cm from the soil surface. with a high base saturation;
P5.Gudunoorhalli	Lamellic Haplustalfs	Abruptic/ Lamellic Luvisols(Cutanic,Colluvic, Raptic)	Argic horizon consists (partially) of lamellae	Argillic with evidence of illuvial clay, like clay coatings, lamellae,
P6.Kandikere	Typic Paleustalfs	Haplic Luvisols(Cutanic, Colluvic)	Argic horizon under ustic moisture regime with an increase of clay of 20% within vertical distance of 7.5cm, have hue of 7.5YR and chroma of 3 to 4.	Argic horizon with textural differentiation , high activity clays and base status, translocation of clay characterized by having a CEC of ≥ 24 cmolc kg-1 clay throughout .
P7.Bidarkere	Typic Rhodustalfs	Skeltic/Rhodic Luvisols(Cutanic)	Argillic horizon throughout the depthin upper 100cm with hue of 2.5YR	An argic horizon starting ≤ 100 cm from the soil surface. with a high base saturation;

Case study 2: Pennar basin in YSR Kadapa district, Andhra Pradesh

The Penneru river basin is a part of the Kadapa basin and is located between latitudes 13˚30’N to 17˚N and longitudes 78˚E to 80˚E (Fig.2). It covers an area of 44000 sq.km and is the second-largest Purana basin in Peninsular India. The study site consists of lower Pulivendla Quartzite and upper Tadipatri formation with various types of rocks and sediments. The boundary between the Tadipatri Formation and the Gandikota Quartzite is gradual and conforms at the Penneru River gorge. The basin has different landforms such as ridges, fans, valleys, plains, channels, and hills. It falls under the Deccan plateau region with specific soil characteristics and a short growing period. The climate in the region is characterized by erratic rainfall, with high-intensity rainfall during the northeast monsoon period. The moisture status of the basin is generally poor. The main crops grown in the area are jowar, finger millet, and pearl millet

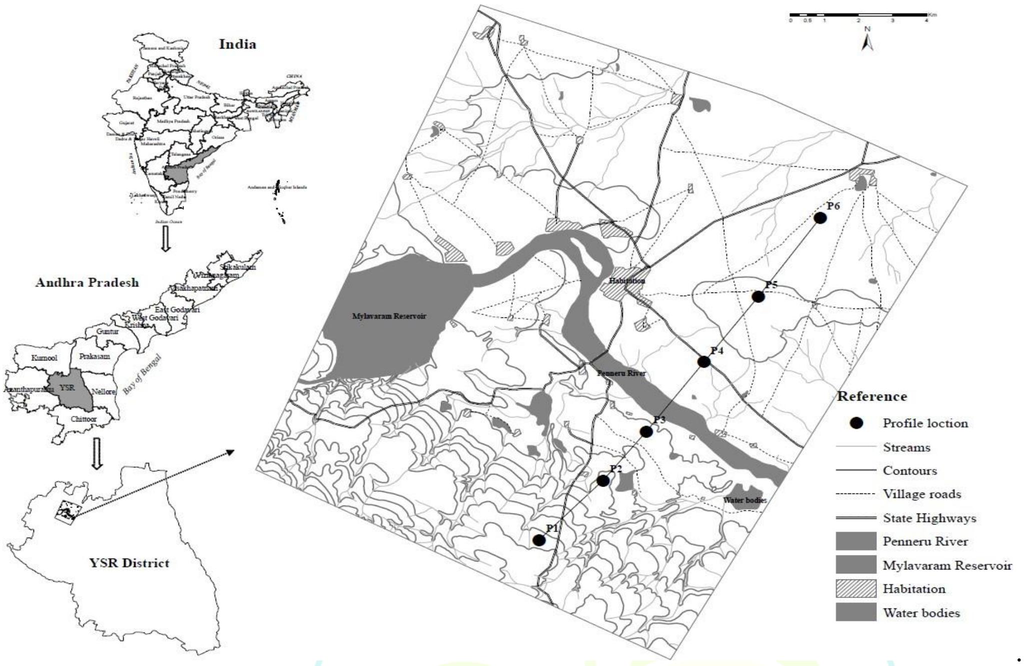


Fig.2. Location map of study area

The soil transect in Gandikota consists mainly of quartzite that overlays Tadipatri shale formations. It spans an elevation range of 340m to 280m near the Chitravathi river in the Kadapa region. The soils in this transect are shallow and skeletal, developed from Gandikota quartzite on the summits (P1, P2) and upper slopes (P3). They start off as red or red-brown soils but gradually change to very dark grayish brown to dark yellowish-brown in P3 near the upper slopes, and eventually become black or very dark gray in the soils on the foot slopes (P5/P6). This transect represents a translocation landscape. The summit soils have A-AC horizons (P1&P2), while the Kondapuram soils (P3) have Ap-Bw horizons, the Kanneleru soils on the back slopes (P4) have Ap-Bw-C-Bw-C-Bw horizons, and the soils on the foot slopes (P5/P6) have Ap-Bw-Bss horizons. The varying arrangement of these horizons, along with the smooth to wavy, sharp to abrupt lower boundaries, and variable thickness of Ap horizons, can be clearly seen in morphological investigations. This is evident in all profiles except for one upslope profile, which lacks these features, and the lowermost profile, which has double the thickness of Ap horizons. This clearly demonstrates the impact of past agricultural activities and lithology-controlled topography on the foot slopes, erosion on the summits, and colluviation in the upper and back slopes. The soils on the foot slopes of this landscape are black to very dark gray and have a clay texture. Interestingly, there is no transition between the soils on the foot slopes (P5/P6), making it difficult to distinguish them from the saprolite with similar rock type (Gandikota quartzite). This may be due to disturbances within the soil structure. The river bed was located within the transect line and provided an opportunity to study its geological subsoil. The back slopes of the river bed had dark brown to brown layers of soil, which are commonly used for paddy cultivation. These soils experience changes in wetness and dryness, leading to deep surface cracks. Similar soil patterns were observed in the basaltic catena of the Jayakwadi project, but they consisted of dark gray soils that shrink and swell. The morphodynamic processes in this area are likely influenced by changes in land use and the slight elevation of the foot slopes above the Penneru valley floor.

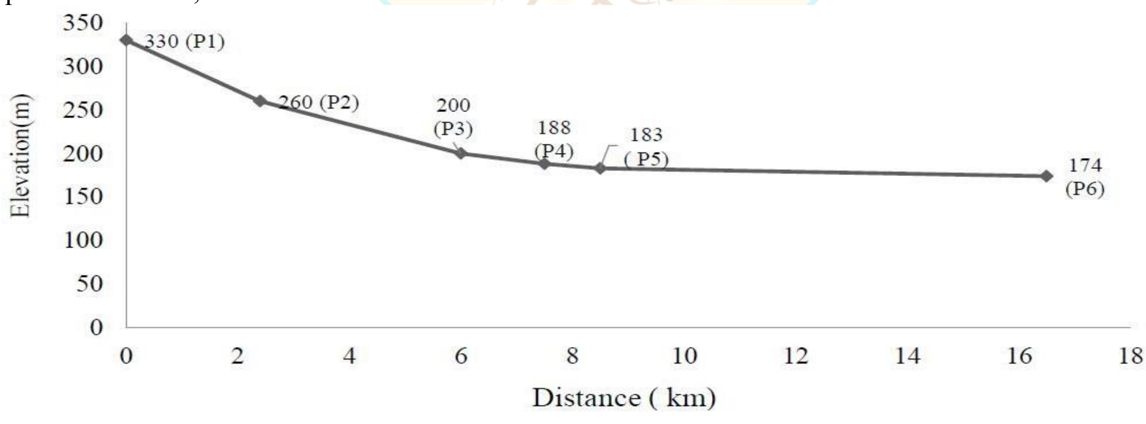
USDA Soil Taxonomy

The classification of these soils is complex due to variations in wet and dry cycles, frequent droughts, and unpredictable rainfall patterns. The climate of the Kadapa basin is semi-arid, with an aridity index of 0.36. The soil temperature remains consistently high throughout the year, with a small difference between summer and winter temperatures. The moisture regime of the soil is ustic. Rainfall data and other parameters were collected for over a century, revealing that the area has an arid to semi-arid

climate. The soil moisture regime in the Kadapa region is classified as aridic. Arid or torric moisture regimes refer to soils that are completely dry for more than half of the time and never become moist for up to 90 consecutive days when the soil temperature at 50 cm (20 in) averages above 8°C.
Hence, the soils in the Chitravathi basin were classified in the subgroups of three soil orders: Entisols, Inceptisols and Vertisols. The soils on the summits (P1/P2) have a clayey skeletal particle size class with more than 35 percent rock fragments throughout the depth. The soils on the upper (P3) and middle backslopes (P4) have a fine loamy particle size class, but the soils on the foot slopes have less than 60 percent clay. These soils are slightly acidic on the summits but become moderately to strongly alkaline across the landscape, with low organic carbon and available nitrogen. They have a high CEC (> 25 cmol/kg) but show more than 15% exchangeable sodium within 100cm in the case of P3 and P6, classifying them as sodic. These soils are classified at the subgroup level according to USDA soil taxonomy. The summit soils are classified as Typic Torriorthents (Kottala-P1), while the Mallambhavi soil (P2) with lithic contact within 50 cm is classified as Lithic Torriorthents. The Kondapuram soil on the back slopes (P3) is classified as Sodic Haplocambids, with a 25 cm thick Bw horizon and an ESP of more than 15 percent at 0.85 to 1.1m. The Kanneluru soil (P4) on the back slopes is classified as Fluventic Haplocambids, with irregular sand to silt proportions but decreasing trends of organic carbon with depth. The soils on the foot slopes are classified as Typic Haplusterts (P5) and Sodic Haplusterts (P6).

World reference base for soils

The Pennar soils in Kadapa district have been categorized into different Reference Soil Groups (RSG) based on their characteristics. For the summits, the RSG is Regosols (P1&P2). The primary qualifiers for P1 are Leptic, while for P2 it is Skelitic (Table 2). The subqualifier for P1 is chromic, with a reddish hue (Munsell colour hue redder than 7.5YR) and a chroma greater than 4. For P2, the subqualifier is clayic, which occurs in one or more layers with a combined thickness of at least 30 cm, within 100 cm of the mineral soil surface. On the midslopes (P3&P4), the soils are classified as cambisols. The primary qualifier for P3 is vertic, while for P4 it is Fluvic. The subqualifiers for P3 are protosodic and Oxy aquic, whereas for P4 it is Endofluvic, clayic, and transportic. On the lower slopes (P5&P6), the primary qualifier is sodic, and the RSG is Vertisols.



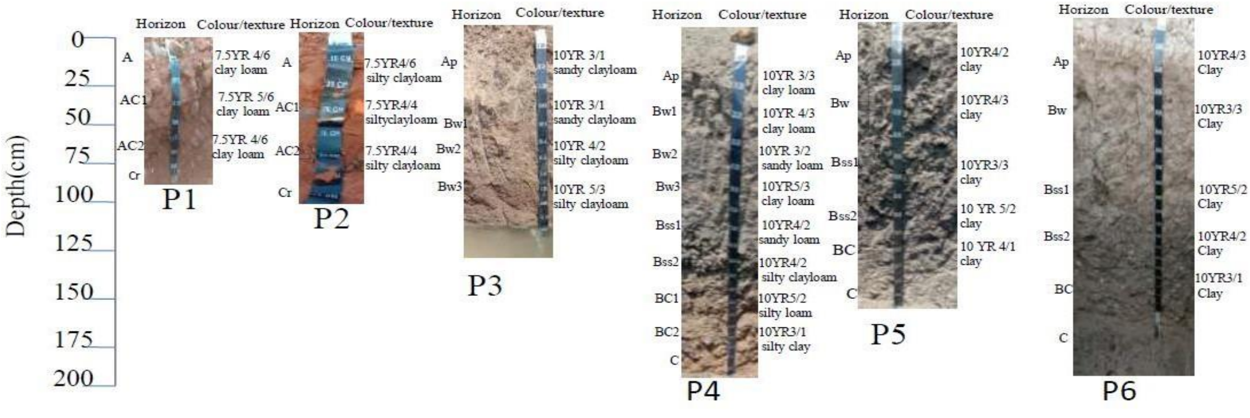


Fig.3. Soil landscape relationships in Pennar basin

Table 2. Soil classification as per USDA soil taxonomy and WRB of Pennar basin

Pedons	Soil taxonomy USDA	WRB	Diagnostic characteristics	
			USDA	WRB
P1 Kottala	Ustic Torriorthents	Lepto Regosols (Chromic)	The moisture control area typically remains dry for less than three-fourths of the total days in a year when the soil temperature at a depth of 50 cm below the surface is 5 °C or higher. It is characterized by a soil temperature regime that can be hyperthermic, thermic, mesic, frigid, or iso, and a soil moisture regime that is aridic or torric, bordering on ustic.	There is no profile development with A-AC horizons that have continuous rock starting at a depth of 100 cm or less from the soil surface.
P2 Mallambhavi	Lithic Torriorthents	Skelitic Regosols (clayic)	Within 50 cm of the soil surface, there is a lithic contact. The moisture control section is typically dry for less than three-fourths of the total days per year when the soil temperature at a depth of 50 cm below the soil surface is 5 ° C or higher.	The classification of Akroskeletic is assigned to soils lacking profile development with A-Ac horizons that contain more than 40% coarse fragments extending to a depth of 100cm, with an average dimension exceeding 6cm.
P3. Kondapuram	Sodic Haplocambids	Vertic Cambisols (Protosodic, Oxyaquic)	Haplocambids with a soil surface horizon that is at least 25 cm thick within 100 cm of the soil surface and has an exchangeable sodium percentage of 15 or higher.	The cambic horizon exhibits vertical characteristics beginning at a depth of 100 cm from the surface of the mineral soil. This horizon possesses sodium (Na) content ranging from 6% to less than 15% on the exchange complex, including both Na and Mg.
P4. Kanneleru	Ustifluventic Haplocambids	Fluvic Cambisols	The control section experiences an ustic	The cambic horizon contains fluvic material,

		(Endofluvic, Clayic, Raptic and Trasportic)	soil moisture regime for less than three-fourths of the time (cumulative) when the soil temperature at a depth of 50 cm below the soil surface is 5 o C or higher. Additionally, there is an irregular decrease in organic carbon content between a depth of 25 cm and either a depth of 125 cm below the mineral soil surface.	which is located between 50 and 100 cm from the surface of the mineral soil.
P5 Seshareddipalli	Sodic Haplusterts	Sodic Vertisols	In regular years, there are wide cracks that measure 5 mm or more in width. These cracks extend through a thickness of 25 cm or more and are located within 50 cm of the surface of the soil. These cracks persist for 210 days or more each year and have a sodium percentage of 15 or higher within 100 cm	The vertical horizon has noticeable smooth sides and shiny wedge-shaped clusters. It begins within 100 cm from the surface of the mineral soil. This layer, which is at least 20 cm thick and starts within 100 cm from the mineral soil surface, contains a minimum of 15% sodium and magnesium.
P6 Peddapasupula	Sodic Haplusterts	Sodic Vertisols	For a duration of at least 6 months in regular years, there should be a sodium percentage of 15 or higher within 100 cm of the mineral soil surface, occurring in one or more horizons.	The vertical horizon has noticeable smooth sides and shiny wedge-shaped clusters. It begins within 100 cm from the surface of the mineral soil. This layer, which is at least 20 cm thick and starts within 100 cm from the mineral soil surface, contains a minimum of 15% sodium and magnesium.

Challenges of soil classification in semiarid regions of South India

The World Reference Base for Soil Resources (WRB) and American Soil Taxonomy (ST) are the two primary soil classification systems in use today. Both systems have undergone extensive testing and data collection to ensure accuracy and reliability. The ST, as outlined by the Soil Survey Staff (2014), consists of six categorical levels: order, suborder, great group, subgroup, family, and series. On the other hand, the WRB has a simpler structure with only two categorical levels: reference soil groups and soil units, as stated by the IUSS Working Group WRB (2015). Unlike the hierarchical nature of the ST, the WRB follows a flat hierarchy. The FAO method (WRB, 1998) or the USDA system (Soil Survey Staff, 2024) are often used for classifying south Indian soils in order to transmit soil knowledge to local usage.

However, the WRB system introduced the qualifier "Raptic" to indicate the presence of lithologic discontinuity in taxon names, whereas the ST system entirely ignored it. The WRB system thus suggested that all taxa in the ST system be assigned to the "Raptic" subgroup. Furthermore, the ST system classified as "shallow" at the family level of classification. The WRB soil classification system faced limitations in accurately characterizing the attribute of continuous rock in Leptosols and Leptic soils. To address this issue, it is proposed that the qualifiers for Regosols be expanded, along with the inclusion of the definition of Paralithic as a prefix and its subqualifiers in the diagnostic characteristics of WRB. These additional qualifiers would encompass Paralithic soils, which are soils that come into contact with other rocks within 100 centimeters of the soil surface. Furthermore, the subqualifiers would include Endoparalithic soils, which exhibit paralithic contact up to 50-100 cm below the soil's surface, and Epiparalithic soils, which exhibit paralithic contact up to 50 centimeters below the soil's surface. This proposed expansion would enhance the classification system's ability to accurately describe and categorize soils with continuous rock.

The classification of soils in semi-arid regions presents several important challenges. One of these challenges is the common occurrence of ochric epipedon with a pale color feature in well-drained soils. This pale color is likely due to clay migration and localized reducing conditions, resulting in a material with low organic carbon content (less than 0.4%) and a reduced amount of free iron oxide. This fine subangular structure is observed in both the Vedavathi and Penneru basins. It has been recognized that the presence of ochric surface horizons has a negative impact on land use. These horizons are associated with lower physical stability, higher erosion potential, crusting and surface sealing, and lower hydraulic conductivity. However, they have also proven to be a valuable tool in evaluating soil suitability, identifying problem soils (such as sealing soils), and developing soil surface management practices, particularly for irrigated crop production. In the classification of soils in semi-arid regions, certain properties must be taken into consideration. This is especially true in areas where red and black soils are spatially associated. For example, the presence of iron oxides, indicated by a red or yellow-brown color, has a positive effect on the physical properties of the soil. Iron oxides help to reduce swelling, dispersion, and compaction. There is a strong relationship between the clay mineralogical composition of the soil, which is related to diagnostic horizons and soil series, and its physical behavior. Poorly drained soils are typically dominated by smectitic clay minerals, which have a high cation exchange capacity (CEC). The CEC, determined by the type and amount of clay present, is related to water retention and swell-shrink phenomena. It has been shown that soils with expansive clays can retain approximately double the amount of plant-available water, but release it slowly. Physical properties such as the coefficient of linear extensibility and Atterberg limits have been successfully used to distinguish between soils with different management problems. These properties should be given due consideration in defining qualifiers in the World Reference Base for Soil Resources (WRB) system.

Conclusion

Soil transects studies in river basins serve the purpose of assessing the effectiveness of different soil taxonomic systems in revealing the internal characteristics and environmental aspects of the soil. In this regard, the WRB system proves to be more advantageous compared to the USDA soil taxonomy, particularly when it comes to showcasing the distinct features of soils with varying textures in semiarid regions. The WRB system offers additional qualifiers like Clayic, Cutanic, Ochric, Rhodic, and colluvic, which necessitate the collection of more physico-chemical data. However, this poses a significant challenge in terms of managing climatic conditions and land use patterns. Hence, it can be concluded that the objectives and scale of a study greatly influence the efficiency of Soil Taxonomy and WRB classification systems in describing soil properties.

Carbon Sequestration in Cotton Growing Soils

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Abstract

Cotton is net negative carbon footprint crop. In last 6 decades (1960-2020) the atmosphere CO_2 increased 100 ppm (From 280 to 418 ppm). Cotton sequesters 2.2 kg of carbon and emits 1.7 kg of greenhouse gas per one kg of fibre. With an extent of 12.5 million hectares cultivation across three cotton-growing regions in India hold significant potential for soil carbon sequestration. Carbon sequestration encompasses soil organic carbon (SOC) and inorganic carbon (SIC) sequestrations, both plays pivotal role in mitigating climate change and determining agro-ecosystem functions. SOC and SIC involve the storage of carbon in various forms through distinct processes. In cotton-growing areas, the annual availability of stalks ranging from 3-5 Mg ha^{-1} contributes to 4-6 g kg^{-1} of soil organic carbon concentration upon incorporation. While organic carbon (OC) is essential (0.3 m soil depth), there is also an inorganic carbon (IC) component in soils (0.3-1.0 m soil depth), especially relevant to rainfed cotton growing areas due to calcification and the formation of secondary carbonates. IC is considered as a potential carbon sink for rainfed cotton growing areas (>63%). In these regions, the dynamics of the IC pool are not well-understood, despite its stability. SIC occurs through the movement of bicarbonate (HCO_3^-) into groundwater and closed systems. Although carbon relatively stable (Crystallized $CaCO_3$), SIC can release CO_2 if carbonates become exposed through erosion. Mineral weathering, dissolution and carbonate formation processes positively impact soil structure. SIC significantly influences the soil fertility, water retention, crop production and provides contributions in ecosystem services like provisioning, regulating, cultural and supporting categories. However, irrigation in conjunction with inputs of nitrogen and sulfur fertilizers can destabilize inorganic C, releasing CO_2 through carbonate precipitation.Factors and consequences associated with SIC emphasize that, in dry climates, calcification is a dominant pedogenic process that retards CO_2 emissions from soils. Recognizing the unique role of soils as potential substrates in mitigating atmospheric CO_2 effects is crucial, particularly in rainfed cotton growing areas. Understanding and managing natural SIC processes of deeper soil depths are vital for sustainable cotton production practices aiming to sequester carbon and enhance ecosystem resilience.

Key words: Rainfed cotton, Inorganic carbon, organic carbon, sequestration

Introduction

Carbon sequestration refers to the capture and long-term storage of carbon dioxide (CO_2) from the atmosphere to mitigate climate change and reduce the concentration of greenhouse gases. This process plays a crucial role in efforts to address global warming by preventing the release of excessive CO_2 into the atmosphere. Carbon sequestration is considered a key strategy in climate change mitigation. However, it is important to note that it should not be seen as a substitute for reducing overall greenhouse gas emissions. Efforts should focus on both reducing emissions and enhancing carbon sequestration to achieve a more sustainable and balanced approach to addressing climate change. There are various natural (Forests, Oceans and Soil) and artificial methods [Carbon Capture and Storage (CCS), Direct Air Capture (DAC), Enhanced Weathering, Afforestation and Reforestation] of Carbon sequestration. In soil, Carbon can be stored in the soil through the decomposition of organic matter and the formation of stable soil organic carbon (Figure 1).

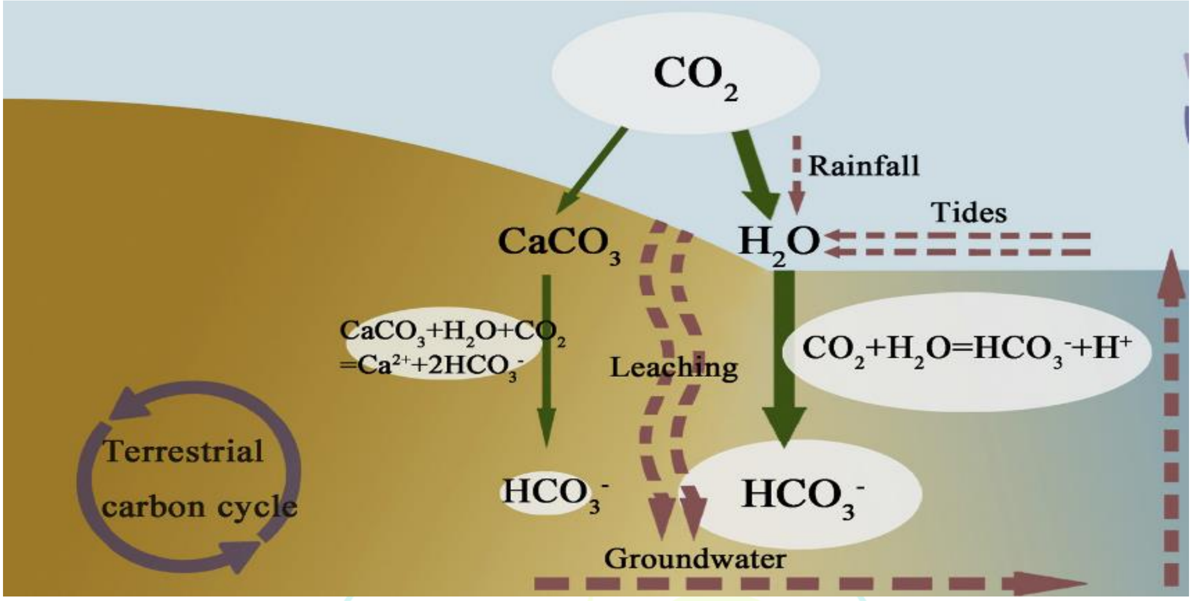

Figure 1. Soil carbon sequestration (adopted from Wang et al., 2019)

Over the last six decades (1960-2020), there has been a notable increase in atmospheric CO2 levels, rising by approximately 100 parts per million (ppm) from 280 to 418 ppm (Figure 1). Cotton, recognized as a C3 plant, significantly contributes to this trend. With its fibers consisting of 97% cellulose, each kilogram of cotton fiber sequesters 2.2 kilograms of carbon while emitting 1.7 kilograms of greenhouse gases. The cultivation of cotton across three primary regions in India, covering an extensive area of 12.5 million hectares, presents a substantial opportunity for soil carbon sequestration (Table 1). Cotton cultivation in India thrives across various soil types, including black soil, calcareous soil, red and laterite soil, coastal alluvial soil, and saline-alkali soils. Throughout the year, cotton is cultivated across three distinct regions: North, South, and Central India. Despite more than 63% of cotton areas in India being rainfed, their capacity for carbon sequestration remains significant. Reports indicate that globally, cotton farms release 15.5 million tonnes of carbon annually. However, calculations by the International Cotton Advisory Committee (ICAC) suggest that these farms capture 99.8 million tonnes of carbon worldwide. On average, cotton farms emit 470 kilograms of carbon per hectare annually while sequestering 3022 kilograms of carbon per hectare (Kranthi, 2023). Based on the calculation, cotton-growing soils in India capture an excess of 320 lakh tons of carbon per year. Additionally, carbon is stored in cotton plant biomass and soil, with soil holding three times more carbon than plants and animal carbon storage combined. Mechanisms such as the residue incorporation, reduced tillage, precision techniques, biochar amendment stabilized organic carbon for SOC and precipitation of calcium carbonate, weathering of silicate minerals, formation of dissolved inorganic carbon (DIC), dissolution, leaching, absorption of CO_2, and alkalinity of soil and water play significant roles in SIC sequestration. Overall, cotton-growing soils act as vital carbon sinks, highlighting the importance of SOC and SIC in these ecosystems.

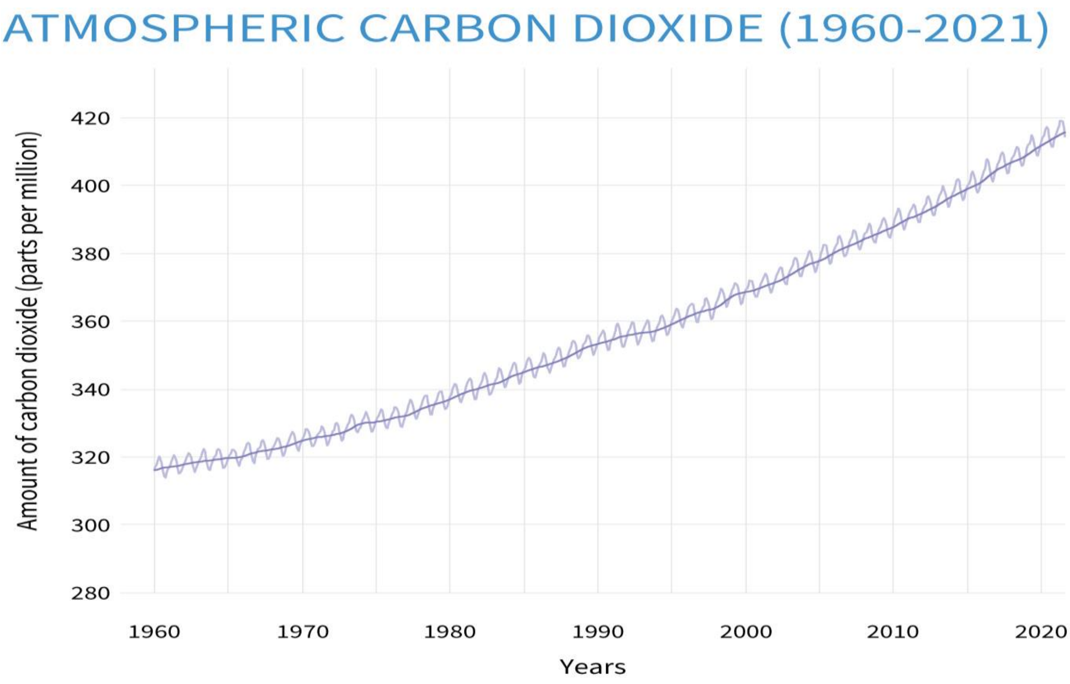

Figure 2. Atmospheric carbon dioxide (ppm)

Table 1. Carbon sequestration potential of cotton growing states of India

States/UTs	Area (In Lakh ha)	Release of Carbon (In lakh ton)	Capture of Carbon (In lakh ton)
Andhra Pradesh	5.69	2.7	17.2
Gujarat	26.82	12.6	81.1
Haryana	6.65	3.1	20.1
Karnataka	6.86	3.2	20.7
Madhya Pradesh	6.5	3.1	19.6
Maharashtra	42.22	19.8	127.6
Odisha	2.3	1.1	7.0
Punjab	1.69	0.8	5.1
Rajasthan	7.91	3.7	23.9
Tamil Nadu	0.68	0.3	2.05
Telangana	18.13	8.5	54.8
Others	0.1	0.05	0.3
India	125.55	59.01	379.41

Soil Carbon

Soil carbon refers to the carbon stored within the soil in various forms, primarily as organic carbon and inorganic carbon. Both soil organic carbon (SOC) and inorganic carbon (SIC) as $CaCO_3$ are important as they determine ecosystem and agro-ecosystem functions, influencing soil fertility, water-holding capacity and other soil characteristics. Soil C is also of global importance because of its role in the global C cycle and therefore, the part it plays in the mitigation of atmosphere levels of greenhouse gases (GHGs), with special reference to CO_2. Soils capture and store both organic (through photosynthesis of plants and then to soils as decomposed plant materials and roots) and inorganic carbon (through the formation of pedogenic calcium carbonates, PC).

Organic Vs Inorganic carbon sequestration

Soil Organic (SOC) and Inorganic carbon sequestration (SIC) refers to the storage of carbon in different forms and through distinct processes. Both organic and inorganic carbon sequestration are essential components of overall carbon management strategies aimed at mitigating climate change. Balancing both approaches can contribute to a more comprehensive and sustainable solution to reduce atmospheric CO_2 concentrations.

Table 2. Comparison of Organic vs Inorganic carbon sequestration

Process	Organic	Inorganic
Nature of Carbon Storage	Involves the storage of carbon in organic compounds. This typically occurs in living or once-living organisms, such as plants, trees, and soil organic matter.	Involves the storage of carbon in mineral forms, such as carbonates. This process is often associated with geological formations like rocks, minerals, and sediments.
Processes	The uptake of atmospheric CO_2 by photosynthetic organisms, such as plants and trees. This captured carbon is stored in the form of organic molecules through photosynthesis.	Often rely on geological and chemical processes. For example, minerals like olivine or basalt can react with atmospheric CO_2 through a process called mineral weathering, forming stable carbonates.
Mechanisms	Forests play a crucial role in organic carbon sequestration. Trees absorb CO_2 during photosynthesis, converting it into organic biomass. Soil organic carbon sequestration also occurs through the decomposition of plant and animal matter.	Carbon Capture and Storage (CCS) is a prominent example of inorganic carbon sequestration. It involves capturing CO_2 emissions from industrial sources and storing them in geological formations like depleted oil and gas reservoirs or deep saline aquifers.
Time Scales	Processes can vary in time scales. For example, the carbon stored in living plant biomass may be released relatively quickly if the plants die and decompose, while soil organic carbon can persist for longer periods.	Long-term geological processes. The storage of carbon in mineral forms can remain stable over geological time scales.
Applications	It is applied in various natural and sustainable practices; including afforestation, reforestation, and agricultural practices that enhance soil organic carbon.	CCS, are often applied to capture and store emissions from industrial sources.

Soil organic carbon

Soil organic carbon (SOC) comprises the organic matter present in soil, including plant and animal residues, microbial biomass, and humus. It plays a crucial role in soil fertility, water retention, nutrient cycling, and soil structure. These types of soil organic carbon can be categorized based on their composition, origin, and stability.

Plant Residues: In cotton growing soils organic carbon derived from cotton plants, including leaves, burs, branches, stalks, roots, and other plant debris (flower, bolls, seeds, lint) that undergo decomposition in the soil. Cotton plant residues (3-5 and 5-7 ton/ ha/year) contribute to SOC through the addition of fresh organic matter to the soil surface and subsequent incorporation into the soil profile. (Silanikove and Levanon, 1986) Although, 38 to 63 M ton of cotton stalks are generated annually in cotton growing soils of India, these wastes not used any scientific residue management. (Velmourougane et al 2022). The sequestrated carbon is classified into fast pool and which degrades with days to months. Soil incorporation of cotton residues enhances the decomposition rate (6-7 months) and nutrient availability.

Microbial Biomass: Carbon stored in living microorganisms, such as bacteria, fungi, and actinomycetes, present in the soil. Microbial biomass carbon (MBC) serves as a dynamic pool of SOC, as microorganisms assimilate and release organic carbon during their growth and metabolism processes. Cotton based cropping system recorded microbial biomass carbon (MBC) of 128 µg g^{-1} (rainfed) and 650 µg g^{-1} (irrigated) of soil (Velmourougane et al., 2014; 2022).

	The initial amount of humus in (1926)			After 96 years (2022)				
Treatments	%	t/ha	C	%	t/ha	Cotton	Total gr	Humus a
Every year 30 t/ha manure+ 25 kg/ha P_2O_5	1.84	68.45	-	0.96	32.5	32.7	306.8	0.108
NPK 250:175:125 kg/ha	1.42	53.25	-	0.87	16.6	33.9	330.4	0.059
Without fertilizer (Control)	1.42	53.25	-	0.64	29.1	9.9	141.0	0.206

Table 3. Changes in the amount of humus (in 0-30 cm layer) and cotton yield in fields with long-term permanent cultivation of cotton (Meylikovich et al., 2022)

Humus: Humus is a complex, amorphous organic substance formed from the decomposition of plant and microbial residues. It consists of 58% of carbon. It is a stable and long-lasting fraction of SOC that contributes to soil aggregation, water retention, nutrient cycling, and cation exchange capacity. Meylikovich et al. (2022) observed that in a 96-year long-term experiment focusing on monocropping of cotton, varying agricultural practices influenced humus consumption for cotton production (Table 3). Specifically, the study examined three treatments: control (0.059 kg), application of 30 tons per hectare of manure along with 25 kg per hectare of phosphorus (0.108 kg), and application of NPK fertilizer at a ratio of 250:175:125 kg per hectare (0.206 kg). These treatments resulted in differing amounts of humus consumption from a soil depth of 0.30 m for the production of 1 kg of cotton. The sequestrated carbon is classified into medium pool and which degrades with years.

Charcoal (Biochar): Cotton stalks are hard wood and their decomposition rate is slow due to high lignin. Therefore, the stalks converted into biochar (16 to 23%). Biochar is a form of charcoal produced from the pyrolysis of organic materials under controlled conditions. It is characterized by its high stability and resistance to microbial degradation, serving as a long-term carbon sink in soils and improving soil fertility and structure. The sequestrated carbon is classified into slow pool and which degrades with hundreds of years. Shi et al., 2020 showed that the one-decade consecutive biochar application (4.5 and 9 Mg ha^{-1} $year^{-1}$) increased soil inorganic carbon (0.4 Mg C^{-1} ha^{-1}, soil organic carbon (9 Mg C^{-1} ha^{-1}), total carbon contents (9.4 Mg C^{-1} $ha^{-1}$and stocks (12Mg C^{-1} ha^{-1}) in 00-15 cm soil depth. The production of inert or black C by natural and anthropogenic fires and recalcitrant and refractory C compounds in soils by plants, soil fauna, and micro-organisms (Goh, 2004).

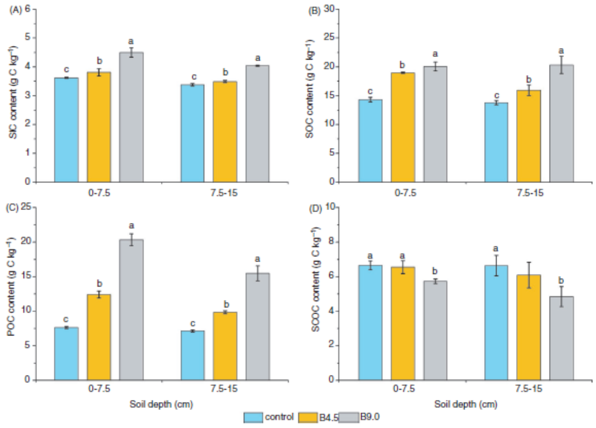

FIGURE 1 Contents of soil inorganic carbon (SIC, A), bulk soil organic carbon (SOC, B), >53 μm particulate organic carbon fraction (POC, C) and <53 μm silt–clay-associated organic carbon fraction (SCOC, D) under the treatments at 0–7.5 and 7.5–15 cm depth (control: no-biochar; B4.5 and B9.0: biochar application at rates of 4.5 and 9.0 Mg ha^{-1} year^{-1}, respectively). Bars are standard error. Different letters indicate significant differences among the treatments ($p < .05$) [Colour figure can be viewed at wileyonlinelibrary.com]

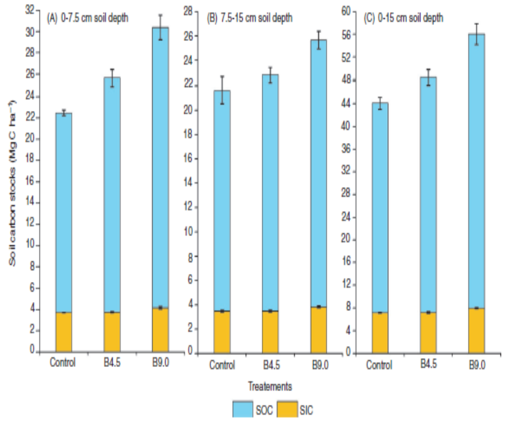

FIGURE 2 Soil inorganic carbon (SIC), bulk soil organic carbon (SOC) and total carbon (TC) stocks at 0–15 cm depth under different biochar treatments (control: no-biochar; B4.5 and B9.0: biochar application at rates of 4.5 and 9.0 Mg ha^{-1} year^{-1}, respectively). The value of TC stocks is denoted by the sum of SIC and SOC. Bars are standard error [Colour figure can be viewed at wileyonlinelibrary.com]

Dissolved Organic Carbon (DOC): Soluble organic carbon compounds present in soil solution, derived from the decomposition of organic matter, root exudates, and microbial activity. DOC contributes to microbial activity, nutrient cycling, and plant nutrition in the soil ecosystem. DOC share in soil carbon is 61-1266 mg kg^{-1}from soils farmland (Smreczak and Ukalsha-Jaruga, 2021).

Table 4. Examples of dissolved organic matter share in soil organic matter of soils from farmland (Smreczak and Ukalsha-Jaruga, 2021)

Site	Soil layer (cm)	Other information	TOC (g/kg)	DOC* (mg/kg)	%
Cropland	0-15	Maize monoculture manured	34.4	**1226**	3.56
		Maize monoculture	25.3	674	2.66
		no amendment	29.2	801	2.74
Forest cropland	0-30*	-	38.4	731	1.90
		-	12.0	150	1.25
Cropland	0-30	Phaeozems	7.65	62.8	0.82
		Luvisols	7.24	**61.3**	0.85
Agriculture areas	0-20	Soil monitoring system of Hungary	22.0	100.9	0.46
cropland	0-10	Soil without amendments	5.98	120.3	2.01
		Soil with sewage and sludge at 30 t/ha	5.83	127.3	2.18
		Soil with sewage and sludge at 30 t/ha	6.12	145.3	2.37

Particulate Organic Matter (POM): POM consists of visible organic particles, such as plant residues and microbial biomass that are relatively less decomposed compared to humus. POM is an important source of labile organic carbon in the soil, contributing to nutrient cycling and microbial activity. Shi et al., 2020 also showed that the one decade consecutive biochar application (4.5 and 9 Mg ha^{-1} year^{-1}) increased particulate organic carbon (POC) of 38-166% in 00-15 cm soil depth than control.

Stabilized Organic Carbon: Organic carbon compounds that are physically and chemically protected within soil aggregates or mineral complexes, making them resistant to decomposition. Stabilized organic carbon forms contribute to long-term soil carbon storage and soil fertility. The encapsulation of SOC in soil aggregate formation and hydrophobic domains of SaM, protecting its accessibility to degrading soil micro-organisms and their enzymes (Goh, 2004).

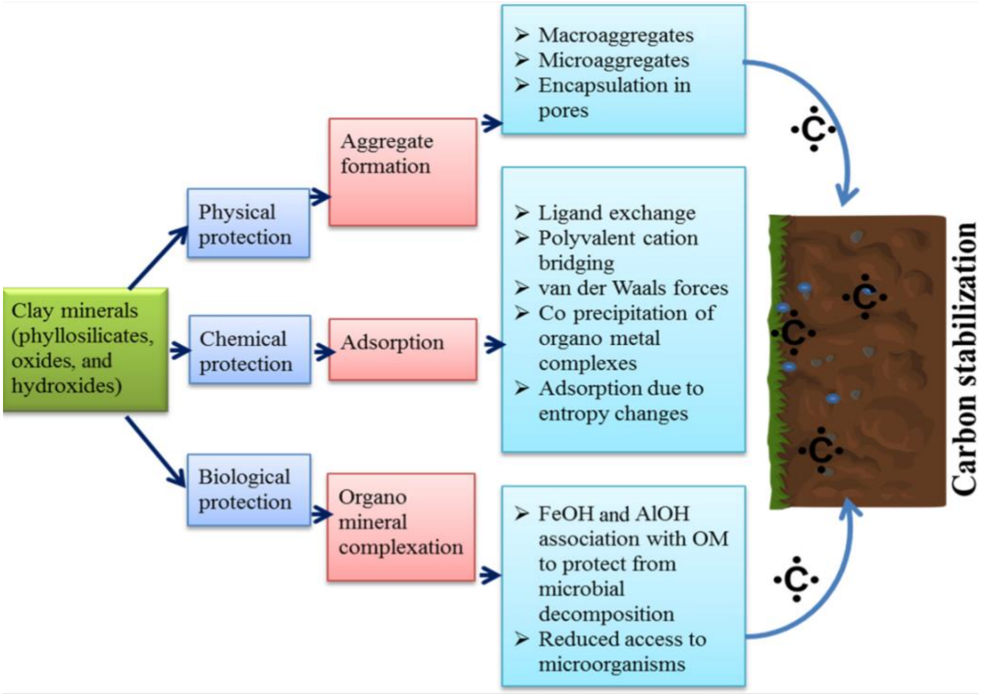

Figure 5. Mechanisms of carbon stabilization in soils by clay-minerals (Adopted from Singh et al., 2018).

Understanding the dynamics and interactions of these different types of soil organic carbon at surface layer (0.30m) is crucial for assessing soil carbon stocks, nutrient cycling, soil health, and the potential of soils to sequester carbon from the atmosphere, thereby mitigating climate change.

Soil Inorganic carbon

Soil inorganic carbon (SIC) refers to carbon compounds that do not contain carbon-hydrogen (C-H) bonds. In the context of carbon sequestration, inorganic carbon is often associated with minerals and compounds that can participate in geological processes. In the top 2 m, the carbon stocks, about 2500 Gt of world soils (Eswaran et al., 2000). The generation's concept shows that carbon sequestration occurs only in the first generation when calcium is released directly from silicates (Monger et al., 2015).

Carbonate Minerals:

Calcite ($CaCO_3$): Calcite is a common carbonate mineral and the primary constituent of limestone, marble, and chalk. It plays a significant role in geological processes, including carbon sequestration through mineral weathering. Calcareous soils of cotton growing areas under rainfed conditions enhance the formation of stable aggregates, and favours infiltration.

Dolomite ($CaMg(CO_3)_2$): Dolomite is another carbonate mineral that consists of calcium magnesium carbonate. It is often found in sedimentary rocks and can contribute to carbon sequestration through mineral weathering. Application of Ca & Mg rich silicate rock powder 10 kg m^{-2} to agricultural soils accelerates the crop yield (7%), biomass (11%) and 4.31 t CO_2 ha^{-1} of SIC by enhancing CS (20%) and increased net carbon capture 1.6-2.4 times of regional level in China (Guo et al., 2023)

Bicarbonate (HCO_3^-) and Carbonate (CO_3^{2-}) Ions - Dissolved Inorganic Carbon (DIC): In natural waters, carbon dioxide (CO_2) can dissolve and react with water to form bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions. This dissolved inorganic carbon is an important component of the carbon cycle in deeper soil depth. Together, inorganic carbon as soil carbonate (~940 PgC) and as bicarbonate in groundwater (~1404 PgC) surpass soil organic carbon (~1530 PgC) as the largest terrestrial pool of carbon (Monger et al., 2015).

Carbon Dioxide (CO_2) - Gaseous CO_2: While carbon dioxide is a gas at standard temperature and pressure, it can dissolve in water to form carbonic acid (H_2CO_3). This carbonic acid can further dissociate into bicarbonate and carbonate ions, contributing to the inorganic carbon content in water and soil. The leaching/absorption of CO_2 is the dominate mechanism of the inorganic C sequestration process in coastal wetlands (Wang et al., 2019)

Alkalinity: Alkalinity in Natural Waters: Alkalinity is a measure of the water's ability to neutralize acids. It is often associated with the presence of bicarbonate, carbonate, and hydroxide ions. Alkalinity contributes to the inorganic carbon content in aquatic systems. Alkaline soils contain considerable inorganic carbon as carbonates. The precipitation of secondary carbonates is major mechanism in carbon sequestration (Rashid et al., 2019).

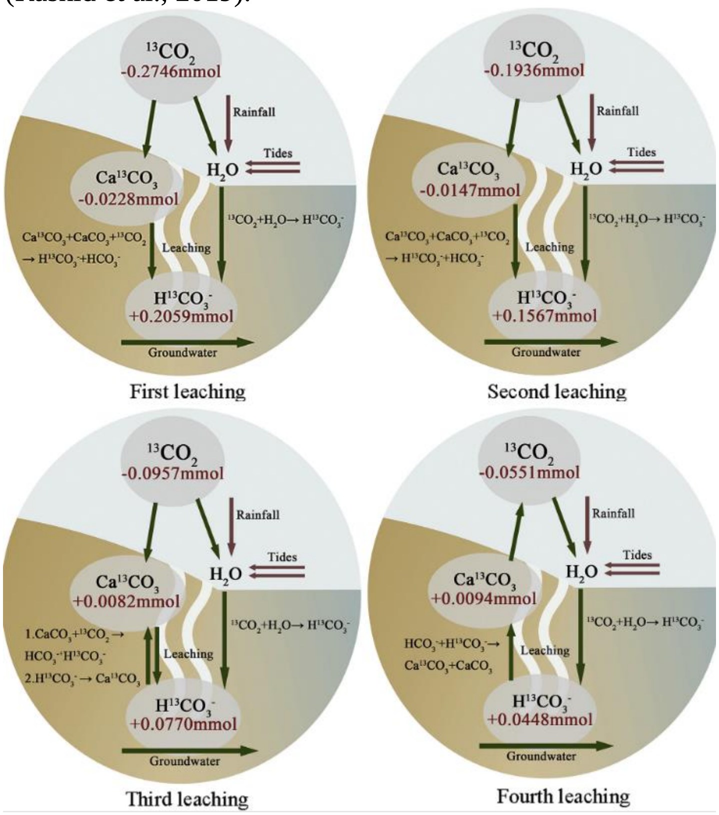

Figure 6. Quantitative processes of atmospheric CO_2 absorbed by coastal saline-alkali soil during successive four times leaching (Wang et al., 2019)

Mineral Weathering Products: Silicate minerals, such as olivine and basalt, can undergo weathering processes that result in the release of cations (e.g., calcium, magnesium) and the consumption of CO_2, leading to the formation of stable carbonate minerals.

These inorganic carbon forms play a role in various geological and environmental processes, including the long-term sequestration of carbon through mineralization. In the context of carbon capture and storage (CCS), the injection of CO_2 into geological formations often involves interactions with inorganic carbon compounds, leading to the formation of stable carbonates. Understanding these processes is crucial for assessing the feasibility and effectiveness of inorganic carbon sequestration strategies. Cotton cultivation and its connection to carbon sequestration can be examined from various perspectives, including the impact of cotton farming practices on soil carbon. It absorbs 0.5 kg of excess carbon than it emits. It's important to note that while certain practices within cotton farming (irrigation, fertilizer management) can contribute to carbon sequestration, the overall sustainability of the cotton industry involves addressing various environmental, social, and economic aspects. Sustainable cotton production often involves a combination of best management practices (Cover cropping, intercropping, mulching and biochar), technological innovations (Precision techniques and Regenerative cotton farming), and conservation measures to minimize negative environmental impacts. Certification systems, such as the Better Cotton Initiative (BCI) and organic cotton standards, aim to promote more sustainable and environmentally friendly practices within the cotton industry, including considerations for carbon sequestration and soil health.

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Soil Health Management to Combat Adverse Effect of Climate Change

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Rainfed agriculture constitutes 80% of global agriculture, and plays a critical role in achieving global food security. However, growing world population, water scarcity, and climate change threaten rainfed farming through increased vulnerability to droughts and other extreme weather events (Srinivasa Rao et al. 2015). A judicious combination of organic amendments and inorganic fertilizers is widely recognized strategy of integrated nutrient management (INM) to sustain agronomic productivity and improve soil fertility. Fertilizer applications and crop sequence can regulate C cycling dynamics and soil C storage through its effects on biological activity in soil and the amount and quality of residue returned to the soil (Gregorich, 2001). Soil management practices greatly affect the soil fertility and soil organic matter (SOM). The overall soil nutrient status and SOM levels depend upon factors such as crop rotation, tillage methods, fertility management including use of inorganic fertilizers and organic manures and other components of cropping system.

Food security faces increasing threats from anthropogenic climate change with current assessment methods predicting between 8 and 80 million additional people at risk of hunger by 2050 (Mbow et al., 2019). Climate change is a defining issue currently. A lot of significant long-term changes are happening in global climatic system which are visible all over the world. The direct solar radiations (enormous amount of heat/energy) striking on earth's surface is being trapped by Green House Gases (GHGs) like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), etc., resulting in atmospheric temperature increase. Specifically, the CO levels are at peak and its and its concentration has reached up to 410 ppm at present, which is a principal cause of warming effect (Srinivasa Rao et al. 2019).

The changing climate especially high temperature and poor or erratic rainfall patterns are aggravating the loss of organic carbon, and thereby it became a challenge for maintenance of organic carbon levels that could bring a positive impact on a long-term basis. Soils have the capacity to store 1500 Pg carbon, thrice the amount stored in terrestrial vegetation and twice that stored in the atmosphere. Soil carbon consists of both soil organic carbon (SOC) and soil inorganic carbon. Soil inorganic carbon is classified as lithogenic inorganic C and pedogenic inorganic carbon. Pedogenic inorganic carbon pool plays an important role in the global C cycle. However, it is well known that SOC also plays an important role in the global C cycle. Lal, 2003 reported global SOC storage is about 128-165 Pg C in croplands that is approximately 8%-10% of the terrestrial SOC pool. The Climate, hydrology, parent material, inherent soil fertility, biological activity, vegetation patterns, and land use are some of the external factors that affect SOC content in soils (Jenny, 1941). However, the adverse effects of climate change can be mitigated through an increase in the SOC content. Soil quality is how well soil does what we want it to do. More specifically, soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. Soil health can be defined as the capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity and maintain the water quality as well as plant, animal, and human health. Doran and Perkin (1994) identified the three main functions of soil: 1. To act as a medium for plant growth; 2. To regulate and partition water flow; and 3. To serve as an environmental buffer;

Soil Functions

Soil, is a non-renewable natural resource and has several functions in the biosphere and for human being. Soil functions are general or specific capabilities of soil for various agricultural, environmental, landscape and urban applications. Specific soil functions are manifold and may be grouped according to the principal purposes.

Climate-resilient agriculture

Climate-resilient agriculture is an approach that includes sustainably using existing natural resources through crop and livestock production systems to achieve long-term higher productivity and farm incomes under climate variabilities. In refers to the ability of an agricultural system to anticipate as well as adapt to, absorb and recover from the impacts of changes in climate and extreme weather. Increase in temperature can increase crop evapotranspiration, soil nutrient mineralization and salinity, reduce crop duration, fertilizer use efficiency and may affect survival and distribution of pests. Thus, changing climate is likely to have a significant influence on agriculture and eventually the food security and livelihoods of a large rural population. Most countries have been facing crises due to disasters and conflicts; food security, however, is adversely affected by inadequate food stocks, basic food price fluctuations, high demand for agro-fuels, and abrupt weather changes(Srinivasarao, 2021).Climate change shows impact directly or indirectly on crop, water and soil as it influences the water availability, changes the intensity and frequencies of drought, effects microbial population, soil organic matter reduction (Figure 1), yield reduction, depletion of soil fertility as driven by soil erosion, etc.

Scenarios in India

- Temperature risen 0.68 ^{0}C in the last century, to rise 1-2^{0}C by 2050, and 3-5^{0}C by 2100
- Rainfall to increase 10% by 2050 with an increased variability causing frequent floods and droughts
- Sea level risen 10-25 cm, to rise 50 cm by 2100
- Retreating glaciers in the Himalayas
- Shortened rabi season
- More incidence of disease and pests

Impact of climate change on soil

Climate change impact is continuously watching on the weather phenomena by meteorologists and climatologists around the world. And the impact is huge: more droughts and heat waves, more precipitations, more natural disasters like floods, hurricanes, storms and wildfires, frost-free season, *etc*. Climate impacts on agriculture lies the biophysical processes are highly dependent on climate variables such as radiation, temperature, and moisture that vary regionally. For example, rates of plant photosynthesis depend on the amount of photosynthetically active radiation and levels of atmospheric carbon dioxide (CO_2). Climate change will also have an impact on the soil. Higher air temperatures will cause higher soil temperatures, which should generally increase solution chemical reaction rates and diffusion-controlled reactions (Manjeet et al. 2023). Furthermore, higher temperatures will accelerate the decay of soil organic matter, resulting in release of CO2 to the atmosphere and decrease in carbon/nitrogen ratios (Buol et al., 1990). The largest producer of GHG emissions are China and United States (accounting for around 42%) (http:/ /cdiac.ornl.gov/trends/emis/tre_coun.html) and the third is India where agriculture is responsible for 18% of total national emissions. Soil organic matter decomposition is temperature sensitive and loss of SOC due to changes in C and N dynamics, altered nutrient bioavailability and reduction in soil biodiversity as result of climate change. This would result in poor soil health and in turn soil fertility.

Impact of climate change on soil quality

- Increased greenhouse gas in atmosphere
- Increased temperature
- Greater evapo-transpiration
- Soil water deficit
- Increased salinization
- More mineralization

Soil degradation, through nutrient depletion and loss of organic matter, causes serious yield decline closely related to water determinants. It affects water availability for crops through poor rainfall infiltration and plant water uptake due to weak roots. Investments in soil fertility directly improve water management. In India, watershed management trials in more than 300 villages found that subsistence farming practices had depleted soils not only of macronutrients but also of micronutrients beyond critical limits. Efficient management of land and water resources on watershed basis not only minimizes the risk of soil erosion hazards and crops failure but also increases the productivity of land per unit area and time.

Soil health management framework

Organic Carbon

GHG emissions have increased by up to 49.5 billion Mg (gigatons or Gt) of CO_2eq during 2010, which was greater than all earlier reported extremes (IPCC, 2014). The outcome of climate change is the change in temperature regime and change in precipitation patterns. The effects of climate change are expected to influence soil moisture conditions with effects on soil temperature and CO_2 levels. The organic carbon (OC) content of the soil is influenced by climatic factors, the biotic activity of plants and microbial communities, as well as the physic-chemical properties of the soil, all of which control its dynamics. Soil organic carbon (SOC) is an important component of the terrestrial carbon pool and plays a crucial role both in maintaining the functioning of ecosystems and in the global carbon cycle (Shibabaw et al. 2023). The amount of organic carbon in the soil is the result of a long-term balance process, between losses and accumulations (Wan et al 2021).

Key Soil Properties

With a change in climate, there would be a change in the chemical properties of the soil as heat and water will bring the chemical changes in the soil. The change in climate has a severe impact on the soil weathering process. It is evident from several studies that the soil CO_2 emission increases with an increase in air temperature. The extent of the increase in soil temperature with each unit increase in air temperature would be 487 units. Microorganism's population, structure, and composition are inhibited by the anticipated extreme temperature (Venati et al. 2020).

Different land management interventions such as minimum tillage, INM affect the soil as well as the production system's sustainability. Extreme weather conditions like high temperature and high rainfall decrease soil organic matter due to rapid oxidation and enhanced erosion process, respectively. Thus, the concept of use of INM, no-tillage and reduced tillage practices are evolved. A long-term study for 35 years (1988-89 to 2022-23) revealed that recommended dose of fertilizer along with farmyard manure helped to build up key soil properties that regulated the soil available nutrients supply to sorghum-wheat cropping system in Vertisols.

Strategies to accelerate Development of ainfed Agriculture

The quantitative and qualitative evaluation of predicted climate change effect on soil health is a difficult task due to uncertainties in the weather forecast. The scope, limit and support to pulses and oilseeds, coarse cereals, fodder, fuel high value enterprises like livestock, dryland horticulture, tree farming, sericulture, organic farming have to be decided.

- Community organization, self-help groups and cooperatives in tune with the socio-cultural values of rainfed farmers have to be revived.
- Upscaling and mainstreaming of proven available technologies and successful policy initiatives.
- Use of modern sciences like biotechnology, modeling, GIS and others in conjuction with available traditional wisdom to improve yield and reduce risk.
- Employment in and outside rainfed agriculture in rural areas to be enhanced to make them income secure and remunerative.
- Land development and water management to be emphasized with new watershed approach, farm mechanization and precision farming to make rainfed agriculture more competitive.
- Synergy between technologies, input supplies, credit, marketing systems policies and institutions.

Site Specific Interventions

1) In situ water management

Contour farming is one of the most effective methods for soil and water conservation and thereby increases productivity in dryland areas. Tilling at right angles to the slope of the land, each ridge acts as a small dam. In contour farming, the guide lines are required for ease in cultivation. Vetiver grass and Leucaena rows (0.5m VI) can be used (Fig. 4). These hedges act as guide lines as well as hedge against the soil erosion. At the AICRP Dryland Agriculture Akola Centre, vegetative barriers of different types and graded bunds were evaluated in sorghum and cotton for four years on each crop. On the basis of four years experimentation, the reduction in runoff was to the tune of 40-50% whereas; the reduction in soil loss was 70-75% in case of vegetative barriers as compared to across the slope sowing. Uniform moisture distribution due to contour cultivation gave higher productivity in case of test crops i.e. sorghum and cotton.

2) Broad Bed and furrow

In black soil areas, a raised land configuration "Broad Bed and furrow" (BBF) system has been found effective for in-situ soil and water conservation and proper drainage. BBF can be successfully used in medium to deep black soil (slope maximum up to 5%) areas receiving 700–1300mm rainfall. The raised bed portion acts as an in-situ 'bund' to conserve more moisture and ensures soil stability; the shallow furrows provide good surface drainage to promote aeration in the seedbed and root zone; prevents water logging of crops on the bed. The BBF design is quite flexible for accommodating crops and cropping systems with widely differing row spacing requirements. At Akola, BBF recorded higher moisture status in soil and higher yields of pigeon pea than no land configuration treatment.

3) Conservation furrows

Opening of furrows after two crop rows, parallel to the rainfed crop rows and across the prevailing land slope, 3-4 weeks after the germination of the main crop with the help of hoe tying rope to its tine is a simple and very low cost in-situ soil and water conservation practice for rainfed areas. This system is quite popular and already practiced by farmers in several SAT regions. During runoff causing rainfall events, the rainwater gets concentrated within these furrows, infiltrates into the soil (root zone) and is available to the crop for meeting the evapotranspiration demand for a longer duration compared to the control. It is suitable for alfisols and associated soil (1-4% slope) areas receiving 400 – 900 mm rainfall. The conservation furrows are temporary and therefore are required to be opened every season with kharif crops. The conservation furrow fields store 4-38 % additional soil moisture over control throughout the growing season, thereby resulting in 12-23 percent higher crop yields.

4) Vegetative bunds /interbund hedge

Most of the farmers' fields are bunded which requires rehabilitation every year, the farmers are unable to do this due to their economical status and hence the effectiveness of bunded area is being hampered day to day. To make graded bunds more effective one vegetative barrier in between two bunds is recommended. An integrated approach of interbund treatment proved beneficial which can increase adoption of the system by farmers. Studies were undertaken at Akola on vegetative barrier in bunded fields to see its impact for soil and water conservation. After five years experimentation on the same field, it was observed that, the productivity of soybean increased to the extent of 11.23% over no barrier and the runoff reduction was observed to be 18.51% in interbund treatment. It was also observed that, during the life span of graded bund, the vetiver barriers get established and takes care of soil and water conservation.

Mitigation and adaptation of ill effect on soil quality

To mitigate the ill-effects on soil quality and to protect the soil and land resource the following management interventions should be given more attention for sustenance of soil quality and climate resilient agriculture systems:

Conservation tillage: Conservation tillage reduced soil erosion, improve soil moisture, increase beneficial soil microbes, less fuel consumption, reduce soil compaction, reduced dust and smoke to pollute air, maintain soil nutrient and fertility. Promotes minimum disturbance to soil structure and enhance organic matter in the soil by increasing the decomposition of plants in-situ.

Components of Conservation Agriculture

1. Minimum tillage
2. Zero Tillage
3. Crop Residues
4. Cover crops
5. Crop rotation
6. Mulching

- **Soil organic carbon**: Loss of soil organic carbon (SOC) from agricultural land is identified as one of the major threats to soils, as it influences both soil fertility and the provision of ecosystem services. Thus, management of agricultural soils has a potential to mitigate climate change through SOC sequestration is important.

- **Tolerant crops:** To mitigate the drought conditions, early maturing and drought-tolerant crop varieties need to be grown.
- **Crop residue retention and recycling**: Crop residues can be returned to the soil for nutrient recycling, and to improve soil physical, chemical and biological properties and enhance the SOC level in soil. Increase water availability for crop production by improving infiltration and evaporation from the top layer and improving soil structure and moisture.
- **Crop rotation**: Effective crop rotations including legumes in cropping systems can help to improve the soil fertility
- **Adoption of soil water conservation practices**: Increased exploitation of ground water resulted in depletion of ground water level hence the holistic management of soil and water resources are indispensable for agricultural sustainability.
- **Land cover management and mulching of soils**: Growing aggressive cover crops and managed fallow systems enhance SOC content.
- **Precision farming**: Precision farming with soil testing-based decisions helps to utilize the inputs in precise amounts to get increased average yields. This is the most recent innovative technology based on sustainable agriculture and healthy food production. It consists of profitability and increasing production, economic efficiency and the reduction in side effects on the environment.
- **Components of precision agriculture**
- Precision agriculture has three components: i) capture of data at an appropriate scale, ii) interpretation and analysis of that data, and iii) implementation of a management response at an appropriate scale and time.
    - ✓ Geo-referenced Information
    - ✓ Global positioning system
    - ✓ Geographic information systems and mapping software
    - ✓ Yield mapping systems
    - ✓ Variable-rate technologies
    - ✓ Ground based sensors
    - ✓ Remote sensing
    - ✓ Decision support systems

Adopting best management practices (BMPs) for crops as per the latest technological advancements for all operations right from the land preparation to harvesting is essential to achieve higher efficiency, profitability and sustainability

Use of nano-technology: Nano-materials in agriculture will reduce the wastage in use of chemicals, minimize nutrient losses in fertilization and will be used to increase yield through pest and nutrient management. At present, the agricultural sector is facing various global challenges; climate change, urbanization, sustainable use of resources, and environmental issues such as run-off and accumulation of pesticides and fertilizers. These situations are further exacerbated by stagnation in crop yields, low nutrient use efficiency, declining soil organic matter, multi-nutrient deficiencies, climate change and shortage of labour besides exodus of people from farming. To overcome all these drawbacks a smarter way i.e., nanotechnology can be one of the sources.

Crop Residue Management

"The portion of a plant left in the field after harvest of the crop that is (straw, stalks, Stems, leaves, roots) not used domestically or sold commercially". Crop residues are good source of plant nutrients and good management of crop residues in an important way for buildup of organic matter status of soil and thereby improved soil fertility.

The country has potential to produced 330 million tonne crop residues every year which can provide 5.6 million tonne of plant nutrients annually. Therefore, the regular recycling of organic waste in the soil is most efficient on the use of organic input is aimed at the conservation and optimized utilization of available resource for maintain soil health and crop productivity

Conclusion

Soil degradation in India is the result of unsustainable and improper input management practices in agriculture, soil compacting, pollution in air, having a major impact on climate change. Maintaining soil Health are essential for increasing resilience to climate change by maintaining or increasing soil organic carbon content and reducing greenhouse gas emissions. Sustainable management interventions and improved soil health are key components in combating and increasing resilience to extreme weather events such as floods and droughts. Improvement in soil quality is one of the factor for sustainable soil health and crop productivity which is mainly evaluated by the influence of climatic and anthropogenic factors on soil properties. The ill effect of climate change scenario on key soil properties can be successfully achieved through sustainable management practices which contribute for improving climate neutrality.

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Soil and Water Conservation for Ecological Restoration: A Case Study

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Abstract: Soil and water conservation are prerequisite for sustainability of agriculture and ecological restoration of any area. Soil erosion disturbs agricultural, environmental and ecological functions performed by the soil and resulted in depletion of soil fertility, decreased moisture storage capacity and consequently in decreased crop productivity in addition to loss of soil fertility and crop yields. Soil erosion also increases environmental pollution, increasing the sediment load in streams and rivers, thereby disturbing the aquatic life. In the long run, soil erosion affects socio-economic conditions of the society by causing floods and silting up of water reservoirs. The Himalayan region of Tehri Garhwal has scattered habitations with scanty, non-perennial and unsafe water resources like springs and streams. Because of hilly and undulating terrain the area is vulnerable to soil erosion resulting into loss of soil fertility and productivity. Deforestation, over-grazing, intensive cultivation, mismanagement of cultivated soils and intensive urbanization are also triggering the soil erosion. Therefore, interventions were undertaken for soil and water conservation for sustainable agriculture along with environmental protection of the streams and springs for sustained water availability and safe drinking water supply with active public participation, training, and awareness programs. Various soil and water conservation structures like chaals/ponds, contour bunds, and terraces were constructed at suitable sites along with rooftop rainwater harvesting tanks in selected villages. Design and commissioning of a small slow sand filtration unit was undertaken at Nakot village for safe drinking water supply. Soil and water quality assessment in the project villages were conducted before and after technological intervention. The beneficiary's opinions, perceptions, apprehensions, as well as expectations from the project reflected positively towards the achievements of anticipated benefits and impacts. The demands and desires expressed by people from other villages in the region to implement similar activities in their villages is self-explanatory towards the success and popularity of the approach adapted.

Key words: Soil water conservation, ecological restoration, drinking water supply, rainwater harvesting, slow sand filtration, health survey

Introduction

Ecological restoration aims to recreate, initiate, or accelerate the recovery of an ecosystem that has been disturbed. Conservation of soil and water resources is important for sustainability of agriculture and environment. Soil and water resources are under immense pressure due to ever increasing population thereby ensuing growing demand for food, fiber and shelter. Soil and water resources are being deteriorated due to different anthropogenic and natural factors. Soil erosion is one of the several major deteriorative processes which results in deterioration of the soil and may lead to the significant loss of soil productivity

Water is precious natural resource for sustaining life and environment. It is in a continuous circulatory movement between land, ocean, and atmosphere – the hydrological cycle[1]. Once viewed as an infinite and bountiful resource, water today defines human, social and economic development. Water resource management is an important parameter for the development of any nation as it directly relates to the development and growth of the economy[2]. Water scarcity is a serious problem in India for both urban and rural communities. Population growth and irrigation requirements have resulted in overexploitation of ground water, whereas urbanization causes reduction in open soil surface and water infiltration rate and a resultant deterioration in water quality[3]. Poor environmental conditions arising from unsafe drinking water, inadequate sanitary measures, unhygienic disposal of excreta, sullage and accumulation of solid wastes resulted in poor public health.

Study Area

The study area comprises a group of villages in Chamba block of Tehri Garhwal district in Uttaranchal state, India and falls in the sub-tropical climatic zone of the Himalaya. The area is hilly terrain and lies between 30^0 18' to 30^0 25' N latitude and 78° 20' to 78° 30' E longitude and falls in the catchment of Maniyar river which is a tributary of Bhagirathi River. Being a hilly area, the altitude ranges between 1150 m and 1900 m. The Krol Belt of Lesser Himalayans dominates the geology of the area. The rocks comprise massive gray limestone, dolomite and some bands of phyllite, slate and quartzite. Because of undulating topography, land use is of much diversified nature, varies from agriculture, horticulture, forestry and wastelands.

Methodology

The Himalayan region of Tehri Garhwal has scattered habitations with scanty, non-perennial and unsafe water resources like springs and streams. Because of hilly and undulating terrain, the area is vulnerable to soil erosion resulting into loss of soil fertility and productivity. Deforestation, over-grazing, intensive cultivation, mismanagement of cultivated soils and intensive urbanization are also triggering the soil erosion. Therefore, interventions were undertaken for soil and water conservation for sustainable agriculture along with environmental protection of the streams and springs for sustained water availability and safe drinking water supply. In view of this, some of the innovative ideas implemented in the study are:

- Delineation of strategies for sustainable availability of water
- Protection of streams and springs with suitable conservation measures
- Construction and demonstration of rain water harvesting structures
- Application of water treatment technologies for safe drinking water supply to villages
- Development of water distribution techniques for irrigation availing natural gradient
- Demonstration of benefits of environmentally compatible intervention.
- Training and awareness programs
- Health survey – pre and post intervention

The study aimed at development of technologies for sustainable soil and water resources management emphasizing environmental protection of the study area.

Interventions undertaken

Soil and water conservation: Various soil conservation measures like 1. Digging of pits in catchment area and farm 2. Gully plugging 3. Construction of check dams and sub-surface dams, 4. Adoption of terrace cultivation in sloping lands, 5. Contour bunding, 6. Contour trenching etc. were undertaken based on soil and site suitability. The conservation measures helped in conserving rainwater and allow it to percolate in soil strata and groundwater recharge.

Water supply and quality: Springs are the major natural sources of drinking water in the area. The water quality assessment of sources of water supply for the study village was carried out to assess the water quality. The water quality varies from place to place depending upon the characteristics of the strata and time of contact of water with the bed rock (Table 1). All the physico-chemical parameters are within desirable limits (BIS:10500-2012). Thus, the quality of water is adequately safe for human consumption.

Rainwater harvesting structures: In hilly region, people use water from springs or seepage from hills coming out as through flow. Many times, such water is not fit for drinking purposes. Women have to fetch water from wells, ponds, lakes etc. from long distances and climb few hundred meters which consume lot of time and energy. Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams[4]. Rainwater is collected from roofs or other impermeable surfaces and is stored for later use especially during scarcity period. The water can be used for non-potable uses such as irrigation, toilet flushing etc. Additionally, if the water is properly treated, it can be used for human consumption.

Slow sand filtration: Slow sand filers are used in water purification for treating raw water to produce potable water[5]. Slow sand filtration is a water treatment process in which the water to be purified is passed through a porous bed of filter medium and filtrate is collected from the bottom[6,7]. During this passage the water quality improves considerably by reduction, removal, and changes in biological, physical and chemical composition of raw water. In a mature bed the formation of a gelatinous layer (or biofilm / the hypogeal layer / schmutzdecke layer) forms on the surface of the bed[8]. It consists of a great variety of biologically active microorganisms, which break down organic matter, while a great deal of suspended inorganic matter is retained by straining.

The pot chlorinator: If water is contaminated but clear, disinfection can be used to kill microorganisms it contains. Using chlorine for this purpose provide a residual that helps in preventing re-contamination[8]. A method or device developed by NEERI has effective chlorination of storage tanks and wells in rural areas for about 12 to 15 days. The filtered water from SSF-plant is stored in a reservoir for supply to consumers. Pot chlorinator is being used to disinfect the water from reservoir prior to public supply. Pot chlorinators also installed in rain water harvesting tanks wherefrom water is used for drinking purpose.

Training and awareness programs: Training was imparted to participants from nearby villages which includes Gram-Pradhan, Elected leaders of the villages, Members of village-panchayat, Ex-Gram Pradhan, President and Representatives of Mahila Mandal, Teachers, Health Workers, Local Social Workers and project personnel working in the area.

Summary and findings

The salient observations and discussion pertaining to work carried out are as follows:

- Water conservation structures improves water availability in the area
- Development of Chaals/ponds were found suitable for groundwater recharge in the area
- Rooftop water harvesting structures found suitable for fulfilling the water need of individual houses for domestic uses during scarcity period
- The filtration units in rooftop water harvesting structures and pot chlorinator system are successful in safe water supply. This technology is simple, economical and most practically suitable hence, conveniently adopted for rural area
- The rural people in general understood and realized the importance of water management and look forward to learn the new things and practicing them in the village
- Such activities were also demanded by the people of other villages in the region, which showed the significance, and development of interest. This also indicated the popularity and positive impact of the work done in this project

Conclusion

The soil and water conservation and rainwater harvesting for groundwater recharge and safe drinking water supply with environmental protection was the main focus for implementing the project. The design, development and commissioning of various structures has resulted improved groundwater recharge and safe water supply in the study area. The design, development and, commissioning of appropriate technological intervention through SSF plant with the introduction of pot chlorinator has resulted in improved and safe water supply in the village. The environmental awareness programs and training has interactive participation to change current non-scientific thinking and practices. The pre and post assessment of socio-economic survey, water quality, health survey and beneficiary's opinion reflect positively in achievements of anticipated benefits and impacts. Improved sense of belonging expressed by way of active participation by the community of villages encourages the activities of the project. The demand and desires expressed by people of other villages in the region to implement the same project in their respective villages is self-explanatory towards the success and popularity of the approach adapted.

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Generation of Detailed Soil Information for the Virudhunagar Aspirational District of Tamil Nadu using Remote Sensing & GIS Techniques for Developmental Planning

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Introduction

Soil and water are the most vital natural resources essential for sustenance of mankind on the earth. Soil and land resource information is essential for developmental planning on watershed basis to mitigate the challenges posed by climate change and GHG emissions etc. Survey involves systematic examination of soils in the field and in laboratory characterization and classifying the soils followed by mapping. Detailed soil survey aims in generating scientific database on soil and land resources to develop a comprehensive Soil information system for planning, designing and implementation of agricultural development and integrated watershed management program.

Aspirational Districts Programme (ADP):

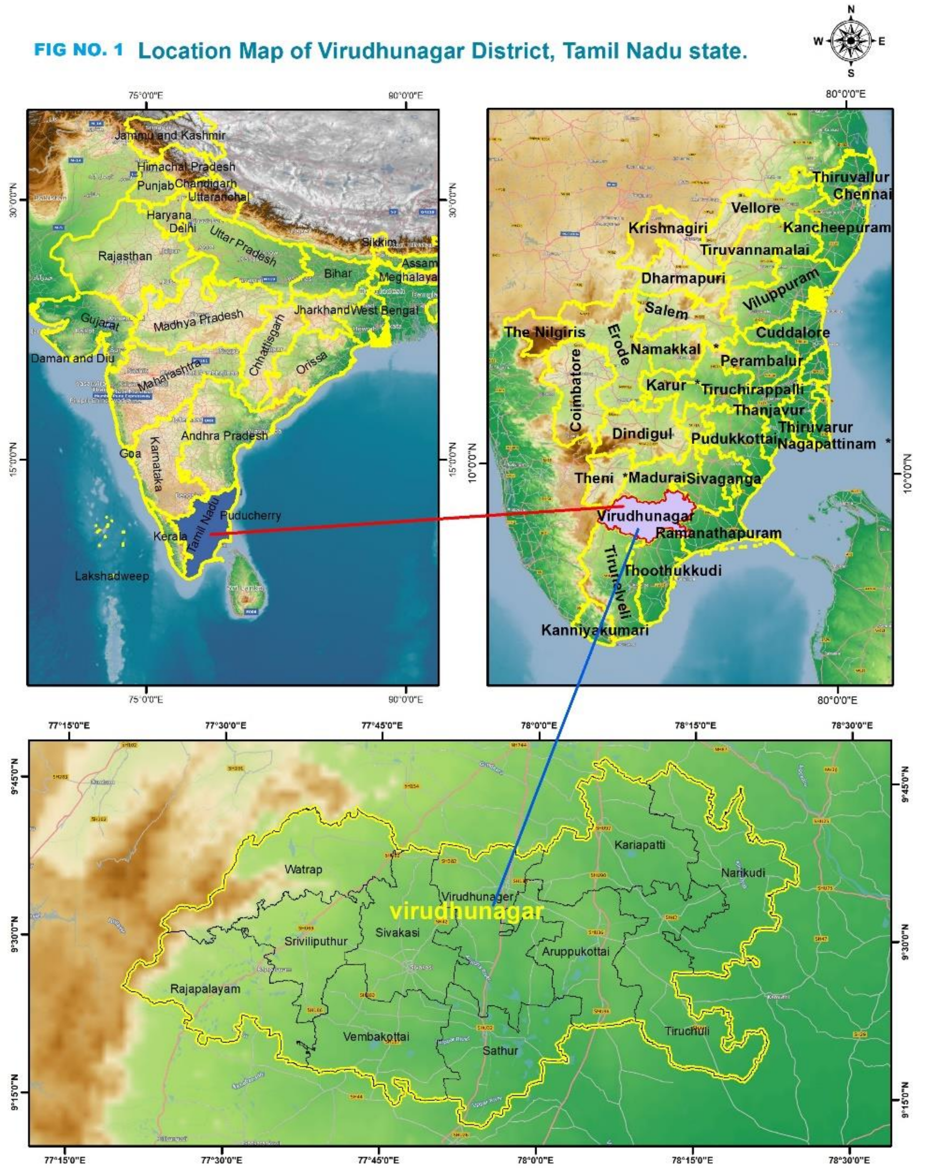
Launched by the Hon'ble PM in January 2018, the Aspirational Districts Programme (ADP) aims to quickly and effectively transform 112 most under-developed districts across the country. The Government is committed to raising the living standards of its citizens and ensuring inclusive growth for all – "**Sabka Saath Sabka Vikas aur Sabka Vishwas**". To enable utilization of their potential, this program closely focuses on improving people's ability to participate fully in the burgeoning economy. NITI Aayog works closely with the respective line Ministries and various development partners to fast-track progress at the district level. The districts are also encouraged to develop and replicate best practices that drive improvement across the socio-economic themes. The Aspirational Districts Programme essentially is aimed at localizing Sustainable Development Goals, leading to the progress of the nation. To boost the agriculture sector "Krishi Kalyan Abhiyan" (KKA) was launched by Ministry of Agriculture and Farmers' Welfare" in the Aspirational districts. Virudhunagar and Ramanathapuram Districts are allotted under Aspirational districts for Generation of Detailed Soil Information and for Developmental Planning.

The present work of Detailed Soil Survey and Land Use data base have been generated in Virudhunagar District from Kanyakumari to Caurvey River Basin 4A (Vaippar and Gundar), Catchment-4A1 and 4A2 and Sub-Catchment 4A1C, D &4A2A using GIS and Remote Sensing Techniques (Watershed Atlas of India, 2012). The database generated out of the survey, help evaluate the productive potentials and limitations of the land resource for optional land use planning and watershed management.

Location of the District

Study area: The Virudhunagar District lies between 77° 20' 11" to 78° 25' 15" East Longitudes and 9° 11' 39" to 9° 46' 41" North Latitudes. Virudhunagar District consist of 11 Blocks such as Srivilliputhur, Rajapalayam, Watrap, Vembakottai, Sivakasi, Virudhunagar, Sattur, Kariapatti, Aruppukottai, Narikudi and Tiruchuli. The location map of the study area is shown as Fig.-1. The district lies under Agro-climatic zone- X- Southern Plateau and Hilly region. The area lies between the Western Ghats Region in the west to Easteren plain in the South East.of India and occupying an area of **4.24 Lakh hectare.** The Geology includes Granite Gneiss, Charnokite, Sandstone, Laterite and Alluvium. The Physiographic unit identified are Hills side slopes, Pediments, Upper pedi-plains, Lower pedi-plains, Alluvial plains and Stream banks.

FIG NO. 1 Location Map of Virudhunagar District, Tamil Nadu state.



The major land use/ land cover categories identified within the study area are: Agriculture, plantation, forest, culturable waste lands, open scrub land, water bodies, habitation and other miscellaneous lands.

Results and Discussion

Based on the Satellite data, Survey of India Toposheets and field survey, the Geology and physiography of the district was identified and delineated. Based on different morphological characteristics of the soil 44 soil series are identified. Major Geology in the study area is Granite Gneiss and major physiographic units in the study area are Upper Pediplains followed by Lower Pediplains. Very deep soil occupied 41.91 % followed by deep soil 19.05 %. Most of the area having very gently sloping of 61.34 % and majority area affected by moderate erosion. The Comprehensive System of Soil Classification (Soil Taxonomy, 2014) was followed to classify the different soils to correlate the physiographic and taxonomic units. Soils of the district were classified under orders Alfisol, Entisols, Inceptisols, and Vertisol. Among them Inceptisols (39.49 %) and Vertisols (28.79 %) dominated in the Virudhunagar District. Majority of the soil series interpreted in Land Capability Classes II (33.66%) and III (39.64%). Present Soil information under different subheads as indicated below

1. Major Soils of Virudhunagar District:

Out of 44 soil series, 23 major soil series and its description given below

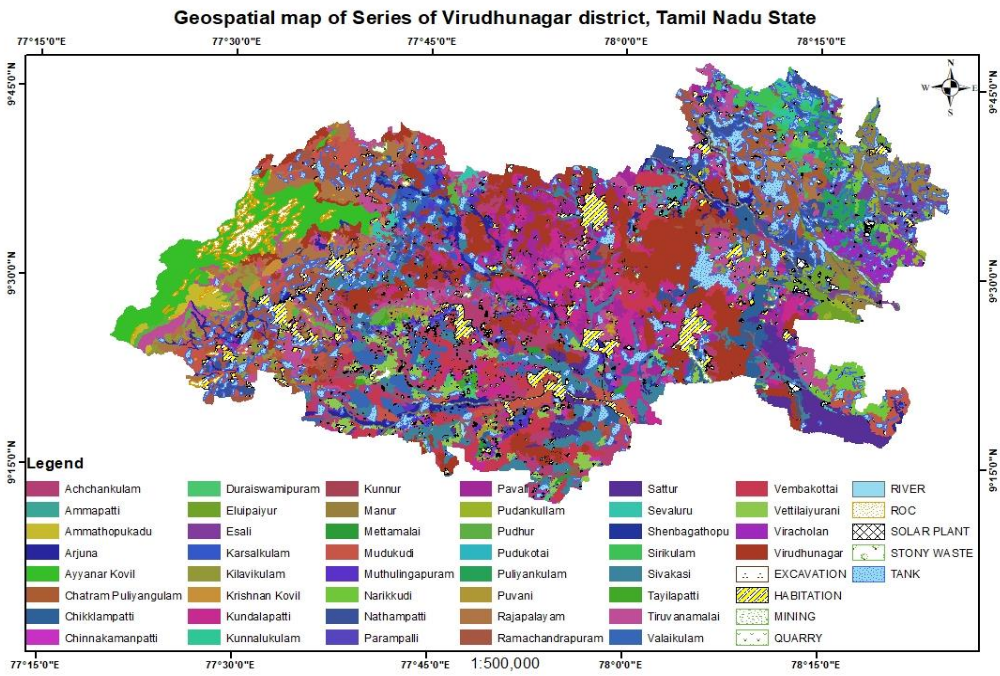
Sl No.	Soil Series	Description
1	Achchankulam	Achchankulam series comprises deep, clay loam to clay texture, very gently sloping to gently (1-5%), slight to moderate water erosion, imperfectly drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Montmorillonitic, isohyperthermic Leptic Haplusterts
2	Ayyanar Kovil	Ayyanar Kovil series comprises shallow, gravelly sandy clay loam skeletal texture, steep to very steep sloping (25 -50%), severe water erosion, excessively drained soils with LCC VI and Soil Taxonomic Classification: Loamy skeletal, Shallow, Mixed, isohyperthermic Typic Ustorthents
3	Ammapatti	Ammapatti series comprises moderately deep, sandy clay loam to sandy clay texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC III and Soil Taxonomic Classification: Loamy, Shallow Mixed, isohyperthermic Typic Calciustepts
4	Chikklampatti	Chikklampatti series comprises deep, sandy clay loam to sandy clay texture, gently sloping (3 - 5%), moderate water erosion, moderately well drained soils with LCC III and Soil Taxonomic Classification: Fine loamy, Mixed, isohyperthermic Typic Haplustepts
5	Chinnakamanpatti	Chinnakamanpatti series comprises shallow, sandy loam to sandy clay loam texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC IV and Soil Taxonomic Classification: Loamy, Shallow, Mixed, isohyperthermic Typic Ustorthents
6	Eluipaiyur	Eluipaiyur series comprises very deep, sandy clay loam to clay texture, very gently to gently sloping (1 - 5%), moderate water erosion, moderately well drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Oxyaquic Haplustepts
7	Esali	Esali series comprises very deep, sandy loam to sandy clay texture, nearly level to very gently sloping (0 - 3%), none to slight water erosion, moderately well drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Typic Haplustepts
8	Kilavikulam	Kilavikulam series comprises deep, sandy clay loam to clay texture, very gently sloping (1 - 3%), moderate water erosion, well drained soils with LCC III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Typic Haplustalfs
9	Kunnalukulam	Kunnalukulam series comprises deep, sandy clay loam to sandy clay texture, very gently to gently sloping (1 -5%), moderate water erosion, moderately well drained soils with LCC II to III and Soil Taxonomic Classification: Fine loamy, Mixed, isohyperthermic Typic Haplustalfs
10	Mettamalai	Mettamalai series comprises shallow, sandy loam to clay loam texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC IV and Soil Taxonomic Classification: Loamy, Shallow, Mixed, isohyperthermic Typic Ustorthents
11	Muthulingapuram	Muthulingapuram series comprises moderately deep, sandy loam to sandy clay loam texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC III and Soil Taxonomic Classification: Loamy, Shallow, Mixed, isohyperthermic Typic Haplustepts

Sl No.	Soil Series	Description
12	Narikkudi	Narikkudi series comprises very deep, sandy loam to clay loam texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC III and Soil Taxonomic Classification: Loamy, Mixed, isohyperthermic Typic Haplustepts
13	Nathampatti	Nathampatti series comprises very deep, clay loam to clay texture, very gently to gently sloping (1 - 5%), moderate water erosion, moderately well drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Typic Haplustepts
14	Parampalli	Parampalli series comprises shallow, gravelly sandy loam to gravelly sandy clay loam loamy skeletal texture, very gently to gently sloping (1 - 5%), moderate water erosion to severe water erosion., well drained soils with LCC IV and Soil Taxonomic Classification: Loamy skeletal, Shallow, Mixed, isohyperthermic Typic Ustorthents
15	Rajapalayam	Rajapalayam series comprises very deep, sandy loam to sandy clay texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Typic Haplustalfs
16	Ramachandarapuram	Ramachandarapuram series comprises very deep, sandy clay loam to clay texture, very gently to gently sloping (1 - 5%), none to slight water erosion to moderate water erosion, poorly drained soils developed with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Vertic Haplustepts
17	Sivakasi	Sivakasi series comprises very deep, sandy clay loam to clay fine texture, very gently to gently sloping (1 - 5%), none to slight water erosion to moderate water erosion, imperfectly drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Montmorillonitic, isohyperthermic Typic Haplusterts
18	Shenbagathopu	Shenbagathopu series comprises shallow, gravelly sandy clay loam loamy skeletal texture, moderately sloping (5 - 10%), severe water erosion, excessively drained soils with LCC VI and Soil Taxonomic Classification: Loamy skeletal, Shallow, Mixed, isohyperthermic Typic Ustorthents
19	Tayilpatti	Tayilpatti series comprises shallow, gravelly sandy loam loamy skeletal texture, very gently to gently sloping (1 -5%), moderate water erosion to severe water erosion, moderately well drained soils with LCC IV and Soil Taxonomic Classification: Loamy skeletal, Shallow, Mixed, isohyperthermic Typic Ustorthents
20	Viracholan	Viracholan series comprises very deep, Sandy loam to sandy clay texture, nearly level to very gently sloping (0 - 3%), none to slight water erosion to moderate water erosion, well drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Fluventic Haplustepts
21	Virudhunagar	Virudhunagar series comprises very deep, clay loam to clay fine texture, very gently sloping (1-3%), slight water erosion to severe water erosion, imperfectly drained soils with LCC II to IV and Soil Taxonomic Classification: Fine, Montmorillonitic, isohyperthermic Typic Haplusterts
22	Vembakottai	Vembakottai series comprises deep, clay loam to clay texture very gently to gently sloping (1 - 5%), moderate water erosion, imperfectly drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Montmorillonitic, isohyperthermic Leptic Haplusterts

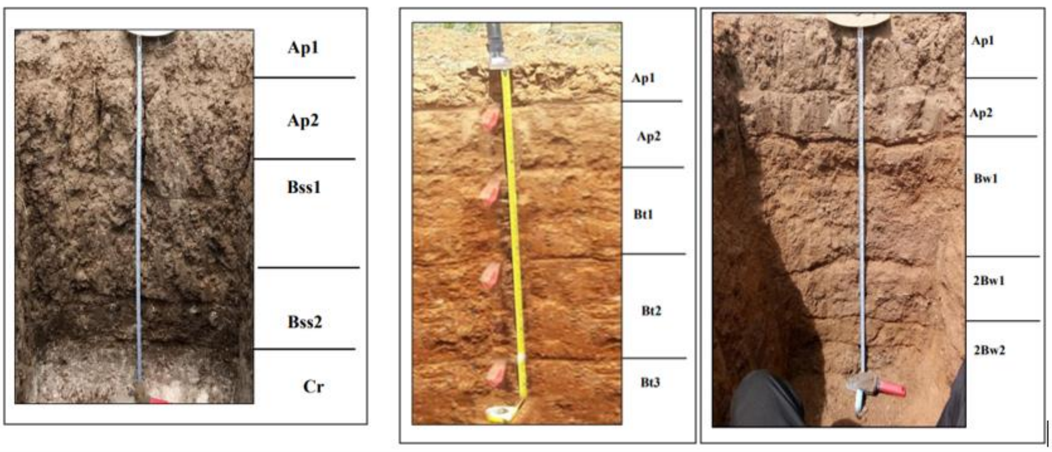
Sl No.	Soil Series	Description
23	Valaikulam	Valaikulam series comprises very deep, sandy loam to sandy clay loam texture, very gently to gently sloping (1 - 5%), moderate water erosion to severe water erosion, well drained soils with LCC II to III and Soil Taxonomic Classification; Fine, Mixed, isohyperthermic Typic Rhodustalfs

Source: Compendium of Soil and Land Resources Database (2014), Soil and Land Use Survey of India, NewDelhi-110012.

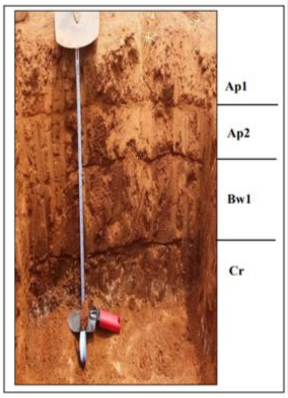
Soil Series Geo-spatial map and glimpses of Profiles and its classification



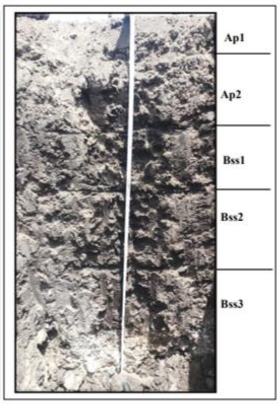
Achchankulam — **Leptic Haplusterts** | **Rajapalayam** — **Typic Haplustalfs** | **Arjuna** — **Fluventic Haplustepts,**



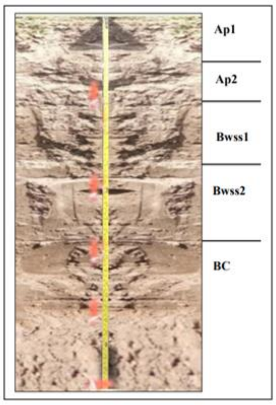
Muthulingapuram
Typic Haplustepts



Virudhunagar
Typic Haplusterts



Ramachandrapuram
Vertic Haplustepts



2. Land Use:

i. Major crops grown and fertilizer recommendation are given below (Table 1)

Table-1. Season wise crops and fertilizer recommendation (Kg /ha) for Virudhunagar district

Season	Crops	Seed rate (Kg /ha)	Spacing (cm)	Fertilizer recommendation (Kg /ha)			
				N	P	K	Micronutrients mixture
Kharif	Paddy	50	12.5 x 10	120	38	38	12.5
Rabi	Sorghum	10	45 x 15	16	8	0	12.5
Rabi	Pearl millet	5	45 x 15	16	8	0	12.5
Rabi	Maize	20	60 x 20	135	62.5	50	12.5
Rabi	Foxtail	5	25 x 10	44	22	0	12.5
Rabi	Black gram	20	30 x 10	12.5	25	0	5
Rabi	Green gram	20	30 x 10	12.5	25	0	5
Rabi	Cowpea	20	30 x 15	12.5	25	0	5
Rabi	Groundnut	140	30 x 10	10	10	45	60 (s)
Rabi	Sunflower	10	60 x 30	30	15	15	0
Rabi	Gingelly	5	15 x 15	23	13	13	0
Rabi	Cotton	2	120 x 60	120	60	60	12.5

***Source:* Additional Director of Agriculture, Sivakasi Taluk, Virudhunagar District (Tamilnadu)**

The following cropping patterns are followed in the survey area of Virudhunagar district:

Sole Crops: Paddy, Jowar, Pearl millet, Maize, Foxtail, Ragi, Black gram, Green gram, Red gram, Bengal gram, Horse gram, , cotton etc .

Inter cropping system: Maize + Cowpea, Groundnut + Gingelly, Cotton + Green gram etc.

Cereals, pulses, and millets, which do not require much irrigation, are the main crops grown. Paddy is grown where tank or bore well irrigation is available.

ii. Soil / Land resource potential and constraints for agriculture:

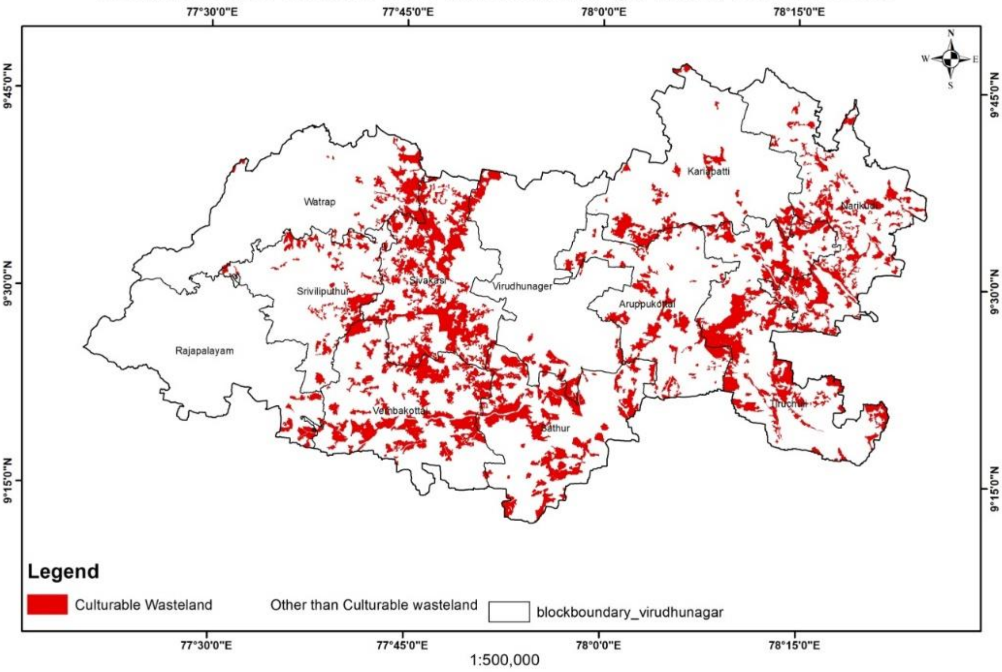
The soils of the district are of poor productivity and are mainly coarse loamy to clay soil (locally known as Karisal mannu). Black soil in the major parts of the district, the recharge potentials are very low and it has also resulted in water quality problems. In order to increase the recharge, tanks, percolation ponds may be provided with the recharge wells/recharge shafts penetrating this impervious layer to make it more effective in recharging the aquifer (A. Balachandran, Central Ground Water Board, 2009). Major area is under very deep soils with low hydraulic conductivity. It is difficult to plough and high-power tillage implements are required. These soils are used for mostly dryland cultivation and partially Occupied as Culturable waste lands.

iii. Culturable Waste Lands of the Virudhunagar District:

Out of 44 soil series identified in this district, 38 soil series are having a culturable waste lands of 68,098 ha (16.10 %). Vembakottai, Sivakasi, Sattur, Narikudi and Tiruchuli blocks are highly affected. Most of the culturable waste lands area is dominated with Acacia species and scrub land. It leads to Increasing biotic pressure, absence of adequate investments and appropriate management practices. Virudhunagar (2.21%), Achchankulam (1.68%), Chikklampatti (1.11%) Vembakottai (1.12%) and Sivakasi (1.06%) series are dominated with culturable waste land and most of them are vertisol in nature.

Alternate land use option for culturable wasteland: Removal of Acacia species and scrub land and grow suitable dry land crops such as Jowar, Pearl millet, Maize, Ragi, Black gram, green gram, Red gram etc. Practice of cultivating crops along with horticulture component such as Mango, Sapota, Guava, Ber, Tamarind, Custard apple, Wood apple, Jamun, Bael, Jackfruit and Cashew plantation in red soil also suggested here. Vegetables such as Drumstick, Curry leaf, Tomato, Chilli and Cluster bean and aromatic crops i.e. lemon grass, citronella and khus grass are also suitable (G. M. Sujith, Alternate Land Use Systems, UAS, Bangalore).

Geospatial map of Culturable waste land of Virudhunagar district, Tamil Nadu State



iv. Central/State sponsored agricultural developmental schemes:

Kalaignar's All Village Integrated Agriculture Development Project (KAVIADP) was initiated in 2021-22 by Govt. of TamilNadu. The programme aims at overall development of villages and transforming them to be self-sufficient. Particularly for selection of wasteland clusters to be converted into agriculture lands, constructing a borewell/tube well and the electricity connection or solar power pump and providing seeds of toor dal, black gram, green gram etc.,

Integrated Wasteland Development Programme (IWDP) was started in the year 1992 by Government of India, mainly for development of wastelands in non-forest areas in totality by involving local people at every stage of development. Major programme implemented for improving the productivity of waste & degraded lands keeping in view the poverty, backwardness, gender & equity is Integrated Wasteland Development Programme.

Conclusions

The study helps in evaluating the land use and land cover in the district of Virudhunagar includes its Blocks and Villages. The study revealed that Sustainable Agriculture Development in the district possible through via. Integrated Nutrient Management, Integrated Wastelands Development Programme, Agroforestry, Social forestry etc in dryland areas. In-situ soil and moisture conservation measures like terracing, bunding, trenching, vegetative barriers and drainage line treatment by vegetative and engineering structures are very essential. Remove Acacia species and scrub lands cultivate them with suitable dry land and Horticulture crops. Dry land field crops such as Jowar, Pearl millet, Maize, Ragi, Black gram, Green gram, Red gram etc. and horticultural crops such as Mango, Sapota, Guava, Ber, Tamarind, Custard apple, Wood apple, Jamun, Bael, Jackfruit etc are suitable here. Planting and sowing of multi-purpose trees, shrubs, grasses, legumes which encourage natural vegetative regeneration. Wood species substitution and fuel wood conservation measures also essential. Awareness programmes, training & extension activitivites essential for sustainable development of the Virudhunagar District. Encouraging people's participation through community organization and capacity building. Development of small water Harvesting Structures and afforestation of degraded forest and non-forest wastelands are also very essential.

Landscape Characterization Using Geospatial Technology for Resource Inventory, Restoration and Ecological Sustainability

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Introduction

Geospatial Technology can create various natural resource information layers in the shortest possible time. Further, their capability to generate information in the spatial domain allows the overlay and further analysis in a systematic and compatible manner. Landscape assessment is a sub-category of Environmental Impact Assessment (EIA) concerned with a landscape's quality assessment. A landscape can be assessed as a part of planning phases to identify the potential of the landscape, keeping in mind a specific objective or concerning a particular development that might affect the landscape. It involves several stages of working, which involve defined phases through which the process undergoes to provide specific results or insights. The methods or aspects considered for landscape assessment depend on its objectives. It may vary from assessing the land management practices in a particular area to studies that identify the effects of anthropological activities in and around forested areas. Such studies are important sources of information as they provide first-hand observations and details regarding the landscape. Some critical information that can be obtained through such studies are the loss of forest cover and its causes, urbanization activities, disaster management data, land degradation and climate change over set periods. If robustly and rigorously applied, landscape assessment can shed light on both the approach and decision-making process of managing landscapes. This landscape assessment provides valuable insights into how the area under study can be effectively used to maintain an ecological balance between all essential factors within the landscape. Macleod and Congalton (1998) list four aspects of change detection that are essential when monitoring natural resources: detecting those changes have occurred, identifying the nature of the change, measuring the areal extent of the change, and assessing the spatial pattern of the change. The FAO project "Green-Ag: Transforming Indian Agriculture for Global Environmental Benefits and the Conservation of Critical Biodiversity and Forest Landscapes" aims the harmonization of India's agricultural and environmental sector priorities and investments. Chambal Landscape, MP, one of the landscape selected and studied, for landscape analysis has a unique set of endemic and globally threatened species in its riverine, ravine, and forest ecosystems.

Study area

The Chambal region is a unique landscape of Madhya Pradesh, which Comprises three districts: Morena, Bhind, and Sheopur. The study area, Chambal landscape, includes Vijaypur and Sabalgarh blocks in Sheopur and Morena districts, covering an area of 97982 ha. The study area is located between 25° 54' 20" and 26° 18' 58" N latitudes and 76° 51' 58" and 77° 23' 10" E longitudes at a height of 175 meters above mean sea level. The notable feature of the landscape is the deeply eroded gullies (ravines) that have developed in the alluvium-derived soils through centuries of severe land degradation caused by indiscriminate land-use practices and surface run-off mismanagement. Deforestation, overgrazing, and ill-considered tillage practices have contributed to wind and water erosion. This susceptibility is partly due to the intensity and concentration of rainfall during the monsoon and partly due to the erodibility of the deep, alluvial soils in this region. The study area hosts several globally significant species, including the critically endangered Gharial (*Gavialis gangeticus*), the critically endangered Red-crowned Roofed Turtle (*Batagur kachuga*), the endangered Ganges River Dolphin (*Platanista gangetica*). Other vulnerable and important species of the sanctuary include the Indian Mugger Crocodile (*Crocodylus palustris) also* known as the Indian Marsh Crocodile) and the Smooth-coated Otter (*Lutrogale perspicillata*). The National Chambal Sanctuary is also listed as an important bird area

(IBA) and is a proposed Ramsar site. At least 320 resident and migratory bird species have been recorded from the sanctuary.

Methodology

Multi-temporal IRS LISS IV data from 2009, 2015, and 2021 were used to map the area's LULC and change detection with respect to each year mentioned. LULC was mapped homogeneously at 1:25,000 scale for all three years for proper comparison and change dynamics. The present study used geospatial technologies to identify trends and patterns of temporal changes in land use/land cover at three different times, i.e., 2009-10, 2015-16, and 2021-22, to assess the impact of past management practices, the present status of the landscape features and decide on management interventions to achieve the objectives. Along with land use land cover, factors with negative ecological impacts on the landscape, like land degradation, fire frequency, forest degradation, flood susceptibility, , sand mining, waterlogging, conversion of ravenous land to agriculture areas, etc., were analyzed along with the climatic data for the current challenges and proposed actions to achieve the expected impacts. Hotspot analysis has been carried out using the Getis-Ord GI* statistic to understand statistically significant clustering in the spatial pattern of remote sensing amenable disturbances / positive contributions. The study documented the present and past status of the landscape features in qualitative and quantitative natures, hotspots of positive and negative changes, drivers of changes, vulnerability, and threats to the system for landscape planning to ensure that its negative environmental impacts are mitigated, and positive contributions are enhanced.

Results and Discussion

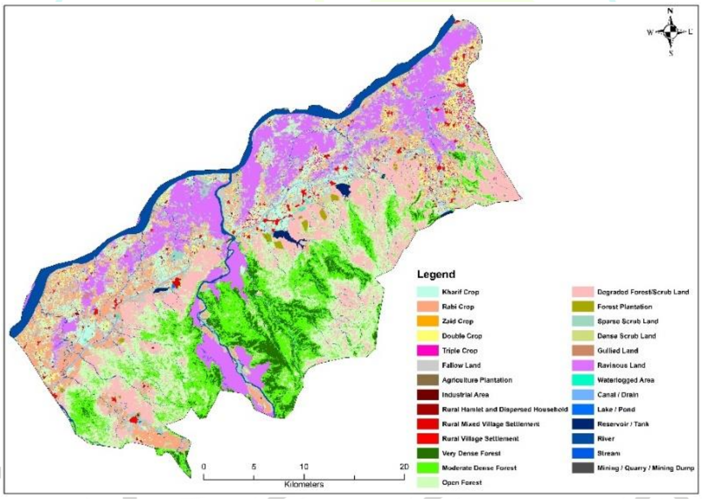
The present study used geospatial technologies to identify trends and patterns of temporal changes in land use/land cover at three different times, i.e., 2009-10, 2015-16, and 2021-22, to assess the impact of past management practices, the present status of the landscape features and decide on management interventions to achieve the objectives. Along with land use land cover, factors with negative ecological impacts on the landscape, like land degradation, fire frequency, forest degradation, flood susceptibility, moisture stress, sand mining, waterlogging, conversion of ravenous land to agriculture areas, etc., were analyzed along with the climatic data for the current challenges and proposed actions to achieve the expected impacts. Hotspot analysis has been carried out using the Getis-Ord GI* statistic to understand statistically significant clustering in the spatial pattern of remote sensing amenable disturbances / positive contributions.

Change detection and thereby hotspot analysis of the study area signifies that in most agricultural areas, positive changes are dominant wherever canal irrigation facilitates the triple crop and double crop.In forest areas, common negative hotspots are due to one step decrease in the canopy density class, which is found all over the areas, especially around the buffer areas of the forest settlements because of the dependence of the people of the settlement areas on the surrounding forest to meet the growing demand for timber, fuel wood, fodder, etc. Month-wise and year-wise, burned area estimations were derived for the fire session for fourteen years—the maximum area burned in 2017, followed by 2009 and 2019. It is observed that there is an inverse relation between the total rainfall, especially during the initial phase of fire season, and the incidence of fire. April recorded the highest burn scar area, followed by March and May.

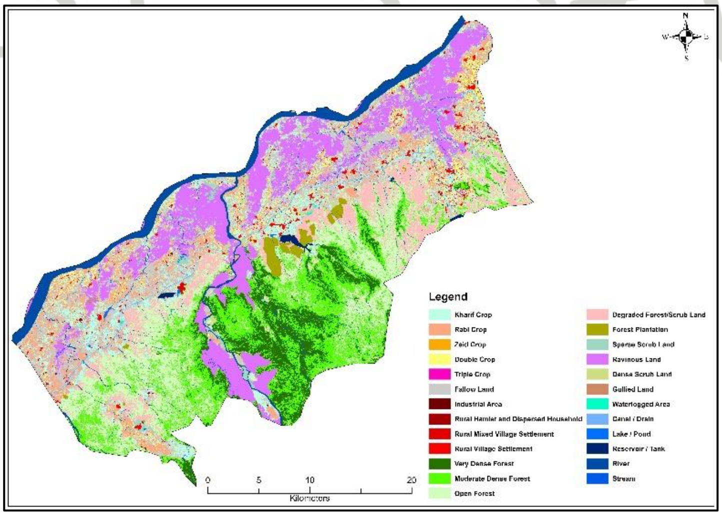
Waterlogged areas observed in the study area are mainly from unlined canal seepage and other irrigation network. Severe sheet water erosion is observed in degraded/scrub forest and moderate sheet water erosion in open forest areas. Reforestation and afforestation of the degraded forest and enrichment planting or gap filling in the open forest areas are some solutions to prevent water erosion. A total of 2.7 km2 of areas are coming under high-risk flood susceptible areas in the study area, followed by 189.00 km2 of moderate-risk areas, 452 km2 of low-risk areas, 357 km2 of very low-risk areas, 7.1 extremely low-risk areas. So, holistic watershed management and improvement of drainage and embankments are requisites for the study area to prevent floods and, thus, the conservation of agriculture and the environmental sector. The study area has a unique set up of ravenous lands, especially along the Chambal and Kuno rivers. In many places, gullies and ravines are converted to agricultural land, which may lead to the devastation of the unique ecological setup of the area and niches of endemic and endangered species thriving here. The study documented the present and past status of the landscape features in qualitative and quantitative natures, hotspots of positive and negative changes, drivers of changes, vulnerability, and threats to the system for landscape planning to ensure that its negative environmental impacts are mitigated, and positive contributions are enhanced.

Conclusion

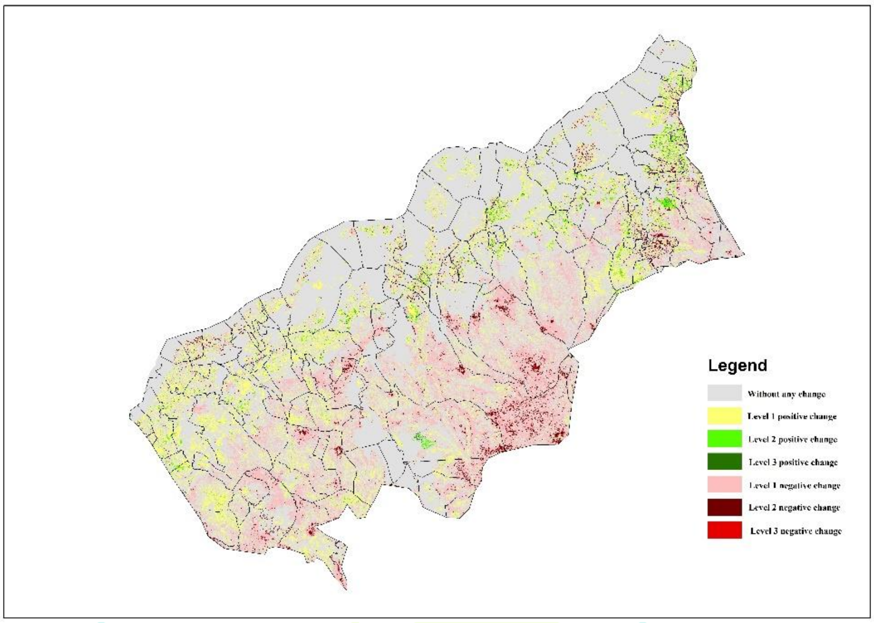
The present study used geospatial technologies to identify trends and patterns of temporal changes in land use/land cover at three different times, i.e., 2009-10, 2015-16, and 2021-22, to assess the impact of past management practices, the present status of the landscape features and decide on management interventions to achieve the objectives. Along with land use land cover, factors with negative ecological impacts on the landscape, like land degradation, fire frequency, forest degradation, flood susceptibility, moisture stress, sand mining, waterlogging, conversion of ravenous land to agriculture areas, etc., were analyzed along with the climatic data for the current challenges and proposed actions to achieve the expected impacts. The study documented the present and past status of the landscape features in qualitative and quantitative natures, hotspots of positive and negative changes, drivers of changes, vulnerability, and threats to the system for landscape planning to ensure that its negative environmental impacts are mitigated, and positive contributions are enhanced. Geospatial technology provides a plethora of information for landscape assessment, monitoring and management.



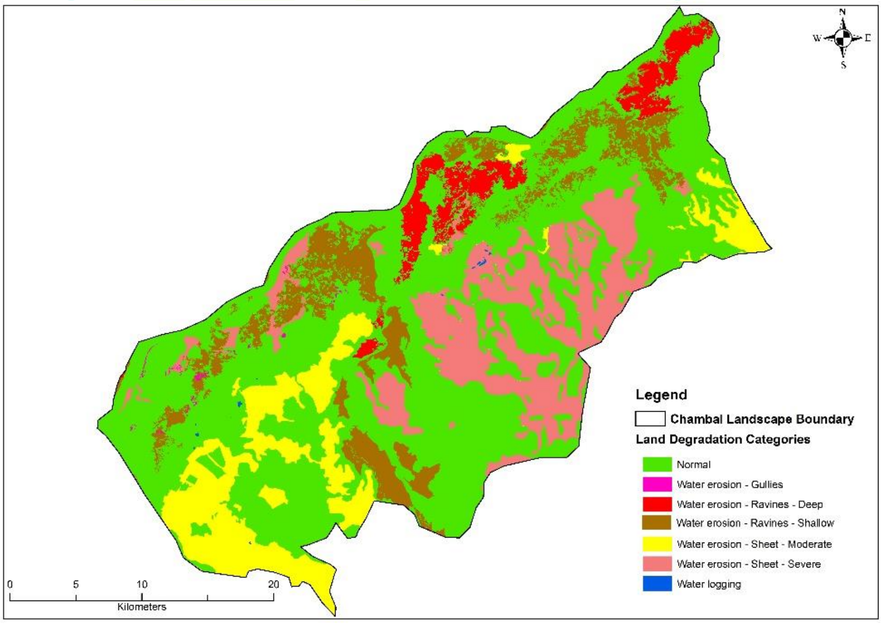
Land use land cover map of 2009-10



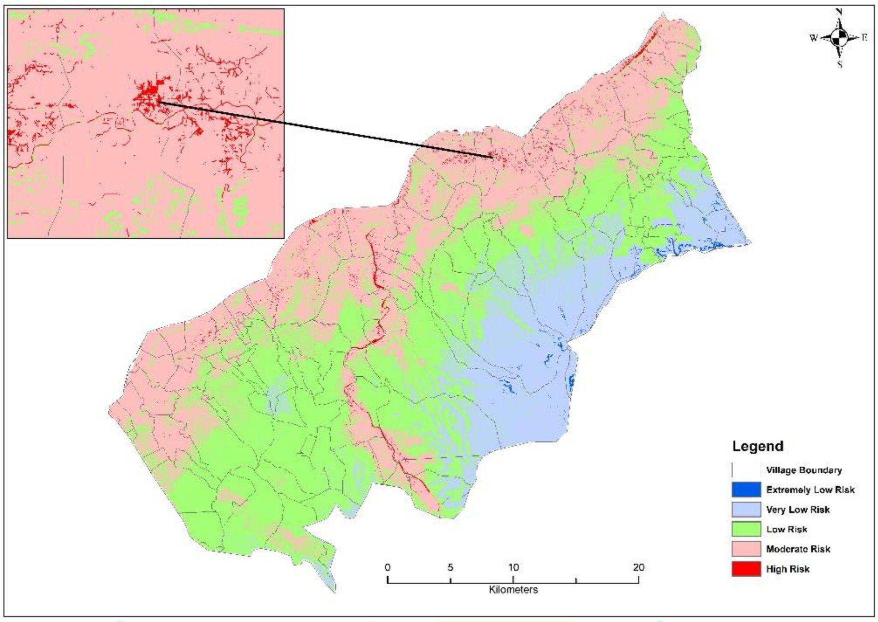
Land use land cover map of 2021-22



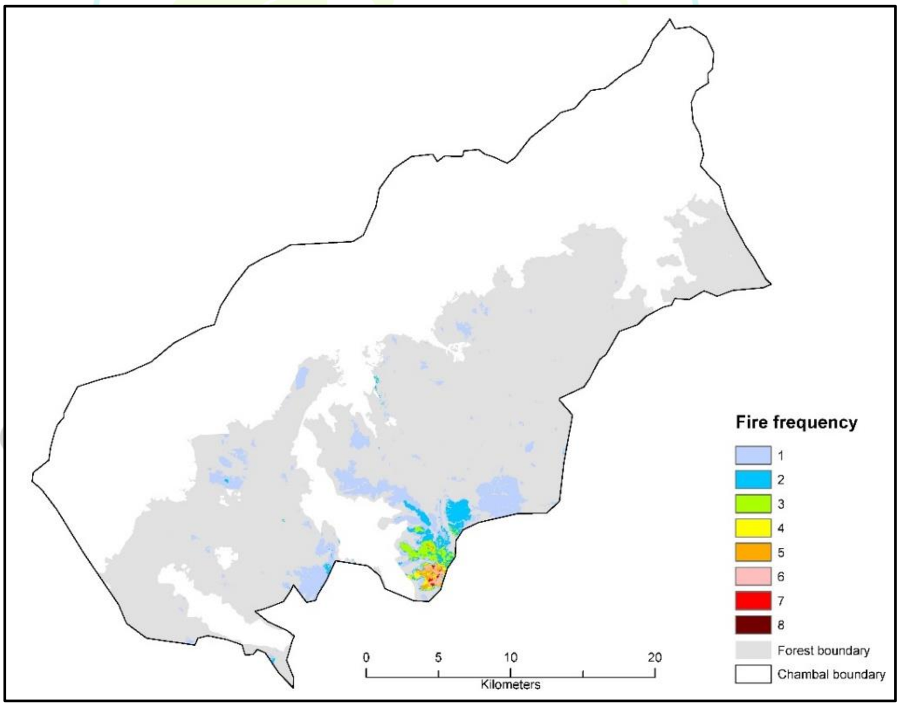
Positive and negative changes



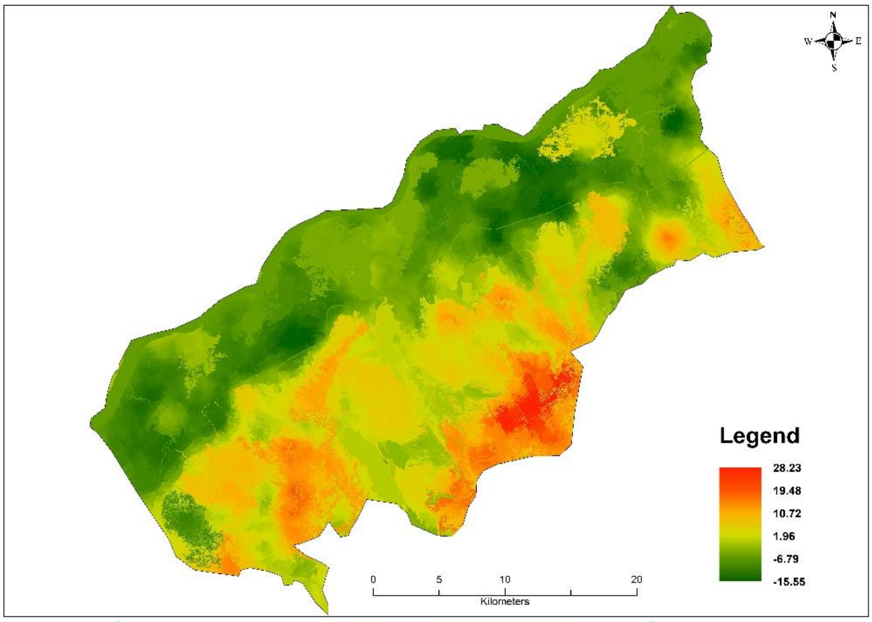
Land degradation of the study area 2021-22



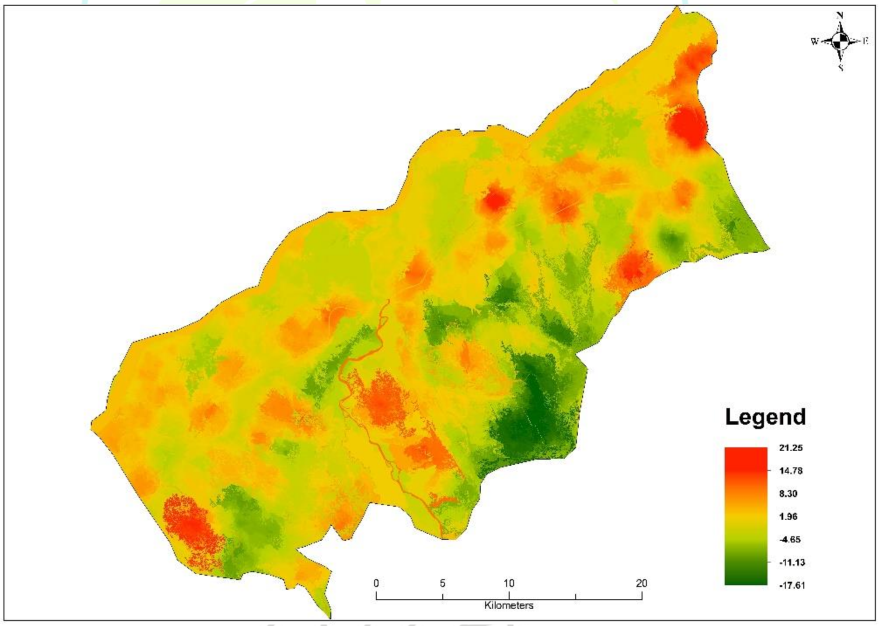
Flood susceptibility map



Forest fire frequency map



Hotspot of negative changes



Hotspot of negative changes

Nutrient Management in Sustainable Vegetable Production

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Vegetable crops are known for their high nutrient demand, prompting increased fertilizer application to enhance productivity. Farmers often apply higher quantities of mineral fertilizers and frequent irrigation to stimulate crop growth and achieve higher yields. However, in India, fertilizer application is primarily confined to nitrogen (N), phosphorus (P), and potassium (K) fertilizers, with the bias towards N followed by P and K, leading to an unbalanced fertilizer application. Additionally, these essential nutrients are typically applied at the time of planting or sowing without considering the specific crop nutrient demands. Furthermore, the continuous addition of mineral fertilizers alone over the years has led to a decline in soil organic carbon and soil fertility status, and resulted in multi-nutrient deficiencies that contributed to reduced yields in various vegetable crops. Excessive and untimely application of nitrogen has reduced shelf life, while an excess of phosphorus has led to the buildup of phosphorus in soils, a common issue in vegetable cultivation areas. Application of organic manure or naturally occurring sources enhances soil health, but does not directly improve productivity due to the relatively low major nutrient content. However, organic manures provide sufficient micronutrients essential for crops. In addition, the release of nutrients from organic manures often does not synchronize with crop nutrient demand. Therefore, integrating both organic and inorganic sources of plant nutrients becomes crucial for sustainable production while preserving the natural resource base essential for long-term sustainability. The assessment of nutrient demands during crop growth stages of many vegetable crops reveals that about 10-15% of the total NPKS uptake occurs during the initial 30 days of plant growth. Peak nutrient uptake commences at 15 days after planting or sowing, reaches its maximum uptake during the peak vegetative growth stage. The total NPKS uptake during the vegetative growth stage accounts for about 75-85% of the total NPKS uptake. At the maturity stage, the crop only extracts 5-10% from the soil. Despite this, farmers often apply a substantial quantity of fertilizers during sowing or transplanting, which might not match the crop's requirements. To optimize efficiency and yield, it's crucial to time fertilizer applications to synchronize with the nutrient demands of the crop. Applying NPKS fertilizers through drip systems according to crop requirements, coupled with the application of necessary organic manures, has shown a 25-30% increase in crop yield compared to traditional methods. Drip fertigation not only enhances yield but also improves nutrient use efficiency, water productivity, and the benefit-cost ratio compared to the broadcast method of fertilizer application. Microbial inoculation further improves nutrient uptake and crop yields. Although progress has been made, there is potential to increase nutrient use efficiency and yields in vegetable crops. Precision agriculture, employing soil moisture and NPK sensors, along with early detection of nutrient deficiencies through unmanned aerial vehicles (Drones) during the initial crop growth stage, could contribute in improving nutrient use efficiency and crop yield. Furthermore, developing cultivars with higher N, P, and K use efficiency is imperative. Research initiatives addressing these aspects are currently underway at ICAR-Directorate of Onion and Garlic Research in Pune, with a specific focus on onion and garlic. By employing onion and garlic cultivars with improved nutrient use efficiency and adopting precision irrigation and fertilizer application technologies, higher nutrient use efficiency and yields can be achieved.

Key words: Organic farming, chemical fertilizers, integrated nutrient management, Micronutrient, Fertigation

Achievements of ICAR-NBSS&LUP

Achievements of ICAR National Bureau of Soil Survey & Land Use Planning (NBSS&LUP)

Government of India established All India Soil Survey Organisation in 1956 with the Headquarters at the Indian Agricultural Research Institute Nagpur with five Regional Soil Correlation Centres at Bangalore, Delhi, Kolkata, Jorhat and Udaipur. Later in 1958, this scheme was integrated with the Land Use Planning Scheme of the Central Soil Conservation Board primarily to carry out detailed soil surveys in the catchment areas of major River Valley projects, with setting-up the organisation, "All India Soil and Land Use Survey". In 1969, it was re-organized and the research aspects of soil survey, classification and correlation was transferred to the Indian Council of Agricultural Research (ICAR), and the developmental activities was retained under the Department of Agriculture, Ministry of Food and Agriculture. In 1976 it became an independent Institute of ICAR named as National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) and continued to function at the IARI, New Delhi. In June 1978, the Headquarters of the Bureau, was shifted to Nagpur. It is located in a new and spacious buildings situated on Amravati Road, 7 km away from main railway station and 1.5 km from Nagpur University Campus. The NBSS&LUP is one among the chain of ICAR Institutes. In line with the recommendations of the Task Force on Land and Soil Resources (1972) which suggested the need for soil correlation, uniform nomenclature and proper soil mapping and also the presidential notification on December 15, 1973, the duties with respect to research, training, correlation, classification, mapping and interpretation were allotted to the NBSS&LUP.

Mission of ICAR NBSS&LUP

To conduct and promote research in the National Agriculture Research System in the areas of Soil Survey, Pedology, Geomorphology, Remote Sensing, Geographic Information System, Cartography, Land Evaluation and Land Use Planning.

Mandate of ICAR NBSS&LUP

To conduct soil survey and mapping of the soils of the country to promote scientific and optimal land use programmes in collaboration with relevant institutions and agencies.
To conduct and promote research in the National Agricultural Research System in the areas of pedology, soil survey, remote sensing applications, land degradation, land evaluation and land use planning.
To impart training and education to create awareness on soil and land resources and their state of health.

Future thrust areas of ICAR NBSS&LUP

- Remote sensing and GIS applications in landforms mapping and soil-landscape modelling using advanced state-of-the-art technologies.
- To carry out pedological research for understanding various soil ecological parameters and increase the scope of future land use planning.
- Soil survey and mapping of the soils at different scales in India and abroad through contemporary soil digital mapping techniques.
- Soil genesis, classification, characterization and correlation, of benchmark soils and its monitoring for futuristic planning.
- Conduct and promote research in soil survey, land evaluation and land use planning using modern geostatistical tools
- Application of Geospatial technologies and latest soil-based information in assessment and monitoring of land degradation.
- Delineation/characterization/refinement of AERs/AESRs/AEZs/AEUs
- Perspective and participatory land use planning.
- Strengthening hyperspectral soil reflectance library and modelling hyperspectral data.
- Preparing dataset for soil carbon sequestration and mapping of India and the World and modelling of soil carbon for perspective planning.
- Enrichment of BHOOMI Geoportal and development of application services.
- Soil and land quality assessment and monitoring.

Regional Centre, Bangalore

To provide soil resources information to the user agencies and coordinate soil survey activities in the southern states (Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Goa including the Union Territories of Pondicherry and Lakshadweep), the Regional Centre, NBSS and LUP, Bangalore was established in 1956. It functioned originally as a part of all India Soil Survey Scheme, which subsequently became the southern Regional Centre of All India Soil and Land Use survey Organization (AISLUS) under the ministry of Agriculture, Government of India. In 1976, this centre came under NBSS & LUP which was established under Indian Council of Agricultural Research, taking a part of AISLUS to carry out soil survey and to conduct research in soil Survey and Land use planning. Thus, centre has the accumulated experience and expertise of 68 years in LRI and related programs for the South Indian states.

Mandate

1. Soil Survey and mapping of the soils at different levels i.e., watershed, tehsil/mandal, district, region, and state level to promote scientific land use programs in collaboration with state departments of agriculture, watershed development, soil conservation, horticulture, sericulture, fisheries and land use organization, state agricultural universities and other user agencies in southern states.
2. Soil correlation classification of benchmark soils at soil series level in liaison with state soil survey agencies
3. To prepare scientific land use plans at village/watershed, taluk, district and state levels by integrating land evaluation, socio-economic data base through close linkage with State Land Use Boards, Departments, Commodity Boards and Forest Departments etc.
4. To conduct and promote research in ares of pedology, soil survey, land evaluation and land use planning.
5. Teaching and research activities in collaboration with University of agricultural Sciences, Bangalore in awarding MSc and PhD degrees.

Collaborations

- Karnataka Watershed Development Department
- State Departments of Agriculture, Horticulture, Sericulture, Forest and related line departments of Karnataka, Telangana, Tamil Nadu, Kerala, Goa
- Indian Institute of Science, Bangalore
- ICAR Institutes: IIFSR, IIHR, ATARI, CRIDA, IISWC, NIANP, NDRI etc
- KVKs
- Rubber Research Institute, Govt. of India, Kottayam
- INRA, France
- ISRO, Bangalore
- SAC Ahmedabad, ISRO, Govt. of India
- Coffee Board, Govt. of India
- Coconut Board, Govt. of India.
- Silk Board, Govt. of India.
- Spice Board, Govt. of India
- Indian Council of Forest Research (Institute of Wood Science and Technology)
- Karnataka State Remote Sensing Applications Centre
- Karnataka State Natural Disaster Monitoring Centre
- SAUs of all South Indian States

- State Soil Survey Organisations
- Karnataka State Agricultural Price Commission
- Indira Gandhi Institute of Development Studies, Mumbai
- Tamil Nadu Planning Commission, Govt. of Tamil Nadu

Research and Development projects in operation and completed

Externally funded projects

1. Rejuvenating Watersheds for Agricultural Resilience through Innovative Development (REWARD)
2. Pilot Project on Crop Diversification
3. Development of an Objective Technique for Land Degradation Assessment
4. Identification, Mapping and Characterization of Fallow Lands for Conversion to Productive Lands in Tamil Nadu using Remote Sensing and GIS tool
5. Watershed Development to Prevent Drought (WDPD)
6. Land resource inventory of selected micro watersheds in seven backward districts of Karnataka under Sujala projects III
7. Livelihood improvement of Tribal communities of selected homeless in H.D. Kote, Mysore Dist, through Integrated land use planning.
8. Desertification and land degradation monitoring, vulnerability Assessment and combating plan
9. Accompanying the adaption of irrigated agriculture to change (ATCHA project)
10. Characterization and mapping of land resources of Goa in reference to cultivated and fallow land use system. A step towards enhancing agriculture productivity
11. Enhancing economic viability of coconut-based land use systems for land use planning in Kerala.
12. Spatial Crop Planning for Sustainable Resource Use and Conservation of Ecological Resources
13. LRI of 42 villages in Palakkad district of Kerala
14. Soil quality assessment of rice growing soils of Kerala.
15. Soil fertility assessment for Kerala state
16. Agro-ecological Units of Kerala.
17. Land Suitability Mapping for optimum crop plan based on food security requirement of Karnataka.
18. Land Resource Inventory of clusters of villages APDMP project in Andhra Pradesh.
19. Estimation of carbon stocks of Western Ghats ever green forest
20. Economic evaluation of watersheds
21. LRI under farmers first project village (Kanakapura) in collaboration with ICAR-IIHR. And NIANP, Bangalore.
22. LRI for rubber growing areas of South India
23. Potential and constraints of oil seed growing areas in India
24. Delineation of potential areas for Telangana state

Institute projects

1. Soil Resources Mapping (SRM) (1:250,000) in collaboration with State Department of Agriculture (1990s).
2. District soil surveys: Kolar, Tumkur, Hassan, Mysore, Chitradurga and Bijapur districts of Karnataka (1:50,000).
3. LRI of Research Farms: Coffee Research Station, Balehonnur, Chikmangalur district, ARS, Nagamangala, Mandya district, Tegur farm of IGFRI, Dharwad district, CTRI (ICAR) Hunsur, IISR (ICAR) Appangala, Kodagu district, Karnataka.

4. LRI for watersheds: Koulagi and Nalatwad in Bijapur district, Kuttinagere, Garakahalli, Liganahalli and Rajankunte in Bangalore (R), Molahalli in Dakshina Kannada, and Pettamaranhatti in Chitradurga of Karnataka.
5. Soil degradation assessment of Karnataka.
6. Agro-Ecological Zoning of Karnataka.
7. LRI of 41 villages under Chikkarasinakere block, Maddur, Mandyadist under Cauvery Command area (2013).
8. LRI of Three villages (Kumaranahalli, Dyapanayakanahalli and Hariyammanahalli) of Harapanahalli taluk in collaboration with Samaja Parivarthna Samsthe (2005).
9. LRI of Triumale Sub-watershed Magadi (2011).
10. Revisiting of watershed with LRI in Rajankunte, Karnataka (2005)
11. LRI-Mehabubnagar mandal, Mehabubnagar District, Telangana
12. LRI-Jalihal hobli, Sindhanur taluk, Raichur district, Karnataka
13. LRI Rayachoti mandal, Y. S. R. Kadapa district, Andhra Pradesh.
14. Kaveripattinam block, Krishnagiri District of Tamil Nadu.
15. LRI of selected blocks in Tamil Nadu
16. Digital soil mapping of Karnataka
17. Revision of soil-site suitability of major crops.
18. Socio Economic Evaluation of Agricultural Land use in India
19. Delineation of Potential Areas for Agricultural Land use Planning
20. Visual signs of Biophysical indicators for assessing the status of degradation of dry Lands in Pulivendula Tehsil, Cudappa district Andhra Pradesh
21. Livelihood improvement of the SC community through the integrated land use planning in selected villages of Kolar district.

Salient Achievement of the Centre

Exploratory soil survey

The Exploratory survey, also known as Rapid reconnaissance soil survey, was carried out in areas where there was no information available on soils. During the survey, the soils occurring in the area were studied in selected transects and mapped at 1: 250 000 scale as association of sub groups. The survey was completed in North and South Arcot districts of Tamil Nadu, North Kanara district in Karnataka, Cannanore district in Kerala and Mehaboobnagar district in Andhra Pradesh by NBSS & LUP, Bangalore to help in the preparation of 1: 1 M Soil map of India in 1982

Soil Resource Mapping Project (at 1:250K scale)

The area covered by various earlier survey programmes was reviewed at National level in the year 1986 and it was found that the area covered was very less in the southern states and for many areas no information was available. So to have a quick appraisal of the soil resources of the country, the Soil Resource Mapping Project was started in 1986 and the work was completed in 1996 for all the states. In this project, a uniform three-tier methodology was followed involving image interpretation, field surveys and laboratory analysis and preparation of soil and thematic maps.

The soil map was prepared by conducting soil survey in window areas, establishing soil-physiographic relationship and then extrapolating this information to adjoining areas. Soils were mapped as association of phases of soil families as mapping units. The phases mapped are surface soil texture, slope, erosion, gravelliness, calcareousness, salinity, sodicity and flooding. The soil legend accompanying the soil map gives description of the dominant and subdominant soils, their taxonomical classification, inclusion and extent of the soil units (Fig. 1.1). This type of mapping at 1:250,000 scale was completed in Tamil Nadu, Kerala, Karnataka and Andhra Pradesh. Goa, Pondicherry (1:50,000) and Lakshadweep Islands (1:16,000) scale the soil information is available in the form of maps and reports to the user agencies.

Reconnaissance soil survey (RSS)

Reconnaissance soil survey was completed in many districts in south India by various agencies. In Tamil Nadu, up to 1975, reconnaissance soil survey of Coimbatore, Trichy, Periyar, Thanjavur, Salem, Dharmapuri, Madural and part of Tirunelveli districts were completed at 1: 50, 000 scale with soil series / association of soil series as mapping units and the remaining districts were mapped at 1: 50,000 scale with association of soil families or sub groups as mapping units. By mid eighties all the districts in the state were covered and about 62 subgroups, 150 families and 350 soil series were identified by the survey.

In Kerala, Reconnaissance soil survey was completed in all the districts by the state soil survey organisation. The National Bureau of Soil Survey and Land Use Planning mapped in the years from 1996 to 1999, about 10 lakh hectares for rubber cultivation in Kerala and Tamil Nadu During the survey about 6000 soil profiles, 10,000 grids and numerous random points were studied, 62 soil series were established and the soils were mapped at 1:50 000 scale with association of soil series as mapping units

In Karnataka reconnaissance soil survey was completed in Kolar, Hassan, Bellary, Chitradurga. Tumkur, Bangalore and Coorg districts at 1. 50, 000 scale with association of soil series as mapping unit. Few taluks in North Kanara, Bijapur, Raichur, Dharwad, Shimoga, Mandya. Mysore and South Kanara were also covered by this survey.

In Andhra Pradesh, Anantapur and Medak districts were covered by the reconnaissance soil survey in full and in other districts like Chittoor, Nellore, Cuddappa, Hyderabad, and Mahaboobnagar only few taluks were covered. Goa, Pondycherry and Lakshadweep were covered by reconnaissance soil survey under the Soil Resource Mapping project during 1986 to 1990.

Detailed Soil Survey

In detailed soil survey, cadastral maps (1:4,000 to 1:10,000 scales) were used as base maps and the soils identified were mapped as phases of soil series, complexes and miscellaneous lands. Several detailed soil survey programmes are in progress Karnataka, in many panchayat unions in Tamil Nadu (about 5 lakh ha covered already), Kerala and Andhra Pradesh.

Detailed soil survey provides site-specific information on various land resources occurring at cadastral level. In this survey, there is no room for any generalisation or extrapolation of information from one farm to another or from one place to another place. The information generated is from site-specific data and each map unit corresponds to a management unit and as such is very valuable for farm or site-specific planning.

Achievements of major projects of the centre

Karnataka Watershed Development project: Sujala-III (2014 -2019), (World Bank funded)

The project has been carried out in 11 rainfed districts covering 14.5 lakh hectares, benefiting 9.0 lakh farmers. ICAR-NBSS&LUP led technical aspects, collaborating with 5 SAUs. LRI cards were generated in Kannada, alongside atlases and reports in English and Kannada. LRI-based treatments covered 90,000 hectares. Stakeholders underwent extensive capacity building. Success prompted NRAA to include LRI-based treatments in PMKSY 2.0 guidelines. This success also spurred REWARD projects in Karnataka and Orissa. A Digital Library and Decision Support System (DSS) were developed, aiding digital watershed planning and granting access to the LRI database for developmental projects.

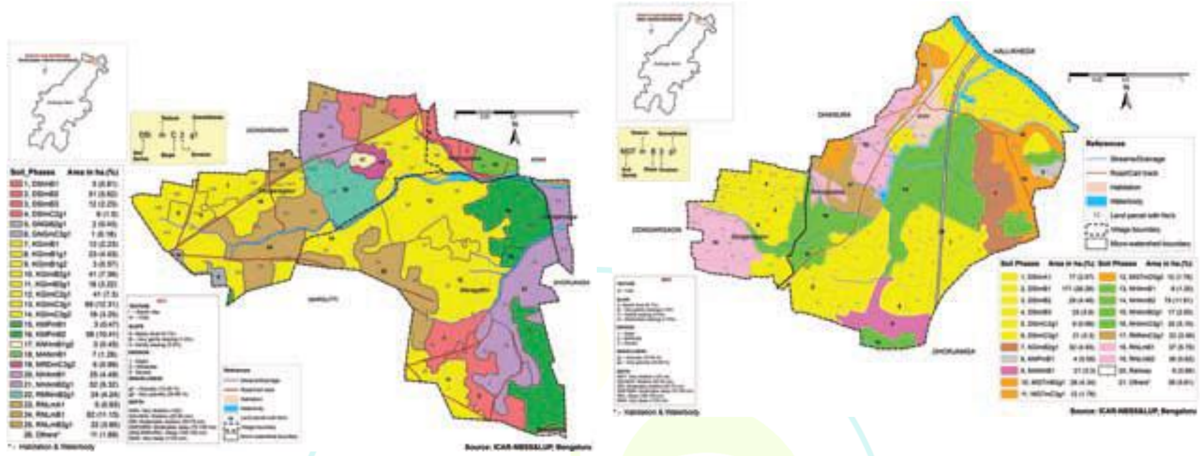


Fig. 1 Soil map of micro-watershed under Sujala project, Karnataka

Morphological evaluation for soil development in delta soils of Andhra Pradesh using legacy data of SRM

The numerical methods and conversion of Munsell notation into the CIELab system were utilized to evaluate the morphological data of 33 soil profiles in the East Godavari district and 27 soil profiles in the Krishna basin. The pedo-transfer functions were developed for drainage index, and RPD.

Land Resource Inventory of Rayachoty mandal, YSR Kadapa district, Andhra Pradesh on 1:10,000 scale

Land Resource Inventory at a 1:10,000 scale was conducted in Rayachoty mandal, YSR Kadapa district, Andhra Pradesh, India. Six landform units were identified and mapped, along with a land use/land cover map. Soil map of mandal generated with 10 soil series and 53 mapping units covering 23,240.7 ha. Land suitability evaluations were conducted for major crops.

LRI of Kaveripattinam block of Krishnagiri district, Tamil Nadu on 1:10000 scale for optimal agricultural land use planning using geo-spatial Techniques

A Land Resource Inventory (1:10,000 scale) in Kaveripattinam block, Krishnagiri district, Tamil Nadu, covered 30,553 hectares. Predominant soils vary from moderately shallow to very deep, with diverse drainage and colors. About 24 soil series and 65 mapping units were tentatively established. Ground truth observations identified 21 land use systems. Six Land Management Units were identified based on soil and site constraints.

LRI of a Cluster of 3 Gram Panchayats of Anantapur District on 1:10000 scale under Andhra Pradesh Drought Mitigation Project (APDMP)

A detailed soil survey at 1:10,000 scale covered 4822 hectares across 18 villages in Anantapurmu district, Andhra Pradesh. Landforms include summits, slopes, valleys, and plains. Major land uses are agriculture, horticulture, plantation, and forestry. Eleven soil series were identified. Soil subgroups include Typic Paleargids, Typic Haplargids, Typic

Haplocambids, Vertic Haplocambids, and Typic Torripsamments. Thematic maps were prepared for pH, EC, erosion, slope, gravels, AWC, soil depth, nutrients. Suitability assessments covered 32 major crops.

Accompanying the Adaptation of Irrigated Agriculture to Climate Change (ATCHA project)

The objective was to implement an Integrated Modeling and Assessment approach, engaging stakeholders to co-develop and evaluate scenarios for sustainable agricultural development in Karnataka amid climate change. The project involved mapping various STICS soil parameters using a digital soil mapping (DSM) approach, assessing the impact of DSM errors on crop model output spatialization, mapping soil texture classes using time series Sentinel-2 images, mapping tank silt application with Sentinel-2 images, creating a spectral library for Karnataka, utilizing soil order knowledge to estimate soil properties from Vis-NIR spectral data.

Desertification and Land Degradation: Monitoring, Vulnerability Assessment and Combating Plans

Its objectives included mapping desertification and land degradation in Andhra Pradesh, Telangana, and Karnataka from 2017-2018, conducting change analysis compared to 2011-2013, developing methodology/tools for vulnerability assessment at a 1:50,000 scale for specific districts, and formulating action plans for combating desertification and land degradation at a 1:10,000 scale, demonstrated in selected micro-watersheds.

Enhancing the Economic Viability of Coconut Based Land Use Systems for Land Use Planning in Kerala State (2014-2020)

Variability in coconut palm health and productivity correlates with regional climate and soil variations, where soil qualities outweigh climate influences. Key soil constraints include acidity, subsoil aluminum toxicity, and deficiencies in macro, secondary, and micronutrients. Management practices, like lime application for acidity and magnesium sulfate for subsoil acidity, can mitigate these constraints within 3 years. Tailored Best Management Practices (BMP) significantly enhance coconut yield, especially in regions like northern Kerala, suggesting the need for region-specific strategies for optimal results.

Livelihood Improvement of Tribal communities of selected hamlets in H.D.Kote, Mysore District through Integrated Land Use Planning

Using a participatory approach, tribal community issues and priorities were identified, and land resources inventoried for integrated land use planning. Implementation focused on improving productivity and profitability through training on value addition and market linkages. Identified problems included drinking water scarcity, crop protection from elephants, and lack of agricultural inputs. Programs addressed these with mini water supply, high-range torches, and community irrigation projects. Additionally, suitable crop varieties and soil-based Integrated Farming Systems (IFS) were introduced, along with skill development in value addition and various trades like tailoring and bakery.

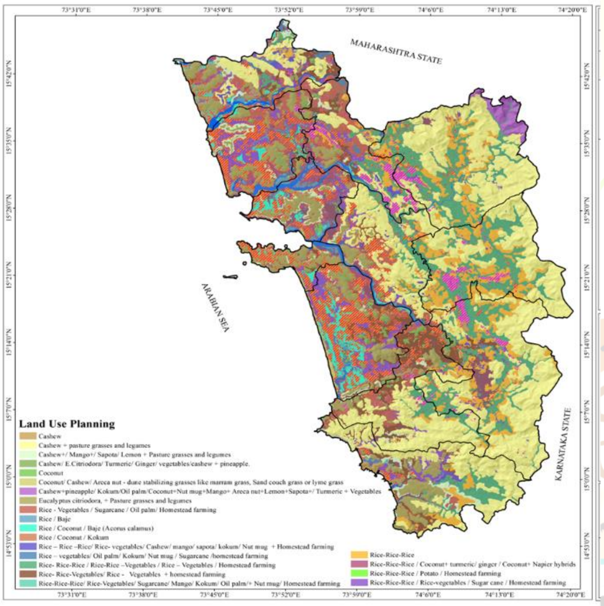
Change in annual household income among Farmers

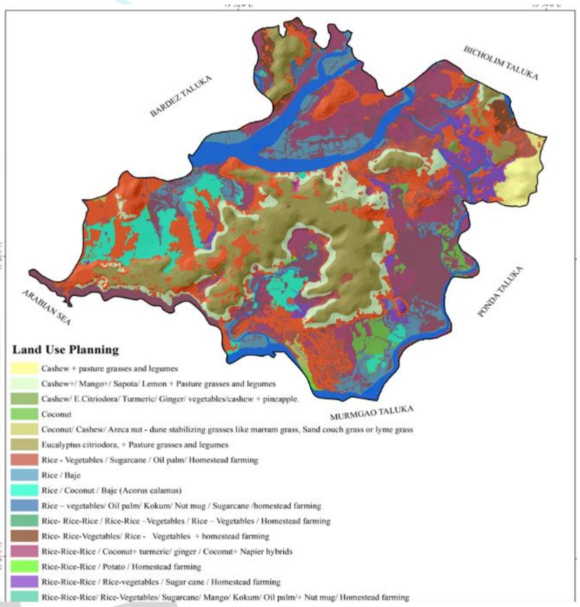
Income group (Rs)	Proportion of Farmers (%)						
	2012-13 (Base year)	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
0-2000	63.27	63.27	61.06	57.52	56.19	16.52	0.43
2000-4000	17.26	2.65	0.00	0.00	1.33	1.34	2.14

4000-6000	11.06	6.64	0.88	1.33	1.33	0.89	14.78
6000-8000	7.96	19.47	12.39	0.88	1.33	1.79	7.92
8000-10000	0.44	5.31	7.52	1.33	2.21	6.25	11.78
>10000	0.00	2.65	18.14	38.94	37.61	73.21	62.96
Average income	1991	2770	4810	9279	13380	24960	25354

Characterization and Mapping of Land Resources of Goa in Reference to Cultivated and Fallow Land Use Systems - A Step Towards Enhancing Agricultural Productivity

Objectives included delineating cultivated and fallow land use systems in Goa using high-resolution satellite data, characterizing land resources at 1:10,000 scale, and developing an agricultural land use plan for intensifying agriculture and rejuvenating fallow lands.



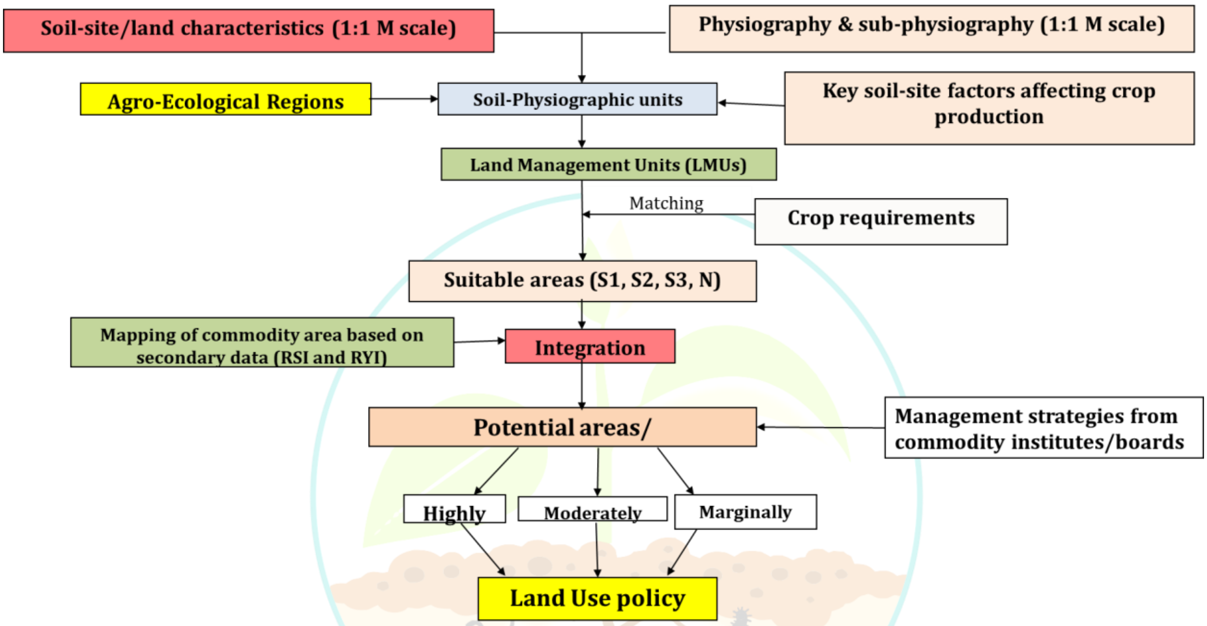


Suggested LUP for cultivable lands:

LMU	Suitable crops and cropping system	Management
LMU1	Coconut, Cashew, Areca nut	• Seeding of Dune grass • Dune thatching • Agro ecotourism
LMU2	▪ Rice – Vegetables ▪ Coconut + Areca nut+ Pepper ▪ Coconut+ Turmeric/ Ginger + pineapple+ Napier grass ▪ Banana + vegetables ▪ Cashew+ Pineapple + Napier grass on bunds ▪ Mango+ sapota+ Napier hybrids with pasture legumes ▪ Mango, Oil palm, Kokum, Nut mug and Sugarcane	▪ Embankment ▪ Liming (11tha^{-1} or 10.5 t ha^{-1}) ▪ Suitable varieties ▪ Homestead farming
LUM3	LMU 2- fruit crops and sugarcane	

Delineation of Potential Areas for Agricultural Land Use Planning

Objective is to develop a for identifying potential areas, delineating and mapping potential areas for major crops at national and state levels, and suggesting an agricultural land use plan. Various crops were considered for identifying potential areas, including rice, wheat, maize, sorghum, bajra, ragi, pigeon pea, green gram, black gram, groundnut, soybean, sunflower, rapeseed and mustard, cotton, sugar cane, and areca nut.



Methodology adopted for identification of potential areas-

Delineation of Crop Colonies for Agricultural Land Use Planning of Telangana State -A step towards enhancing Agricultural Productivity and Profitability

The objectives of the project are multifaceted. Firstly, it aims to delineate and map the extent and distribution of crops, including horticulture, in the state of Telangana, while also proposing the establishment of crop colonies. Additionally, the project seeks to recommend policy interventions aimed at augmenting the productivity and profitability of these crops. A key aspect of the project involves comparing the current area under a specific crop with the estimated highly potential area within each zone, thus informing strategies for optimizing crop cultivation across different regions of the state.

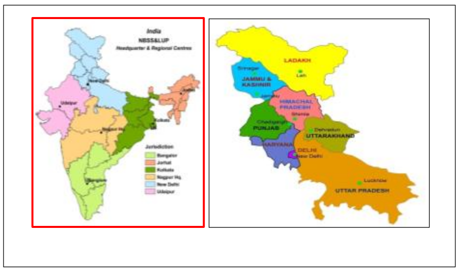
Suggested crop allocations for different areas based on PCZ

Crops	Area expansion			Area to be restricted			Over utilization of area		
	CTZ	NTZ	STZ	CTZ	NTZ	STZ	CTZ	NTZ	STZ
Cereals	Maize, Rice	Bajra, Maize, Wheat, Rice	Bajra, Jowar, Korra, Ragi	Bajra, Jowar, Korra, Ragi, Wheat	Jowar, Korra, Ragi	Maize, Wheat			**Rice**

Pulses	Anumula, Bengal gram, Cowpea, Green gram, Horse gram, Pappu	Anumula, Bengal gram, Black gram, Cowpea, Green gram, Red gram	Bengal gram, Black gram, Green gram, Horse gram, Red gram	Black gram, Red gram	Horse gram	Cowpea			
Oilseeds	Ground nut, Palm oil, Sunflower, Linseed	Sesame, Soybean, Safflower, Rapeseed and mustard	Castor, Groundnut, Safflower, Sunflower	Castor, Safflower, Sesame, Soybean	Castor, Ground nut, Sunflower	Palm oil, Sesame, Soybean			
Commercial crops	Cotton, Sugarcane	Cotton, Sugarcane	-	-	-	Cotton, Sugarcane			

Regional Centre, Delhi

ICAR-NBSS&LUP, Regional Centre, Delhi is one of the oldest centres of ICAR-NBSS&LUP, and is involved in soil resource mapping, soil correlation & classification, and undertaking research, assessment of land degradation & land use planning in Northern Region of the country comprising the states of Punjab, Haryana, Uttar Pradesh, Himachal Pradesh, and Uttarakhand, and Union territories of Chandigarh, Delhi, Jammu & Kashmir and Ladakh. Total area under its jurisdiction is about 66.8 million ha which covers approximately one fifth of total geographical area of the country. This center is presently located in sprawling green campus of IARI, New Delhi and ranks as pride centre with immense responsibility towards mapping and managing natural resources of Himalaya Ecosystem, and Indo – Gangetic plain.



Mandates

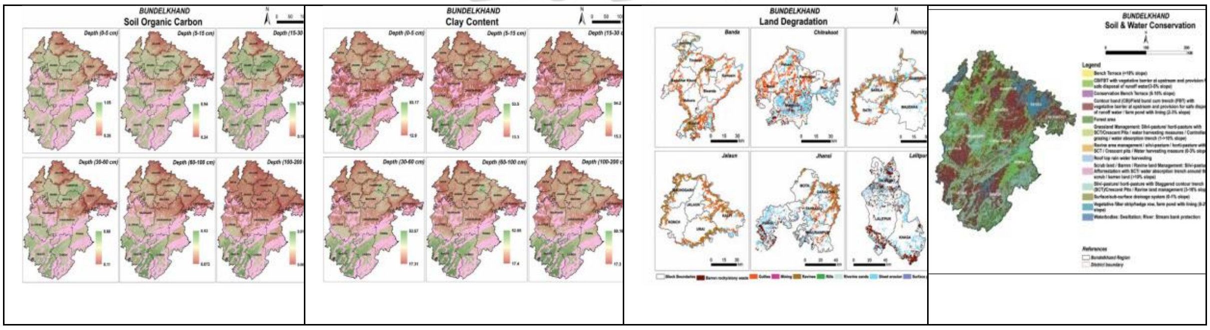
- To undertake soil survey and mapping at different levels (state, region, district, watershed, village and farm) to promote scientific & optimal land use planning.
- To conduct and promote research in National agricultural research system in the areas of pedology, soil survey, land evaluation and land use planning.
- Soil correlation, classification and characterization of benchmark soils at different categorical levels
- To impart training and education and promote awareness on the soil resources and its state of health & utilization.
- Coordination for land resource inventory with different institution and user agencies.

Major activities & achievements:

Land Resource Inventory (LRI) -

Flagship Project for Sustainable LUP – LRI of Bundelkhand Region for Sustainable LUP:

The Flagship LRI project was initiated for managing land resources for enhancing productivity and appropriate land uses for livelihood security of the region. The primary objective was to generate a high resolution digital LRI of the region comprising 14 districts of states (UP and MP) and covering an area of 7.09 mha by adopting hybrid methodology of using legacy datasets and digital soil mapping with geo-spatial information. Digital soil maps of 9 key soil properties, *viz.,* depth, pH, EC, SOC, CaCO3, sand, silt, clay, and AWC for six standard depths were prepared. Land degradation status in the Bundelkhand region was assessed. Based on the database, soil and water conservation plans, land suitability assessment and crop suitability maps, were generated in the GIS environment. Technology for LRI of Bundelkhand region for sustainable land use planning has been developed (ICAR technology certificate received).



Land Resource Inventories (on 1:10,000 scale) by using Geospatial Techniques:

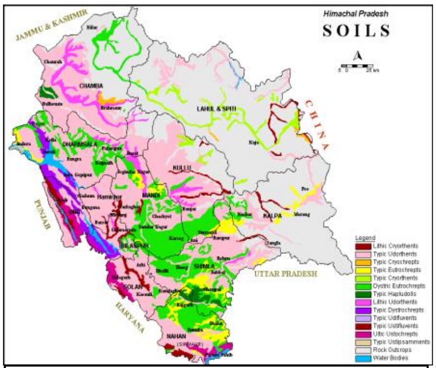
Detailed LRI of 12 blocks and 3 districts (on 1:10,000 scale) representing different AESR in Himalayan region and Indo-Gangetic Plains has been carried out for agricultural land use planning.

Block Level : ***Himalayan Region***: Leh Block, (Leh district, Ladakh UT), Pangi Block (Chamba district, HP), Lahul Block (Lahul & Spiti district, HP), Nagrota Bagwan Block (Kangra District, HP), Chamba Block (Tehri Garhwal, Uttarakhand) and Bhimtal block (Nainital district, Uttarakhand); ***IGP Region:*** Rajpura block (Patiala district, Punjab), Odhan block (Sirsa district, Haryana), Lakhan Majra block (Rohtak district, Haryana), Jagner block (Agra district, UP), Baragaon block (Varanasi district, UP), and Dhanpatganj block (Sultanpur district, UP).
District Level: Sirsa district (Haryana), Shahid Bhagat Singh Nagar district and Patiala district of Punjab.
Regional Level: Mandi Region and Kangra region of Himachal Pradesh.

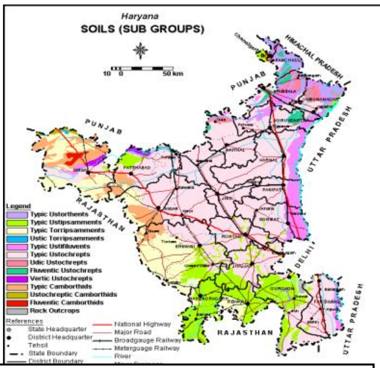
Agricultural Land Use Planning (LUP) for Livelihood Security:
LUP of Nagrota Bagwan Block (Kangra District, HP), Rajpura block (Patiala district, Punjab), Baragaon block (Varanasi district, UP) and Mathura District (UP).
Aspirational districts (NITI Aayog. Demand driven): Balrampur, Bahraich, Chitrakoot, Saraswati and Sonbhadra districts of U.P.
Externally Funded:
- LRI of 11 micro-watersheds of 2 districts of Himachal Pradesh (under WDC-PMKSY-2.0)
- Pilot Project on Crop Diversification
- Research study on soil sample collection and testing for assessing SHCs Scheme (NITI Aayog, GOI, New Delhi sponsored)
- Bioremediation of chemical contaminants and with high dynamic flux used for irrigation in urban and peri-urban agriculture (NASF -funded)
- Mapping and Assessment of Land Degradation in Major Ecosystems of India using Geospatial Technologies (ICAR -Extramural Project)
- Soil resource mapping of Five districts (on 1:50000 scale) of U.P. (UPRSAC sponsored).

Soil Resource Mapping of States (on 1:250, 000 scale) in Northern Region of India:
The soil resource mapping on 1:250, 000 scale, of the states in northern region (*i.e.* Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir, Uttrakhand and Uttar Pradesh) has been completed. The salient achievements are given as below:
Soil Resource mapping of J&K state *(now UTs of Jammu and Kashmir, and Ladakh)*: Soils are mapped into 140 soil mapping units as a associations of soil families. Soils belong to 4 Orders, 9 Sub orders, 15 Great Groups, 27 Subgroups and 66 Soil families. Entisols are dominant soils (34%), followed by Inceptisols (6.4%), Alfisols (0.5%) and Mollisols (0.2%). About 7 m ha (31.6%) area is affected by various soil degradation problems. Water and wind erosion affected 24.6% and 6.1% of the area, respectively.
Soil Resource mapping of Himachal Pradesh: Soils mapped into 95 soil mapping units. The soils belong to 4 Orders, 6 Sub orders, 12 Great groups, 17 Subgroups and 43 Soil families. Entisols are dominant soils (51%), followed by Inceptisols (20%), Mollisols (0.8%) and Alfisols (0.4%). About 54% of TGA is affected by various soil degradation problems, mainly due to water erosion.
Soil Resource mapping of Uttar Pradesh: soils belong to 5 Orders, 11 Suborders, 22 Great groups, and 44 Subgroups. Inceptisols occupied nearly 70% followed by Entisols (18.96%), Alfisols (4.89%), vertisols (1.57%) and mollisols (0.22%). About 52.12% of the TGA in the state is affected by various soil degradation problems.
Soil Resource mapping of Punjab: Soils mapped into 124 soil mapping units. The Inceptisols covers 50% area, followed by Entisols (20%), Aridisols (16%) and Alfisols (4%). The dominant soils are coarse-loamy (52%), followed by fine-loamy (32%), and sandy (12%). About 25% area suffers from various degradation problems such as water erosion, wind erosion, salinity and sodicity, stoniness and coarser texture.
Soil Resource mapping of Haryana: Soil mapped into 199 map units of associations of soil families with phases. The soils have been classified into 6 Orders, 15 Sub orders, 11 Great groups, 19 Subgroups and 27 Soil families. Inceptisols are the dominant soils (58%) by Entisols (28%), Aridisols (9%) and Alfisols (2%). About 33% area affected by different types of degradation.

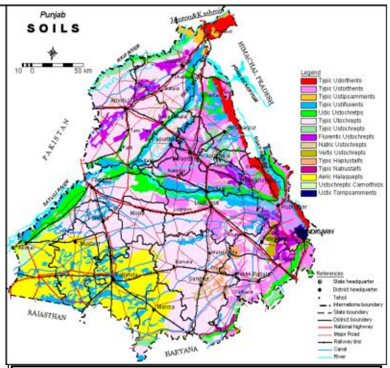
Soil Resource mapping of Delhi: Soils of Delhi belong to 2 Orders, 4 Suborders, 4 Great groups, 6 Subgroups and 12 Soil Families. Major soils belong to Inceptisols (81.3%) followed by Entisols (18.7%).



Soil s of Himachal Pradesh



Soils of Haryana



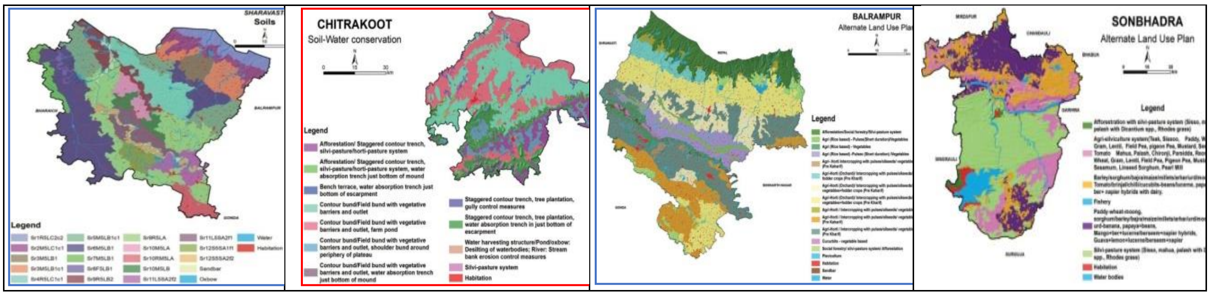
Soils of Punjab

Soil Erosion status of Northern States (1:250,000 scale):
Soil erosion status of Himachal Pradesh has been assessed. About 22% of TGA of the state has annual soil loss within the tolerance limit (<5 t ha^{-1}). About 7%, 5% and 27% area are experiencing annual soil loss in the range of 5-10, 10-15, >15 t ha^{-1}, respectively. Soil erosion in Punjab, highlights the extent of water induced soil erosion in the state. About 87%, 6%, 2% and 4.02% area have annual soil loss of <5, 5-10 and 10-15 and > 15 t ha^{-1}, respectively. Soil erosion status in Haryana highlights the extent of water induced soil erosion in the state. About 77 and 23% area of the soil erosion is affected by water and wind erosion, respectively. About 53 and 12% area under water and wind erosion, respectively, has annual soil loss of < 5 t ha^{-1}. About 23 and 9% area under water and wind erosion respectively are experiencing annual soil loss in the range of 5-10 and 10-15 t ha^{-1}, respectively. These areas require appropriate conservation measures. Only 4% area has soil loss >15 t ha^{-1}. **Soil Resource Mapping of District level (on 1: 50,000 scale):** Soils of 17 districts of North India have been mapped, characterized, classified and interpreted.

Watershed/Village/ Farm level: Soil Resource inventory of watersheds (Moolbari & Behdala (HP); Danda & Khulgad (Uttarakhand) and Buraka (Haryana); villages (Shikopur & Sirsi (Haryana) and Jainpur (UP) and farms (IGFRI farm, Jhansi; CIPHET Farm, Ludhiana; KVK, IARI farm, Shikhopur and IARI farm, New Delhi, have been carried out.

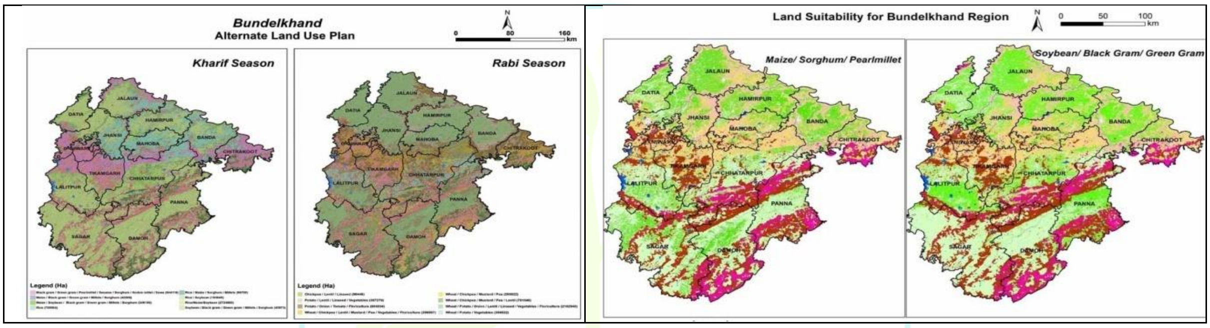
Mapping and Assessment of Land Degradation in Major Ecosystems of India:
ICAR-NBSS&LUP RC,Delhi has contributed in mapping and assessment of land degradation in Jagner block (Agra district, Uttar Pradesh, Dhanpatganj block (Sultanpur district, U.P.) and Nagrota Bagawan block (Kangra district, H.P.). The geospatial datasets on SRTM DEM (30 m), Landsat ETM+, Landsat 8 OLI, Resourcesat-2 and Sentinel-2 data were used for mapping and assessment of land degradation on 1:10,000 scale in five major ecosystems of India.

Sustainable Agricultural Land Use Planning (LUP):
Land use planning for Aspirational districts:
Soil resource maps, Soil and water conservation plans and alternate land use plans of aspirational districts of Balrampur, Bahraich, Chitrakoot, Saraswati and Sonbhadra districts of U.P, has been generated under 27 Aspirational districts of India as assigned by NITI Aayog, GOI.



Land use planning for Bundelkhand Region:

Based on the database, crop suitability and alternate land plan were generated in the GIS environment.



Scheduled Caste Sub Plan (SCSP):

For improving livelihood security through integrated natural resources management in the identified village of Yamuna Nagar district, Haryana. Input distribution of quality seeds, fertilizers and animal feed to SC households were distributed to improve the crop and livestock productivity. Trainings were imparted for crop diversification and improved animal productivity as a component of Land Use Planning (LUP) technology.

National Important Priority/ Pilot work:

Pilot Project on School level Soil Health Programme, initiated by M/o. A&FW and DSE&L, M/o Education, New Delhi for awareness generation on soil through school students, and spread the messages to the stakeholders were completed as team member. A pilot project was undertaken in 20 schools of 13 districts of India (50 SHCs for each school). Study materials & manuals on soil sampling & testing procedures for class VIII to XI, teachers manuals, & posters were prepared; SHCs were generated by registering students. The to be rolled out in 1000 schools.
Extension/Outreach Activities: Scientist-farmer interactions, field Days-cum-demonstrations, Krishi Mela's, Mahila Kisan Diwas, training programmes, and various extension outreach activities /events were organized for awareness of soil health management and increasing crop productivity.

Regional Centre Jorhat

About the Centre

The Regional Centre, Jorhat started working in the year 1979. The Centre's jurisdiction is the North Eastern Region (NER) of the country comprising of eight states *viz.*, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura. The Regional Centre, Jorhat is mandated to generate resource information on land, soil and to develop land use plan for the entire NER using remote sensing and GIS techniques. The activities of Regional Centre are grouped into three categories viz. research, human resource development and capacity building of farmers through farmers-scientist interaction.

Salient Achievements since inception of the Centre

1. Soil resource mapping of North Eastern Region at state level (1:250,000 scale)
2. Soil resource mapping for district planning (1:50,000 scale)
3. Soil nutrient status mapping for Assam and Tripura States
4. Land resource inventory of *Jhum* intensified areas of Mokokchung district, Nagaland
5. Soil resource mapping of 110 blocks in the NER.
6. Agricultural land use planning of Jorhat district and other blocks under study.

Externally funded projects

1. Land resource inventory of Ri-Bhoi district of Meghalaya sponsored by Govt. of Meghalaya.
2. Land resource inventory of Arunachal Pradesh at large (1:10000) scale for agricultural land use planning using geo-spatial technique. *(Sponsoring Agency - Department of Agriculture, Government of Arunachal Pradesh)*

Ongoing projects - *Institute Projects*

1. Sensor based surface and deep soil carbon modelling for predicting active and passive poos of carbon in different landforms of Arunachal Pradesh.
2. Land Resource Inventory of Upper Brahmaputra Valley Region of Assam for Optimal Agricultural Land Use Planning using Geo-Spatial Techniques
3. Digital Mapping of soil attributes in Central Brahmaputra Valley Region of Assam.
4. Hindon Roots Sensing HIROS River Rejuvenation through Scalable Water and Solute Balance Modelling and Informed Farmers' Actions.
5. Hyperspectral characterization of soils of Indian soils and development of soil spectral library and models for quick assessment of soil properties.

MoUs signed between ICAR-NBSS&LUP, Regional Centre, Jorhat, and other organizations

1. MoU done between ICAR-NBSS&LUP, Regional Centre, Jorhat and Rain Forest Research Institute, ICFR&E, Jorhat on training provided to staff of RFRI in fields of laboratory analysis and RS & GIS.
2. MoU done between ICAR-NBSS&LUP, Regional Centre, Jorhat and Department of Agriculture, Govt. of Arunachal Pradesh on the project "Land resource inventory of Arunachal Pradesh in large scale for agricultural land use planning using geo-spatial techniques".

Awards

1. Dr. K. K. Mourya received Second prize in poster presentation on "Soil characterization and land suitability evaluation for land use planning using geospatial techniques in the lower Brahmaputra valley zone of Assam". In 3rd International Conference on Biodiversity, food security and climate change organised at Assam Agricultural University, Jorhat, Assam during 25-28 April 2023.
2. Dr. U. S. Saikia, received Best Trainee award for successfully completing 5 days online training programme on "Innovative Extension Strategies for Sustainable Natural Resource Management in Rainfed Agriculture" during 30th October- 03rd November, 2023 at ICAR-CRIDA, Hyderabad organized by ICAR-CRIDA & MANAGE, Hyderabad in collaboration.

List of Major Few Recent Publications

1. Ray, Prasenjit, Gogoi, S.N., Bandyopadhyay, S., Padua, S., Jena, R.K., Roy, P. Deb., Ramachandran, S., Sharma, G.K., Sah, K.D., Trivedy, K., Singh, S.K. and Ray. S.K. (2018) Fertility status of mulberry (Morusindica L.) growing soils of upper Brahmaputra valley region of north eastern India. *Range Management & Agroforestry*, 39(2):147-155.
2. Sharma, G. K., Jena, R. K., Moharana, P. C., Ray, P., Ali, S., Mourya, K. K. and Das, B. 2023. Assessment of the hydrogeochemistry of shallow water aquifers using corrosion indices and geospatial techniques in the regions of the Brahmaputra River basin, India. *Environmental Science: Water Research & Technology*. (IF 5.189)
3. Moharana, P.C., Dharumarajan, S., Yadav, Brijesh, Jena, R.K., Pradhan, U.K., Sahoo, Sonalika, Meena, R.S., Nogiya, M., Meena, R.L., Singh, R.S., Singh, S.K., and Dwivedi, B.S. 2023. Prediction of soil inorganic carbon at multiple depths using quantile regression forest and digital soil mapping technique in the Thar desert regions of India. *Communications in Soil Science and Plant Analysis*. https://doi.org/10.1080/00103624.2023.2253840. (NAAS 7.80)
4. Omuto, C.T., Scherstjanoi, M., Kader, M.A., Musana, B., Barman, A., Fantappiè, M., Jiménez, L.S., Jimenez, W.A., Figueredo, H., Balta, R. and Santander, K., 2023. Harmonization service and global library of models to support country-driven global information on salt-affected soils. *Scientific reports*, 13(1), p.13157. (NAAS 10.6)
5. Mukhopadhyay, R., Fagodiya, R.K., Narjary, B., Barman, A., Prajapat, K., Kumar, S., Bundela, D.S. and Sharma, P.C., 2023. Restoring soil quality and carbon sequestration potential of waterlogged saline land using subsurface drainage technology to achieve land degradation neutrality in India. *Science of The Total Environment*, 885, p.163959. (NAAS 15.80)
6. Mukhopadhyay, R., Fagodiya, R.K., Prajapat, K., Narjary, B., Kumar, S., Singh, R.K., Bundela, D.S. and Barman, A., 2023. Sub-surface drainage: A win-win technology for achieving carbon neutrality and land amelioration in salt-affected Vertisols of India. *Geoderma Regional*, 35, p.e00708. (NAAS 10.10)

Figure 2 Scientists and technical staff in interaction with farmers.

Figure 1 Scientists in talk with locals.

Figure 4 NBSS Stall at International Conference at AAU, Assam

Figure 3 Celebration of Hindi Diwas at Centre

Regional Centre, Kolkata

Regional Centre, Kolkata is one among the five regional centres of ICAR-NBSS&LUP, responsible for conducting flagship land resource inventory programme of West Bengal, Bihar, Jharkhand, Odisha and Andaman & Nicobar Islands. The Regional Centre is a self -equipped unit, engaged in satisfactory execution of land resource inventory at farm/ village/ block/ district levels together with soil correlation and classification, pedological research, remote sensing and GIS application for land management practices, assessment of soil degradation and henceforth optimizing suitable agricultural land use plan at site specific mode. At present, 19 projects are being conducted by the regional centre Kolkata, among which, 7 are from externally funded and 12 as institute project. The centre is also actively engaged in SCSP and TSP programmes and has benefitted about 500 farm families of West Bengal through land resource inventory based agro-technology transfer. Capacity building programmes on land resource inventory and agro-technology transfer are being conducted every year to sensitize the stake holders for efficient planning and policy making on agricultural land use plan.

Soil resource mapping of Eastern region for planning at state level (1:250,000 scale)
The soils of the region were surveyed and mapped on 1:250,000 scale following three tier approach. Soil physiographic models were used for mapping the soils of the region and maps are published state wise on 1:50,000 scale. Inceptisols were the dominant soils in West Bengal, covering 49% area of the state, whereas, the extent of Alfisols and Entisols were 25% and 23 % area in the state. In Bihar, Inceptisols were the dominant soil order covering 42.4 % area of the state, whereas, the contributions of Alfisols, Entisols and Vertisols were 16.7, 36.8 and 0.3 %, respectively, in the state. In Jharkhand, Alfisols were the dominant soil order, covering 54.6 % area of the state. In Odisha, Inceptisols cover 48.8 % area, whereas, the extent of Alfisols, Entisols and Vertisols were 33.5, 10.2 and 5.52% of area of respectively.

Soil resource mapping for district level planning (1:50,000 scale)
District level soil resource mapping has been accomplished on 1:50,000 scale with soil series association as mapping unit. The exercise has been completed and reports are available for Bankura, Barddhaman, Birbhum, Hughli, Kochbihar, Nadia and Purulia districts of West Bengal; Madhubani district in Bihar; Lohardaga and Ranchi districts in Jharkhand; Puri and Sambalpur districts in Odisha and South Sikkim district in Sikkim.

Nutrient status mapping for soil health monitoring
District level soil nutrient mapping status mapping has been accomplished in Jharkhand, West Bengal and Sikkim at 2.5 km, 1.0 km and 0.5 km grid interval, respectively. The spatial database has been created in Arc GIS 9.3 using spatial interpolation technique by geo-statistical method. In West Bengal, about 52.3 to 81.8 % of area was affected with slight to strong acidity, 55 to 92.9 % of area under potassium deficiency, 48 to 88 % of area under phosphorus deficiency and 59.7 to 83.3 % of area under zinc deficiency. In Jharkhand, soils of about 49 % of the state are extremely to strongly acidic and 36% area under moderate to slight soil acidic.. Block level soil nutrient mapping of 38 blocks of Dumka, Jamtara, Hazaribagh and Ramgarh districts of Jharkhand has also been performed at 500 m grids interval. The data indicate that multi-nutrient deficiencies of phosphorous, nitrogen, sulphur, boron and soil acidity problems had been the reasons for low agricultural productivity in these districts.

Established soil series for developing benchmark sites in the region
Data collected during soil resource mapping of India on 1:250,000 scale; data recorded during district surveys and the soil survey data of other state agencies were utilized. The information on soil series is published in the shape of bulletins for each state of the region. Total 62 soil series are established in the region comprising 38 soil series in West Bengal, 2 soil series in Bihar, 6 soil series in Jharkhand, 11 soil series in Odisha and 5 soil series in Sikkim.

Soil erosion assessment for monitoring degradation status

Following multi-criteria overlay, several critical parameter of soil erosion was integrated in GIS for West Bengal, Odisha, Jharkhand, Bihar and Sikkim for developing quantitative soil erosion of different states of the region.

Assessment of Distribution and Extent of Acid Soils of Eastern States

Acid soils occupy about 90 M ha (more than 25% of TGA of the country) and are spread across Himalayan Region, Eastern and North-eastern Plains, Peninsular India and Coastal Plains. About 25 Mha of cultivated lands comprise chemically degraded acid soils soil with pH <5.5. It revealed that 84.9% of TGA of Jharkhand has been affected by soil acidity, whereas, for West Bengal, Odisha, Bihar and Sikkim the distribution of acid soils were 53.6, 85.3, 55.7 and 25.1% of TGA of respective states.

Agro-ecological zoning of West Bengal

For delineating the uniform area with respect to climate, soils and land use, agro-ecological maps have been prepared within the agro-ecological region and sub-regions by superimposing bio-climate, length of growing period map, soils and landforms on 1:1 million scale in GIS. In the exercise 29 nine agro-ecological zones have been carved out for West Bengal.

Characterization and Delineation of Prime Lands of West Bengal

Prime lands were delineated separately for red and lateritic and alluvial tracts and later on combined to obtain the tentative prime agricultural land map for the whole state. The exercise revealed an area of 33929.45 sq.km (38.23 % of TGA) and 3818.79 sq.km (4.3 % of TGA) in alluvial and red and lateritic tract, respectively as prime lands which accounts for 50182.66 sq.km (56.54 % of TGA) in the state.

Landform identification and mapping of Aspirational Districts of Eastern India

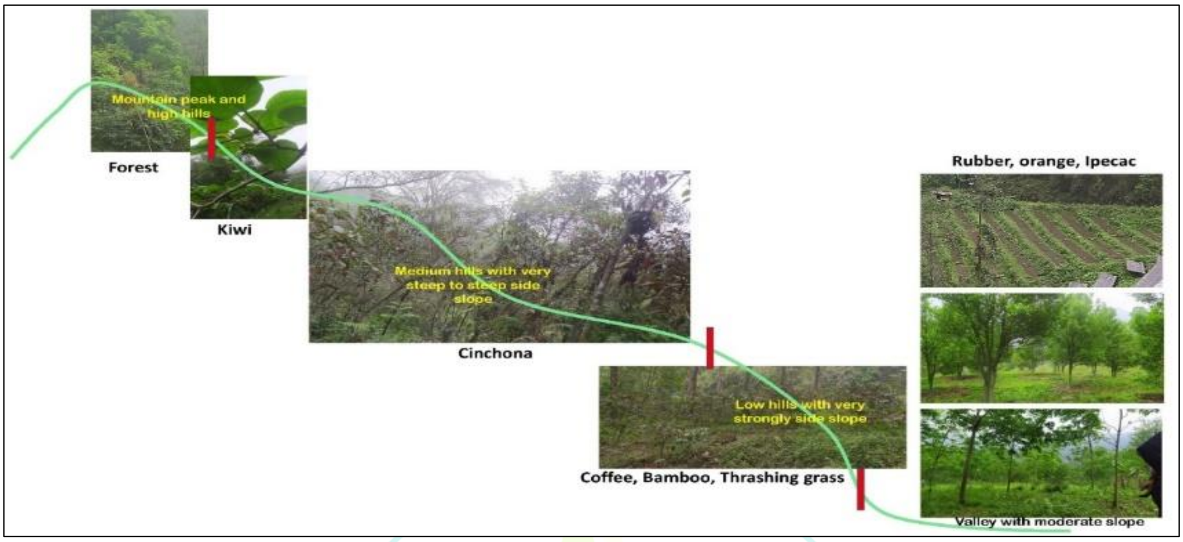
Delineation of landforms were completed for 47 Aspirational Districts of Eastern States, which included 13 districts from Bihar, 19 from Jharkhand, 10 from Odisha and 5 from West Bengal.

Land Resource Inventory at 1:10,000 scale for optimizing agricultural land use plan using geo-spatial techniques in following districts level and blocks level as well.

Katihar District, Bihar; Hazaribagh District, Jharkhand; Sahibganj District, Jharkhand
Jalpaiguri District, West Bengal; Maldah District, West Bengal; Bolangir District, Odisha
North & Middle Andaman District, A & N Islands; Tirap District, Arunachal Pradesh
Longding District of Arunachal Pradesh; Motihari Block of East Champaran District, Bihar
Hemtabad Block of North Dianjpur District, West Bengal

Land resource inventory of Cinchona and other medicinal plants growing area of Darjeeling district on larger scale using geo-spatial techniques

A land use model was suggested as soil resources on mountain peaks and high hills are marginally suitable for cinchona and other medicinal plants. However, these soils are best suited for forest (pine, pipli, *etc*.) and kiwi, which require well-drained, sandy loam soils with a soil pH of less than 6.5 and a minimum winter temperature of 7°C. It is proposed that, mountain peaks and high hills of the study area (elevation 2029-1500 m) be kept for the forest as a buffer zone, with a portion used for kiwi cultivation as a pilot study because these landforms experience slightly lower temperatures than others areas and the soils also have requisite parameters suitable for kiwi cultivation. Cinchona cultivation may be limited to medium hills with very steep to steep side slopes (1800−800 m elevation).



Rejuvenating Watershed for Agricultural Resilience through Innovative Development (REWARD), Odisha Project (Funded by DSC&WD, Govt. of Odisha).

The Project Implementing Agency (PIA), DSC&WD, Govt. of Odisha had assigned to accomplish LRI of 4 numbers of SWS clusters to ICAR-NBSS&LUP, RC., Kolkata as the Lead LRI technical Partner namely, Jujumora-1 and 2 from Sambalpur and Baipariguda 1 and 2 of Koraput district of Odisha encompassing 34 numbers of MWS covering an area of 28,738 hectare in the state during 2022-23. LRI has been accomplished in assigned all SWS clusters. Standard Operating Procedure (SOP) for LRI at cadastral level i.e. 1:8,000 scale (at micro-watershed level) for the state of Odisha with special emphasis to Easternghat Highlands and Easternghat and Mahanadi basin Physiographic Confluence has been validated and established. Research findings revealed that typical higher altitudinal Easternghat Highlands of Koraput comprises soils in two major geologic formations viz., Charnockite and Granite-gneissic Complex. Formation of very deep and highly matured soil profiles with paleo or relict type Alfisols (Rhodustalfs and Paleustalfs) attributed to rapid pedogenic processes facilitated relatively high annual rainfall, densely covered mixed deciduous vegetation and long term indigenous farming practices in the Easternghat Highlands. The physiographic confluence of Easternghat and Mahanadi Basin in Sambalpur consists of three major geologic formations viz., Granite-gneissic Complex as major one intruded with Quartzite ad Khondalite. The soils of this zone showed relatively less matured soils with moderately shallower soil profiles. This was due to land degradation due to deforestation facilitated heavy soil erosions by the mighty river Mahanadi and its tributaries coupled with seasonal droughts in summer and winter. Soils on Quartzite and Khondalite were amongst the least developed due to higher rates of erosion and lower rates of paedogenesis (Ustorthents, Haplustepts).

Community consultation programmes were periodically organized in presence of members of local Gram-sabha to identify farming community groups to adopt LRI based crop suitability plan and nutrient management plan for successful implementation. Micro-watershed wise DPR has been developed based on LRI and hydrology outputs for each SWS clusters and accepted by local Gram Sabhas and approved by the respective collectors of the district concern.

Development of high-resolution geo-smart soil management zone as an agro-technology implementation platform in Eastern Himalayan foothills of Jalpaiguri District, West Bengal

Raster based high resolution (30m) soil information at six depths and gSMZs are in huge demand for scientists, students, researchers across public and private institutes including NGOs of R&D sectors besides farmers and executors of the district; specifically, for those working in the aspects of climate change and land degradation models. The district being production hub of Tea and Pineapple (agri-horti export hub), the products will catch holds major agro-industries related to fertilizer & irrigation; as the information will serve them as a ready reckoner for input allocation in the district.

The project has been selected as one of the best projects among Agri Grand Challenge Awardees 2022 during ISCTA 2023 International conference at Biswa Bangla Convention Centre, Kolkata on 19 Dec, 2023 and processing is on for upscaling and commercialization of the work with C-DAC, Kolkata, MeitY, GOI under Agri Grand Challenge scheme by MeitY, GOI.

Soil Carbon Research

1. Conceptualizing 'SOC-4 per Thousands' through LRI based long-term soil organic carbon restorative land use plan in a humid sub-tropical region of Eastern India

The concept of carbon sequestration @ four per 1000 target set by the conference of parties (COP 2021), Paris agreement for land/soil evaluation to reduce CO_2 emission by 30% by 2040 was employed in Mal block of the Jalpaiguri district. It has been found that 25.8% of areas of the block under different land-use systems could not sequester @ four per thousand under present land use, soil, and input management practices, which urgently require practices of conservation agriculture. Highest priority to Conservation agriculture (CA) land use system where <4 per (25.8%) thousand Carbon sequestration in a subtropical forest, tea and Agriculture land use system.

2. Soil Carbon Research on Cinchona (Cinchona sp.) a sustainable land use practice in the Eastern Himalayas of India

Different soil properties, including the total microbial count, hydrolytic enzyme activities, and different C fractions and their indices, were evaluated in soils collected from natural forest, cinchona and horticulture at two soil depths, i.e., 0–15 and 15–30 cm. The LUSs significantly influenced the clay, total nitrogen (TN), available phosphorus (AP) and available potassium (AK) contents, pH, microbial properties, and the C parameters. Labile C fractions and total organic C (TOC) were the highest in forest soil, followed by cinchona and horticulture; however, a completely reverse trend was observed in the passive C pool content

3. Soil Carbon Research in Longding district, Arunachal Pradesh

Soil organic carbon and CEC were higher in surface horizons and it generally decreased with depth. A significant positive correlation between CEC and organic C suggested a strong association between them. The clay content was higher in the soils of moderately steeply sloping low hills developed from the argillaceous parent materials as a result of hydrolysis aided by the acid decomposition products of the organic matter. The soil organic C varied significantly in different land-use systems following the order forest > jhum fallow > jhum> agriculture.

4. Status of Soil Carbon Malda District, West Bengal

The surface soil organic carbon stock was also estimated which depicted the highest stock in medium range (10-20 Mg ha^{-1}) followed by moderate stock in high range (>20 Mg ha^{-1}) and lowest stock in low range (< 10 Mg ha^{-1}) consisting of 62.2%, 22.0% and 9.4% of the TGA, respectively. The northern and north-western part of the district is physiographically depicted as "Tal" region and comprised of depressed lowland in major area with swamps. Thus, the prevailing reduced soil system and high crop residue deposition (rice and makhana) resulted higher organic carbon status as well as stock in the plough layer of this region. Rice based cropping systems and application of organics extensively resulted a major area with medium SOC status and stock followed by low and high status, respectively.

Pedological Research

1. Pedomorphology vis-à-vis Soil-Mineralogical Assemblage in Topographical Sequence of Chhotanagpur Plateau of Jharkhand

High redness rating and low sand/silt and silt/clay ratio at higher elevations of Rajmahal trap, Hazaribagh plateau and Ranchi plateau indicates rapid pedogenic processes and formation of Paleo-Alfisols (Rhodustalfs and Paleustalfs). High CEC/Clay in lower elevations of Rajmahal trap and Hazaribagh plateau indicates formation of more 2: 1 type of interstratified minerals. Predominant occurrence of amorphous iron (Fe) in soils of Rajmahal basalts was indicated by high ammonium oxalate extractable Fe. Higher proportions of dithionite extractable Fe of clay in gullied lands, uplands of Hazaribagh plateau and hillocks of Ranchi plateau indicate the prevalence of crystalline Fe in Chhotanagpur granite gneissic complex. More crystalline nature of soil clays at higher elevation of Ranchi and Hazaribagh plateaus are noted as indicator of laterization processes. Presence of considerable amount of interstratified type of 2:1 minerals at lower elevations may attribute to restore better organic carbon sequestering capacity supporting long-term agricultural practices in the region..

2. Pedomorphic characteristics vis-à-vis soil-landform relationship of Katihar district, Bihar

The present study describes a comprehensive account of the landforms and soil development in the Katihar district representing North Bihar IGP. The lower the sand/silt ratio, the higher is the maturity of soils indicating relatively higher profile development. The results obtained from this study showed reversed trends for P-43 in window area 1 and P-37 in window area 2 even these profiles are nearer to the river and showed relatively higher profile development as compared to the pedons away from the river. Silt/clay ratio had a sequence of P70 > P43 > P58 > P65 and P37> P5 > P24 in window areas 1 and 2, respectively indicating that the soils away from the river showed an irregularity in their development. The index of weathering (IW) showed that the pedons in nearly level young alluvial plain (P70 in window area 1 and P37 in window area 2) had high values as compared to very gently sloping alluvial plain and away from the river. The average CEC/clay ratios of all soils were more than 0.20, indicating mixed mineralogy in the study area. The Quaternary and modern surficial alluvium deposited by the main rivers and their tributaries are consisting moderate alkalinity and less calcareous nature. The high CEC in lower Ganga basin is due to soils with slightly heavier texture as compared to Mahananda sub-basin that carry lighter texture sediments from Himalayas during rapid sedimentations.

3. Conceptualizing Pseudo-Andic properties of soils of North and Middle Andaman district, Andaman and Nicobar Islands

Soils of Andaman do not qualify for Andisol characteristics. However, Swadeshnagar (interspersed valleys), Chitrakut (Coastal Plains) and Baratang series (Volcanic Mudflats) exhibited some pseudo-andic characteristics owing to low bulk density (0.96-1.08 Mg/m3), ratio of acid oxalate extractable iron (Fe_o) to the citrate-bicarbonate-dithionite (CBD) extractable iron (Fe_d) of more than1.0 with a range from 1.26 (interspersed valleys) to 2.85 (volcanic mudflats), ratio of), ratio of acid oxalate extractable aluminium (Al_o) to the citrate-bicarbonate-dithionite (CBD)extractable aluminium (Al_d)more than 2.0 with a range from 2.20 (coastal plains) to 6.27 (volcanic mudflats) and percentage of ratio of acid oxalate extractable aluminium plus the half of acid oxalate extractable iron (Fe_o) more than1.0 with a range of 1.16 (interspersed valleys) to 1.74 (volcanic mudflats). Hence it is proposed "Andic" intergrades in other soil orders. They are classified as *Aquandic Endoaqualfs* in mudflats, *Aquandic Endoaquepts* in coastal plains, and *Aquandic Fluvaquents* in interspersed valleys.

Land Use Planning

1. Sustainable Agricultural Land Use Planning of Aspirational Districts of Eastern India

As per the Recommendations of *NITI-Aayog*, Govt. of India, sustainable agricultural land use planning of 45 Aspirational districts of Bihar, Jharkhand, Odisha and West Bengal has been undertaken. Landform delineation of 24 districts has been accomplished using Sentinel-2 data along with SRTM-DEM as base map. Sustainable agricultural land use plan with geo-referenced soil data base has been uploaded in *Aspirational District Dash Board* of *Bhoomi geo-portal* for 4 districts of West Bengal, 5 from Bihar, 2 from Odisha and 2 from Jharkhand

2. District level LUP of Nadia, West Bengal (LGP -Bengal Basin-AESR 15.1)

In Nadia district, all the land management units (LMUs) were evaluated for identifying economically viable and bio-physical suitable crops and cropping systems. Nine LMUs were delineated in the district. Different constraints were identified in each farming system and options were suggested to improve the productivity of crops. Evaluation of soil site suitability for different crops revealed that 22.7, 15.4, 9.5 and 5.1 per cent area of the district are highly suitable for rice, jute, rapeseed/mustard and groundnut respectively and about 44, 19, 80, 79, 42, 20 and 30 per cent area of the district are moderately suitable for rice, wheat, jute, rapeseed/mustard, sesame, sugarcane and groundnut respectively. Multiple Goal Linear Programme (MGLP) model has allocated area for different crops with respect to each defined goal.

3. Land Shaping Technology in Gosaba, S 24 Parganas district of WB (LGP & Coastal Eco-system

approach through land shaping technology facilitated in managing soil and water resources for enhanced crop production towards improving livelihood security of the farmers. Major interventions were: (i) Land shaping techniques (land modification through farm pond, deep furrow and high ridge, shallow furrow and medium ridge and paddy-cum-fish cultivation); (ii) Improved and salt tolerant paddy varieties; (iii) Multiple cropping/ crop diversification (low water requiring cropsc); (iv) Improving homestead production system; and (v) Promotion of vermi-composting and green manuring for reducing input cost.

4.LUP at Kultali block of S 24-Parganas district, West Bengal (LGP delta and coastal plains)

Adoption of 'Aisle' or embankment cultivation in collaboration with Ramakrishna KVK Nimpith was demonstrated in farmer's field as an alternative for resource-poor farmers in different LMU's. After land shaping treatment, the farmer diversified with other crops such as okra on the land embankment (in 0.17 ha, Rs.1600 net income), ridge gourd on pond embankment (in 0.011 ha, net income Rs.3850) during *kharif* season. Bottle gourd was raised on pandals which gave a net income of Rs.3050. The overall study revealed that a maximum increase in net returns was observed in LMU-5 (266%) followed by LMU-4 (259%) and LMU-1 (245%). On average, Aisle-based alternate LUP revealed an increase in Annual Net Returns in 2019 by 215% as compared to 2018, whereas, the B:C ratio has increased substantially by 172% from the previous year.

5.LUP in Majherpara village, Canning II block, S 24 Parganas district, West Bengal under coastal area

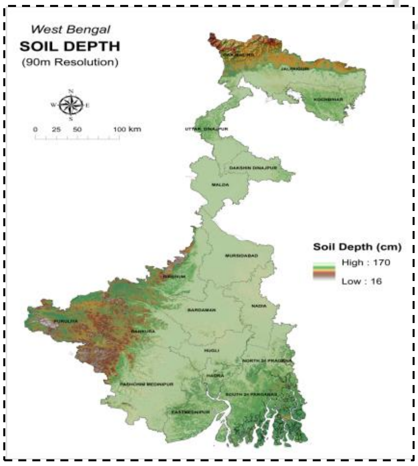
Land suitability assessment for crops showed that about 19.4% of TGA accounts for a marginally suitable class for the majority of the *rabi* and *kharif* crops due to severe salinity and drainage limitations prevailing in large parts of Majherpara-III and Majherpara-IV. These soils were recommended for multi-tier horticulture, integrated paddy-fishery cum backyard livestock, and coconut plantation. Alternate land use options were suggested using LRI based land suitability evaluation for crops. Before LRI intervention, annual net returns from crops were Rs. 71,556/- with average annual benefit to cost ratio of 1.60 only from existing land use. LRI technology offered the options for right crop diversification at right soils including options for growing paddy, maize, pea, and jute as major crops and turmeric, colocasia, cucurbits as horticultural crops. Best management practices (BMP) appear to increase yield, B-C ratio and net returns by many-folds. The average yield gain has been noted 42.0% in LRI technology-based crop performances.

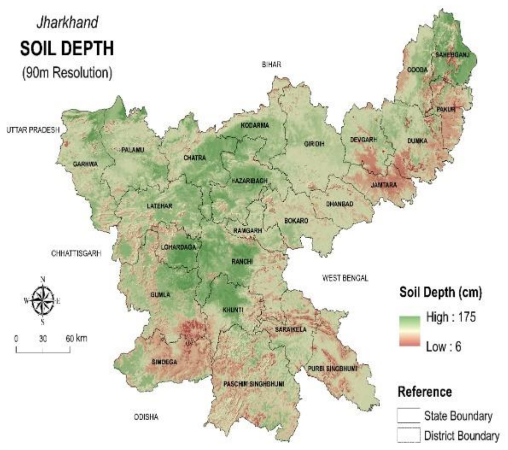
Soil Health Card Programmes

2508 numbers Soil health card were distributed among the farmers of Motihari block of East Champaran district, Bihar and Gosaba block of S 24 Parganas of West Bengal.

Future Outlook of Remote Sensing & GIS: Upscaling LRI databases to Digital Soil Mapping of Eastern Region

Available soil resource information from 1: 250,000 scale SRM data and 1:10,000 or larger scale LRI data has been upscaled to DSM various soil attributes of West Bengal. DSM output is of utmost need for the planners and policy makers of Eastern Region. The endeavor gives accurate prediction based on analysis of physical, climatic and environmental co-variates. Digital Soil Map of Soil Depth attribute of West Bengal and Jharkhand have been figured as follows:





Environmental Covariate & their Pattern Distribution

Regional Centre, Udaipur

The Western Regional Centre of ICAR-National Bureau of Soil Survey and Land Use Planning sanctioned during the Vth Five Year Plan became functional at Vadodara in 1981 to cater the needs of the state of Rajasthan and Gujarat. The Centre was shifted to Udaipur, Rajasthan in 1990 and functioned in the space provided by the Department of Soil Science and Agricultural Chemistry, Rajasthan College of Agriculture, Udaipur. Maharana Pratap University of Agriculture and Technology, Udaipur has transferred 1 ha land in University Campus for construction of office-cum-laboratory building and presently the office is functioning in this new premises from August 2003.The operational jurisdiction area of ICAR- National Bureau of Soil Survey and Land Use Planning, Regional Centre, Udaipur is western part of country including Rajasthan and Gujarat state.

Mandates

- Soil survey and mapping of the soils of the states of Rajasthan and Gujarat.
- To conduct and promote research in National Agricultural Research System in the areas of pedology, soil survey, and land use planning.
- Soil correlation, classification and characterization of benchmark soils and soil series.
- Teaching and research activities in collaboration with Agricultural University, Udaipur.
- Liaison with state soil survey/ watershed department and user agencies.

Major On-going Activities

Land Resource Inventory

- Land Resource Inventory of Amreli District, Gujarat for Optimal Agricultural Land Use Planning using high resolution satellite images.
- Land Resource Inventory of Dang District, Gujarat for Optimal Agricultural Land Use Planning using high resolution satellite images.
- Land Resource Inventory of Narmada District, Gujarat Using the New SOP for Optimal Agricultural Land Use Planning.
- Land Resource Inventory of Dahod District, Gujarat Using the New SOP for Optimal Agricultural Land Use Planning.
- Land Resource Inventory of Vadodara District, Gujarat Using the New SOP for Optimal Agricultural Land Use Planning.
- Land Resource Inventory of Tapi District, Gujarat Using the New SOP for Optimal Agricultural Land Use Planning.
- Land Resource Inventory of Anand District, Gujarat Using the New SOP for Optimal Agricultural Land Use Planning.
- High resolution soil mapping of Barmer district, Rajasthan for optimal agricultural land use planning using digital soil mapping techniques.
- Land Resource inventory of Pokharan and Jaisalmer tehsil of Jaisalmer district, Rajasthan for optimal agricultural land use planning using geo-spatial technique.
- High Resolution Soil Mapping using Digital Soil Mapping Techniques in Central Region of Gujarat

Land Use Planning

Sustainable agricultural land use planning of Aspirational district of Western India (Jaisalmer, Baran, Dholpur, Dahod, Narmada,)

Schedule Caste Sub Plan

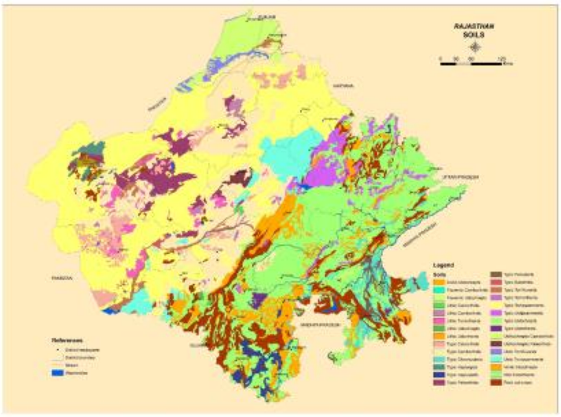
Livelihood improvement of the SC community through the integrated approaches of natural resource management in the South-eastern region of Rajasthan (SCSP).

Salient Achievement of the Centre

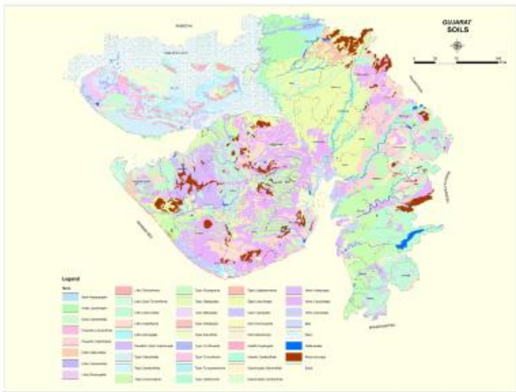
Soil Resource Map of Rajasthan and Gujarat on 1:250,000 scale.

Rajasthan has geographical area of 34.2 m ha and accounts for 11% of total geographical area of the country. The soil mapping units, including rock outcrops, cover 99.7 % and the Ranns, water bodies, habitation comes around 0.34 % of the TGA. The state has been broadly described in 117 soil series out of which 22 soil series have been correlated. The soils belong to 5 Orders, 8 Suborders, 16 Great groups, 32 Super groups and 86 Families. Gujarat covers an area of 19.6 m ha and account for 6 % of the total geographical area of the country. The soil mapping units, including rock outcrops, cover 86.4 % and the Rann of Kachchh covers another 11.0 % of the TGA. The soils belong to 5 Orders, 11 Suborders, 20 Greatgroups, 45 Subgroups, 124 Families and 145 Soil series. The Inceptisols are dominantly observed covering 51 %, followed by Entisols, Aridisols, Vertisols covering 13.8, 10.6 and 8.9 % of TGA, respectively.

Soils of Rajasthan



Soils of Gujarat



Soil degradation status of Rajasthan and Gujarat

Approximately 11.6 m ha land representing 33.2 % of total geographical area of Rajasthan is affected by various soil degradation problems induced mainly by human–intervention. Water and wind erosion were dominant degradation problems followed by salinity, sodicity, flooding and physical deterioration. The wind erosion, causing loss of top soil and/or terrain deformation, and has affected 6.6 m ha representing 19.4 percent area. Water erosion has been observed in 3.0 m ha, representing 7.1 % of TGA. Salinity alone, and in combination with water/wind erosion and flooding, has been found to affect 1.4 m ha, representing 4.0 % area. The area not fit for agriculture, including rock outcrops and Rann/salt flat and active sand dunes accounts for 5.2 m ha, representing 15.2 % of the TGA. About 8.1 m ha area, representing 41.5 percent of TGA in Gujarat is affected by various soil degradation problems included mainly by human- intervention. The most serious problem is of water erosion, causing loss of top soil and/or terrain deformation, and has affected 5.2 m ha representing 2.3 percent of the TGA. Salinity alone and in combination with water/wind erosion and flooding has been found to affect 2.5 m ha representing 12.7 percent area. The area not fit for agriculture, including rock outcrops and Rann/salt flat, accounts for 1.8 and 11.0 % of the TGA, respectively.

Integrated National Agricultural Resources Information System-Soil Resource data base

Attributes of 375 mapping units delineated in soil resource map of Rajasthan on 1:250,000 scale have been entered in MS Access programme. This information is being utilized to prepare digitized soil map of Rajasthan and thematic maps.

Soil survey of Rajasthan on 1:50000 Scale

Soils of three districts (Ajmer, Bhilwara and Bundi) of Rajasthan have been surveyed and mapped on 1:50,000 scale and 39, 40 and 17 soil series have been identified, respectively.

Land Resource Inventory for farm planning in different agro-ecological regions of India

The detailed soil survey and land evaluation of cluster of ten villages in Bhadesar tehsil of Chittorgarh district of Rajasthan was undertaken at cadastral level (1:4000 scale) to identify potential and constraints at village level, suggesting suitability of crops and alternative land use options.

Land Resource Inventory of KVK Farms in South-eastern Rajasthan

Detailed soil survey of six KVK farms (Pratapgarh, Banswara, Dungarpur, Rajsamand, Bhilwara and Chittaurgarh district) of MPUAT, Udaipur of Rajasthan covering an area of 137 ha area of has been carried out using cadastral maps on 1:4000 scale located in sub-humid southern plains and aravalli hills humid southern plain agro-climatic zones. The soils of six KVK belong to 3 orders, 3 sub orders, 3 great groups, 7sub groups, 6 family, 27 soil series and 46 mapping units.

Resource characterization and constraint analysis of productivity in land use planning of micro-watershed Changeri district Udaipur

Detailed soil survey of the watershed was completed on cadastral map of 1:4000. Soil map was digitized using GIS, Geomedia and thematic maps for various soil parameters have been prepared. Suitability for 9 crops under rainfed condition and 5 crops under irrigated condition have been evaluated by matching soil site characteristics with crop requirements.

Identification, characterization and delineation of Agro-economic constraints of oilseed-based production system in rain fed ecosystem

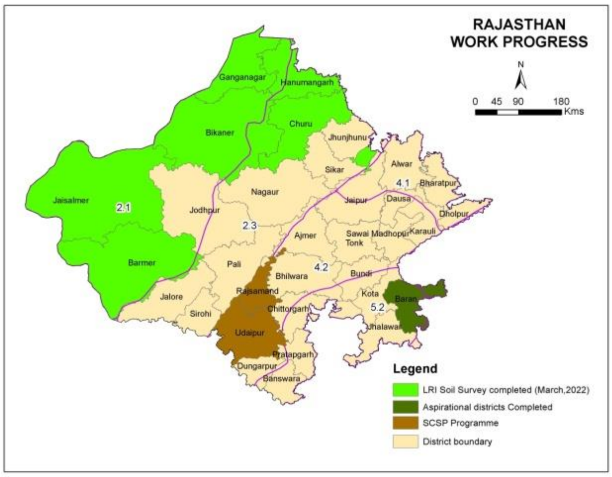
Socio-economic survey was undertaken to identify constraints in production for mustard in Bharatpur district of Rajasthan and Groundnut in Rajkot and Junagarh districts of Gujarat. 144 farmers representing marginal, small and large holdings were selected in major oilseeds producing tehsils of the district.

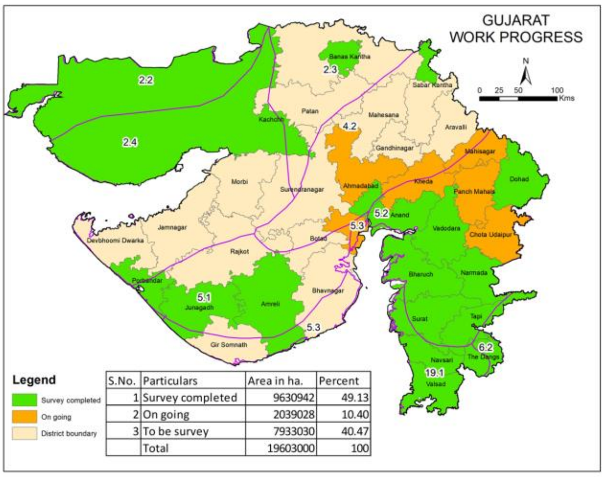
Reflectance Libraries for development of soil sensors to assess the soil resources

Reflectance at different wavelengths were recorded at four sites in the state of Gujarat (Manasa-Vijapur and Bhuj area) and Rajasthan (Gogunda- Udaipur area) have been selected for study of reflectance characteristics in relation to surface features and soil properties. Major landforms / physiography have been delineated on the basis of image attributes like shape, pattern and colour with reference to the SOI toposheet, existing land use and variation in soil characteristics.

Land Resource Inventory of Rajasthan and Gujarat on 1:10000 Scale

In present situation, 49.13% of total geographical area (TGA) of Gujarat state has been surveyed and 10.40% area of TGA will be targeted for the year 2023-24 as priority state. Similarly, 27.55% area of TGA of Rajasthan state has been surveyed. Besides that, 6.40 and 4.53 lakh ha area was also surveyed for the aspirational districts in the state of Gujarat and Rajasthan, respectively.





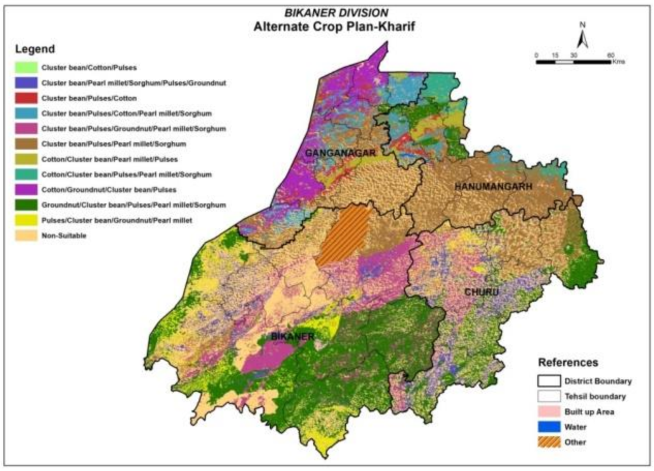
Soil survey of Gujarat on 1:10000 Scale

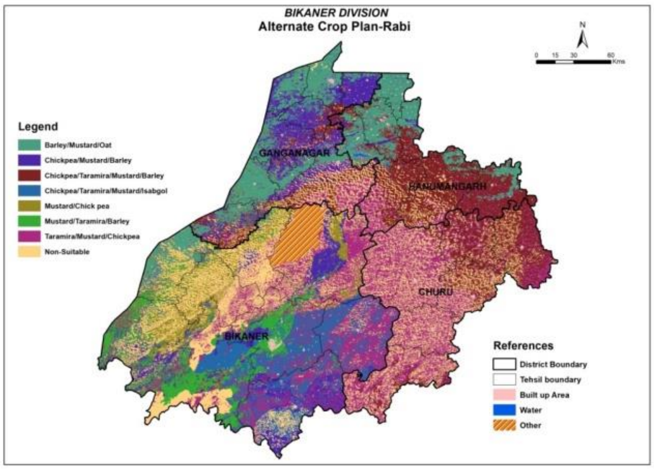
The soils of the Dang district have been categorized into 08 soil series and mapped into 14 soil phases. The soils of the Dangs varying from shallow to deep, sandy loam to clay texture, slight to moderate surface stoniness, gentle to steep slope, well drained, non-moderate calcareous, moderately acidic (pH 5.4) to slightly alkaline (pH 7.6) and dark reddish brown (5YR 3/2 to 5YR 2.5/2) to very dark grayish brown to dark brown (10YR 3/2 to 7.5YR3/3) in colour. The surface layers generally had SOC content greater than 1%, with the exception of the Mahal series which had a SOC content of 0.65%. The soils of the district are characterized by the presence of high levels of N, P, and K content. The soil analysis revealed Zn deficiency in approximately 15% of the total geographical area of the district. Soils of Amreli district, Gujarat has been categorized into 15 soil series which mapped into 42 soil phases. The Kadiyali soils, which make up 32% of the district's land, are described as fine loamy, mixed, hyperthermic Vertic Haplustepts. The morphological and physio-chemical analysis of soil profiles revealed variations in soil depth, ranging from 20 cm in the Trambakpur series to 135 cm in the Lapaliya series. The clay content exhibited a range of values in both the surface horizons, ranging from 9.92% to 50.3%, and the subsurface horizons, ranging from 8.70% to 58.4%. The district encompasses a land area of 360,165 hectares. The district has been divided into 7 landforms and 56 terrain mapping units. The district's soils were mapped into 23 soil series and 51 mapping units. The soils of the district are varying from very shallow to very deep, loamy sand to clay texture, nearly level to steep slopy, slightly-very severely eroded, nil to very strong surface stoniness and non-calcareous to volatile calcareous in nature. The morphological and physio-chemical analysis of soil profiles revealed variations in soil depth, ranging from 20 cm to 150 cm. The clay content exhibited a range of values in both the surface horizons, ranging from 10.0% to 42.8%, and the subsurface horizons, ranging from 8.6% to 51.5%. The soils of the Narmada district have been categorized into 22 soil series *viz.,* Dhanikhod, Vaviala, Jesalpur, Nandpara, Rajpura, Savli, Tilakwada, Chimbapani, Kokam, Sagai, Undava/Nichli mathasar, Upli Mathasar, Uman, Bharada, Chuli, Khocharpada and Phokarabadi, whereas the Movi, Nani singoli and Kanbudi, Patlamau and Wadva. The Chimbapani and Chulli soils series, make up 24.5 and 23.2% area of the district's land, respectively.

Potential area identification of major crops in Gujarat

Soil and site suitability was evaluated for rice, wheat, cotton, sugarcane crops in 14 map unit of 11 soil series in Ankleshwar taluka, wheat groundnut, cotton, rice, pigeon pea in 12 map unit of 10 soil series in Khedbramaha taluka whereas pearl millet, cotton, wheat and rice in 19 map unit of 10 soil series in Dholka taluka. Soil and site suitability evaluation are further applied for pearl millet, guar, moong, cotton in 30 map unit of 18 soil series in Rapar taluka and groundnut, coriander, cumin, sorghum and chickpea in 28 map unit of 16 soil series in Porbandar taluka.

Alternate land use plan (ALUP) for Bikaner division of Rajasthan





Alternate crop plan for Bikaner division, Rajasthan

Alternate land use plan (ALUP) of the division is suggested for *kharif* and *rabi* seasons. Among the suggested ALUPs, Groundnut/Cluster bean/ Pulses/Pearl millet/Sorghum for Bikaner and Churu districts whereas, Cluster bean/Pulses/Pearl millet/Sorghum and Cotton/Groundnut/Cluster bean/Pulses for Sri Ganganagar, and Cluster bean/Pulses/Pearlmillet/Sorghum and Cotton/Cluster bean/Pulses/Pearl millet/Sorghum for Hanumangarh district are the major crops/cropping systems covering maximum area during *kharif* season. Similarly, for *rabi* season, Taramira/Mustard/Chickpea is proposed as the most suitable ALUP for Bikaner and Churu districts whereas Barley/Mustard/Oat/Vegetables and Chickpea/Taramira/Mustard/Barley are the major ALUPs for Sri Ganganagar and Hanumangarh, respectively.

Division of Soil Resource Studies

Inventorying Natural Resources

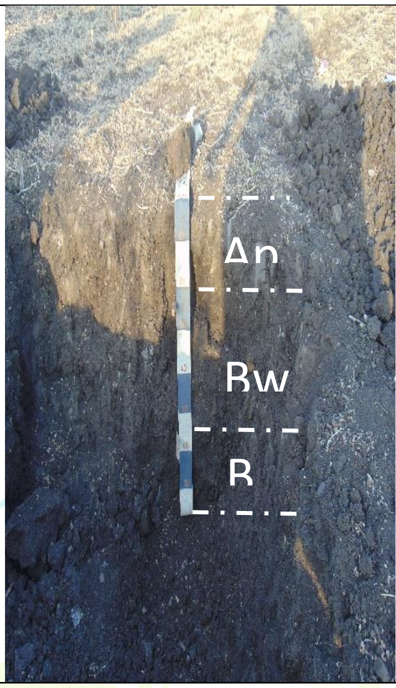
Land Resource Inventory of Ahmednagar District (Northern Part), Maharashtra on 1:10000 scale using geospatial technique for agricultural land use planning

The landforms of norther part of the district are pediment, foothills, upland, escarpments, degraded hills, plateau, alluvial plains and valley. Soils occurring on degraded hills, foot hills, plateau and valley positions of were generally shallow and moderately deep to deep. Hills, plateau and foothills landform were represented by acidic/neutral Inceptisol and Vertisol whereas, alkaline Inceptisol and calcareous/sodic Vertisol were present in the pediment, pediplain and alluvial plain.

- Surface soil texture varied from clay-to-clay loam. Soil pH varied from 6.2-9.2 and was significantly affected by different landforms. The soils of degraded hills and upland has neutral to slightly alkaline pH (7.3-8.1), whereas, pediment and valley has slight to moderately alkaline pH (8.1-8.6) at 0-30 cm depth. Organic carbon generally decreased with depth and it varied from 0.30 to 1.25 % in surface and from 0.20 to 1.16 % in the sub-surface.
- Sub-soil sodicity development in the Sodic Haplusterts (ESP >15 %) whereas, Typic Haplustepts and Typic Haplusterts are non-sodic (ESP <<15 %) were observed. Sodic soils in the alluvial plain and valley position exhibited very poor saturated hydraulic conductivity (sHC) in the surface (1-2 cm hr-1) and sub-surface layers (nil-0.2 cm hr-1).
- Moderate to strong salinity in sub-soils of some sodic Vertisols with indiscriminate use of water for irrigation in sugarcane cultivation (about 60 % of irrigation water utilized solely for sugarcane) were observed.

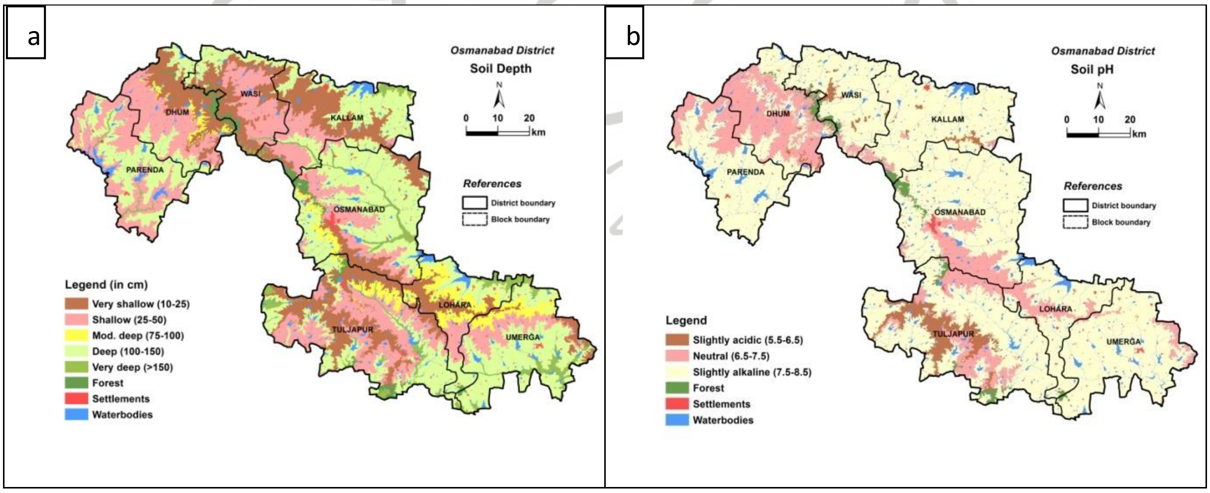
Land resource inventory and land use planning of Osmanabad district, Maharashtra using geospatial techniques

Soils from 8 landform units (LU) were characterized to establish soil-landform relationship. Terrain mapping units (TMU) under different LU were modified/correlated and merged based on similar soil characters and finally 19 TMU were taken for the purpose of soil mapping. Soils of the district were correlated based on their position in the landform, soil depth, carbonate content, physical and chemical characteristics (Figs 1 a-c). Dominant soils were selected based on their spatial distribution and accordingly 19 soil series (Linear Ridges-2; Narrow valley-1; Pediments-4; Subdued Plateau -2; Scarp slope-2; Undulating lowland-3; Undulating upland- 3; Valley floor -2) has been identified in the district. Soils of the area are grouped into three orders viz. Entisols, Inceptisols and Vertisols. Soil pH, EC, bulk density (BD), organic carbon content (OC), Exchangeable Na, and K of the soils were analyzed. Soils are moderately to strongly alkaline and non-saline whereas BD varies from 1.28-1.50 Mg m^{-3}. Soils developed over subdued plateau, linear rides, scarp slopes and piedmonts are dominantly very shallow to shallow, moderately alkaline, whereas soils developed on undulating uplands, undulating lowlands, valley floors and narrow valleys are deep to very deep and are alkaline.
Soils are dominantly calcareous with the development of slickenslides in most of deep to very deep profiles and are dominantly clayey in nature and have Vertic property. Thematic maps of depth, pH, TMU and LU has been finalised (Fig. 2 a-d).



Profile No.2,Non- Calcareous Depth:0-25cm Land use: Soyabean, Tur, Wheat Location:Kesarjodga,Umarga, Osmanabad Lat : 17° 41'27.4092"Long : 76° 27'53.29" 2022 osmanabd\27-02-2022\folder\2 (a)	Profile No.3, Calcareous Depth:0-78cm Land use: Gram,Soyabean,Wheat Location : Toramba, Lohara, Osmanbad. Lat :17°56'8.9412"Long :76° 26'49.38" 2022 osmanabd\02-03-2022\New folder\3 (b)	Profile No.9, Calcareous Depth:0-150cm Land use: Orange Orchards Location : Pargao, Washi, Osmanabad Lat :18°40'18.35''Long :75°40'42.17'' 2022osmanabd\18-2-2022\New folder\9 (c)

Fig.1 a-c. Dominant soil groups of Osmanabad District.



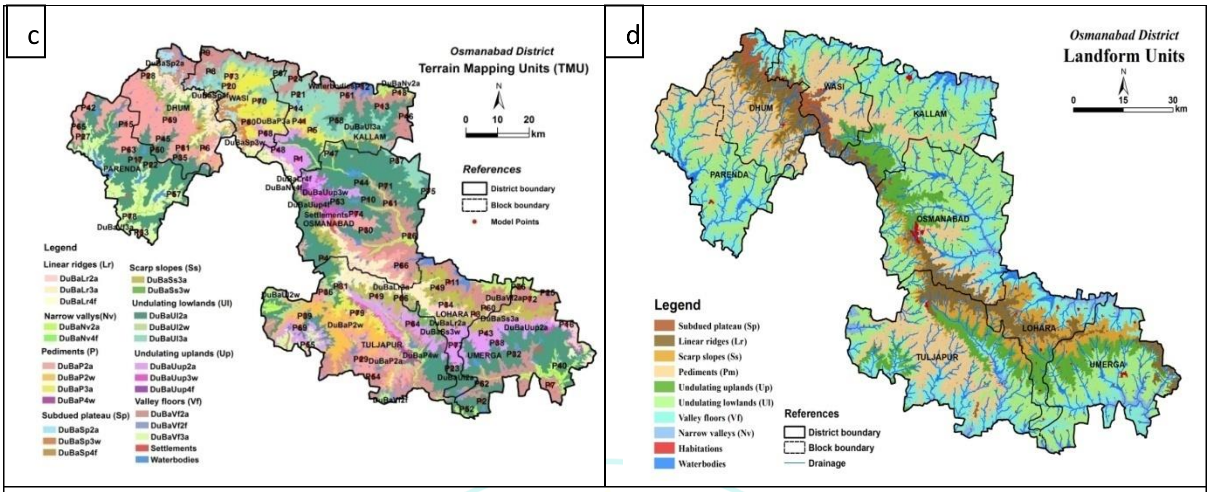


Fig.2 a-d. Thematic Maps of (a) Soil Depth, (b) Soil pH, (c) Terrain Mapping Units, (d) Landform Units of Osmanabad Dist.

Basic Pedological Research

Role of crystalline and non-crystalline nano clays in pedogenetically important soil orders of tropical India

Nature and Composition of nanoclays of major soil groups of India

The detailed nature and composition of nanoclays in some selected Vertisols and Ultisols were investigated. Dominant presence of Nanoclays (<0.1 µm); 98 % within fine (< 0.2 µm) and 60-95% within total clay (<2 µm) fractions of Vertisols (Typic Haplustert) of Maharashtra common in central part of tropical India were observed. Also preferential movement of nanoclays were observed within soil clays. Nanoclays are dominantly smectitic (> 90 %) with subordinate amount of kaolin. The Ultisol clays collected from Meghalaya contained 15-36 % nanoclays within clay fraction. Nanoclays were dominated by Kaolin, Gibbsite followed by HIV/Chlorite.

Relationship between mineral composition of nanoclays and forms of soil K

In Vertisols, positive and significant correlation of water soluble, exchangeable and non-exchangeable K with quantity of clay sized mica suggested the mineral as major K source. However, nano-sized mica, kaolin and smectite are not significant source of K in soil. Also nano-sized smectite and kaolin are non-selective in fixing K. In Ultisols, positive and significant correlation of non-exchangeable K with nano sized hydroxy interlayered vermiculite and kaolin suggested the mineral as major K source (Table 1). Also it has been observed that nano mica could also fix larger amount of K as higher degree of correlation coefficient has been observed.

Table 1. Correlation between quantity of minerals and different forms of potassium in Ultisols of Meghalaya

Parameters	Water soluble K	Exchangeable K	Non-Exchangeable K	
			HNO_3 extractable K	$NaBPh_4$ extractable K
Nano Kaolin (Int with Vm)	0.245	-0.356	0.727*	0.864*
Nano HIV	0.611	0.337	0.756*	0.742*
Nano Mica	-0.637	-0.219	-0.661	-0.542
Clay HIV	0.563	0.176	0.636*	0.669*
Nano Ch	0.69	0.383	0.623	0.514
Nano Mica-Vm (Int)	0.382	-0.11	0.802*	0.965**
Nano Mica-Chl (Int)	0.528	0.029	0.856*	0.916*

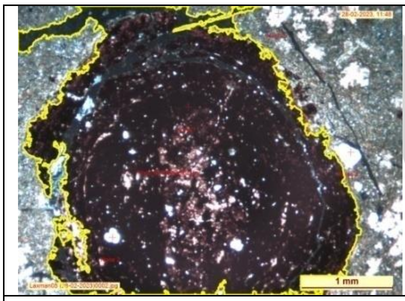
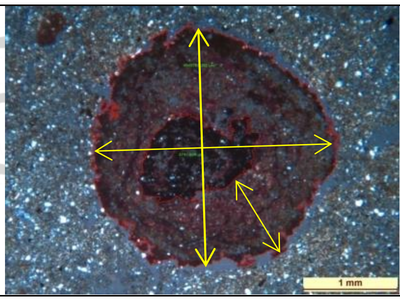
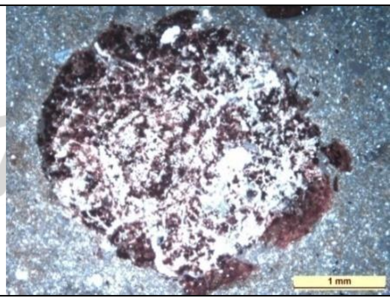
Clay Mica	-0.571	-0.442	-0.418	-0.179
Clay Kaolin (Int with Vm)	-0.342	0.062	-0.714*	-0.883*
Total Mica (Nano + Total Clay)	0.408	0.073	0.786*	0.911*

Conceptual model of organic carbon stabilization as governed by the nano size soil minerals

Indian soils in general, contain both crystalline (layered phyllosilicates, oxides and hydroxides) and non-crystalline short range ordered (amorphous aluminosilicates and ferri-aluminosilicates) nano-clay (< 100 nm) minerals, which appear to have a positive role in soil organic carbon (SOC) stabilization. The proposed conceptual model indicates that nano sized crystalline layer silicates in soils break down at acidic pH in highly weathered humid tropical soils, resulted in formation of nano size non-crystalline minerals with positive charge surfaces. These positively charged minerals then form complexes with metal humus, effectively sequestering SOC. Moreover, these non-crystalline minerals can trap SOC by creating hydroxy interlayering within crystalline minerals in humid tropical climates. Thus, in acidic soil reactions, hydroxy interlayered nano-sized crystalline minerals and non-crystalline clay minerals emerge as the primary substrates for SOC stabilization, contradicting the long-held notion linking SOC accumulation solely to the content of expanding crystalline clay minerals.

Quantification of micromorphological features of soils for its implication in climate change research

Semi-quantitative estimation of Fe-Mn nodules, pedogenic carbonate (PC), non-pedogenic carbonate (NPC), voids, and weatherable minerals present in humid tropical (HT) climate to arid dry (AD) climate indicated variability from surface to subsurface soils (Fig. 3). Study showed that iron nodules are in different forms, i.e. rounded to sub-rounded with concentric rings having an inner core ferrous whereas outer core ferric. Semi-quantitative data on iron nodules indicated that, in most cases, there is a nearly complete transformation from ferrous to ferric, showing an impact of climate change. Similarly, PC and other minerals were also quantified (Figs. 3; d, e). The presence of voids was quantified, and work on their relation with different soil properties is under process (Fig.3 f).

		
(a) Concentric iron nodules with dissolution features in the soils of Lakholi Kanhar, Raipur. XPL, 2.5x, 3 -18cm (472/1). (Area:8410498.973 μm^2)	(b) Conversion of ferrous to ferric iron from inner to outer ring, an indicator of climate change in Lakholi Kanhar, Raipur, XPL, 2.5x, 41-63cm, (474), (total area of the concretion is 4945763.280 μm^2, inner core 5741.904 μm^2, transformed area 4940021.38 μm^2	(c) Dissolution of iron nodules in the soils of Lakholi Kanhar, Raipur. XPL, 2.5x, 41-63cm (474).

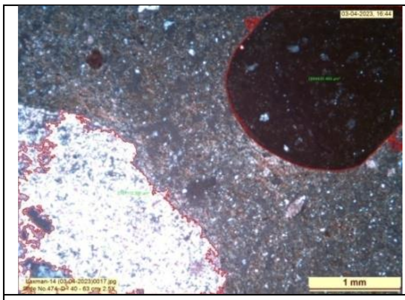
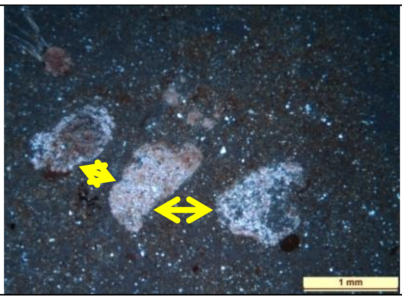
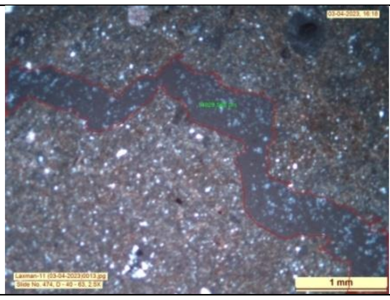
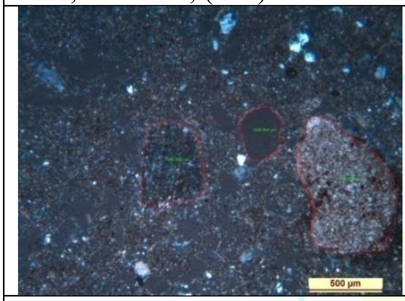
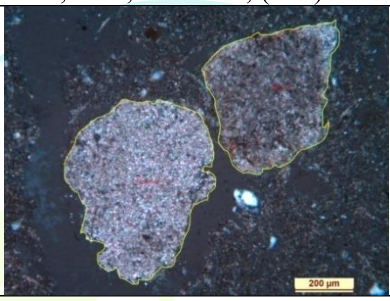
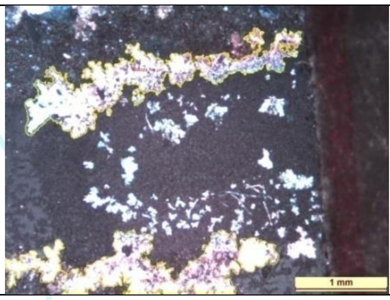
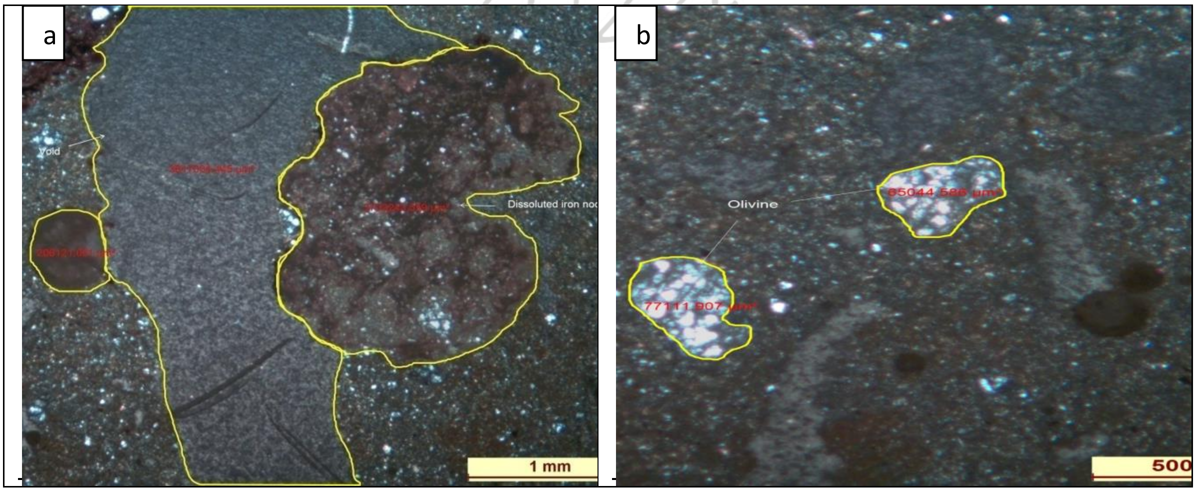
		
(d) Pedogenic carbonate as well as iron nodules occurring together in a soil matrix of Lakholi Kanhar, Raipur. XPL, 2.5x, 41-63cm, (474)	(e) Three PC grains in different stage of weathering indicating the impact of climate change in the soils of Lakholi Kanhar, Raipur. XPL, 2.5x, 41-63cm, (474).	(f) Curved plainer voids in the soils of Lakholi Kanhar, Raipur. XPL, 2.5x, 41-63cm (474)
		
(g) Pyroxene (Hypersthene) along with quartz in different stage of weathering in the soils of Joldarsi, Bellary. 10x, xpl, 0 - 17 cm (353)	(h) Dolomite in the soils of Joldarsi, Bellary. XPL, 10x, 0 -17 cm (353).	(i) Pyroxene (Aegirine-Augite) in different stage of weathering in the soils of Joldarsi, Bellary. XPL, 10x, 0 -17 cm. (353).

Fig. 3 (a-i) Representative photomicrographs of Fe-Mn nodules, pedogenic carbonate (PC), non-pedogenic carbonate (NPC), voids and weatherable minerals in soils under cross-polarized light

The estimation of weatherable index mineral particularly of olivine, pyroxene, pedogenic carbonate (PC) and iron nodules present in SHM climate of IGP soils indicated variability from surface to subsurface soils (Fig. 2). It was observed that olivine mineral having dominant constituents of Fe-Mg silicates and pyroxene having dominant constituents of Ca, Fe, Mg silicates and iron nodules, are in different stages of weathering, and it is supposed to be the major source of nutrient in IGP soils besides the presence of micaceous minerals in the groundmass. Their quantified value is given in the body of respective minerals and their variation is due to climate change.



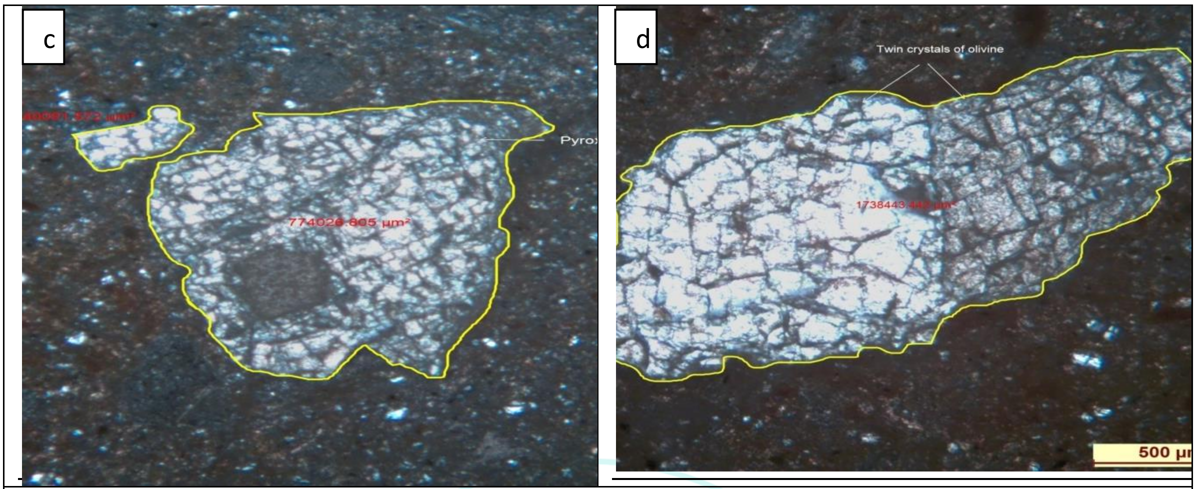


Fig. 2. Semi-quantitative estimates of micromorphological index minerals with their area in the soils of Burdwan Dist. W.B. (a) Fe-Mn nodules , 2.5x,XPL,29-37cm; (b) Olivine, 2.5x,XPL,29-37cm; (c) Pyroxene, 2.5x,XPL,76-84cm. (d) Twin crystals of olivine, 5x,XPL,76-84cm

Evidence of presence of palygorskite in Vertisols of Yavatmal

The X-ray diffractograms indicate the presence of clay size palygorskite mineral with smectite, mica and kaolinite in some soils of Yavatmal district (Fig. 4). The netlike structure of Palygorskite minerals on wetting and presence of Excess Mg in exchange complex are responsible for low sHC even in non-sodic soils.

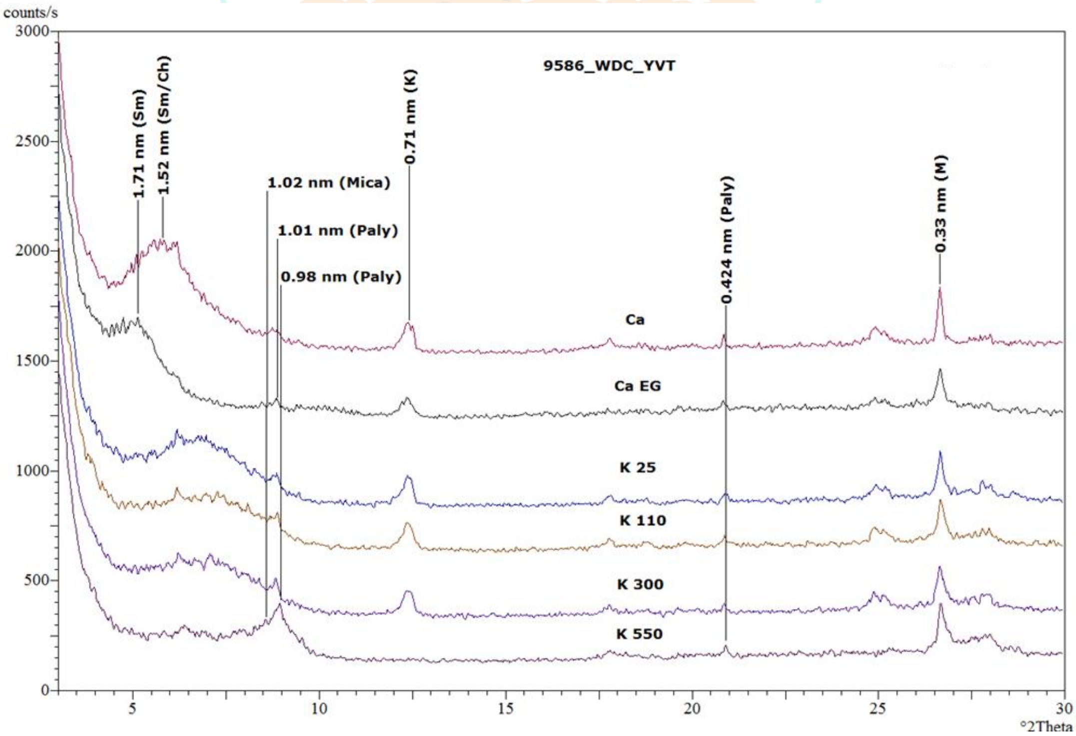


Fig. 4. XRD diagram indicating presence of clay size palygorskite mineral with smectite, mica and kaolinite in soils of Yavatmal district.

Pedodiversity of Vertisols

Pedodiversity of Vertisols in different Agro Ecological regions of India

This study was initiated to understand the variability of Vertisols with respect to AER characteristics and level of management. A total of 436 Vertisol soil profiles data was compiled from 9 different AERs

(Fig. 5). The majority of profiles occur in AERs 4, 6, 10, 11, 12, and 19. The depth of the Vertisols varied from shallow (37 cm) to very deep (>150 cm) with a mean depth of 133 cm across the AERs. The soil depth varied considerably (37-160 cm) in AER 6, 10 and 12 (Fig. 5), whereas the Vertisols of AERs 7 and 11 did not vary significantly in depth.

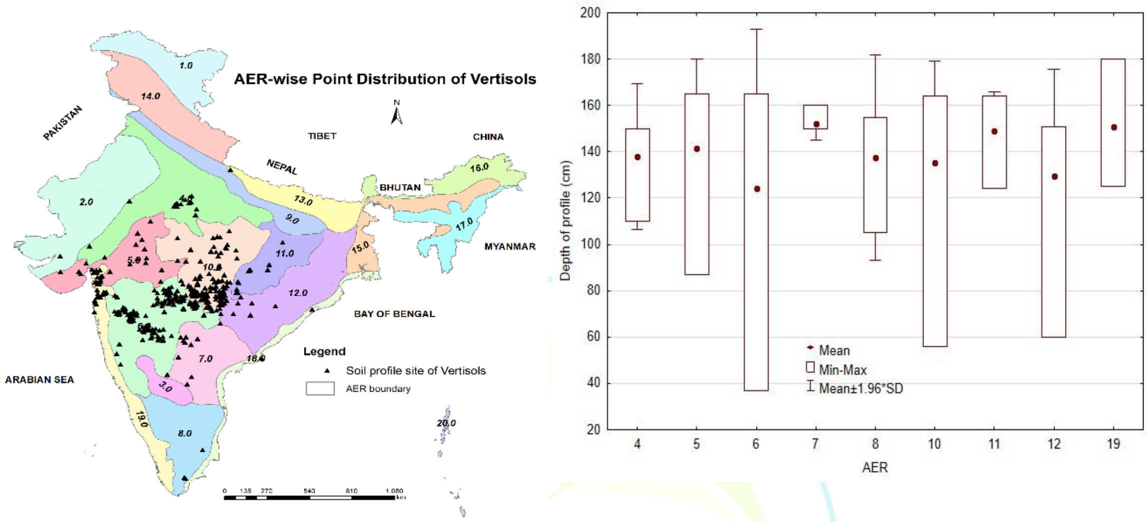


Fig. 5. Distribution of Vertisols in different Agro Ecological Regions (AERs) of India and the variability in their depth across the AERs

A study on the pedodiversity of Vertisols was initiated in 2022 and the morphological, physical, and chemical data of 454 Vertisol profiles were compiled and the variability in their depth in different Agro Ecological Regions (AERs) were analysed. During the reporting period, Vertisol legacy data of 604 profiles across the various AERs of the country were added and total profiles in the dataset is 1058. The surface horizon thickness varied from 8 to 23 cm due to variation in land use management. The initial depth of slickenside occurrence varied from 16 cm to 57 cm and the thickness of the slickensided horizons varied from 27 cm to >90 cm. Various types of cracking patterns viz., irregular, hexaconal, and criss-cross were observed in the surface of the Vertisols. The depth of surface cracks was higher (30-52 cm) in AER 6 and 7 than the other AERs indicating the soil moisture deficit in these AERs. The width of the cracks at the surface varied from 0.5 cm 11 cm. Generally, the colour of the Vertisol surface horizons varied from 10YR 3/4 to 10YR 3/3 and the subsurface horizons from 10YR 2/1 to 10YR 5/6 due to the influence of parent material and soil moisture regime. Some Red Vertisols are also found in AERs 6 with the colour hue varying from 7.5 YR to 5 YR. Few Vertisols under perennial crops in AER 19 had granular structure due to high organic matter addition and no tillage. The Vertisols of AER 6 and 7, particularly in the central Maharashtra region were mostly calcareous, sodic and showed effervescence to diluted HCl but the coastal Vertisols formed from basaltic alluvium deposits were non-calcareous and non-sodic. The coastal Vertisols in the AER 19 were very deep and exhibited well-drained conditions.

Eco-Restoration of the Pench National Park

This project has been taken up to generate the baseline data of the degraded sites of the forest eco-system caused due to the various developmental activities in Pench National Park. 217 grid samples were collected and characterized for pH, EC, organic carbon (Fig. 6), available bases, micro- and macro-nutrients for different land covers. The baseline information was generated under this project for the degraded sites of Pench National Park due to various anthropogenic activities, for developing an appropriate rehabilitative plan to restore the forest ecosystem.

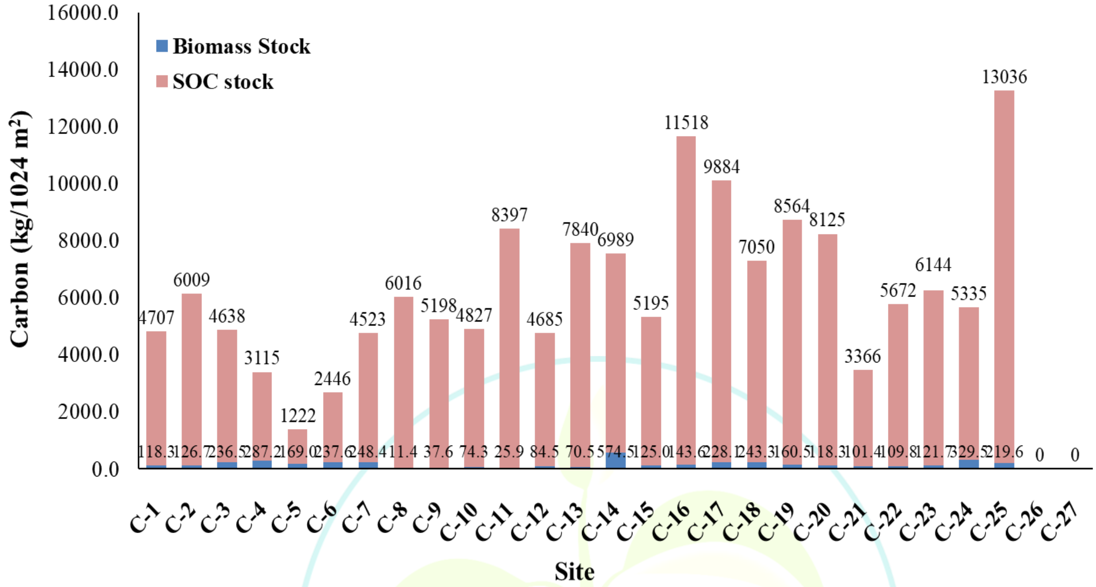


Fig. 6. Total carbon stock of 0-30 cm (biomass + soil) of the 27 sites

Apart from Physical and chemical properties. Soil biological parameters were also studied since living organisms, including plants and microorganisms, lead to carbon capture and storage *via* different biological processes. In this objective we studied (a) microbial biomass carbon, (b) soil basal respiration, (c) metabolic quotient (qCO_2), and (d) soil dehydrogenase activity to know the overall microbial activity, representing the living SOC. The microbial parameters of all the twenty-seven sites selected for carbon assessment were studied and mentioned in the baseline assessment. Our study suggests that soil microbial parameters (SMBC, SBR, SMBC/SC, qCO_2) are key soil health and fertility indicators. Land use/cover alters the SOM content and soil microbial functions. The management strategies focusing on the conservation of natural forests and minimizing land disturbances will effectively prevent soil carbon flux as CO_2 and maintain the soil carbon stock.

Cumulative K release from five different soil series representing Alfisols of Indo Gangetic Plain (IGP)

Surface soil samples (0-25 cm) of 5 soil series representing Alfisols of IGP were studied for their ability to release non-exchangeable K by Ba-K exchange process ($BaCl_2$ extractable K). The soils were neutral to highly alkaline with medium to high available K status. The Hirapur series soil released highest amount of K whereas the Hanrgam series soil released the lowest amount of K. The cumulative K release from this soil corresponded to their available K content. In general, the rate of K release from soils was decreased with increasing number of extractions **(Fig. 7**). This might be due to removal of most interlayer K by Ba^{2+} ions and remaining interlayer K exchange has been considerably reduced. The difference in cumulative K release among the soils can further be explained after mineralogical study of the soils.
The soils were also studied for evaluating their capacity for K supply and replenishment by characterizing the K quantity-intensity(Q/I) relationship.

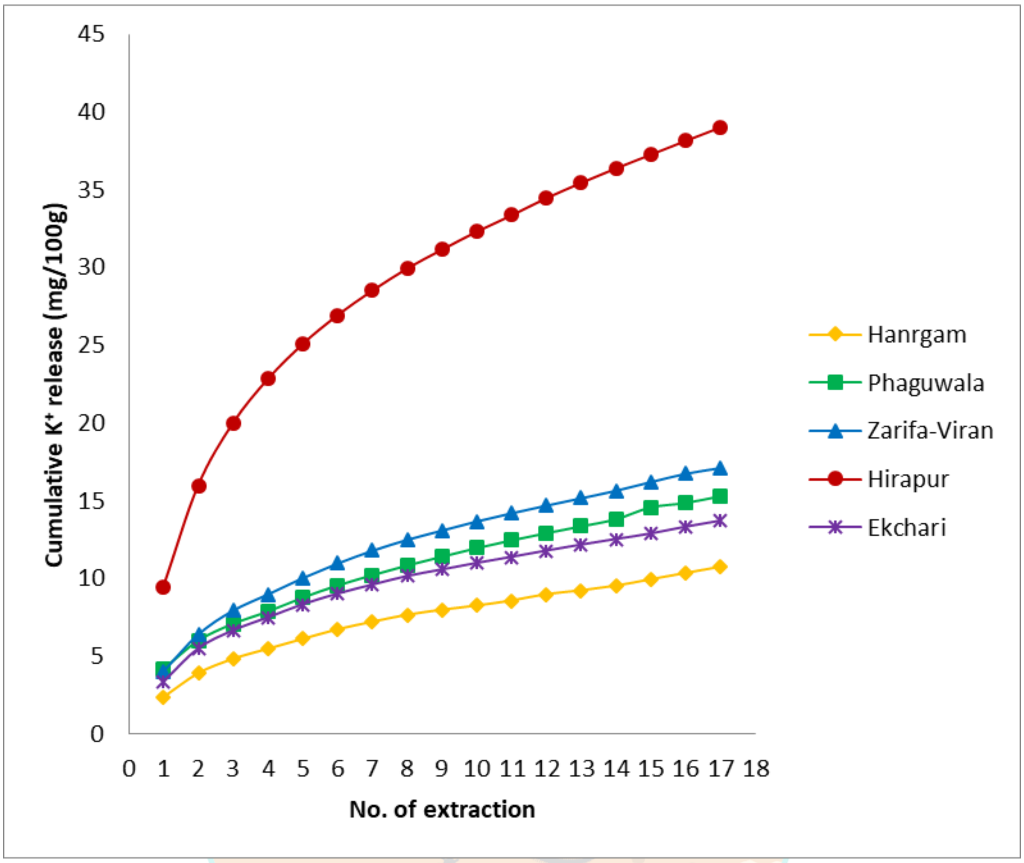


Fig. 7. Relation between cumulative K release of soils and number of extractions

Salient findings

- The equilibrium activity ratio (ARe^K) varied from 19.5 x 10^{-4} to 106.7 x 10^{-4} and from 11.8 x 10^{-4} to 37.8 x 10^{-4} at surface and subsurface soils, respectively. The highest ARe^K was observed in Aligarh soils and the surface soils have higher ARe^K than the subsurface soils.
- The free energy of exchange (ΔG^o) was significantly higher in the surface than the subsurface in all the soils. The Bardhaman and Bhagalpur soils showed ΔG^o values more negative than -3500, hence these soils are inherently less fertile in K.
- The Sangrur soils have the lowest potential buffering capacity (PBC^K) of 35 $cmol_c$ kg^{-1} indicating their poor ability to replenish solution K as compared to other IGP Alfisols.
- The CK_0 value was very low (6.7 mg L^{-1}) in Bardhaman surface soil indicating lower content of immediately available K for plant uptake. The highest CK_0 value (34.1 mg L^{-1}) in Aligarh surface soils indicates maintenance of greater solution K concentration, which is beneficial for plant K uptake.

Division of Remote Sensing Applications

The Division of Remote Sensing Applications (RSA) was established in 1985 as a Research Division at ICAR-NBSS&LUP to conduct research in the application of remote sensing technologies for an inventory of soil resources, characterization of watersheds, assessment of soil degradation, and ecological studies for land resources management. The division is also carrying out studies to develop innovative techniques for using the latest satellite data in soil characterization and mapping applications. The major infrastructure facilities at the Division are the Soil spectral reflectance laboratory with ASD Field Spec Spectroradiometer, Digital image processing facilities with RS and GIS software viz. Geomatica, ArcGIS, ERDAS, ENVI, Ecognition, TNTMips, Scanex, and ILWIS, a modest laboratory for analysis of soil physical and chemical parameters and Data Centre with the latest remote sensing and GIS softwares.

The salient achievements of the Division are

- **Landform mapping for Land Resource Inventory**: The digital terrain database and landform maps at state, district, block and watershed levels in different agro-ecological sub-regions of central India were developed by using geospatial techniques. Landform analysis was carried out based on the visual interpretation of high-resolution IRS-P6 LISS-IV, Sentinal-2 data in conjunction with SRTM-DEM (30m). The developed landform maps were used in conducting a soil survey at various scales.
- **Land Resource Inventory at block Level.** The land resource inventory in Dhanora block in Seoni district, Madhya has been conducted on 1:10 scale scale by using high-resolution Carosat-1 merged IRS-P6 LISS-IV data for land use planning and management. The landform, slope and land use/land cover maps were integrated to develop a Landscape Ecological Unit map. LEU-soil relationship was developed and soil map with phases of soil series has been prepared.
- **Land Resource Inventory Panchayat level:** In Miniwada Panchayat of Katol tehsil, Nagpur district, Maharashtra and geo-spatial database was developed on 1:10 scale. In addition, decadal cropland dynamics from 2003 to 2013 were also studied. The results indicated that area under soybean had increased replacing cotton. Seamless DEM of 10 m resolution was generated from seven Cartosat-1 stereo pairs using Intergraph LPS. The Resourcesat-2 LISS IV images and ortho-rectified Cartosat-1 data were fused to get PAN-sharpened data for the panchayat. Base maps were generated with DEM (10 m) extracted from Cartosat-1 stereo pairs and Resourcesat-2 LISS IV images. GPS-based points on landscape, landforms, slope and land use/land cover covering different landforms were collected in the panchayat to validate the landforms. A total of 60 profiles have been studied and soil samples were collected in the study area covering 1621 ha. A total of 23 phases have been identified, seven phases in Mw-1, four phases in Mw-2, two phases in Mw-3, four phases in Mw-4, two phases in Mw-5 and four phases in Mw-6.
- **Spatial Modelling for Delineation of Agro-Ecological Zones (AEZ's) of India for Smart Agricultural Planning using Earth Observation Time-series Data:** The Length of Growing Period (LGP) map with a 15-day interval was generated by integrating mean annual PET and soil AWC maps of India. The LGP maps show a total of 23 classes, where the hyper-arid with an LGP of less than 30 days was found especially in western Rajasthan, and the per-humid zone with an LGP of more than 345 days was found especially in the northeastern region of India. Thematic layers of bioclimatic zones of India and LGP were integrated by using the intersection tools of GIS and derived a total of 116 classes of bioclimatic zones and LGP classes combination. While generalizing the classes, areas with less than 1000 ha were merged with adjacent classes by using bioclimatic zones of India and LGP classes as a reference. During the generalization process, various terrain parameters like elevation and hillshade generated from SRTM 30 m resolution DEM data were used. Subsequently, distinct 97 bio-climatic and LGP classes were delineated. It was observed that the higher area is covered by Semi-Arid Moist with LGP 105-120 days, and the smaller area is covered by Semi-Arid Moist with LGP 75-90 days.
- **Comparison between Remote Sensing and Conventional Soil Mapping:** The study indicates that the remote sensing technique saves about 30 to 40 percent time and 20 to 30 percent cost with

acceptable accuracy when compared with conventional techniques. The soil map prepared by remote sensing showed an accuracy of 59 to 73 percent as compared to the conventional soil mapping approach (having accuracy of 67 to 85 percent) at 90 percent probability.

- **Land Productivity Potential:** The land productivity potential (LPP) of Wardha district, Maharashtra has been evaluated by integration of terrain parameters, soil variables and MODIS NDVI 16-days composites in GIS. The results indicated that nearly 15% of TGA for cotton, 47% for soybean and 52% for wheat had good to very good potentials.
- **Fallow land mapping in Goa:** A methodology is developed for fallow land mapping of Goa state on 1:10 scale using temporal RS data and a fallow land map was prepared. An android based mobile application software "Potential Crop Zone (PCZ) Mapper" was also developed for easy visualizing and dissemination of Land Resource Information of Goa (LRIS Goa).
- **Land degradation assessment:** Under an ICAR sponsored extramural project, methodology for mapping and assessment of type and severity of land degradation at 1:10 scale has been developed using temporal Sentinal -2 satellite data, SRTM DEM 30m and soil survey data. Land degradation was assessed by integrating soil loss computed by using RUSLE, chemical and vegetal degradation. Field information on soil, terrain, landforms and land use systems were collected to assess and validate various land degradation processes. Composite Land Degradation Index (LDI) and Land Degradation Information System (LDIS) in GIS environment have been developed for 10 blocks in different ecosystems.
- **Soil quality assessment**: Sustainable Vegetation Index (SVI) derived from remote sensing data was used as an indicator of soil quality. SVI values under different land utilization types (LUTs) in Parsori watershed, Katol tehsil, Nagpur, Maharashtra have been determined using NDVI data for the last 14 years. These have been categorized under poor, moderate, good and very good classes. SVI values were correlated with different soil variables to identify important variables influencing SVI. Amongst soil variables, soil depth, clay, $CaCO_3$ and -33KPa soil moisture showed good correlation with SVI. Topo-transfer functions were developed for prediction of organic carbon, clay and soil depth from terrain parameters.
- **Digital soil mapping**: Digital soil map of Tendulwani watershed of Nagpur district, Maharashtra was prepared using terrain attributes derived from Cartosat-1 DEM and legacy soil data. Major landform units were derived from object-based analysis of terrain attributes along with NDVI. Delineated landforms were validated through field survey. The landform, slope and land use/land cover maps were integrated in GIS. A composite map of 35 LEU units was developed. Legacy data was used to develop LEU-soil relationship and applied to generate the digital soil map. 5 soil series and 26 phases were delineated.
- **Development of soil spectral library and spectral data modelling:** Under NAIP project, soil spectral library of alluvial soils of Punjab and salt-affected alluvial soils of Haryana of IGP (4142) was developed. Soil reflectance spectral models have been developed for reliable prediction of SOC (r^2=0.76), available N (r^2= 0.88), available P_2O_5 (r^2= 0.83) and available K (r^2=0.75), ECe (r^2 = 0.94), Ca^{2+}+Mg^{2+} (r^2 = 0.81), Na^+ (r^2= 0.88), Cl^- (r^2= 0.92) and SO_4^{2-} (r^2= 0.67). In addition, soil reflectance library of 2567 surface soil samples (< 2 mm) from Birbhum, Jalpaiguri and 24 Pargana districts of West Bengal was developed and related with legacy soil chemical data of pH, OC, available N, P, K, S, Cu, Fe, Mn and Zn to develop spectral models. Relatively good calibration models have been obtained for EC, OC, available nitrogen, phosphorus (P_2O_5) and potash (K_2O). Spectral reflectance characteristics of 193 soil samples of basaltic terrain in Nagpur district were characterized for developing spectral models for the prediction of soil properties. Relatively good spectral models were obtained for prediction of sand (r^2: 0.79) clay (r^2: 0.60), moisture retention at 33 kPa (r^2: 0.68), moisture retention at 1500 kPa (r^2: 0.66), pH (r^2: 0.77), OC (r^2: 0.66), available Fe (r^2: 0.73), available Mn (r^2: 0.66), available Cu (r^2: 0.66) and available Zn (r^2: 0.71).

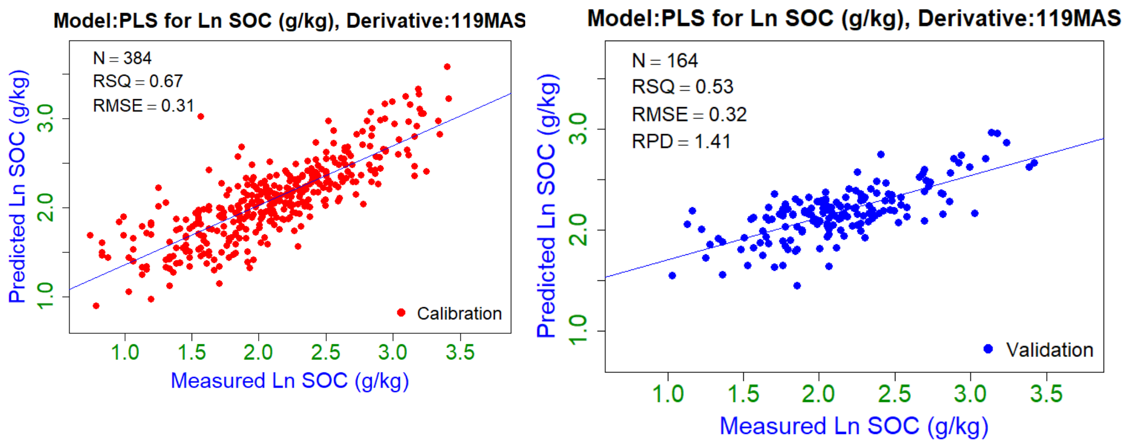


Fig. 1 Scatter plots of measured and predicted values for SOC (g/kg) in calibration and validation data in soils of Maharashtra

- **Hyperspectral remote sensing of Red and associated soils:** Under DST funded project, spectral reflectance characterization of about 2200 soil samples of red and associated soils of southern India was carried out to develop soil spectral library for characterizing the soil quality attributes and to evaluate the potential of hyperspectral input in digital soil mapping of key soil attributes. A good SOC spectral model with 8 PLSR factor was obtained which resulted in excellent prediction of SOC (r^2= 0.83, RMSEP= 0.179) in the validation dataset. AVIRIS-NG hyperspectral data have been used for the digital mapping of soil quality attributes in the Kalagatahundi watershed of Chamrajnagar district.
- **Soil Information System of India:** Under the institute funded project, a prototype geoportal of soil information system of India has been developed. It contains seamless datasets of soils on the 1:250,000, 1:1,000,000 scale, soil profile locations with attributes, soil loss map, harmonized degraded soils and wastelands, AER, AESR databases at the national level. Further, it has been enriched with raster images of DEM (SRTM 90 m, ASTER 30m and Cartosat 30m), IRS P-6 LISS-III and AWiFS and Landsat natural color composites.
- **District level Soil Information System:** Under the institute funded project, District level Soil Information System (DSIS) has been designed and developed at district level (1:50, 000 scale) to store, process and manage the geospatial soil database. Under this project, soil resource database for 54 districts across India have been processed, standardized and developed as per the standard schema of DSIS.
- **Land Resource Inventory of Vidarbha Region for Sustainable Land Use Planning:** The primary objective of this study was to generate a high-resolution digital land resource inventory of Vidarbha region and suggest land use plans, including cropping/farming systems and soil and water conservation plans. The legacy soil data were collated, digitized, and georeferenced in the first stage to locate 'blind spaces' for which no information is available. In the second stage, sampling strategy of seven districts was generated through the cLHS approach, and soil survey was carried out in 233 sites across the districts. A total of 861 soil samples collected and analyzed. The digital soil mapping technique was used to generate the spatial distribution map of nine key soil physico-chemical properties *viz*. depth, pH, EC, SOC, sand, silt, clay, available water capacity (AWC), and $CaCO_3$ content across six standard depths as per Global Soil Map specifications at high resolution (30m). Land suitability evaluation was done for twenty major crops grown in the region using an analytical hierarchical process (AHP) in the GIS environment, for agricultural land use. The predicted SOC content maps are shown in figure 2.

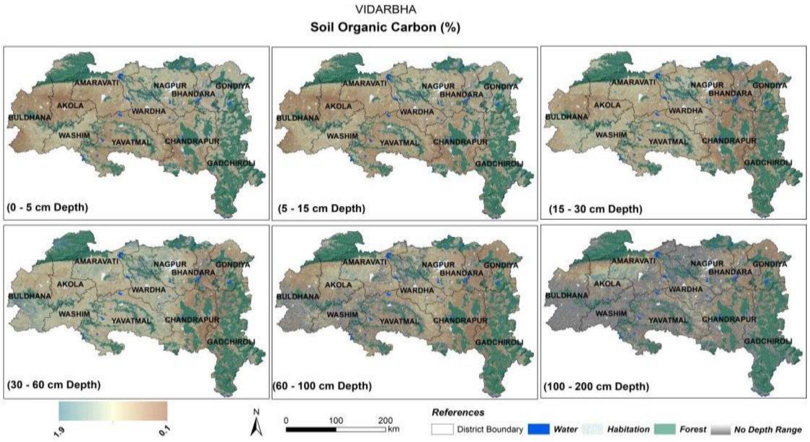


Fig.2 Depth-wise soil organic carbon content in Vidarbha region, Maharashtra

- **Identification of suitable areas for pomegranate cultivation in India:** In collaboration with ICAR-NRCP, Solapur, by using the revised climate, terrain and soil parameters in the GIS-based multi-criteria model, the suitability maps for pomegranate for 18 states have been revised, finalized and validated by ICAR-NRCP. Subsequently, state and district-wise area analyses have been carried out based on the thematic maps finalized in GIS. the state-wise thematic maps on various input parameters were finalized. The soil suitability maps of Karnataka and Telangana for pomegranate are shown in figure 3.
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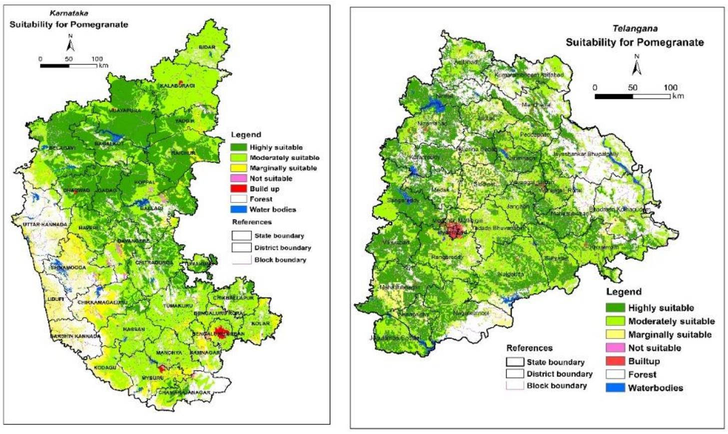


Fig. 3. Suitability maps for pomegranate in Karnataka and Telangana states

- **Development of the Indian National Soil Grid:**

ICAR-NBSS&LUP is engaged in preparing predicted soil properties maps at various resolutions using digital soil mapping techniques. Some of them are soil organic carbon and sequestration potential map of India at 1 km resolution, soil properties maps of different states at 250/100 m resolution, and soil properties maps of various regions. To disseminate these data, a soil grid Geoportal on BHOOMI Geoportal platform has been developed with the help of HTML, JavaScript, CSS, php web service, MySQL database and GeoServer (Fig.4). The portal developed, allows the user to select the region, soil physical and chemical properties, resolutions and depths. The standard depths available are (0-5cm, 5-15cm, 15-30 cm, 30-60 cm, 60-100 cm, and 100-200 cm). The user can create a graph of the variation in a soil property along with depth at pixel level.

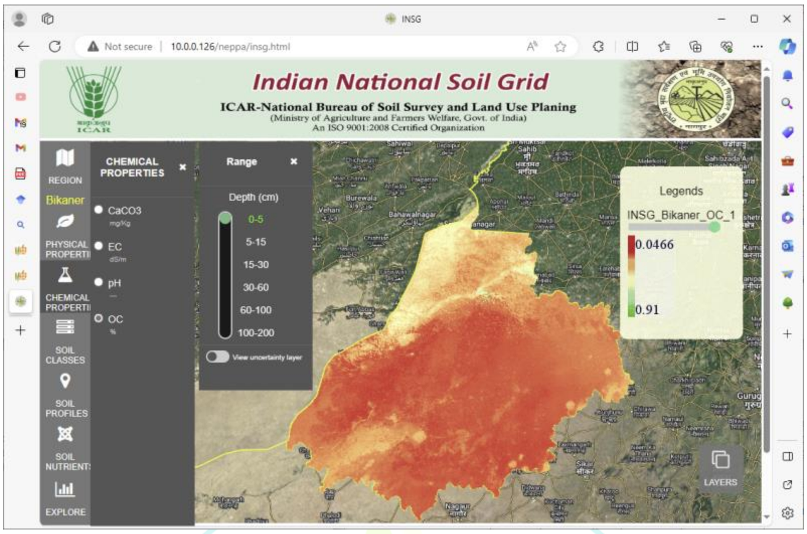


Fig.4: Front page Indian National Soil Grid.

- **Development of Indian National Soils Archive:** ICAR-NBSS&LUP has collected a large volume of soil samples across the country in the past under various projects on different scales with precise locations. This has eventually helped, the establishment of an Indian National Soil Archive (INSA) which will be helpful in studies related to digital soil mapping, soil spectroscopy, comparison of current soil conditions in a particular location to that of past, and other studies arising from the changing climatic conditions. The Indian National Soil Archive consists of: (i) a soil sample storage room where soil samples are kept with QR code levels, (ii) a web application to create and update database on the soils and generation of QR codes and reports, (iii) an android mobile application to scan the QR code to generate reports of a particular sample. Developed with the help of HTML, JavaScript, CSS, php, MySQL and GeoServer, the Indian National Soil Archive also shows the user the availability of soil samples and databases in a particular region on spatial maps (Fig.5). More than 1000 soil samples have been stored and the database has been updated in the system.

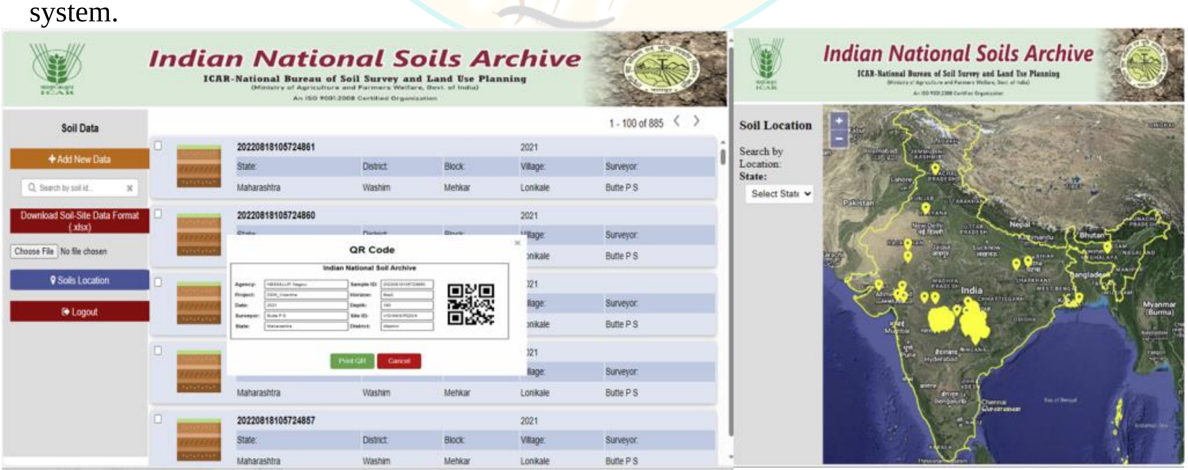


Fig.5: Front view of Indian National soils archive

- **National Soil Spectral Library:** The framework of the National Soil Spectral Library has been designed to host spectral libraries of different types of soils of India with large sample sizes. The user can visualize the spatial distribution of the samples and can select them based on administrative and AER/AESR boundaries. By clicking on any point, the spectral reflectance curve can be drawn. Also, multiple spectra can be drawn on the same plot to compare more than one soil. User-friendly options for zooming a part of the spectra and taking snaps of it are provided. The soil properties can be visualized by clicking on the legend in the plot (Fig.6). Developed with html, php, and CSS for the front end, java script for the back end and MySql for the database.

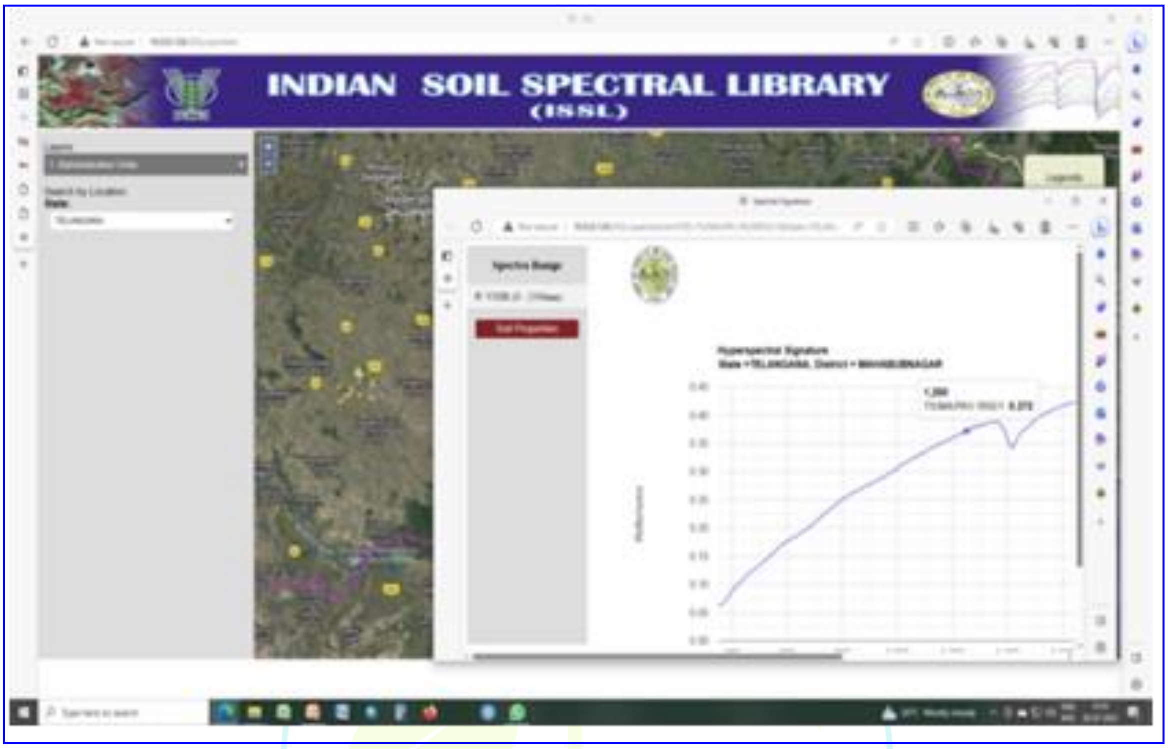


Fig.6: Front-page of Indian soil spectral library developed

- **Development of the BHOOMI Geoportal Platform:** The BHOOMI Geoportal has been designed and developed by using open-source Geoserver software. By using programming languages like HTML, CSS, JavaScript, PHP, JQuery various functionalities were developed to easily catalogue, retrieve, query and visualize the geospatial information. The NBSS Geoportal portal contains data on major physiographic and sub physiographic units of India, agro ecological regions (1992, 2015) and agro-ecological sub regions of India (1999), agro ecological units of Kerala, soil loss of India, organic carbon status in India, various soil based thematic layers on 1:1 M scale, soil resource database on 1:2,50,000 scale, soil loss map, various terrain and soil based thematic layers at block level for 135 blocks, major crop growing areas and potential crop growing areas for 17 crops at state level, land degradation status in irrigated and rainfed areas were processed and deployed as web map services in geoportal. A dedicated dashboard has been developed by using JavaScript programming to easily query and assess the status of data availability at block level under different states. This developed dashboard also helps to generate the Centre-wise report on the availability of soil data at a 1:10,000 scale. The physiography, sub-physiography, landforms and TMUs for 10 aspirational districts have been processed and deployed on the Geoportal. The developed Google Form-based ‘Soil Map Users Survey’ has been deployed on BHOOMI Geoportal to get feedback from the users and stakeholders to improve the future soil survey programmes of the Bureau. To strengthen the ‘BHOOMI Geoportal Interoperable Platform’ was developed to deploy various vector and raster datasets through API’s from other Geoportals. The deployed soil information on 1:1m scale on BHOOMI Geoportal is shown in figure 7.

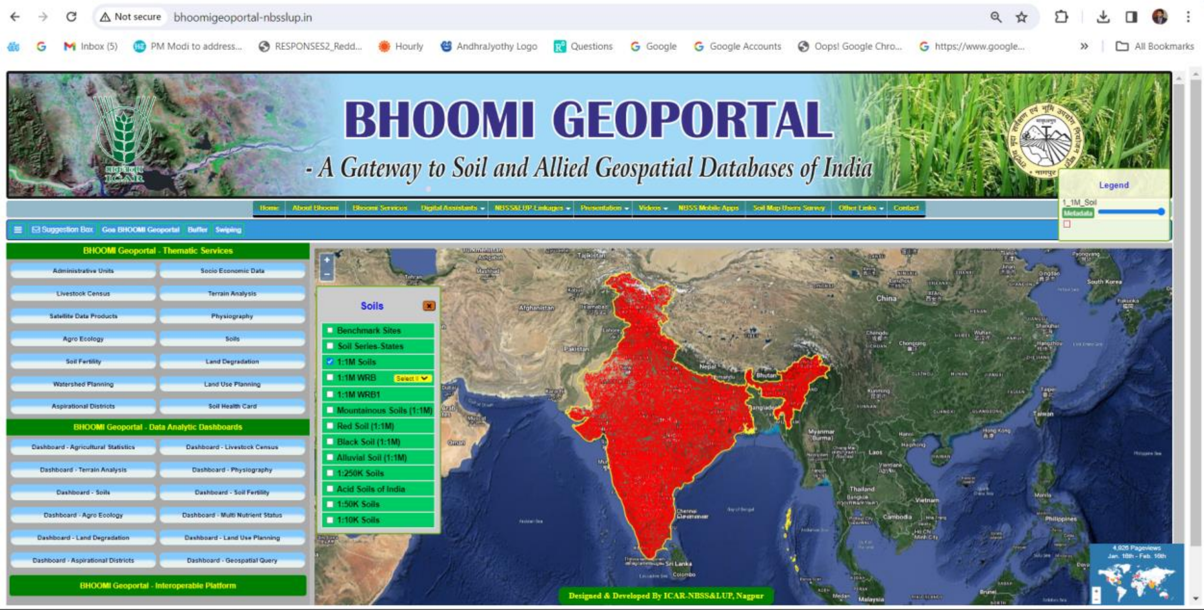


Fig.7: The deployed soil information on 1:1m scale on BHOOMI Geoportal

- **Real-time Field data collection and transmission:** Android mobile application software has been designed and developed for online soil survey data transfer and storage during fieldwork. The system is developed for the collection of the data by point and click method in the Android device. Provision is also made to attach the geo-tagged profile and site photographs in the given form. Once the form is filled, the data is stored and displayed in the designed pdf format.

- **Capacity Building in the Area of Remote Sensing & GIS Applications in Natural Resources Management**
  The Division has conducted various capacity-building programmes in the area of Remote sensing and GIS applications in natural resources management. The programmes were aimed to up-scale the skills of manpower to cater to the needs of national, regional and district-level developmental agencies. During the programmes imparted practical knowledge in the fields of remote sensing and GIS. The trained personnel would be able to use these state-of-the-art technologies in their operated fields at local level. The technological expertise was imparted to different clients from ICAR, SAU's, State Departments and KVK's.

Collaborations Developed by the RSA Division

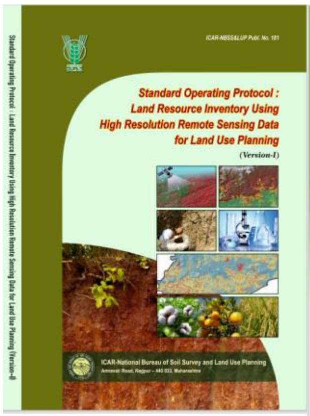
- ICAR-Indian Institute of Oil Palm Research, Pedavegi
- ICAR- National Centre for Pomegranate, Solapur
- ICAR-Indian Institute of Soybean Research, Indore
- Space Application Centre (SAC), Ahmedabad
- Department of Science Technology, New Delhi
- ISRO-National Remote Sensing Centre, Hyderabad
- Department of Agriculture, Govt. of Telangana
- NITI Aayog, New Delhi
- Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur
- Vasantrao Naik Marathwada Krishi Vidyapeeth (VNMKV), Parbhani
- Vasantdada Sugar Institute, Pune
- Department of Agriculture, Govt. of Goa
- Soil and Land Use Survey of India (SLUSI), New Delhi
- Neopark, Mumbai
- Food and Agriculture Organization (FAO), Rome

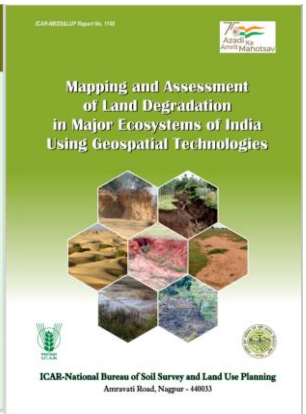
Future Thrust Areas of the Division

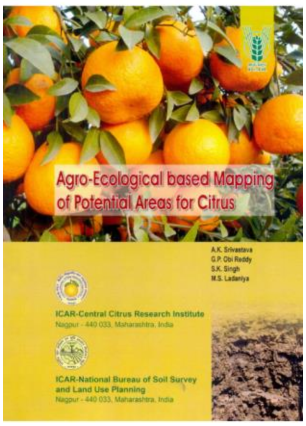
- Remote sensing and GIS applications in the characterization and mapping of landforms, land use/land cover and soil resources,
- Strengthening hyperspectral soil reflectance library and modelling hyperspectral data for soil attributes prediction and digital mapping of soil properties
- Application of Geospatial technologies in the assessment and monitoring of land degradation/problematic areas/drought at different scales.
- Enrichment of NBSS BHOOMI Geoportal and development of application services for quick dissemination of soil information to different users
- Provide scientific inputs and support to Divisions and Centres of NBSS&LUP in remote sensing and GIS applications
- Capacity building on geospatial technologies in NARS for land resource management
- Development of collaborations on geospatial technologies applications in land resource management with national and international institutes.

Recent Publications

In the last five years, the Scientists of the Division have published about 65 research papers, 10 books 38 book chapters and 9 technical bulletins and guided 8 Ph.D students from different SAU's.







Division of Land Use Planning

Land evaluation and land use planning research in India was initiated in 1984 and soon a division of land use planning was formally established in 1992 as a part of a research institute namely the National Bureau of Soil Survey and Land Use Planning. Since then, the division has been serving as an interface between soil data users and the Bureau. The main focus has been an interpretation of soil survey data and generating products that could be useful to policymakers, administrators, decision-makers, and farmers. With time, the availability of bio-physical information such as soil data, climate data, socio-economic data, etc. has improved. The tools and techniques have advanced at a faster pace than the data acquisition. Perhaps no other country in the world is facing land-use conflicts as much as India. The ensuing text provides a brief account of land use planning research in India. In an agrarian economy like India, a tiny land parcel by western standards is often the only source of living for a rural family. With 183 million ha area categorized as cultivable land and a population above a billion, India has less than 0.14 ha of cultivable land per person. Compared to highly populated China (0.08 ha/person), it seems to be better but the comparable economy of Brazil has 0.37 ha/person asides greater area under forest (World Bank Report). The last decade has been a decade of land conflicts as numerous protests have been reported from different parts of the country. A subtle shift from fertility-based demand for land to location-based demand has accelerated price rise in the country and successive Governments have been forced to revise the land acquisition policies effected from time to time. The significant spurt in demand for land for different purposes is now causing rapid changes in the way lands are managed in the country where land is a scarce resource. This article is centered on the research in the field of land use planning in the country.

Land use planning research in India

The land use planning research in India and abroad has been done mostly by soil scientists with expertise in soil survey. The National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) is entrusted with research, training, correlation, classification, mapping, and interpretation of soil information. Therefore, work done in India is mostly confined to the research work by NBSS&LUP that could be broadly divided into four categories in chronological order.

- During the early years, zonation of the country based on length of growing period criteria was focused.
- Development of soil suitability criteria for major crops of the country followed by crop experiments to evaluate the developed criteria including soil attribute.
- LUP at different planning levels/units like village, watershed, district based on soil distribution, topography, and climate.
- Customized LUP like identifying suitable areas for commercial crops-rubber, tea etc.

Zonation of the country: Based on the concept of length of growing period (LGP) which is an index of crop production that considers soil moisture availability for the crop, the country was divided into 20 Agroecological (AER) regions. Four basic maps i.e. soil, physiography, length of growing period (LGP), and bioclimate are required to delineate agro ecological regions (AER) (Sehgal et al. 1992; Sehgal et al. 1993) agro- ecological subregion (AESR) and agro- ecological zone at the state andagro-ecological unit at the watershed level. The concept of length of growing period (the period for which soil moisture is adequate to meet crop water demands) formed the basic tenet of agro-ecological zoning. Since the soil and climate data were available at a coarse scale, the map served as a general guide for guiding the planners and policymakers in framing state-funded schemes. Later the agro ecological regions were further divided into agroecological sub-regions. In the next stage, soil suitability criteria were developed for major crops of the country. This work was essential to evaluate if the land was being utilized for a crop with scientific rationale. This exercise involves rating of the soil site parameters as highly suitable (S1) with slight limitations, moderately suitable (S2) with moderate limitations, marginally suitable (S3) with severe limitations, and unsuitable (N). For evaluating soil suitability for an intended crop, few or all of these characteristics may be includedin a set of criteria. Later, the climate of the soil unit is compared with the crop requirements, then soil and physiographic properties are examined to meet crop requirements. These criteria are usually dynamic and are revised with advancements in knowledge of a particular crop and soil. Such criteria have been developed for all major crops grown in the country. During an early part of the new millennium, National Agriculture Technology Project (NATP) was taken up by the bureau. Soil suitability criteria for five different agro-ecosystems were developed. Simultaneously, different land use options were also evaluated in these five agro-ecosystems. For example, in the coastal eco-system, the land use options identified based on the bio physical and socie economic resources included plantation of cashew, casuarina, and palmyra on coastal sand, rubber, and pepper plants on foothills and crops like paddy, pulses, cotton, and vegetables on coastal alluvium. In the arid zone, less water requiring crops like mustard, cumin, and psyllium (isabgol) were introduced and evaluated. The research efforts in general identified three broad categories of state intervention 1) introduction of new crops and livestock components based on soil suitability and potential for enhanced agricultural productivity 2) introduction of new varieties commiserate with the soil information/properties and 3) adoption or changes in land management techniques. These findings facilitated the planners to assess the potential of different crops and possible changes in land use in different agro-ecosystems.

Emerging paradigm shift in land use planning

The last decade has witnessed a major change in the way land use plans are prepared. The Indian experience showed that farmers do not adhere to the land use plans or grow crops according to soil suitability irrespective of the location and findings of soil suitability studies. The reasons for noncompliance were varied, for in- stance socio-economic compulsions (market availability, family needs, cash crop), management issues (spatial distance from village, labour availability, land size), resource availability (credit, tools). Further, the top-down approach adopted by the researchers was not readily acceptable. Therefore, inclusive land use planning was emphasized during the recently concluded National Agriculture Innovation Project (NAIP) implemented by the bureau (NAIP 2009 to 2014). Moreover, in addition to the soil resources, common property resources such as community water tanks, pasture lands, community lands; Non-Timber Forest Produce (NTFP) were also included for arriving at a land-use plan for a village. Crop diversification was also promoted with the active participation of the farmers. Landless villagers participated in the process as they had stakes in common property resources, The study was executed in three districts of Maharashtra with varied climate, crop, physiographic and socio-economic conditions. Though poverty prevailed in all the clusters, technological solutions differed as the status of available resources differed.

In Gondia district non-timber forest produce (NTFP) is a major source of living and the share of agricultural income from sole rainfed paddy crop is secondary. The soils are mostly Typic Haplustepts or Vertic Haplustepts. Land use planning was therefore aimed at optimal use of water resources, use of common property resources especially for landless villagers and. implemented successfully to enhance paddy yields by 56 to 112% additional income (Rs. 14,525./ha.) in the six NAIP villages and later in nearby three villages. Limited water availability constrains the preparation of paddy nurseries and thus delays transplanting. This used to result in a negative impact on rice yields; community nurseries utilized available water in an organized way and facilitated early transplanting that led to an early harvest and hence opened a new possibility of rabi crop raised on residual soil moisture. The rice- fallow system was then replaced by the rice-rabi system. After evaluation of many combination(s), it was apparent that farmers preferred utera crop of linseed after rice because paddy soils are difficult to till after harvest. The system has implications for the 11.6 million ha. rainfed paddy area of the country. The landless villagers decided to use common property resources such as water tanks, grazing lands, tank beds for fish farming, goat keeping, and growing summer crop in dry beds of water tanks. Successful implementation of these land use plans produced an outcome that provides a new way of using more than 6000 water bodies in the district. Group of 18 villagers trained in fish farming earned

Rs.18000/year from a water tank. The impact of this intervention led to higher auctioning of tanks by the forest department. The fish farming potential of the district was thus identified. Similarly in an innovative way, dry beds of seasonal water bodies were used for raising watermelon crop by a group of 30 farmers of the village. This activity generated employment to 30 households during summer (a lean season) in a village of 200 households. Each villager earned Rs.10000/person on average. These villagers also continued their NTFP collection activities during summer to the possible extent. Thus a farming system of rice-utera linseed— NTFP was developed to provide livelihood requirements. The paddy farmers adopted best management practices. They abandoned the traditional practice of planting 8 10 plants per hill, reducing seed cost by 75%. The six NAIP villages are estimated to have saved Rs. 5,51,100during the last 5 years on seed cost alone. Balloon gobar gas costing Rs.2000, a cheap polythene unit also proved its potential in reducing pressure on forest (fuelwood). Such eco-friendly technology has great potential for the entire district.

In the Dhule district the two clusters namely Shirpur and Sakri, differ in the amount of rainfall received soils, physiography, etc. Sakri cluster receives more than 1000 mm rainfall where paddy, cotton, maize, and sorghum crops are grown. Based on soil information, the farmers were advised to grow rice variety Phule Radha. Similarly suitable maize and cotton varieties were introduced. Most of the lagers in the clusters are marginal farmers. Unlike Gondia, they do not derive substantial income from NTFP. Therefore, intensification of agriculture was emphasized. Selection of crop variety based on soil type enhanced income viz Rs.30000-40000/ha in cotton with 32 "additional yield, Rs.10000- 13000/ha from maize with 33.35% increase in yield,Rs. 10000 12000/ha in rice. The farmers used to grow wheat in approximately 20-30 ha area during rabi season. Soil suitability map indicated that more than 1900 km2 area in the district could be brought under onion crop which could fetch attractive returns. In the Sakri cluster, 10 farmers replaced wheat with onion crop in 1 ha each for seed production and later the number of farmers growing onion increased to 160 with 80 ha area. The farmers have earned Rs. 1, 00,000/ha on average and the onion produce from the cluster have become a selling brand in Dhule APMC, because of its quality. The farmers have constructed a storage structure for onion. They also do grading, packing, marketing. Those farmers who could not shift to the onion and decided to continue with the wheat crop joined together to develop a seed bank. The seed produced by them was sold in nearby villages which enhanced crop income by Rs. 15000 20000/ha. Theproject staff succeeded in transforming a few villagers into enterprising managers by providing a mini rice mill. This mill with a 500 kg per hour processing capacity generates employment for two persons for at least one month. A group of villagers managethe mill and have used the earnings from mills for the construction of a shed for the mill. Part of the earnings is now contributed to the sustainability fund regularly. In the Shirpur cluster mean annual rainfall is only 500 600mm. Therefore, the NAIP team focused on enhanced cotton productivity which is a main crop for the cluster. Appropriate varieties (MRC-7347, NHM-44, and Express fusion BT) suited to shallow, medium, and deep soils were introduced in the villages. Proper selection of variety contributed to enhanced income Rs. 11,121/ha on average. Onion was introduced in the Shirpur cluster as well. The average productivity of onion was 90.5 q/ha with a net income of Rs. 110125/ha and 4.13 benefit-cost ratio. Crossbreed cows were introduced in the two clusters for marginal farmers, only 5 beneficiaries were assisted, yet within two years, the farmers have developed a marketing linkage for the marketing of milk. Another outcome of an intervention is the adoption of a micro-irrigation system by 25 farmers. Now 6.40 ha area is grown to vegetables which are sold in Surat metropolitan market. Thus, the rice onion system has evolved in the Sakri cluster while the cotton onion system has spread in the Shirpur cluster. Enhanced income over the last four years has improved education status with greater females (45.5%) attending the school. The villagers have stopped migrating bordering in Gujarat state for employment (25% reduction in migration).

Digital soil mapping for precise land use planning

ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP), Nagpur has recently worked on digital soil mapping with the objective to develop soil properties map as per *GlobalSoilMap* Specifications. DSM originally focused on the soil-landscape modelling, which quantified the relationships between soil properties and environmental variables. The emphasis of soil mapping is gradually shifting from the soil variation and predictive techniques design to the application in various fields like agricultural management, ecosystem services assessment, land evaluation *etc*. The up-to-date multi-scale soil maps have been new global imperative and have attracted much attribution. Like conventional soil mapping, the major stakeholders of digital soil maps are farmers, land use planners, researchers and policy makers. Carbon sequestration studies, land degradation assessment, water resource management and climate change analysis are some of the major fields in India where quantitative soil information is needed. For instance, soil carbon studies have become increasingly important for environmental reasons to know not just the carbon storage at particular time also the changes or trend with time. The widespread availability of digital elevation data and other DEM attributes, mapping of soil organic carbon mapping is possible at higher resolution. DSM can be useful in regular monitoring soil health Card data launched by Government of India to help the farmers to access the status of soil, to identify the crop suitability, nutrient availability and providing further recommendation for improving the soil quality. Availability of digital soil maps helps in preparing soil health cards by providing site specific quantitative information and also in identifying the suitability of land resources for different crops. DSM can be used to create initial soil survey maps, refine or update existing soil surveys, generate specific soil interpretations, and assess risk. It can facilitate the rapid inventory, re-inventory, and project-based management of lands in a changing environment.

Recently there is a spurt in goal driven or customer specific land use planning. For instance, forest department of Maharashtra sought an advice on forest species that could be promoted in bio-physical environment prevailing in different forest divisions. Many industries have entered into an agreement for customized soil data that could be used for infrastructure works like power transmission. Optical fibre cable network and so on. The development of climate resilient agriculture is one of the ambitions of Maharashtra government. The first phase of soil survey in 500 villages under this project is already completed and the efforts are on to make 5000 villages in the state as a model of climate resilience.

The PoCRA project comprises mapping and generation of soil database for 15 districts of Maharashtra. At present, 8 districts of Marathwada region namely Aurangabad, Parbhani, Bid, Hingoli, Nanded, Latur , Jalna and Osmanabad have been completed (**Fig. 1**). The soil properties generated are soil depth, soil texture, available water capacity, soil organic carbon, pH, have been estimated based on predictions generated from the digital soil mapping methodology. The quintessential input parameter detrimental to building the DSM model is the legacy soil data which has already been acquired from the 700 soil profiles captured from the surveys conducted in the first phase. The environmental covariates is comprised of Landsat 8 images, Normalized difference vegetation index (NDVI), Soil adjustment vegetation index (SAVI), Enhanced vegetation index (EVI), GREEN, RED and NIR band. The terrain parameters like elevation, slope, topographic wetness index (TWI) and topographic position index (TPI), LS factor, Multi-resolution Ridge Top Flatness (MrRTF), and Multi-resolution Index of Valley Bottom Flatness (MrVBF), Valley Depth, Channel network base level, vertical distance to channel network and Landform features were used for prediction. Additionally, mean annual temperature and mean annual precipitations are used as climate variables derived from World climate.

Methodologies such as identifying the efficient cropping zones and using multi-criteria approach (AHP) for soil-site suitability were utilized for sustainable production and the relationship between soil appropriateness and crop yields and further suggesting alternate land use plans for Vidarbha region (**Fig. 2**).

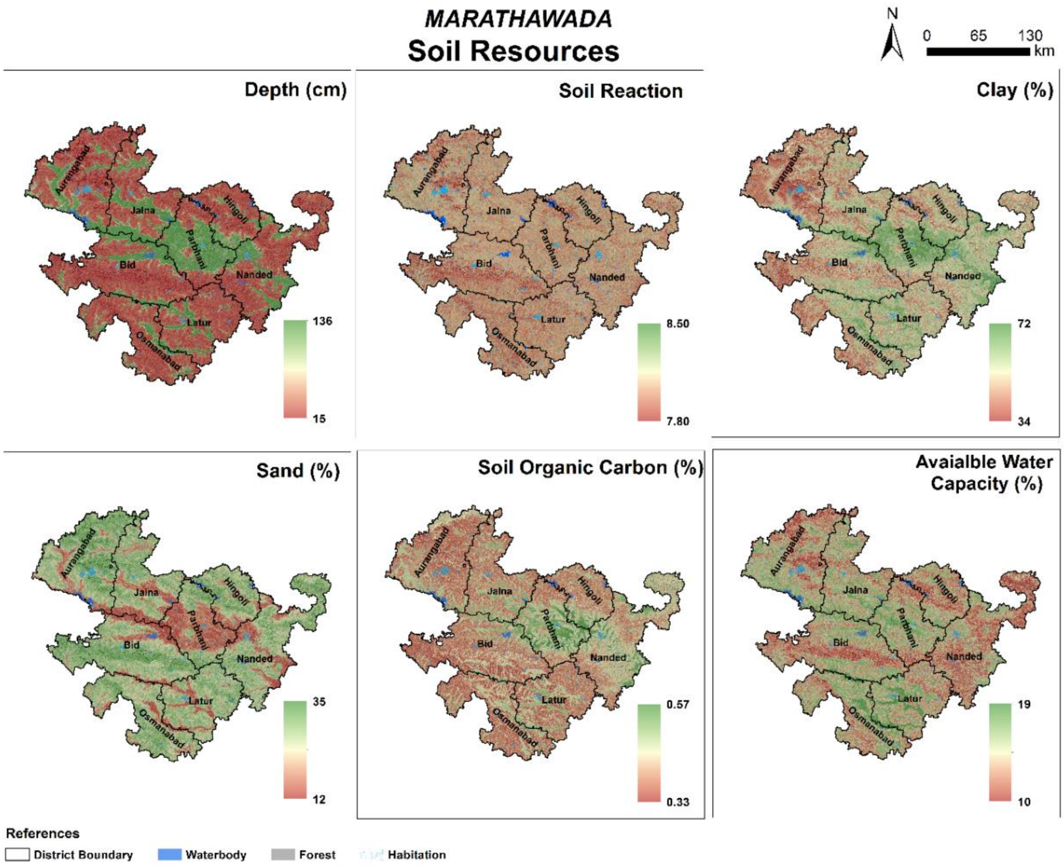


Fig. 1 Prediction of soil properties in the Marathawada region of Maharashtra under POCRA project

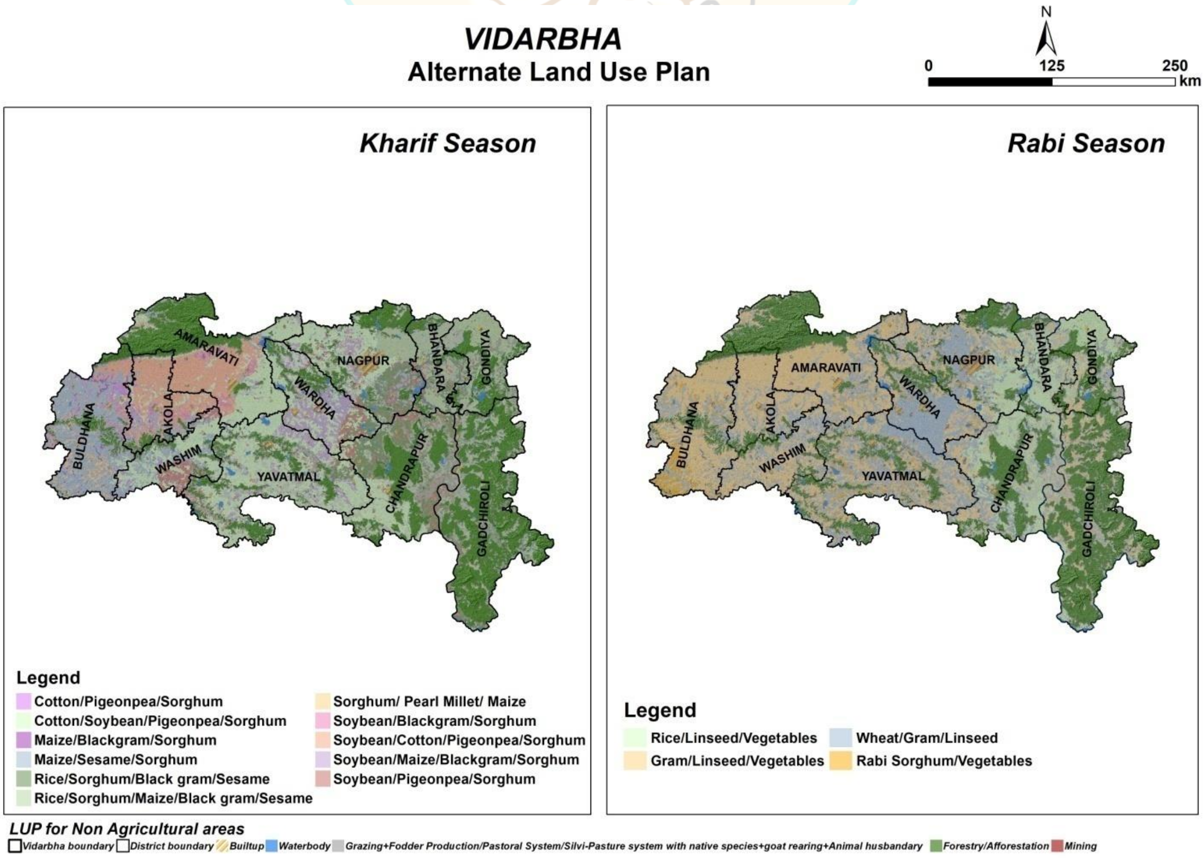


Fig. 2 Alternate land use plan for the Vidarbha region of Maharashtra

Summary

Research work in the field of land use planning was reviewed and important milestones such as the development of Agro Ecological Region map of the country, development of soil suitability criteria for different crops grown in the country, customized soil survey for a commodity of interest like rubber, land use plans implemented at watershed and village levels. The constraints in developing land use plans like scale, need to refines oil suitability criteria. The following target is set fast paced soil surveys and customized land use plans to promote a specific commodity by using digital soil mapping techniques.

- Field validation of land use plans and Development of Resource Information System for land use planning for Maharashtra
- Revision of crop suitability criteria
- Extension of crop colony concept for the whole Maharashtra
- Land Use Planning using Digital Technology

Compendium of Abstracts

SESSA 2024

Theme 1

Land resource inventorization and its advancement in assessing the soil ecosystem services

PS 1/1

Delineation of Landforms in Tumkur District, Karnataka, Using Geo-Spatial Techniques

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Understanding soil development is pivotal in agriculture, considering its connection to soil types, land arability, geological features, hydrological dynamics, and shallow groundwater systems, all influenced by landforms. This study employs geo-spatial techniques to characterize the major landforms of Tumkur district in Karnataka, utilizing automated, GIS-based procedures. The Tumkur district, situated in AER 8 (Eastern Ghats and Tamil Nadu uplands) and AESR 8.2 (Central Karnataka Plateau), features hot semi-arid and hot, moist semi-arid eco-regions, characterized by moderate to deep red loamy soils, low available water capacity, and a growing period of 120-150 days. Sentinel-2 imagery and ALOS-DEM (12.5 m) were employed in the study, with DEM derivatives extracted using Saga-GIS software, encompassing parameters such as hill shade, slope, aspect, topographic wetness index (TWI), multi-resolution index of valley bottom flatness (MrVBF), multi-resolution index of ridge top flatness (MrRTF), plan curvature, profile curvature, valley depth, flow accumulation, and slope length. Integration of DEM parameters and satellite images through Object-Based Image Analysis (OBIA) techniques in GIS facilitated the delineation of distinct terrain objects by synergizing spectral and contextual information. The object-based classification of Tumkur district resulted in Deccan Plateau physiography (D) and South Deccan Plateau (Ds) sub-physiography. Within each sub-physiography unit, landform types, namely Granite-Gneiss complex (Gn) and Quartzite Schist (Qs), were delineated based on geological origin. Further classification into seven landform units—Alluvial plains (Ap), Denudational Hills (Dl), Inselberg (Ib), Linear Ridge (Lr), Pediment (Pm), Pediplain (Pp), and Valley floors (Vf)—was achieved based on topography, size, scale, shape, local geological formations, high-resolution DEM, and satellite data, utilizing OBIA techniques in GIS.

Key words: Object-based image analysis, geo-spatial techniques, GIS, landform

PS 1/2

Assessment and Mapping the Soil Fertility Status in Intense Tomato Growing Soils of Eastern Dry Zone of Karnataka

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A study was conducted in intensively growing tomato fields of Eastern Dry Zone of Karnataka in 2023, to assess the soil fertility status by collecting one hundred (100) soil samples in intensively cultivating tomato cropping system at two depths (0-15 cm and 15-30 cm) in Kasaba cluster of Chintamani taluk, Karnataka. Soil are analysed for various chemical and nutrient elements using standard procedures, and prepared the soil fertility maps using Arc GIS software. The results revealed that, weighted average (0-30 cm) of nutrient status of nitrogen, phosphorous, potassium, calcium, magnesium and sulphur content of both the depth showed variation in their availability and its segregation on the map when nutrients are classified based on LMH approach, majority of the samples found to be acidic with pH range of 5.0-6.5 (53.20% area), low EC content (0.5-1.0 dSm^{-1}), organic carbon content rated as low ranged from 0.25-0.50% and covering 66.54% area. Major and secondary nutrients were depicted on the map which had low available nitrogen content with less than 200 kg ha^{-1}(94.61% area), medium available P content ranged between 22.5-56 kg ha^{-1}(66.13% area) and available potassium content was depicted to be medium with range of 141-336 kg ha^{-1}(85.56% area). The secondary nutrients were sufficiently present in the soil, covers 61.31% and 96.88% of area by exchangeable calcium and magnesium. Whereas, available sulphur was present with a range of 10-15 mg kg^{-1} (96.39%) indicate its sufficiency in the tomato growing soils. The variation of nutrients status also its distribution in the study area depicted on the maps emphasises the availability of nutrients at different concentration which depends mainly on the cropping intensity, kind and amount of organic manures and inorganic fertilizers applied by farmers, cultivation practices and organic residues present in the soils.

Key words: Global positioning system (GPS), Arc GIS, soil fertility, intensive cropping, weighted average

PS 1/3

Pedological Approach to Climate-Smart Agriculture: A Case study in Southern Transition Zone of Karnataka, India

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Climate-smart agriculture (CSA) is increasingly seen as a promising approach to feed the growing world population under climate change. Soil genesis, development and classification are key components for sustainable soil resource management and crop production and towards CSA. The CSA concept encompasses productivity, adaptation, and mitigation. Farm-scale soil mapping at 1:10,000 scale is detailed information on soil, water, climate, hydrology, land use, cropping patterns, and socio-economic conditions. The land Inventory was carried out in the Nuggihalli block, Hassan district of Karnataka, which represents agro-ecological subregion of (AESR) 8.2 with the help of remote sensing techniques. The major crops are ragi, coconut, maize, potato and vegetables. A 15-soil series with 55 phases were identified. The soils are red gravelly mixed shallow to very deep, well-drained soils with moderate to severe erosion. Due to excess sand and fine gravel, these soils are poor in water-holding capacity, organic carbon and nutrient status. Based on the site and soil variability, lands are evaluated and 19 different crops are assessed for suitability and mapped. Mitigation was adopted to avoid alternate crops, where soil quality is poor and productivity and adaptation were priorities of moderate and marginal soils. Integrating an approach to promoting all natural resources based on soil quality can provide potential opportunities for adopting CSA in this region.

Key words: Climate-smart agriculture, mitigation, Nuggihalli, productivity, soil quality

PS 1/4

Application of Remote Sensing and GIS in Assessing Land Use Land Cover Changes in Morshi Taluk, Maharashtra, India

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The rapid growth of the population and human activities on Earth is significantly altering the natural environment. Consequently, this paper endeavours to assess and delineate changes in Land Use/Land Cover in Morshi Taluk, Amravati District. The research was focused on application of remote sensing and GIS in assessing LULC changes in Morshi Taluk from the years 2014 to 2022. The LULC maps for these years were generated through supervised classification, employing both the maximum likelihood algorithm and a multi-sectoral supervised classification algorithm tailored to Landsat sensor data. The Extract by Mask tool was employed to isolate the desired location, followed by the application of image classification tools using various band combinations, such as false-colour composite (5,4,3). The classification scheme for LULC was executed based on Landsat 8 TM satellite images. Research found that major changes happened in urban area, water body, agriculture area and waste land. Here, in 2014, the built-up area constituted 1.67% of the total land, experiencing an increase of approximately 0.7% by 2022. Over the decade, the agricultural (crop land) area decreased by 2.98%, while waste land, representing 4.96% of the total area in 2014, increased by nearly 0.34% by 2022. The water body, constituting 3.94% of the total area, increased by almost 1.94% over the same period. Analysis of LULC trend of Morshi will help to understand and take necessary action to the line department to reduce the impacts of LULC changes as well as provide change scenario and which will be help to appropriate land use planning and management of Morshi Taluk.

Key words: Land use-land cover, Morshi taluk, RS&GIS, supervised classification

PS 1/5

Assessment of Land Suitability for Major Crops Using Geospatial Techniques in the Sudali Micro-Watershed, Chikkaballapura District, Karnataka

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Land evaluation serves as the foundation for long-term planning and management of land resources. Land productivity is decreasing due to soil degradation caused by poor land management and intense cultivation. As a result, melding crop requirements with available resources through land suitability analysis has become critical to maintaining agricultural land production. Land resource inventory was carried out in Sudali micro-watershed covering an area of 635.67 ha situated between 13°36′10.555″-13°38′8.846″ North latitudes and 77°51′4.474″-77°52′56.554″ East longitudes in the Chikkaballapura district of Karnataka state. Cadastral map was used as a base map and the satellite images (QuickBird, 0.50m) along with SOI toposheets were used for the delineation of landforms and physiographic units. The major landforms identified under this micro-watershed were uplands and lowlands. Horizon wise soil samples were collected and analysed for various physical and chemical properties. Based on the analytical data and the morphological features a total of 13 soil series and 42 soil phases were identified and a soil map was prepared. Ramenahalli (RNH) series was the major soil series occupying an area of 103 ha followed by Thimmasandra (TSD) (76 ha) and Niduvalalu (NDL) (53 ha). The soils of Sudali micro-watershed were moderately shallow to very deep with sandy clay to clayey texture, moderately acidic (5.8) to moderately alkaline (8.3) in soil reaction, and non-saline in nature. These soils were low in soil organic carbon content (1.2 to 4.9 g kg^{-1}). The exchangeable cations viz. calcium, magnesium, sodium and potassium ranged from 2.50-8.94, 0.97-2.22, 0.03-1.02 and 0.06-0.16 cmol (p+) kg^{-1}, respectively. Soil suitability was assessed for major crops and it was found that more than half of the micro-watershed area is highly suitable (S1) for the cultivation of crops like sorghum, ragi, green gram, horse gram, onion and chilli. The database could be of immense use in choosing the best cropping system suitable for the given land. These also would provide information to policy makers.

Key words: Crop suitability, land resource inventory, nutrient status, soil series

PS 1/6

Soil Fertility Constraints in Vidurashwattha Micro-Watershed of Gauribidanur taluk, Chikkaballapura district, Karnataka

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The degradation of soil fertility due to imbalanced fertilizer application poses a significant challenge to Indian agriculture, particularly in the context of the growing demand for food on limited arable land. To address this challenge and enhance agricultural productivity, site-specific nutrient management strategies are essential. This case study was conducted in the Vidurashwattha micro-watershed, covering 523.58 ha in the Chikkaballapura district of Karnataka. Forty-three surface soil samples were collected at 0-15 cm depth with a 320 m grid interval using a composite sampling procedure. These samples underwent analysis for macro and micronutrients. Soil fertility maps, including pH, electrical conductivity (EC), organic carbon (OC), nitrogen (N), phosphorus (P), potassium (K), sulfur (S), boron (B), iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn), were generated using GIS-based techniques. The findings indicated that the soils exhibited a neutral to strongly alkaline pH range (6.79 – 8.53) and were non-saline (<2 dS/m). Approximately 36% and 45% of the micro-watershed area showed medium (0.5 – 0.75%) and high (>0.75%) soil organic carbon content, respectively. The entire micro-watershed displayed low (<280 kg ha-1) available nitrogen content. Available phosphorous status ranged from low (<23 kg ha-1) to high (>57 kg ha-1), with a major portion rated as medium. Approximately 51% and 31% of the micro-watershed area exhibited medium (145-337 kg ha-1) and high (>337 kg ha-1) available potassium content, respectively. Available sulfur content was found to be high (>20 ppm) across the entire micro-watershed. Micronutrient status, including Fe, Mn, Zn, and Cu, was sufficient in the micro-watershed. However, a substantial area displayed low (0.5 ppm) available boron content. The mapping of soil nutrient status proved valuable in identifying site-specific nutrient deficiencies and sufficiencies, facilitating the adoption of precise nutrient management practices in the watershed.

Key words: Macronutrients, micronutrients, micro-watershed, soil fertility

PS 1/7

Soil Resource Appraisal under Different Land Use Systems in Bhandara District

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The study conducted during 2022-23 aimed to characterize soils under diverse land use systems and assess depth-wise fertility status in Bhandara district. Four land use types (Agriculture, Horticulture, Forest, and Pastureland) were investigated at different locations. Soil samples were collected at 20 cm intervals to bedrock. Morphological analysis revealed distinct colors and structures across land use systems. Physical properties exhibited variations in bulk density (1.33-1.57 Mg m^{-3}) and particle density (2.48-2.71 Mg m^{-3}). Soil texture ranged from clay loam to sandy clay. Chemical analysis indicated pH levels from 6.18 to 8.48, non-saline electrical conductivity (0.20-0.29 d Sm^{-1}), and organic carbon content (4.0-7.4 g kg^{-1}). Calcium carbonate varied (3.85-9.25%) indicating moderate calcareous nature. CEC ranged from 39.69 to 55.46 cmol (p+) kg^{-1}. Available nitrogen content ranged from 129.98 to 226.77 kg ha^{-1}, indicating a low range. Available phosphorus content varied from 10.29 to 19.32 kg ha^{-1}, categorized as low to medium. Available potassium content showed variations from 227.65 to 483.42 kg ha^{-1}, ranging from moderately high to very high. Available sulphur content ranged from 10.23 to 20.68 mg kg^{-1}, indicating a low to medium range. Zinc content was sufficient in surface soils (0.32 to 1.39 mg kg^{-1}) but deficient in sub-surface soils across all land use systems. Iron content ranged from 7.72 to 17.25 mg kg^{-1}, sufficient in surface soils and deficient in sub-surface soils in all land use systems. Manganese, copper, and boron content showed sufficient levels across all land use systems, with manganese ranging from 8.89 to 21.72 mg kg^{-1}, copper from 1.69 to 6.69 mg kg^{-1}, and boron from 0.48 to 1.16 mg kg^{-1}, reaching a medium to high range. Fractional distribution of zinc in Bhandara district soils followed the order: residual > Fe-Mn oxide-bound > carbonate-bound > organic-bound > exchangeable and water-soluble Zn fraction. Extractable zinc concentrations were generally low due to the dominance of the stable fraction in the soil. The study provides comprehensive insights into soil properties under different land uses in Bhandara district, essential for sustainable land management practices.

Key words: Fertility status, land use systems, soil characterization, soil properties, sustainable land management

PS 1/8

Irrigation Water Quality Appraisal for Sustainable Agriculture in Nuggihalli block,Hassan District, Karnataka: A Hydro-chemical Perspective

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The hydro chemical properties of irrigation water play a crucial role in crop growth, soil health,and water use planning. To ensure suitable water quality for irrigation, the present study was conducted to evaluate the hydro chemical properties of irrigation water in the Nuggihalli blockof Hassan district, Karnataka. Water samples were collected from 63 locations, out of which, 56 were from borewell, and remaining 7 were from lake, tank, and canal sources. The water samples were analyzed for pH, electrical conductivity (EC), cations- sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+) and anions- carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride (Cl^-), sulfate (SO_4^{2-}), and boron (B). Additional indices such as Total Dissolved Salt (TDS), Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP) were calculated for better insights. Piper, Riverside, Wilcox,and Donan diagrams were also prepared for detail hydro chemical analysis. The Irrigation Water Quality Index (IWQI) and Drinking Water Quality Index (DWQI) were evaluated for measuring the suitability of water for irrigation and drinking purposes. The water samples werealkaline in reaction (pH: 7.4-9.5), EC ranged from 0.17-1.72 dSm^{-1}. The Na^+ and Mg^{+2} was thedominant cations, while HCO_3^- was the dominant anion with the mean values of 3.88, 3.39, and 5.57 meq L^{-1}, respectively. All the samples recorded safe level of SAR (<10), while significant variation was observed in SSP (14.1-79.6%), and RSC (-3.4 to 5.7 meq L^{-1}). According to the applied classifications based on IWQI, 2/3rd of the borewell samples can be used with no to low restriction, and the remaining 1/3rd can be used with moderate restriction.This highlights the need for regular water quality monitoring in the Nuggihalli block for sustainable utilization of irrigation water. Moreover, out of the 63 water samples, 34 qualifies as excellent/good for drinking purpose (DQI 0-50), and the remaining 29 were poor/very poor/unsuitable for drinking. The results from this study would help scientists and decision makers for making sustainable water and irrigation management programs.

Key words: Donan diagram, drinking water quality index, hydro chemical properties, irrigation water quality index, Nuggihalli, Piper diagram

PS 1/9

Soil Fertility Evaluation of Soybean Growing Area from Ausa Tahsil of Latur District

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Soil is a vital resource that can be called the "soul of infinite life." The essence of life in soil is its productive capacity, *i.e.*, soil productivity depends widely on soil fertility, farming practices, and climate. For this reason, the present study entitled "soil fertility evaluation of soybean growing Area from Ausa tahsil of Latur district" was conducted to evaluate the fertility status of the soils in studied area. For this purpose, a total of 100 GPS marked soil samples were collected from twenty villages with five soil samples from each village of Ausa tahsil were distributed according to their representative depth with. Of these,50, 40 and 10 samples were identified and categorized as Inceptisols, Entisols and Vertisols, respectively. Furthermore, the collected soil samples were analyzed for their physico-chemical properties (pH, electrical conductivity, organic carbon and calcium carbonate) and available nutrients (nitrogen, phosphorus and potassium). Ausa tahsil soils (Inceptisols, Entisols, and Vertisols) were neutral to moderately alkaline in soil reaction, harmless in electrical conductivity, i.e., without adverse effects on crops, low to moderately high in organic carbon content and non-calcareous to calcareous in nature. According to the concept of “soil nutrient index”, the availability of these soils was low in available Nitrogen and Phosphorous while, very high in available Potassium was noted. Furthermore, soil fertility maps were prepared to show nutrient requirements based on the fertility status of soils for making forecasts based on cropping patterns to achieve good crop yields for the studied area.

Key words: Available N, P and K, $CaCO_3$, EC, OC, pH, soil fertility, soil fertility maps

PS 1/10

Prediction and mapping of soil profile organic carbon stock using Vis-NIR Laboratory spectroscopy

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There is increasing demand for soil organic carbon (SOC) stock estimation both at local and global scale. To fill this demand, Visible and near infrared (Vis-NIR) laboratory spectroscopy may be consider as a complementary approach to wet chemistry. The present study was carried out to estimate SOC stock from Vis-NIR laboratory spectroscopy using direct and indirect approach. In indirect approach, SOC and bulk density were estimated by PLSR models and these estimations were multiplied with layer depth for SOC stock calculation, whereas in direct approach, SOC stock was estimated directly by PLSR models. We tested prediction of SOC stock based on two different calibration scenarios: one scenario did not take care of the profile's locations (non-clustering calibration) while the second scenario was based on clustering of profile location (clustering calibration). 361 samples belonging to 84 profiles of three villages (Adimali, Vattavada and Marayoor) in Kerala, were used for this study. In the non-clustering calibration, 3/4th of the dataset (63 profiles having 272 samples) was used for calibration and remaining 1/4th samples (21 profiles having 89 samples) were used for validation. In the clustering calibration, the samples belonging to 2 villages were used for calibration and validated on remaining village. The results highlighted that i) Indirect approach provides better estimation of SOC stock than direct approach, whatever the scenario (clustering and non-clustering calibration), ii) Performance of SOC stock estimation based on the clustering scenario varies from poor to accurate accuracy, depending on the villages used in calibration set. iii) SOC stock maps produced by ordinary kriging using observed data and predicted data by clustering calibration followed similar patterns and indirect estimation SOC stock from Vis-NIR laboratory spectroscopy can be used for large scale measurement and mapping.

Key words: Calibration scenario, laboratory spectroscopy, PLSR models, soil carbon stock, soil organic carbon

PS 1/11

Characterization and Evaluation of Land Resources of Rahuri Block, Ahmednagar District, Maharashtra

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Detailed soil survey (1:10000 scale) was carried out using base map prepared from satellite data (IRS- P6 LISS IV and Cartosat-1) and Digital Elevation Models (DEM) in conjunction with Survey of India (SOI) Toposheets of 1:50000 scale in Rahuri block, Ahmednagar district of Maharashtra. On the basis of landform, slope, land use/ land cover and ground truth, four landscape ecological units (LEUs) were delineated and four soil series were identified in the block. Four soil series occur on summits, escarpment, upper pediments and plains respectively. These series were mapped into nine soil mapping units as phases of soil series. The representative pedons were very shallow to deep and their sand, silt and clay ranged from 14.4 to 43.7, 19.7 to 23.2 and 39.2 to 65.9 per cent. These pedons were neutral to strongly alkaline (pH 7.1 to 8.9), non- saline with low to high organic carbon (0.28 to 1.7 %) content, low to high calcium carbonate (3.15 -14.00 %) and high CEC [> 31 cmol (p^+) kg^{-1}]. Exchangeable complex of these pedons were dominated by Ca^{2+} followed by Mg^{2+}, Na^+ and K^+ cations with high base saturation (84.40 - 98.36 %). Soils were classified as Lithic Ustrothents, Typic Calciustepts, and Sodic Calciusterts. The soils were evaluated for their suitability for commonly grown crops (jowar, bajra, wheat, maize, gram and soybean) and were moderately to marginal suitable for crops. Thus, the detailed soil survey in Rahuri block, Ahmednagar district, Maharashtra, using satellite data and DEM resulted in the identification of four landscape ecological units and four soil series, providing valuable insights into soil characteristics and suitability for various crops, indicating moderate to marginal suitability for commonly grown crops.

Key words: Crop suitability assessment, detailed soil survey, landscape ecological units, soil characteristics, soil series mapping

PS 1/12

Potential Area for Barley (*Hordeum vulgare*) Production in Rajasthan and Gujarat

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Globally, barley crop has been under cultivation in 46.90 million ha with the annual production of 142.64 million tonnes. In India, barley registered 1.69 million tonnes production during 2022-23 from 0.62-million-hectare area with average national productivity of 27.33 q ha^{-1}. Among barley growing states, Rajasthan holds the top slot in production (56%), followed by Uttar Pradesh (30%), Haryana (3%) and Madhya Pradesh (3%). Barley is a common grain that is high in fiber which might lower cholesterol, blood sugar, and maintain insulin levels. It consumed as food, feed and used to brew alcoholic beverages worldwide. Barley, the fourth most important cereal crop in the world, has outstanding salinity and drought tolerance, relative to other cereal crops and grown on problematic soils and marginal lands. It may be treated as climate resilient crop in drought prone area of arid and semiarid regions. ICAR-Indian institute of wheat and barley research also promote public private partnership in malt barley production for better grain and malt quality. We have mapped the suitable, moderately suitable and marginally suitable area for barley production in western India. Using SRM datasets (1:250,000 scale) the soils of Rajasthan and Gujarat were evaluated for delineating the potential area for barley production. The factors like climate, soil depth, length of growing period, drainage, texture, pH, $CaCO_3$ in root zone, salinity and sodicity were considered for mapping of potential area. Soils of Rajasthan were evaluated as highly suitable (17.6 % area), moderately suitable (21.2% area) and marginally suitable (10.8% area) for barley production. Soils of Gujarat were assessed as highly suitable (18.4% area), moderately suitable (20.0 % area) and marginally suitable (25.9 % area) for barley production. Out of 33 districts of Rajasthan 12 districts has >2 lakh ha area as highly suitable whereas out of 33 districts of Gujarat only 3 districts has > 2 Lakh ha area as highly suitable for barley crop production. Such study can support the scientific land utilization with optimized and sustainable natural resource management for high- and better-quality crop production in country.

Key words: Barley, potential area, SRM data, western India

PS 1/13

Soil Characteristics at Various Topo-Sequences in Bastar Plateau of Chhattisgarh

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A study was conducted on the soils of Jagdalpur block in Bastar plateau of Chhattisgarh state in a topo-sequence in order to characterize and classify them using high resolution satellite data sentinel-2 (10 m resolution) and ALOS-DEM (12.5 m resolution). DEM were interpreted to terrain features like landforms namely subdued hills, undulating uplands, undulating lowlands, upper valley, narrow valley, wide valley and alluvial plains. The investigation revealed that the soils of the study area belong to *Alfisols*. The soils on subdued hills were very shallow and moderately deep on side slopes. These were well drained, gravely clay loam on the surface to clay loam in the sub-surface with redder hue (2.5YR 6/4) on summit and on the side slopes, and soils were grayer in colour together with yellower hue in the sub-surface. The soils were moderately deep to very deep, well drained, with redder hue on undulating land to grey colour in the upper valley together with sandy clay loam to clay loam in texture and medium moderate sub-angular blocky structured. Further the soils in the narrow and wide valley and alluvial plains were deep to very deep, clay loam to clayey on the surface and clayey in the sub-surface with greyish in colour (10YR 6/4). Soils had medium, moderate sub-angular blocky structure from undulating upland to upper valley and became platy breaking to medium, weak sub-angular blocky structure. Soils were slightly acidic to moderately acidic soil reaction increased down the profile and slope. Argillic horizons were characterized on the undulating upland, low land and upper valley and side slopes of hills whereas cambic horizons were characterized on other landscape barring to summit on subdued hills. Elluvial and illuvial horizons (Bt) were prominently marked in the soils of undulating upland, undulating lowland and the upper valley. Mean thickness of argillic horizon was 24 cm in the soils of undulating upland, 25 cm in the soils of undulating low lands; and 47 cm thick in the upper valley. CEC of surface horizon was 6.8 and 11.9 cmol (p+) kg^{-1} on the summit and the side slopes and almost comparable between 9 to 10 cmol (p+) kg^{-1} at undulating upland, and upper valley. The figure was lowest 7.6 cmol (p+) kg^{-1} at the undulating low land and highest 19.7 cmol (p+) kg^{-1} in the alluvial plains. Over all, lower cation exchange capacity was indicative of dominance of Kaolinite type of clay minerals together with the oxides of iron.Four soil series was defined namely Tondapal-Keshapur (*Lithic Ustorthent*) on hills, Jamawada-Badebadam (*Typic Haplustalf*) on sideslope, Chhotemurma (*Typic Haplustalf*) on undulating upland, lowland and upper valley together with Manjhiguda (*Typic Haplustept*) series on narrow valley, wide valley and alluvial plains.

Key words: Bastar plateau, characteristics, landforms, satellite data, topo-sequence

PS 1/14

Land Resources Characterization of Madpal Watershed in Bastar Plateau Region of Chhattisgarh using Remote Sensing and GIS Techniques

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The current investigation was conducted in the Madpal watershed in Bastar district of Chhattisgarh state, which represents the Danadakarnaya region of the eastern plateau to characterize and map the land resources using high-resolution satellite data Sentinel-2 (10 m resolution) and ALOS-DEM (12.5 m resolution). Object based image analysis (OBIA) was done by means of segmentation in eCognition developer (ver 9.8) to classify landforms and landuse/land cover classes in the study area. DEM was interpreted for topographical features and identified various landforms such as undulating uplands, undulating lowlands, upper valley, valley and flood plains with three slope classes namely, very gently sloping, gently sloping and moderately sloping. Land use/land cover were studied using remote sensing data and classified as crop lands, forest, scrublands, habitation with Badi Cultivation and waterbody. Landforms, slope, and land usage are all integrated and classified 13 landscape ecological units (LEUs). The soils on undulating lands were moderately shallow to moderately deep, well drained, gravely clay loam on the surface to clay loam in the sub-surface with redder hue (2.5YR) on top of the landscape and classified as *Lithic Ustorthents* and on the side slopes classified as *Typic Haplustalfs* with diagnostic sub-surface argillic horizon. The soils developed in valley and flood plains were very deep, clay loam to clay at surface and clayey in the sub-surface, imperfectly drained and were classified as member of *Typic Haplustepts* sub-group of *Inceptisols.* Thickness of such argillic horizon was 20 cm on uplands to 45 cm thick on upper valley. Thickness of cambic horizon other diagnostics feature of these soils were varied from 13 cm in undulating lands to 91 cm in flood plains. Soils were slightly acidic to moderately acidic in soil reaction (pH 5.4 to 7.4) and the pH increased down the profile and slope. Very low CEC was indicative of dominance of kaolinite type of clay minerals together with the oxides of iron. Magnesium is the dominating cation on the exchange complex followed by calcium, potassium and sodium. Base saturation of soils varied from a minimum mean value of 50.63% at upper valley to a maximum of 84.61% in flood plain. Four soil series were identified namely Dongriguda 1 & 2 (Typic *Ustorthents*), Dhurguda (Typic *Haplustalf*), and Semra (Typic Haplustepts). Extent of soil series in the watershed was mapped in the watershed. The mapping unit was soil series and its phases. The soils of undulating uplands were mapped into two series namely Dongriguda-1 series with its two phases and Dongriguda-2 series with its three phases series. The soils of undulating lowlands and upper valleys were mapped into six phases of Dhurguda series. Other soils of the watershed in valley and in the flood plains were classified into seven phases of Semra series.

Key words: Bastar plateau, **c**haracteristics, GIS, landforms, watershed, remote sensing, satellite data, topo-sequence

PS 1/15

Impact of Land Use Change on Soil Properties: A Pedological Analysis

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The dynamic relationship between land use change and soil properties has profound implications for ecosystem sustainability and agricultural productivity. This abstract presents a comprehensive pedological analysis aimed at unravelling the intricate connections between alterations in land use patterns and shifts in soil characteristics. The study employs advanced soil sampling techniques and laboratory analyses to investigate the impact of diverse land use changes, including urbanization, deforestation, and agricultural intensification, on key soil properties. These properties encompass soil texture, structure, nutrient content, microbial diversity, and other vital indicators of soil health. Through a systematic review of case studies from various geographic regions, the abstract explores the temporal and spatial variations in soil properties in response to specific land use changes. It investigates the resilience of soils to anthropogenic activities and assesses the potential for sustainable land management practices. The findings presented in this abstract contribute valuable insights to the field of pedology, offering a nuanced understanding of the intricate interplay between land use dynamics and soil properties. Moreover, the research underscores the importance of incorporating pedological considerations into land use planning and management strategies to ensure the long-term health and productivity of terrestrial ecosystems. This work aims to stimulate discussions and collaborations among researchers, policymakers, and practitioners concerned with the sustainable management of land resources. By fostering a deeper comprehension of the impact of land use change on soil properties, this research strives to inform decision-making processes geared towards fostering resilient and productive landscapes in the face of evolving environmental challenges.

Key words: Land use change, soil properties, pedological analysis, sustainability, anthropogenic impact

PS 1/16

GPS Based Delineation and Characterization of Soils of 'C' and 'D' Blocks of Central Campus, MPKV, Rahuri

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The present study was conducted during the year 2022-2023. The geo-referenced soil samples from C and D block were collected using GPS system to delineate the fertility Map of macro and micronutrients and quantify the biological properties. During the surface soil sampling, survey number, latitude, longitude and elevation of sampling sites were recorded using Global Positioning System (GPS). Three representative soil profiles from each block and layer wise 14 soil samples were collected from C and D Block. The collected soil samples were analyzed by using standard analytical methods. The fertility Maps of available macro and micronutrients were prepared by using Arc-GIS 10, Version 10.1 software. The pH of soil in block C varied from 7.17 to 9.11, categorized under neutral to very strongly alkaline; while, EC varied from 0.10 to 1.91 dS m^{-1}. The organic carbon and calcium carbonate content in soils of block C varied from 0.24-0.60 per cent and 6.75 – 15.00 per cent, respectively, were categorized under very low to moderate category and medium to high category, respectively. The pH of soil in block D varied from 7.30 to 9.65, categorized under neutral to very strongly alkaline; while, EC varied from 0.02-0.74 dS m^{-1}. The organic carbon and calcium carbonate content in soil were varied from 0.24-0.66 per cent and 6.50 – 13.75 per cent per cent, respectively, were categorized under very low to moderately high category and medium to high category, respectively. The available nitrogen, phosphorus, potassium and sulphur content ranged from 131.71-247.74, 10.08-28.80, 170.40-739.20 kg ha^{-1} and 10.00-33.25 mg kg^{-1}, in Block C and 141.12-257.15, 5.60-23.24, 145.60-694.40 kg ha^{-1} and 6.13-19.25 mg kg^{-1} in Block D, respectively. Soils of C block was recorded very low to low in available nitrogen, very low to high in available phosphorus and moderate to very high in available potassium content and deficient to sufficient in available sulphur. The soils of Block D were low in available nitrogen, very low to moderately high in available phosphorus and moderate to very high in available potassium content. The 31 per cent soils were deficient and 69 per cent were sufficient in available sulphur. The available iron, manganese, zinc, copper and boron in soil varied from 3.35-5.85, 7.39-16.79, 0.31-0.84, 2.17-5.52 and 0.22-0.88 mg kg^{-1} in block C and 3.63-8.44, 14.08-21.13, 0.36-1.08, 3.06-13.45 and 0.28-0.66 mg kg^{-1} in block D, respectively. In block C, the count of fungi in soils varied from to 10.40 to 16.34 x 10^4 cfu g^{-1}, the bacterial count in soils varied from 19.23 to 29.45 x 10^6 cfu g^{-1} soil and the count of actinomycetes in soils varied from 9.32 to 16.86 x 10^5 cfu g^{-1} soil. In block D, the count of fungi in soils varied from to 5.69 to 11.64 x 10^4 cfu g^{-1}, the bacterial count in soils varied from 11.32 to 27.32x 10^6 cfu g^{-1} soil and the count of actinomycetes in soils varied from 10.00 to 17.23x 10^5 cfu g^{-1} soil.

Key words: Geo-referenced soil samples, fertility mapping, macronutrients and micronutrients, soil pH and electrical conductivity, microbial population dynamics

PS 1/17

Macronutrient Status of Soil in Barshitakli tahsil of Akola District

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This research, conducted during the agricultural year 2020-21, aimed to evaluate the micronutrient status of soils in Barshitakli tahsil of Akola District. The physico-chemical properties and major nutrient status of surface soils were investigated to provide insights into the agricultural fertility of the region. The soils under study exhibited a slightly to moderately alkaline reaction, with electrical conductivity (EC) values within safe limits. The organic carbon content in these soils ranged from medium to moderately high, indicative of their organic matter status. Free calcium carbonate ($CaCO_3$) content varied from moderately calcareous to calcareous, suggesting a potential influence on soil properties. Analysis of available major nutrients revealed low to medium status for nitrogen (103.48-290.30 kg ha^{-1}), low to medium status for phosphorus (P_2O_5) (9.70-22.01 kg ha^{-1}), and medium to high status for potassium (K_2O) (263.25-544.54 kg ha^{-1}). The available sulfur (S) content ranged from 8.20 to 20.65 mg kg^{-1}. Correlation studies indicated an inverse relationship between major nutrient availability and soil pH, highlighting the impact of pH on nutrient availability. Furthermore, an increase in organic carbon content correlated with increased levels of nitrogen, phosphorus, potassium, and sulfur. Soil fertility index calculations, based on a six-tier system, categorized nitrogen as low, phosphorus and sulfur as moderate, and potassium as very high. This classification provides a comprehensive understanding of the soil's fertility status, guiding agricultural practices for optimal nutrient management. In conclusion, the findings of this study offer valuable insights into the micronutrient dynamics of soils in Barshitakli tahsil. The assessment of physico-chemical properties and major nutrient status provides a foundation for informed soil management practices, ultimately contributing to sustainable agricultural productivity in the region.

Key words: Micronutrient status, soil fertility, agricultural productivity, physico-chemical properties, nutrient management

PS 1/18

Fertility Status of Soils under Nagpur Mandarin Orchards of Katol Tahsil, Nagpur District

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The present investigation in relation to "Fertility status of Nagpur Mandarin Orchards of Katol Tahsil, Nagpur District" was under taken during 2020-2021. Fifteen orchards were selected from seven location of Katol tahsil viz., Ladgaon, Dhiwarwadi, Fetri, Lamdhan, Kalkuhi, Parsodi and Amnergondhi (rithi). The soil samples were collected from 0-30 cm (surface) and 30-60 (subsurface) cm. The result revealed that, soil reaction of study area exhibited slightly acidic to slightly alkaline in nature. In all locations, there were no much variation in electrical conductivity of soil and these soils were non-saline in nature. Soils were medium to high for organic carbon content and slightly calcareous to calcareous for calcium carbonate content. The available nitrogen was ranged from (250.88 to 398.68 kg ha^{-1}) in surface while, from (240.45 to 380.61 kg ha^{-1}) in subsurface, available phosphorous was observed in range (11.85 to 26.36 kg ha^{-1}) in surface and (11.63 to 24.35 kg ha^{-1}) in subsurface indicating that, soils are low to medium in category for both available nitrogen and phosphorous. Available potassium ranged from (300.49 to 483.13 kg ha^{-1}) in surface and (280.20 to 460.84 kg ha^{-1}) in subsurface which indicate that available potassium was high to very high in soil. Available Sulphur ranged from (10.25 to 15.24 kg ha^{-1}) in surface and from (8.36 to 14.84 kg ha^{-1}) in sub-surface that indicates it low to moderate in soil. The DTPA extractable micronutrient Fe, Mn, Cu and Zn in soil ranged from 4.59 to 7.74 mg kg^{-1}, 2.81 to 9.70 mg kg^{-1}, 1.03 to 3.70 mg kg^{-1} and 0.46 to 0.85 mg kg^{-1} respectively in surface soil layer and it ranged from 4.00 to 6.34 mg kg^{-1}, 2.01 to 8.61 mg kg^{-1}, 1.00 to 2.36 mg kg^{-1} and 0.45 to 0.79 mg kg^{-1}respectively in subsurface layer soil. Thus, the study highlighted slightly acidic to slightly alkaline soil reactions, non-saline conditions, medium to high organic carbon levels, slightly calcareous to calcareous calcium carbonate content, and varying nutrient statuses, with high to very high available potassium and acceptable micronutrient levels, providing crucial insights for sustainable cultivation practices.

Key words: Nagpur mandarin, soil properties, organic carbon, micro nutrients

PS 1/19

Comprehensive Soil Fertility Mapping and Nutrient Characterization in Kanker District, Chhattisgarh: A GIS-Based Geostatistical Approach

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The study was carried out on soil fertility mapping and identified the limiting nutrients as production constraints and characterization of major soil types for *Kanker* district of Chhatisgarh 2018-19. The objectives of the study were to map the special distribution of soil macro and micro nutrients (Fe, Mn, Zn, Cu and B) through geostatistical techniques in GIS environment, to validate the soil fertility maps, to optimize nutrient recommendations on the basis of developed fertility maps, and to carry out the soil profile study for characterization of major soil types in the district. Fertility mapping of the district, 850 soil samples were taken from covering entire district using Simple Random Sampling without Replacement (SRSWOR). Selected farmers were categorized *viz.* large (>3ha), medium (1-3 ha), and small (<1ha) for sampling. The soils were slightly acidic to neutral in reaction ranging from 5.3 to 7.4 with mean of 6.33. It identifies significantly different mean pH among all the soil types. The mean EC of all the samples was 0.13 with values ranging from 0.06 to 0.19 dS m^{-1}, which are suitable for all crops. The values of pH and EC followed the trend as *Vertisols* > *Alfisols* > *Inceptisols* > *Entisols* of the soil type. The SOC was significantly different among the different soil types and the mean varied from 0.31 in *Entisols* to 0.65 in *Alfisols*. *Alfisols* have been identified as soils having higher SOC than the *Inceptisols* and *Vertisols*. All the samples analyzed were under low or medium categories of available N ranging from 148 kg ha^{-1} to 426 kg ha^{-1} with mean values were 244 kg ha^{-1}. The available nitrogen followed the similar trends as SOC in case of soil types and blocks. All the soil samples collected were either in low or medium categories of P availability to plants. There was no significant difference in P according to block. Among different soil types, the P values vary significantly, except between *Alfisols* and *Inceptisols*. All the soil samples collected were either in medium or high categories of K availability to plants. The Kanker block showed having significantly higher K than other blocks. Among different soil types, the K values vary significantly. *Vertisols* were found to have highest mean K followed by *Alfisols*, *Inceptisols* and *Entisols*.

Key words: Fertility mapping, macronutrient, micronutrient, geostatistical technique

PS 1/20

Characterization and Classification of Soils in the Melghat Region for Suitability and Alternate Land Use Planning

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Melghat region, a sub-division of Amravati District covered 3970 Sq km area of Chikhaldara and Dharni tahsils, out of which 2200 Sq km is protected forest for tiger reserve. There are 314 villages predominated by *Korku* tribes, struggling for livelihood security on the small land/pattas allotted to them after their displacement from protected forest area. Profile soil samples were collected from the selected 44 sites in the area by using remote sensing data during the year 2017 to 2021. The eroded valley is at the elevation of 320–1188 meters above MSL, lies between 20^{O}51' to 21^{O}46' North Latitude and 76^{O}38' to 77^{O}33' East Longitude. Slope of the soils ranges from Very Gently Sloping (1-3%) to Moderately Steepy Sloping (15–30%) and were classified under Slight to Very Severe erosion class and classified under Well Drained to Excessive Drained Class. Soil depth varied from 19 to 122 cm, developed on very gently sloping to Gently Sloping lands with Slightly to Moderately soil erosion. Dark grayish brown (10YR3/2) to light brownish gray (10YR6/2) soils were dominant at higher elevation and Very dark gray (10YR3/1) to Yellowish brown (10YR5/8) were accumulated at lower elevation. Soil consistence varied from slightly hard to very hard (Dry), friable to very friable (moist) and non-sticky and non-plastic to very sticky and very plastic (Wet). The horizon boundaries were clear and smooth in distinctness and topography. Texture of the soils varied from Clay-to-Clay Loam. Bulk density of surface soils varied from 1.16 to 1.52 Mg m^{-3} and available water content ranged from 6.14 to 16.84%. The soils were neutral to moderately alkaline in nature. EC of these soils was ranges from 0.07 to 0.46 dSm^{-1}. OC content of surface soils ranged from 0.25 to 1.06 %. $CaCO_3$ content in surface soils varied from 0 to 6.2 %. The exchangeable Ca, Mg, Na and K content in soils ranges from 4.00 to 40.00, 3.00 to 22.97, 0.32 to 1.13 & 0.25 to 2.48 cmol (P+) kg^{-1}, respectively.CEC of the soils was relatively high, highest CEC 61.90 cmol (p+) kg^{-1} of the surface soils in was observed in the soils under intensive agriculture.BSP of the soils was medium to high ranges from 57.3 to 99.73% andESP of these soils ranges from 1.1 to 3.8%. Available N status of the soils was Low to Medium (94.20 kg ha^{-1} to 407.58 kg ha^{-1}), available P status was Low to Moderately High (8.95 to 29.58 kg ha^{-1}) and available K content was Low to Very High (110 to 616 $kgha^{-1}$). Available Zn and Fe content was Low to Moderate, whereas available Mn content was Low to Moderately high and available Cu content in soils were Moderately High to High. About 75% soils comes under Class-III (moderately good cultivable land) and in Class-IV (Fairly-good land suitable for limited cultivation), remaining 25% soils in Melghat region comes under Class-V, Class-VI and Class-VII not suitable for arable farming but well to fairly well suited for grazing and forestry. As perLand irrigability classification, 38% soils comes under Class-B(2) and 32% soils comes under Class-C(3) havingmoderate and severe soil limitations for sustained use under irrigation, whereas 30% soils comes under Class-D(4) and Class-E(5)non-suited for irrigation. These hilly region soils are classified as Entisol(34%), Inceptisol(48%), and Vertisol (18%), and as per land evaluation and soil site suitability, medium deep and deep soils are suitable for cultivation of sorghum, soybean, pigeonpea, chickpea and wheat crops, whereas, shallow soils are suitable for silvipasture and agroforestry. Thus, for food and feed security of tribals of Melghat region cultivation of sorghum/ soybean and pigeonpea as intercrop in *kharif and* on the basis of availability of irrigation rabi chickpea / wheat crops are suggested.

Key words: Melghat region, soil survey, classification, land valuation, soil site suitability

PS 1/21

Soil Fertility and Leaf Nutrient Status of Banana Growing Orchards in Western Vidarbha Region of Maharashtra

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The cultivation of bananas faces various challenges, including nutrient management, which plays a crucial role in determining plant growth, yield, and overall fruit quality. It requires high amount of nutrients, which are supplied only through soils with proper fertility status. An investigation was conducted during the year 2021-22 on field of 53 banana growing farmers from 14 villages in Akot and Telhara tehsils of Akola district whereas Anjangaon (Surji) and Achalpur tehsils of Amaravati district from western *Vidarbha* of Maharashtra state where, soil fertility and leaf nutrient status of banana soils were studied. The study area covered 20^0 17’ and 21^0 16’ N latitude and 76^0 7’ to 77^0 4’ E longitudes of Akola district and 20^0 32’ to 21^0 46’ N latitude and 76^0 37’ to 78^0 27’ E longitudes of Amravati district. The investigation revealed that banana-growing soils foundneutral to highly alkaline, non-saline, and non-calcareous to calcareous in nature with low to high organic carbon content. Soil primary nutrient status (N, P_2O_5, and K_2O) showed wide range, varied from 122.22 to 288.16 kg ha^{-1}, 11.09 to 59.24 kg ha^{-1}, and 163.41 to 883.67 kg ha^{-1}, respectively. Secondary nutrients such as exchangeable calcium and magnesium also displayed wide range,varied from 13.60 to 47.90 cmol(p^+) kg^{-1} and 3.80 to 39.80 cmol(p^+) kg^{-1}, respectively. The soil available sulphur content ranged from 7.47 to 36.10 mg kg^{-1}. Soil available micronutrients revealed diverse concentrations as: available Fe (2.86 to 22.26 ppm), available Mn (2.73 to 23.24 ppm), available Cu (1.15 to 6.69 ppm), and available Zn (0.29 to 1.44 ppm). In case of leaf nutrients, the overall observed range of total N, total P, and total K were found to be 1.82 to 3.95 percent, 0.14 to 0.48 percent and 2.25 to 6.34 percent, respectively. The secondary leaf nutrients ranged from 0.87 to 3.24 percent for total Ca, 0.24 to 1.15 percent for total Mg and 0.22 to 0.67 percent for total S in of banana orchards. The leaf micronutrients concentration ranged from 113.4 to 296.91, 308.76 to 2048.46, 1.81 to 17.34 ppm and 9.69 to 53.89 ppm for total Fe, Mn, Cu and Zn, respectively. The soil and leaf nutritional status of banana growing orchards also revealed that high-yielding banana orchards had a higher trend of all nutrient concentration than low-yielding orchards. Thus, nutrient-rich soils contribute to higher banana yields, emphasizing the importance of proper soil fertility management for enhanced crop productivity.

Key words: Banana, leaf nutrient status, soil fertility, western Vidarbha

PS 1/22

Kinetics of Potassium Release as Influenced by Natural Zeolite on Cotton in Salt Affected Soil

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The research, conducted during the kharif season of 2022-23 at the shade net located at the Department of Soil Science, Dr. PDKV, Akola, Maharashtra, investigates the effectiveness of zeolites, known for their eco-friendly and cost-effective nature, as a soil conditioner. Employing a pot experiment in a completely randomized design, eleven treatments were explored, including different combinations of 100% and 75% recommended dose of fertilizer (RDF) with organic amendments (FYM), gypsum, and varying levels of zeolite. Results revealed that Zeolite @ 450 kg ha^{-1} + 100% RDF and Zeolite @ 300 kg ha^{-1} + 100% RDF demonstrated superior performance in dry matter yield, root:shoot ratio, and cotton chlorophyll content. Moreover, these treatments exhibited enhanced potassium dynamics, including water-soluble K, exchangeable K, available K, non-exchangeable K, along with substantial and sustained potassium release, cumulative K, and kinetics of zero order, parabolic diffusion, and Elovich in the soil. Application of Zeolite @ 450 kg ha^{-1} + 100% RDF showed an improvement in the 'a' value, indicating enhanced potassium release. The term 'b' in the parabolic diffusion equation, representing the rate of non-exchangeable K release, was positively influenced by this treatment. Overall, this study underscores the potential of zeolites, especially at higher application rates in combination with 100% RDF, for improving soil fertility, nutrient dynamics, and crop performance in cotton cultivation.

Key words: Zeolites, soil conditioner, pot experiment, recommended dose of fertilizer, cotton chlorophyll content

PS 1/23

A Strategic Examination of Soil Micronutrients of Bhandara Tehsil, Maharashtra to Foster Soil Health and Sustainability

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The research conducted during the 2021-2022 period in Bhandara tehsil, Maharashtra, aimed to assess the available micro-nutrient status in paddy fields using GPS-based sampling of 105 soil samples across 21 villages. The analysis, carried out at the Soil Science and Agricultural Chemistry Section, College of Agriculture, Nagpur, revealed the soil texture to range from clay loam to sandy clay loam. The study area exhibited slightly acidic to slightly alkaline and non-saline characteristics. Results indicated mean values of 0.42 mg kg^{-1} for Zn, 5.44 mg kg^{-1} for Fe, 6.39 mg kg^{-1} for Mn, 0.98 mg kg^{-1} for Cu, and 0.90 mg kg^{-1} for B. The soil nutrient index suggested low availability of Zn, moderate availability of Fe, moderately high availability of Mn and B, and high availability of Cu. Suboptimal nutrient management practices by farmers may contribute to the region's poor fertility status. To address this, a Data-Driven Decision Support System (DSS) for micronutrient management has been proposed, utilizing the Rice Knowledge Bank from IRRI. Farmers in Bhandara tehsil are advised to implement practices such as using chelated micronutrient fertilizers, organic manure application, seed treatments, water management, integrated crop-livestock management, renewable energy use, and incorporating legumes or cover crops. These practices aim to enhance soil carbon, fostering improved uptake and availability of micronutrients for plant growth. The study emphasizes the importance of informed decision-making for sustainable soil management and crop productivity in the Bhandara tehsil region.

Key words: Micronutrients, paddy, Bhandara, soil nutrient index, decision support system

PS 1/24

Evaluation of Soils for Crop Suitability in Saurashtra Region-A Case Study of Amreli District, Gujarat using High Resolution LRI Datasets

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The research conducted in Amreli district, Gujarat, aimed to assess the soil resources for major Kharif and Rabi crops using high-resolution land resource inventory and GIS analysis. The district, situated in the south-central part of the Saurashtra region, covers a geographical area of 7.431 lakh ha. Physiographically, it represents the most elevated land in Saurashtra, characterized by a primarily plain topography with isolated hill ranges, and is drained by the Shretrunji River. The district experiences a humid coastal climate, with temperatures ranging from 8.01 °C in January to 43.7 °C in May, and an average annual rainfall of 706 mm during the South-West monsoon from June to September. Utilizing ICAR-NBSS&LUP standard operating protocol (SOP), a land resource inventory was prepared on a 1:10,000 scale, dividing the study area into 74 terrain mapping units (TMU). This base map was instrumental in conducting a detailed soil survey, marking 90 sampling sites using the cLHS method. The collected soil samples were analysed as per USDA soil survey manual procedures, resulting in the compilation, correlation, classification, and mapping of soil data into 42 phases comprising 15 soil series. The soil resources of Amreli district were evaluated for suitability for major Kharif and Rabi crops based on FAO and ICAR-NBSS&LUP criteria. The findings indicated that 26.8% of the area was suitable and 40.5% was moderately suitable for cotton, 22.6% was suitable and 49.8% was moderately suitable for groundnut, 57.8% was moderately suitable and 28.9% was marginally suitable for wheat, and 50.3% was moderately suitable and 29.0% was marginally suitable for gram. The study highlighted the utility of high-resolution GIS data in analysing information across space and time for assessing the suitability of natural resources for crop production.

Key words: Amreli district, GIS analysis, land resource inventory, crop suitability, soil survey

PS 1/25

Hydropedology: Concept and Application in KRP Dam Catchment of Tamil Nadu

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Hydropedology is interactive pedologic and hydrologic processes and properties in the Earth's Critical Zone. As such, for Hydrology, Pedology has been fundamental for enabling a foundation for the processes associated to the generation of runoff and groundwater recharge, especially concerning the micro-morphological analysis of the soil and the horizons which may impede the water flow, and their relationships with the soil structure. For Pedology, Hydrology can be fundamental to the understanding of the soil formation processes in the different landscapes, in the context of materials deposition as well as the shaping of the relief, as consequence of the soil-climate-drainage interaction, and its importance for pedogenesis. Therefore, the understanding and the deepening of the pedologic analyses, on a microscale and in toposequence in a specific landscape, and its insertion in the theories of Hydrology will allow the development of more realistic, physically based hydrological models and less parameterization dependence, this now being one of the most important challenges for the hydrologist. A detailed soil survey at farm scales at 1:10,000 was carried out in the KRP dam catchment for resource generation. Paddy ecosystems in the catchment are suspected to be major sites for soil degradation, demanding a detailed study to understand the changes in soil quality on excess irrigation. Ten (10) soil series (management units) were established in the KRP dam catchment. Using detail soil information, landform characteristics and water movement and management is key in sustainable natural resources management in the catchment.

Key words: Hydropedology, landform, KRP dam, soil variability, management

PS 1/26

Geospatial Integration for Comprehensive Soil Studies and Land Use Planning: A Focus on Soil-Landform Relationships Using Satellite Imagery and GIS

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In the pursuit of rational land use planning, comprehensive knowledge about the extent, distribution, potential, and constraints of soils in a given area is essential. This study employs soil analysis, encompassing the formation, identification, description, delineation, and classification of various soil types through morphological observations in field and laboratory investigations. Additionally, a geomorphological site analysis provides a structured framework for soil study, classification, and mapping. To enhance the precision of soil analysis, time-series satellite images from LANDSAT-8 (OLI/TRIS) and Sentinel were interpreted to derive theme layers, particularly focusing on landform delineation. Each landform unit was assessed for soil physical, chemical, and fertility properties. This research, utilizing geospatial tools, thoroughly investigates both soil and landform components, emphasizing the establishment of relationships between them. The results highlight the significance of integrating local ground information with space-based support through GIS (Geographical Information System) for establishing meaningful relationships between soil and landform units. This approach not only enhances the understanding of the complex interplay between soil and landform dynamics but also underscores the practical utility of geospatial technology in facilitating comprehensive soil studies and land use planning.

Key words: Landform, soil relation, Bali Island, Sundarban, Geo-spatial technology

PS 1/27

Soil Information Systemfor Land Use Planning of Ithalapur Village of Parbhani District by Using RS and GIS Techniques.

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The study was aimed at to characterize the soils of the study area to develop Decision Support System by analyzing their morphological, physical, chemical properties of the soils. In addition, it was also aimed to evaluate the quality of ground water for irrigation. Geographically, The Ithalapur village lies between 19°12'20.5''N to 19°10'32.3''N Latitude and76°47'19.1''E to 76°45'24.7''E East Longitude. The soils of Ithalapur village were very shallow to very deep (0 to 110 cm), black (10YR 3/1) to very pale brown (10YR 7/2) in colour, silty clay loam to clayey in texture, The soils were slightly to moderately alkaline, non-saline, low to moderate in organic carbon content and calcareous in nature. The soils were well fertile with CEC range of 29.16 to 60.76 cmol(p^+) kg^{-1}. Taxonomically, these soils were classified into Entisols, Inceptisols and Vertisols and at family level these soils classified as Very-fine, smectitic, isohyperthermic, Typic Haplusterts; Fine, smectitic, isohyperthermic, Typic Ustothents; Fine, smectitic, isohyperthermic. As per the soil suitability criteria on optimum yield basis (FAO, 1983), the soils of Typic Haplusterts were highly suitable for sorghum, pigeon pea, cotton, sugarcane and moderately suitable for soybean. The soils of Typic Ustothents and Calcic Haplustepts was moderately suitable for sorghum, soybean, cotton, pigeon pea and Typic Ustothents was marginally suitable for sugarcane. Soil information system, the web page model that has been created for the proper understanding of the study area sophisticated with the idea for the sustainable agriculture and proper use of the landform for farmers. The link is generated of soil information system of Ithalapur Village webpage using Qgis2web plugin as follows ithalapurdss.github.io/DSS-ITHALAPUR/.

Key words: Soil characterization, groundwater quality, Ithalapur village, decision support system, sustainable agriculture

PS 1/28

Prediction of Soil Depth in Hill Ranges of South Gujarat of India Using Digital Soil Mapping Approach

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In order to make judgements about which crops are suitable in a particular area and location, precise spatial information on soil depth at the block and district levels is required. In the present study, high-resolution (30 m) soil depth map of Dang district, Gujarat is prepared using digital soil mapping approach. A total of 64 soil sample sites were studied, collected and organized for mapping. Quantile Regression Forest (QRF) was employed to predict the soil depth in the district. Topographic attributes derived from digital elevation model, normalized difference vegetation index, enhanced vegetation index, soil adjusted vegetation index, landsat-8 data and climatic variables are used as covariates. 10-fold cross-validation was used to evaluate model. The classical uncertainty estimates such as coefficient of determination (R^2) and root mean square error (RMSE) were calculated for the validation datasets in order to assess the model performance. QRF model explained variability for prediction of soil depth (R^2 = 18.7%, RMSE = 26.1 cm). Aspect and normalized difference vegetation index are found to be most important variables for prediction of soil depth. The predicted soil depth in the district is ranged from 50 to 80 cm, and the current high-resolution (30 m) soil depth maps are valuable for mitigating the effects of climate change by facilitating the adoption of suitable agricultural practices.

Key words: Soil depth mapping, digital soil mapping, quantile regression forest, high-resolution mapping, climate change adaptation

PS 1/29

Characterization and Classification of Soils of Jalna District of Marathwada Region by Using Remote Sensing and GIS Techniques

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The current study aimed to characterize and classify soils in the Jalna District of the Marathwada Region by using remote sensing and GIS techniques. The focus was on analyzing soil properties including morphology, physical and chemical composition. Ten-soil profile were selected by using satellite data (LISS-III) , SOI Toposheet and DEM were developed to interpret terrain features. The results revealed variations in soil morphology, physical characteristics, and chemical properties across different topographic positions. The soils in the Jalna district exhibited a wide range of characteristics, depth varied from very shallow to very deep (19 to 150 cm); color ranged from yellowish brown (10 YR 5/6) to Very dark greyish brown (10 YR 2/3); structure subangular blocky to angular blocky; consistency slightly hard to very hard in dry conditions, friable to firm in moist conditions and slightly sticky to very sticky and plastic in wet conditions. Bulk density across pedon's ranged from 1.19 to 1.84 Mg m^{-3}, saturated hydraulic conductivity varied from 0.21 to 12.60 cm hr^{-1}. Sand, silt and clay content between 0.61 to 80.4 per cent, 13.9 to 48.08 per cent, 5.8 to 72.96 percent respectively. Available water capacity of the soil ranged from 4.81 to 23.52 per cent, plant available water capacity (PAWC) varying from 19.86 to 399.82 mm. The pH values between 7.56 to 8.74. Electrical conductivity varied from 0.11 to 0.47 dSm^{-1}, organic carbon ranged from 3.1 to 6.73 g/kg, calcium carbonate content ranged from 3.50 to 36.5 per cent, indicating a slightly to highly calcareous in nature of the soils. Cation exchange capacity varied from 23.62 to 68.71 cmol (p+) kg^{-1}, base saturation ranging between 71.53 to 104.27 per cent. Exchangeable calcium, magnesium, sodium, and potassium contents ranged from 17.06 to 49.92, 0.27 to 19.22, 1.50 to 9.44, and 0.01 to 2.19 cmol (p+) kg^{-1} respectively. Taxonomically, these soils were classified into Entisols, Inceptisols, and Vertisols. Furthermore, at the subgroup level, they were categorized as Calcic Haplustepts, Typic Haplustepts, Calcic Haplusterts, Typic Haplusterts, and Typic Ustorthents.

Key words: Remote sensing, GIS techniques, Soil characterization, Marathwada region, pedological classification

PS 1/30

Web Based Decision Support System for Hingoli District of Maharashtra

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The study was carried out to develop web-based decision support system (DSS) for Hingoli district of Maharashtra by characterizing, classifying and evaluating the soil and quality of irrigation water and further developed thematic maps by using GIS. Satellite data (LISS-III) and DEM were interpreted to terrain features such as broad landform units. Ten representative pedons from different landform units were characterized and classified and 50 soil surface samples and 20 ground water samples were collected and analyzed. The web map project was generated by using QGIS2WEB tool in leaflet library. The project was uploaded on GitHub page to generate web link which can easily assessed by end user. The morphological, physical, chemical characteristic of soil and ground water data indicated that the factors that reduces the crop yield are hydraulic conductivity, drainage, soil pH, high ESP, texture, high $CaCO_3$, Ca:Mg ratio, low PAWC, soil depth, CEC. The suggestive interventions to overcome the limitations for Vertisols and Inceptisols are deep ploughing once in three years, adopting BBF technology, application of FYM and green manuring/intercropping with pulses, soil always to be kept under cover and maintain Ca:Mg ratio>2. The special management practices for Calcic Haplusterts and Calcic Haplustepts is breaking of hard pan by subsoiler and for Sodic Haplusterts are application of gypsum or press mud @ 2.5t ha^{-1} and alternate opening of ridges and furrows for improve soil condition. These soils are suggested shallow and deep rooted and short as well as long duration crops and adoption of recommended crop rotation and intercropping. If the irrigation facilities are available rabi crops, vegetable crop and fruit crop like tamarind and aonlawere suggested. Whereas turmeric is not suggested in Sodic Haplusterts. The suggestive interventions for Entisols are application of tank silt, FYM, compost and green manuring or intercropping with pulses crop, soil erosion control measures adopted based on soil slope. These soils suggested for shallow rooted and short duration crops in kharif. The rabi crops and vegetable crop suggested if the irrigation facilities is available.In addition, for all soil types suggest that, if the soils under continuous irrigation needs to be adopt salinity control measures in all types of soils. Nutrient management adopted as per the soil test report, application of recommended dose of macro and micro nutrients through inorganic and organic fertilizers.The developed DSS available on web link (https://hingolidss.github.io/Dept-SSAC-VNMKV-Parbhani/) which can easily be assessed by end user for selection of crop, and soil specific soil use management practices for sustainable yield.

Key words: Decision support system, web-based mapping, soil and water quality, GIS application, sustainable agriculture

PS 1/31

High Resolution Digital Soil Texture Mapping of Jalpaiguri district, West Bengal using Machine Learning Model

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Capturing spatial distribution of soil texture at high resolution through digital soil mapping is an effective strategy for precision agriculture and meeting climate change mitigation targets. Soil texture being the main governing factors for moisture and thermal regime as well as have direct impact on water and nutrient use efficiency needs to be predicted at high resolution for effective implementation of agro-technology in an area. This study was aimed at predicting soil particle size distribution and textural classes for Jalpaiguri district of West Bengal, India, at 30m spatial resolution upto 2m depth using digital soil mapping approach (DSM). Total 141 geo-referenced soil profiles were collected from the district and analyzed for sand, silt and clay fractions using international pipette method. Landsat 8 OLI data, terrain attributes (SRTM DEM30m), and bioclimatic variables (WorldClim) were used as covariates in the digital soil mapping approach using machine learning models. Equal-area quadratic splines were fitted to soil profile datasets to estimate percentage of sand and clay content at six standard soil depths (0–5,5–15,15–30,30–60,60–100and100–200cm) and the quantile regression forest (QRF) algorithm was used to predict the particle size distribution down the depths at 30m resolution. The means and clay content varied from 33 to 49% and 11.8 to 16.6 %, respectively from surface to down the profile. Overall, clay content has decreased down the depth, whereas sand content has increased along the soil depth. All three variables of satellite, terrain and climate are important in predicting clay content at surface whereas only climate and terrain variables are playing important role in clay distribution down the profile. The independent validation of modeled against observed values showed good LCCC of 0.55-72 and 0.60-0.71 and acceptable RMSE of 6.07-7.99 and12.24-18.03 for clay and sand content, respectively. Results showed QRF model performed well in predicting sand and clay content in all six-depth interval. The variation in soil texture shows abundance of loam and silty loam texture in upper part of soil profile and a progressive transition towards sandy loam texture at lower depth below 60cm of soil profile. A sudden change in texture between 60 and 100 cm suggested the presence of lithological discontinuity (LD), which the uniformity value (UV) index derived digital LD map further supported. Study showed LD initiates at a depth of 30 cm in the northwestern part in the upper course of Teesta River and at a depth of 100cm the it spreads across the study area. This may be associated with depositional and sedimentary cycles caused by various drainage systems and transition zones created by geotectonic activity at foothills of Himalayan Mountain range. The modeled soil texture along with LD map at high resolution (30m) along the soil depth may provide a base for site-specific input management for enhanced water and nutrient use efficiency viz. better ecosystem services such as food production, climate change mitigation, and soil quality.

Key words: Soil texture, digital soil mapping, precision agriculture, climate change mitigation, particle size distribution

PS 1/32

Genesis and Distribution of Calcareous Soils in hot moist sub-humid Bengal Basin of Eastern India

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The presence of calcareous soils in the hot moist sub-humid ecoregion of Bengal basin in Eastern India (AESR 15.1) has been revealed through a detailed study of land resource inventory in Malda district, West Bengal. Soils of Malda district exhibited the presence of inorganic carbon in the form of carbonates dominated by calcium carbonate. A considerable amount of calcium carbonate in the ranges of 5-10 % and 10-15% have been found in 16.0% and 7.7% of TGA, respectively. It has been observed that the northern and eastern part of the district consisting of Gazole, Bamongola, Old Malda, Habibpur, Chanchal I & II, Harishchandrapur I & II, part of Manikchak, Ratua II and English Bazar blocks represents <5 % calcium carbonate equivalent containing 69.3% of the TGA. The analytical database proved that the soils in the active alluvial plains formed from the alluvium of Ganga River showed high (5-15%) content of calcium carbonate equivalent, which could be attributed to the calcium rich Himalayan sedimentation carried by Gandak and Burhi Gandak rivers adjoined to Ganga in its path. Moreover, the soils in old and young alluvial plains deposited by Mahananda, Tangon and Haria rivers possess comparatively less calcium carbonate (< 5%) in the surface soils. The vertical distribution of calcium carbonate showed the formation and genesis of calcareous soils. These rivers originated from the eastern part of Himalaya carry non-significant amount of calcium carbonate along its path. The carbonates found in the region are both pedogenic as well as geogenic in nature indicating a signature of climate change in this region and thus has major role on soil management interventions for future land use planning.

Key words: Calcareous soils, Bengal basin, Calcium carbonate, Land resource inventory, Soil management

PS 1/33

Advanced Geospatial Techniques towards Characterizing Soil-Landform Relationship in Eastern Ghats Landscapes of Odisha at Large Scale

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The present endeavor is aimed at characterization and classification of Red Ferruginous Paleo- Alfisols in Eastern Ghats Landscape of Odisha using high resolution satellite data at cadastral level on micro-watershed basis (at 1: 8,000 scale). The study area has been spread in 34 selected micro- watersheds from Sambalpur and Koraput districts of Odisha covering about 29,000-hectare land areas. World View 2.0 imagery (0.5 m resolution) along with World View 1.0 m DEM were used to derive landforms and current land use up to revenue plot level. Soil phase map derived from intensive soil survey has been intersected and harmonized with revenue plot number considering maximum likelihood approach to generate plot wise unique soil ID. Thematic and interpretative layers were henceforth generated against each revenue plot. The exercise was helpful in generating land resource inventory cards towards crop suitability plan and nutrient management plan for one lakh farmers thriving in the study area. Research findings revealed that typical higher altitudinal Eastern Ghat Highlands of Koraput comprises soils in two major geologic formations viz., Charnockite and Granite-gneissic Complex. Soils on hills were deep, well drained, slightly gravelly, loamy to clay loam textured and classified as *Typic Rhodustalfs*, whereas, soils on uplands were very deep red ferruginous *Paleo-Alfisols*, clay loam to clayey textured and classified as *Rhodic Paleustalfs* and *Typic Paleustalfs*. Soils on plains and valleys were very deep, moderately well to imperfectly drained, silty clay loam to silty clay and clayey textured and classified as *Typic Endoaqualfs*, *Aquic Haplustalfs*, *Oxyaquic Haplustalfs*, *Aquic Rhodustalfs* and *Oxyaquic Rhodustalfs*. Formation of deep and matured soil profiles attributed to faster pedogenic processes due to relatively higher rainfall, lower maximum and minimum temperatures, densely packed natural vegetation and age-old indigenous farming practices by the farmers in this zone. The physiographic confluence of Garjat Hills, Dandakaranya and Mahanadi Basin in Sambalpur consists of three major geologic formations viz., Granite-gneissic Complex as major one intruded with Quartzite ad Khondalite. Soils on Quartzite and Khondalite were amongst the least developed due to higher rates of erosion and lower rates of paedogenesis. The soils were shallow to moderately deep, severely gravelly sandy loam to sandy clay loam in texture, excessively drained and classified as *Lithic Ustorthents, Lithic Haplustalfs, Lithic Rhodustalfs* and *Typic Haplustalfs*. Granite-gneissic landscape comprises versatile landforms viz., uplands, undulating plains and valleys. The upland soils were deep to moderately deep, well drained, slightly to moderately gravelly, loamy to sandy clay loam textured and classified as *Typic Rhodustalfs, Typic Haplustalfs* and *Ultic Haplustalfs (Red Ferruginous Paleo-Alfisols*, whereas, undulating plains and valleys comprise deep, non-gravelly, moderately well to poorly drained sandy loam to clay loam textured soils and classified as *Aquic Haplustalfs*, *Typic Endoaqualfs* and *Oxyaquic Haplustalfs*. Soils of Mahanadi Basin showed relatively less matured soils with moderately shallow to deep soil profiles. The present investigation provides an ample scope for planners and policy makers to use the land resource information as technical know-how guidelines for agricultural land use planning at micro-watershed level through community consultation programmes.

Key words: Eastern Ghats, land resource inventory, micro-watershed, physiographic confluence of Odisha, red ferruginous Paleo-Alfisols, world view imageries

PS 1/34

Spatial Prediction of Soil Organic Carbon using Random Forest Model in Vadodara District of Central Gujarat

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Spatial information of soil carbon content at district and national level is essential for soil quality and environmental monitoring. In the present study, the distribution of soil organic carbon (SOC) was investigated using digital soil mapping in Vadodara district, Gujarat, India. To achieve this goal, soil survey work was carried out and total 77 pedons were collected from the study area. The random forest (RF) model technique used for the prediction of SOC in the study area. Equal-area quadratic splines were fitted to soil profile datasets to estimate SOC at six standard soil depths (0-5, 5-15, 15-30, 30-60, 60-100 and 100-200 cm). Landsat data, terrain attributes and bioclimatic variables were used as environmental variables. In this study, the widely used recursive feature elimination (RFE) and selection algorithm available in the R package was applied for feature selection. Results showed that the mean SOC content varied from 0.08 to 0.83% in different depths. The model performance was evaluated based on Coefficient of determination (R^2), RMSE and Lin's Concordance coefficient (CCC). Overall, the R^2 ranged from 0.24 to 0.57 and CCC values ranged from 0.25 to 0.55 for all depths. Root mean square error (RMSE) was varied from 0.13 to 0.20. The present high resolution SOC maps help to assess and monitor the soil health and preparation of proper land use planning.

Key words: Digital soil mapping. random forest model, soil organic carbon, validation

PS 1/35

Digital Soil Mapping for Assessment of Soil Ecosystem Services

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Soil plays a vital role in earth's critical zone by performing various soil functions thus providing numerous goods and services for the sustenance of life, which are widely referred as soil ecosystem services (SES). The innumerable functions performed by soil systems and the resultant services are mainly categorized as provisional, regulating, cultural as well as supporting services. Detailed assessment of various forms of ecosystem services is vital for highlighting the importance of soil capital, which plays a vivid role in interconnecting diverse ecosystem services. Digital Soil Mapping (DSM) approaches making use of digital technologies, geospatial data including remote sensing data/products, data analytics, and statistical/machine learning based methods for generation of geospatial soil information systems, could be an efficient tool for detailed assessment as well as evaluation of numerous SESs under diverse landscapes. DSM approaches focusing on mapping soil functions / threats allows the integration of diverse spatial and non-spatial data sources related to land management, climate change scenarios, human behaviour etc. which are vital for the economic evaluation and assessment of soil resources. Such assessments play a major role in evaluation of vital SESs such as food and water availability, forest products, biodiversity pool, nutrient cycling, water regulation, erosion and landslide regulation, carbon regulation, climate regulation, greenhouse gas regulation, soil formation etc. Advanced proximal sensing as well as spectroscopic techniques are known for their ability to provide non-destructive as well as rapid means of generating soil data and associated soil information systems. Adoption of various proximal sensing techniques such as portable X Ray fluorescence (pXRF), electromagnetic induction (EMI), Ground-penetrating radar (GPR),pH and Electrical Conductivity (EC) Sensors, unmanned aerial vehicle (UAV) based soil sensors etc. yield vital information regarding different soil functions, when coupled with advanced machine learning/geostatistical techniques could generate detailed spatial soil information systems.DSM can be coupled with ecosystem service models to quantify the provision of various services by soils across different land uses and management practices. DSM outputs can be integrated into multi-criteria decision analysis frameworks to support decision-making processes that involve trade-offs among different SESs. It is also expected that DSM will facilitate data sharing and stakeholder collaboration by providing standardized, accessible datasets and tool, thus promoting interdisciplinary research for addressing soil-related challenges and enhancing ecosystem service provisioning. Such vital insights from evaluation/assessment of SESs are expected to help us in making better choices related to land use/management decisions aimed at optimal and sustainable use of global soil resources.

Key words: Soil ecosystem services, digital soil mapping, soil functions, remote sensing, proximal sensors, machine learning, sustainability, decision making

PS 1/36

A Comparative Analysis of Soil Taxonomy (2022) and WRB (2022) Classifications for Categorizing Selected Soils in parts of South India

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The USDA soil taxonomy and WRB for soil classification have been used for analysis and classification of the Vedavathi River basin in Chitradurga district and the Pennar river basin in Kadapa district. Seven unique soil types with distinct textures have been found in the Vedavathi basin. Soil Taxonomy (ST) classifies the soils from the Kannivimaramma series—dissected buried plains—as Typic Natrustalfs. The world reference base (WRB), on the other hand, classifies these soils as Abrupt-cutanic solonetz, with cutanic, colluvic, and hypernatric qualifiers as supplements. The upland soils of the Vedavathi basin are categorised as Typic Rhodustalfs (Ambalkere, P4 and Bidarkere, P7), Lamellic Haplustalfs (Gudunoorhalli, P5), and Typic Paleustalfs (Kandikere, P6) at the subgroup level of soil taxonomy.In WRB classification, these soils are classified as Luvisols with rhodic qualities (P4&P7), Abruptic/Lamellic (P5), and Cutanic/Colluvic (P6). Six soils in the Penneru transect are classified as Ustic or Lithic Torriorthents on summits (Kottala-P1 & Mallambhavi-P2), Sodic or Fluventic Haplocambids on the back slope (Kondapuram-P3 & Kanneleru-P4), and Sodic Haplusterts on the foot slopes (Seshareddiplaai-P5 & Peddapasupula-P6). Interestingly, both the WRB and ST systems classify foot slope soils as Sodic Haplusterts.To enhance our understanding of sustainable soil management techniques in agriculture and conservation initiatives, it is crucial to gather and categorize soil resource data that aligns with soil taxonomy and the WRB system.

Key words: Semi-arid region, soil classification, south India, texturally contrast soils, transect

PS 1/37

Land Resource Inventory and Suitability Evaluation using Geospatial Techniques for Land Use Planning in Anjaw District of Arunachal Pradesh

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Land Resources Inventory plays a pivotal role in assessing soil characteristics and optimizing land utilization within specific agro-climatic conditions. Agricultural land use planning is very crucial as far as sustainable utilization of land resources at the village level is concerned. The present study was undertaken in the Anjaw district of Arunachal Pradesh, which comes under the Mishmi hill ranges of the eastern Himalaya. This study involved a large-scale (1:10,000) characterization and mapping of soil resources using new SOP methodology, developed by ICAR-NBSS&LUP. Land use/land cover (LULC) and landforms were delineated at a 1:10,000 scale for the study area using high-resolution satellite data (Alos Palsar and Sentinel 2). Landscape ecological units (LEU) were delineated by integrating the LULC and landform information in GIS environment. Landform analysis revealed a predominantly hilly terrain, with high hills (31.76% TGA) as the largest landform class, followed by moderate hills (19.50% TGA) and glacial landforms (26.60% TGA). Forests has been the dominate land use/land cover, covering 69.43% of TGA, followed by snow cover (26.6% TGA), Agriculture plantation (1.78% TGA), and minimal agriculture crop land (0.02% TGA). In total, 12 soil series were identified and mapped in 16 phases, with the Helmet top series (Fine loamy mixed, Thermic, Oxic Humudepts) occupying the largest area at 28.3% of TGA. Moderate (9% TSA) to slightly (19% TSA) acidic soil pH was found within the total surveyed area (TSA). The high (>3%) SOC content (86.5% TSA), medium category of CEC (10-15 cmol (p+) kg-1) and BS (35-50%), deficient Zn content among the micronutrients were found as dominant class of soil parameters in Anjaw district. Topography is the main limiting factor in LCC. The evaluated suitability classes of tea showed that 18.7% of TSA of the district was found moderately suitable due to fertility limitations, whereas, more than 95% of TSA was found not suitable for maximum crops like paddy, maize, mustard, millet, citrus, cardamom, lemongrass, pineapple due to the topographic positions ranging from very steep to very strongly sloping. The information generated on the land resource inventory in the study would be useful in the formulation of suitable strategy for effective utilization of the land resources in the easternmost part of the country.

Key words: Land resources inventory, soil characterization, land capability classification, crop suitability, Eastern Himalayas

PS 1/38

Predictive Soil Mapping of Soil Organic Carbon in Gujarat Plains and Hills Region of India using Digital Soil Mapping Technique

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Accurate and detailed spatial information on soil organic carbon at both district and national level is crucial for effective soil quality assessment, determining efficient methods for carbon management and environmental management. A digital soil mapping study was done to map soil organic carbon (SOC) in the Gujarat plains and hills regions in western India, covering 2825 km^2area of Narmada district. Equal-area quadratic splines were fitted to soil profile datasets to estimate soil organic carbon at fourstandard depths (0-5, 5-15, 15-30 and 30-60 cm) using randomforest (RF) technique.Landsat data, terrain attributes and bioclimatic variableswere employed as environmental variables.Results showed that the mean soil organic carbon content in soil varied from 0.23 to 2.42% in different depths.The model performance was evaluated based on Coefficient of determination (R^2), RMSE and Lin's Concordance coefficient (CCC). Uncertainty analysis was also performed for predicted SOC maps for all depths. Overall, the R^2 ranged from 0.08-0.41 and CCC values ranged from 0.27-0.56 for all depths. Root mean square error (RMSE) was varied from 0.36-0.45. Predicting of soil organic carbon was more accurate up to a depth of 15cm (R^2 = 37-41%), but performance decreased in the depth interval of 15-60cm (R^2 = 8-18%). The high-resolution SOC maps aid in soil health assessment and land use planning.

Key words: Digital soil mapping, random forest model, concordance coefficient, soil organic carbon.

PS 1/39

Characterization of Hydromorphic Soils of West Coastal Regions of Southern India

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The present paper characterizes hydromorphic soils occurring along toposequences in the west coast regions of southern India. The soils are developed from riverine and marine alluvium occupied by mangroves or paddy fallows. Five profiles along toposequences from 0 to –6 m above MSL were studied to characterize soil properties. The soils are deep (100-150cm) to very deep (>150 cm), having water saturation at the bottom. Jarosite mottles throughout the depth indicate sulfide oxidation, and glaying at the profile bottom indicates intermittent or permanent waterlogging. The soil pH and EC ranged from 3.3 to 8.1 and 1.5 to 13 dS m^{-1}, respectively. The CEC (3.31 to 16.0 cmol (+) kg^{-1}) and EC (1.8 to 8.2 dS m^{-1}) were gradationally increasing towards lower topography, whereas the acidity was increasing towards higher topography (pH=6.7 to 4.3). The soil organic carbon (SOC) ranged from 0.24 to 3.14%, and surface soils have higher organic carbon than subsoil. The soils are sodic throughout the soil depth because of the influence of marine sediments. Thus, the landscape soil relationships were generally constant, with strongly acidic–sodic soils occurring in the upper slope where the dry spell is more compared to saline-sodic soils in lower positions where soluble salts are high due to marine deposition.

Key words: Hydromorphic soils, soil characterization, toposequence, marine sediments

PS 1/40

Spectral Assessment of Soil Properties – Case Study

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Diffuse reflectance spectroscopy is a promising tool that allows rapid acquisition of soil attributes cost-effectively and helps supplement the wet chemistry for the global demands of large quantities of data for spatial modelling. The present study assessed the spectral prediction of soil properties such as pH, EC, soil organic carbon (SOC), cation exchange capacity (CEC), exchangeable sodium percent (ESP), field capacity (FC), and permanent wilting point (PWP) with the help of Random Forest technique. The lab ASD spectrometer was used to acquire spectral data of about 228 profile samples collected from the semi-arid region of the Southern Karnataka plateau. The soil properties were predicted using the random forest regression (RF) model. The RF model fits well for soil particle size classes such as clay (R^2=0.65), sand (R^2=0.60), and CEC (R^2=0.74). Similarly, water retention characteristics viz., FC (field capacity) and PWP (permanent wilting point) were also well predicted by the RF model (R^2=0.65 and 0.72, respectively). The SOC was poorly predicted with an R^2 of 0.22 and RPD of 1.2 due to its lower content (0.04 mg kg^{-1}) and narrow range (0.008 to 0.2 mg kg^{-1}) in the soils of the southern Karnataka plateau. Thus, the diffuse reflectance spectroscopy coupled random forest regression technique could be a useful supplementary method for rapid prediction of soil particle size (sand and clay), CEC, and water retention characteristics (FC and PWP) compared to properties related to soil solution chemistry such as pH, EC, soil organic carbon (SOC).

Key words: Diffuse reflectance spectroscopy, random forest regression, soil properties, spectral prediction

PS 1/41

Soil Suitability Evaluation of Barley as Prospective Alternate Land Use Option in the IGP for Food, and Nutritional Security -A Case Study

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Barley (*Hordeum vulgare* L.) is the fourth most important cereal crop in the world after wheat, rice, and maize. Its grains are used as human food, animal feed, and malt for industrial uses in many developed and developing countries including India. Major barley growing states In India are Rajasthan, Uttar Pradesh, Haryana, Punjab, Madhya Pradesh, Uttarakhand, Himachal Pradesh, Bihar, Jammu and Kashmir, West Bengal, Chhatishgarh, and Sikkim. It has outstanding ability to grow in a wide range of environments such as drought, salinity, alkalinity, marginal areas, and requires low inputs compares to many other cereal crops. Due to such qualities, barley is being considered as poor man's crop. Further, in the past decades it has gained currency as a cereal-based functional food because of its nutraceutical properties, and consequent health benefits such as anticancer properties, activate immune function, and reduce risk of cardiovascular disease and stroke. Notwithstanding, still rice-wheat cropping system is predominant in the IGP region of India. However, in the past couple of decades, this system is reported to produce several ill effects on soil/land resources quality. Therefore, urgent attention is required to address the soil related problems by utilizing the land according to their suitability, and thus, to achieve higher agricultural productivity and food security. In the above endeavor, land/soil suitability evaluation strategy seems to be the ideals solution for crop choices in areas where they are best suited. Thus, in view of the above, current and potential soil suitability of barley was evaluated for its cultivation prospects as an prospective alternate land use option in the IGP region of India by taking Mathura district of Uttar Pradesh, as a case study area. Results revealed in terms of both current and potential soil suitability evaluation maximum study area for barley cultivation found to be moderately suitable (S2) which constitutes to 55.6% and 80.6%, respectively. However, in terms of current soil suitability only 13.2% area evaluated to be highly suitable (S1) which registers a slight increase to 16.2% (potential suitability) whereas, 11.0% area evaluated to be presently not suitable (N1). Improvement in potentially suitable areas mainly ascribed to the rectification of moderate correctable limitations such as drainage, soil pH, EC, and soil fertility (organic carbon) limitations on account of adoption of best agronomic management practices and advancement of science led technological interventions. The study concludes that the barley crop has fair prospects as an alternate land use option in the area to ensure higher productivity, food and nutritional security.

Key words: Barley, land use plan, Indo-Gangetic Plain, soil suitability

PS 1/42

Large-Scale Soil Mapping (1:10,000) using Geospatial Techniques- A Case Study of Lakhpat, Kutch District, Gujarat

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Large-scale (1:10000) soil mapping is a major source of information for planners and executives to use soil information to enhance agricultural productivity. Lakhpat is part of the west coast belonging to the Gujarat coastal plain physiographic region and the Kutch Peninsula sub-physiographic region comes under 2.4 AESR (hot, arid climate with hot summers and cool winters). Cotton, castor and pigeon pea were the major crops; mango and papaya were the major fruit-growing areas in this block. A base map of the study area was prepared using Indian Remote Sensing satellite data (IRS-P6 LISS IV and Cartosat-1), Digital Elevation Models (DEM) and Survey of India (SOI) toposheets (1:50000). Based on spectral signature (tone, texture, and pattern), geology, slope, and land use, two major landforms *viz.*, coastal plain and pediment were delineated. Based on landform, slope class and land use six land ecological units (LEUs) were delineated to characterize the land resources. After correlation, the soils have been classified into three soil series and mapped into eight soil phases. Horizon-wise soil samples were collected and analyzed for major physical and chemical properties. The soils of Lakhpat Taluka were slight to strongly alkaline in reaction (pH 7.6-8.5), non-saline (EC 0.06-0.26dS $m^{-1)}$ and low to medium in organic carbon (0.16-0.83%), calcium carbonate (6.9-51.5%) with moderate CEC [11.6-40.6cmol (p^{+}) kg^{-1}] and high base saturation (42.7- 148.2%) status. Among the exchangeable cations Ca^{2+} and Mg^{2+} were the dominant cations followed by Na^{+} and K^{+}. The exchangeable sodium percentage (ESP) and exchangeable magnesium percentage (EMP) ranged from 1.5 to 5.9% and 5.7 to 14.3%, respectively. The soils were classified as Typic Haplustepts and Lithic Haplustepts. The large-scale datasets of Lakhpat taluka can be extended to the west coast sub-physiography region for land use planning. The study helps the policymakers to take appropriate measures for sustainable management of soil resources toward achieving better land use planning.

Key words: Geospatial technique**,** Gujarat coastal plain, land ecological unit, Typic Haplustepts

PS 1/43

Spatial Variability Assessment of Soil Properties using Geostatistical Approach in Hot Sub Humid Northern Plains, India

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Spatial variability of soil properties and their impact on the growth and yield of crops are significant concerns for sustainable and site-specific nutrient management. The present study was conducted in soils of hot sub humid northern plain of Punjab to understand the spatial variability of important soil properties using geostatistical methods. Soil properties like pH, electrical conductivity (EC) soil organic carbon (SOC), available nitrogen (AN), available phosphorus (AP), available potassium (AK) and micronutrients like Zinc (Zn), Copper (Cu) Iron (Fe) and Manganese (Mn) vary spatially and determine the soil fertility. The data were analyzed with descriptive statistics and geostatistical methods. The spatial maps were prepared with ordinary co-kriging (OK) technique after semivariogram modeling and cross-validation approach. A total 311 geo-referenced surface soil samples were collected and analyzed for soil pH, EC, SOC; Available nutrients (AN, AP & AK); and DTPA-extractable micronutrients (Zn,Cu Fe and Mn). The results showed a significant variation in soil pH (acidic to alkaline), EC (0.1-1.9 dS/m), SOC (0.2-1.7%), major nutrients AN (113-517 kg ha^{-1}), AP (2.2-72 kg ha^{-1}), and AK (10.1-662 kg ha^{-1}). Coefficient of variation (CV) indicated that EC, SOC, AP, AK, DTPA extractable Zn, Fe, Cu and Mn were high in heterogeneity (CV > 35%) whereas, the AN, showed moderate heterogeneity (CV 15-35%) and pH had low heterogeneity (CV <15%). Principal component analysis (PCA) representing 63.41% of the total variance, first PC explained 21.66 % of the total variation while, PCs second, third and fourth explained 16.49, 13.81 and 11.43, respectively. The spatial maps represent the distribution of soil properties in the study area. Soil pH was negatively correlated with DTPA-Zn (-0.210**) and DTPA-Fe (-0.378**), while, highly positive correlated with AP (0.200**) and AK (0.261**).

Key words: Soil properties, spatial variability, PCA, semi-variogram, hot sub humid northern plains

PS 1/44

Landform, Soil and Landuse Relationship in Basalt Landform of Satara District, Western Maharashtra Region

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Satara district is located in the western part of Maharashtra, between 17° 41' 29.04" N latitudes and 74° 0' 3.37" E longitude. Geographical area of the district is 10,484 sq. km. Geographically area can be divided in to three parts, Western ghat section, central part and eastern part. The district is situated in the river basins of Krishna and Bhima River. District experiences minimum temperature 11.68°C and maximum 37.5°C. Climate ranges from the rainiest in the Mahabaleshwar area which has an average annual rainfall over 6000 mm to the driest in Man tahsil where the average annual rainfall is about 500 mm. The main objective of present study was to bring out the relationship between landform, soils and land use in Satara district of Western Maharashtra region. A Cross section covering eight physiographic units namely plateau, plateau slopes, undulating lands, gently sloping uplands, very gently sloping uplands and valley representative of the basalt landforms in Satara district were selected for the study. The relationship between landforms, soils and land use was established. The study revealed that a close relationship exists between landforms, soils and land use. Mostly rocky and barren lands occur in hills under scrub forest. Very shallow, immature soils with patchy cultivation occur in plateaus whereas, very shallow to shallow, immature to moderately developed soils under patchy rainfed crops and plantations occur in plateau slopes. Shallow to moderately shallow, calcareous soils under rainfed crops occur in undulating lands. Moderately deep to deep, calcareous, well-developed soils found in gently sloping uplands cultivated to both rainfed and irrigated crops in patches. Deep to very deep, calcareous soils with well-developed slicken sides found in very gently sloping lowlands and valleys, which are intensively cultivated to both rainfed and irrigated crops. The study reveals that, the relationship between landform, soil development and land use found in a toposequence.

Key words: Basalt, landform, landuse, physiography, soil.

PS 1/45

Genesis of Paddy Growing Soils of the Lower Brahmaputra Plains of Assam adjoining Foothills of Meghalaya Plateau

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The present study was aimed to understand the genesis of paddy growing soils inalluvial plains of Brahmaputra adjoining foothills of Meghalaya Plateau in the Rangjuli block of Goalpara district of Assam. Representative pedon was selected and mineralogical investigations such astotal elemental analysis (Si, Al, Ti, K, Na, Mg and Ca), molar ratios (SiO_2/R_2O_3, K_2O/Al_2O_3), weathering indices and X-Ray Diffraction (XRD) analysis were performed. Results revealed that the dominant clay mineral of these soils was kaolin (K) (varied from 79 % to 66 % with increasing depth of profile) with various proportions of other 2:1 clay minerals and mixed layer minerals such as vermiculites (Vm) (4-3%), Smectites (Sm), hydroxy-interlayered vermiculites (chlorites) (HIV-Ch) (3-0%), mica (9-17 %) and unweathered quartz (2-8 %) and feldspars (3-2 %). In an acid weathering environment under the humid tropical climate with abundant Al^{3+}, hydroxy-Al-interlayering in the expansible 2:1layer silicates is a primary reaction towards the interstratifications of 2:1 and 1:1 layer, and such interstratified minerals are common in acid ferruginous soils of India. Moreover, kaolin decreases and mica increases with depth, and the sum of these two minerals were fairly constant from the A to the B horizon. The higher amount of kaolin in the upper horizon than the lower horizon suggests higher degree of interstratification in the upper horizon. Higher mica content in the lower horizon suggests restricted weathering of mica in the lower horizon. Kaolin was interstratified with 2:1 mineral *i.e.*, vermiculite or HIV (Sm/K or Vm/K). The occurrence of mica, HIV and HIV-Ch in the clay fractions indicates that mica has been transformed to vermiculite and then to HIV. The Al^{3+} released during tropical weathering is adsorbed in the interlayer of vermiculites to form HIV and further to Vm/K (kaolin) possibly via HIV-Ch stage. These paddy soilsof alluvial plainsshowed advanced silicate weathering, as well as lithological discontinuity indicating the deposition of weathered parent materials from fine sized alluvial sediments of Ildek river originating from Garo hills of Meghalaya along with *in-situ* weathering. Due to dominant kaolinitic mineralogy and resultant low clay CEC, these soils should be maintained with high organic matter to increase CEC and prevent leaching of K.

Key words: Brahmaputra valley, mineralogy, Meghalaya plateau, pedogenesis, weathering.

PS 1/46

Adoption Behaviour of Soil Reclamation Measures by the Farmers

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The predominant reason of poor soil quality due to land degradation relates to the washing away of top soil and organic matter, intensive deep tillage which breaks stable soil aggregates and disturbing the habitat of soil microflora use and management. Vertisols and associated soils are the most widely distributed soil. In Amravati district farmers are not able to grow second crop (rabi) due to high intensity short duration rainfall with intermittent long dry spells, leaving very less residual moisture in the soil. Soil reclamation measures need to be adopted by the farmers to improve the soil health in the study area. Hence, the research was conducted in Amravati district to study the adoption behaviour of farmers in Amravati district. Exploratory design of social research was used to study the present research. From 14 tahsils of Amravati district, five tahsils were selected *viz*. Chandurbazar, Morshi, Daryapur, Nandgaon Khandeshwar and Teosa. From the selected tahsils, two villages were randomly selected and in consolidation ten villages were selected for the study. From selected tahsils 12 farmers selected randomly comprising total sample of 120 respondents. The interview schedule was constructed by formulating relevant questions in accordance with the study objectives. From the study it was revealed that more than three fourth of the respondents (78.33%) were found in less favourable category of attitude, while remaining 21.67 per cent respondents had unfavourable attitude towards adoption of soil reclamation measures. On an average only 36.25 per cent farmers shows favourable attitude towards adoption of soil reclamation measures. Knowledge is an important component of adoption process, where majority of farmers (76.67%) had low knowledge of soil reclamation practices, while 90 per cent respondents had low adoption of soil reclamation practices. Mean knowledge shows that selected farmers had only 27.67 per cent knowledge and 19.95 per cent adoption of soil reclamation practices. In relational analysis coefficient of correlation was determined and found that attitude was highly significant with knowledge (0.447) and adoption (0.609) at 0.01 level of probability. The constraints were recorded from the respondents and enumerated on the basis of its importance and loss of damage in percentage. Further Rank Based Quotient (RBQ) was determined and priority constraints were decided on the basis weighted score. Major constraints ranked for adoption of soil reclamation practices were Labour shortage, lack of awareness and knowledge, time consuming, costly affair, lack of training and inadequate availability of organic matter. It was evident from the study that farmers possessed low to medium level of knowledge about land reclamation practices. As knowledge becomes prerequisite for formation of attitude and ultimate use of the technology, an organized effort is required by government in association with the Non-Government Organization to educate the farmers regarding the land reclamation practices for sustainable production. It was painful to know that majority of farmers were low adopters of land reclamation practices. The present study revealed that high initial cost in under taking land reclamation practices was the major constraint in adoption. There is an immediate need to tackle this problem by developing a strategy for the supply of inputs on cost effective basis, or on subsidized rate.

Key words: Soil degradation, vertisols, rainfall impact, soil reclamation, adoption constraints

PS 1/47

Spatial Variability in Organic Carbon of Soils in Permanent Benchmark Sites of Jabalpur in AESR-10.1 Under Rice-Wheat Cropping System

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The study aimed to found the spatial and vertical variability in Organic Carbon of soils for regulating the nutrient availability under Rice-Wheat cropping system in permanent bench mark sites (PBMS) of Jabalpur in AESR-10.1 region. Rice wheat cropping system is dominant cropping system in AESR-10.1 Jabalpur region in Madhya Pradesh, India. organic carbon (OC) has an justify role in the nutrient availability. SOC is a key property which are resultant of all soil physical, Chemical and biological property of soil thus it varies vertical and spatial effect on site of Jabalpur district. Collected 45 soil samples to examine the SOC results were interpreted. Three locations treated as main plot and five depths used as sub treatment for analysis the soils. Magarmuha soils has lowest OC values while soils of Khamaria showed significantly higher values of OC than Udna and Magarmuha. Rice wheat cropping system is dominant cropping system in AESR-10.1 Jabalpur region in Madhya Pradesh, India. Since Rice –Wheat cropping system has a proliferous Root System thus study the vertical and spatial difference on SOC helps to judging the overall effect of soil diversity in soil fertility Management of Soils in these areas were necessary for full potentially use of nutrient balance of these PBMS sites.

Key words: Spatial variability, SOC, AESR-10.1, rice-wheat cropping system, PBMS.

PS 1/48

Digital Mapping of Soil Properties in Barmer District of Rajasthan for Optimal Agricultural Land Management

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Digital soil mapping (DSM) has now been widely used globally for mapping soil classes and properties. Due to the increasing popularity of DSM and the strong demand in data sharing, various digital soil maps are available with distinct quality (e.g., resolution, extent, modelling approach, uncertainty, etc.). As there is a lack of information about the spatial variability of soil properties in the Thar desert, the main aims of this research are to spatially predict soil properties through random forest model techniques. The soil properties (depth, pH, EC, SOC, available nutrients) were predicted at a district level and at multiple depths 0–5, 5–15, 15–30, 30–60, 60–100 and100–200 cm using the GlobalSoilMap project specification. To achieve this goal, 97 soil profiles and local environmental covariates like Landsat data, terrain attributes and bioclimatic variables were used. 10-fold cross-validation was used to evaluate model. Result showed that soil depth in the study area ranged from 55 to 200 cm. Elevation, MRVBF and land use were the most important covariates for predicting soil depth. RF model explained R2 = 12% and RMSE = 44 cm for predicting soil depth. R2 values of SOC were observed 0.961 and 0.368 during model training and testing, respectively. The values of prediction interval coverage probability (PICP) recorded 87.2–89.7% for available N, P and K at different depths. The PICP recorded 86.4-91.1% for micronutrient at different depths. Temperature-related variables and remote sensed data products are important for predicting SOC concentrations in arid regions. The uncertainty was expressed as difference between lower and upper prediction limits at a 90% confidence interval. The wide range of uncertainty suggests that there is room to improve the current spatial predictions of soil properties. We anticipate that this digital mapping of soil properties will be useful for land use planning in arid regions.

Key words: Digital soil mapping, random forest, soil properties, desert ecosystems

PS 1/49

Altitudinal Variation in Soil Physico-chemical Properties of Stakmo Valley of Cold Arid Region

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In the Leh and Kargil districts of the cold desert region, the landscape is characterized by a barren, treeless expanse sculpted by high vertical cliffs of black, grey, and brown shimmering sand. The stratification of these cliffs, arranged in a superimposed manner with their vertical faces towards streams or rivers, creates a unique topography. The harsh climate-driven processes contribute to the region's high variability in soil characteristics, setting it apart from other zones due to differences in climate, topography, vegetation, and rocks. The study, conducted under the National Mission on Sustaining Himalayan Ecosystem Task Force-6 Himalayan Agriculture in 2018 and 2019, aimed to investigate altitudinal changes in soil physical and chemical properties across the Stakmo valley of Leh District. The altitude in this region ranges from 11,692 to 12,621 feet above mean sea level, experiencing a cold desert climate with extremes of heat and cold, excessive dryness, and minimal rainfall (approximately 100 mm). Covering every household in the region for sampling, the study collected composite soil samples from different altitudes at Stakmo village, representing varied altitudinal heights where people reside and cultivate their lands. Samples were collected from the surface layer (0 - 30 cm depth), with soil depth varying from 30 to 55 cm. Results indicated significant correlations between soil physio-chemical properties and elevation gradient. Organic matter content and bulk density showed a negative correlation with altitude, decreasing with increasing altitude. Soil organic carbon increased with altitude. $CaCO_3$ exhibited a negative correlation, decreasing with altitude. Soil pH and electrical conductivity showed minor changes with the elevation gradient. Silt had a significant positive correlation with altitude, increasing with elevation, while sand and clay showed negative correlations, decreasing with altitude. Macro-micro nutrient analysis revealed significant correlations. Percentage availability of N, Cu, and Fe increased with altitude, while P, K, Zn, and Mn showed negative correlations with altitude. Micro-nutrients Cu and Fe exhibited positive correlations with altitude, while Zn and Mn showed negative correlations. Soil health cards were prepared for each household, indicating the significant impact of altitude on the physico-chemical properties of soil. Understanding these soil property changes is crucial for comprehending their effects on the plant community, local residents, and the genetic diversity of plants in the valley.

Key words: Altitudinal variation, soil properties, cold arid region

PS 1/50

Soil Nutrient Mapping of ICAR-IARI Jharkhand Research Farm with Machine Learning Technique

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A study was conducted to characterize the spatial variability of nutrients at ICAR-IARI's Jharkhand research farm. Soil samples (over 200) were collected from selected areas of the agricultural research farm. Sampling of the surface soil (0-15cm) was conducted using GPS after harvesting Kharif crops and from uncultivated soils. The coordinates of the sample points were recorded using GPS. The results indicated that the majority of the study area exhibited low pH and EC, low organic carbon, low available nitrogen, available phosphorus, available potassium, total carbon, and nitrogen. Soil texture varied from sandy loam, silty loam, loam to sandy clay loam. Therefore, it can be concluded that the majority of the farm area under study is characterized by poor soil fertility. The random forest regression algorithm was used for classification. In this algorithm, soil properties were predicted for each 10x10 m grid using satellite-derived images as proxies for soil forming factors (terrain, climate, and vegetation). ALOS PALSAR DEM (12.5 m) and its derivatives such as elevation, slope, valley depth, distance to channel network, multi-resolution valley bottom flatness, slope length factor, etc., were used as terrain predictors. Sentinel 2A images (10m) with 11 bands and vegetation indices derived from them were used as vegetation predictors. The random forest model was developed using the 'Random Forest' package. For training the model, a total of 200 samples were collected randomly in the study area, and 51 soil samples were analyzed for different soil properties (EC, pH, OC, Avl. N, P, K, S, total C, and N). Separate models were created for each property. Tenfold cross-validation was used to check the accuracy of the model. The study found that the random forest model, developed using the mentioned bands and indices in combination, provided an acceptable level of accuracy. Additionally, it will aid in studying the long-term effects of different crop management practices on soil properties.

Key words: Spatial variability, soil fertility, random forest regression, satellite-derived predictors, crop management practices

PS 1/51

Phosphorus Fractions Under Different Soils of Wheat Growing Area in Buldhana District

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The research conducted during 2020-2021 investigated “phosphorus fractions under different soils of wheat growing area in Buldhana district”. A total of 50 farmers were selected from 12 different villages, including Deulgaon Kol, Konati, Kumbefal, Shendurjan, Dusarbid, Kingaon Raja, Pimpalgaon, Zotinga, Sakharkherda, Ambewadi, Agefal, and Linga. Soil samples were collected from the surface (0-15 cm) at these locations. Analysis before wheat sowing revealed that aluminium-bound phosphorus ranged from 2.91 ppm to 4.16 ppm, and post-harvest values varied from 3 ppm to 4.22 ppm. Sialoid-bound phosphorus before sowing ranged from 28.35 ppm to 36.81 ppm, while post-harvest values varied from 28.74 ppm to 37.32 ppm. Iron-bound phosphorus before sowing ranged from 18.83 ppm to 24.45 ppm, and after harvest, it varied from 19.09 ppm to 24.79 ppm. Reductant phosphorus before sowing ranged from 26.90 ppm to 34.92 ppm, with post-harvest values varying from 27.27 ppm to 35.41 ppm. Occluded phosphorus before sowing ranged from 151.44 ppm to 209.73 ppm, and post-harvest values varied from 153.53 ppm to 212.63 ppm. Calcium-bound phosphorus before sowing ranged from 12.04 ppm to 19.49 ppm, with post-harvest values varying from 12.21 ppm to 19.76 ppm. Organic phosphorus before sowing ranged from 187.95 ppm to 263.66 ppm, and post-harvest values varied from 194.99 ppm to 248.17 ppm. Total phosphorus before sowing ranged from 444.10 ppm to 565.35 ppm, and post-harvest values varied from 452.50 ppm to 579.52 ppm. The study revealed a significant and positive correlation between all forms of phosphorus and wheat yield, indicating an increase in grain yield with an increase in phosphorus fraction.

Key Words: Wheat yield, aluminium-bound P, iron-bound P, calcium-bound P, reductant and occluded P

PS 1/52

Prediction of soil depth using Digital Soil Mapping – A case study in Hingoli district, Maharashtra

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Information on soil depth is critical in different related applications such as runoff calculations, estimating available water capacity / content, nutrient holding capacity etc. A study was conducted to predict soil depth in Boldagaon watershed, Hingoli district, Maharashtra through digital soil mapping using the legacy soil data. Total of 100 soil sample data spread over in the Hingoli district were used to build the prediction model. Environmental covariates representing the soil forming factors C (Climate), O (Organism), R (Relief), P (Parent material) were used as input parameters. R related covariates derived through SRTM Digital Elevation Model (DEM) 30m were slope, relative slope position, valley depth, MRRTF, MrVBF, channel network distance, channel network base level. For O related covariates, three cropping seasons data over five years (2017-2022) Landsat 8 satellite data obtained through USGS Explorer were used. Spectral bands, NDVI, SAVI, EVI, LST were derived from the satellite data. Mean annual temperature and mean annual rainfall for 30 years (1970 to 2000) were obtained from Worldclim database. The geology of the area is deccan trap formation represented by almost horizontal lava flows of basaltic composition and the parent material developed through weathering and soil forming processes under the prevailing semiarid subtropical region. The soils are developed from the parent material either in-situ formation in plateau and hills and alluvium in valley and pediplain region. The calibration model employed Quantile Random Forest algorithm run in Python. The predicted soil depth values were validated through field observations and soil profile data studies covering an area of 11092 ha. The performance of the model was evaluated using statistical indices (coefficient of determination / explained variance (R2), root mean square error (RMSE), mean error (ME) and concordance correlation coefficient (CCC)). The validation results showed that the R2=0.5, RMSE = 33 cm., and CCC= 0.68. The terrain covariate MRVBF was the most influencing parameter contributing to the prediction. Uncertainty analysis showed that the predictive soil map has minimum errors.

Key words: Digital elevation model, environmental covariates, quantile random forest

PS 1/53

Enhancing Soil Properties Prediction through Differential Transformation of VNIR Spectral Data

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The total of 564 surface soil samples were collected across the 6 districts of Maharashtra *viz.* Sangli(101), Amravati(102), Chandrapur(102), Pune(94), Raigad(103), Jalgaon(62) based on stratified random sampling technique considering terrain and NDVI characteristics. The samples were processed, analyzed for available Fe, Mn, Zn and Cu and soil diffuse reflectance spectra were recorded for each soil sample using a FieldSpec Pro FR spectroradiometer at wavelengths from 350 to 2500 nm with a spectral sampling interval of 1 nm. The original spectra were, then averaged at every tenth-nanometer wavelength interval from 350 to 2500 nm by integration technique, which were further processed with moving average filter and Savitzky-Golay filter for noise removal. These resulting spectra were transformed to 1st, 2st derivative spectra by applying 1st, 2st or 3st order polynomial and 3, 5, 7, 9 no. of smoothing points which gave 54 derivative spectra from one sample, called as pipeline. The available Fe value ranged from 0.24 to 345.25 (mgkg^{-1}) with CV of 133% exhibiting variability in data. About 75% soil sample were above the critical limit (4.5 mgkg^{-1}) for Fe. The available Mn was above the critical limit (3 mgkg^{-1}) in 75% samples with CV of 121.2%. The available Zn value ranged from 0.08 to 62.43 mgkg^{-1} with about 50% soil samples were below the critical limit (0.6 mgkg^{-1}) for Zn deficiency. All the available Cu samples were above the critical limit (0.2 mgkg^{-1}) and value ranged from 0.44 to 22.84 mgkg^{-1}. The soil properties were normalized by applying square root and natural log transformation and outliers were removed using interquartile range method. The final dataset was divided into calibration (70%) and validation set (30%) using Kennard-Stone method and calibration set were used for spectral modeling using PLSR algorithm and validation set were used for model validation. The accuracy of different regression models was assessed based on r^2, RMSE and RPD. Relatively good spectral models were obtained in calibration for sqrt-Fe(ppb) [r^2=0.69, RMSE= 36.17], ln-Mn(ppb) [r^2=0.52, RMSE= 0.69], ln-Zn(ppb) [r^2=0.69, RMSE=0.41] and ln-Cu(ppm) [r^2=0.65, RMSE=0.38], which also resulted in good prediction in the validation datasets for sqrt-Fe(ppb) [r^2=0.66, RMSE= 49.21], ln-Mn(ppb)[r^2=0.47, RMSE= 0.83], and ln-Cu(ppm)[r^2=0.53, RMSE=0.38] whereas performance of ln-Zn (ppb) was poor [r^2=0.28, RMSE= 0.51]. It was observed that different transformed spectra were suited for different soil properties and even for similar soil properties with normalized data gave different selection of transformed spectra. As transformation of spectra help to reduce noise in spectral data and increase the signal to noise ratio, it is recommended to use different transformation of spectra for enhancement of model performance.

Key words: Maharashtra, diffuse reflectance spectra, Savitzky-Golay, PLSR, RMSE, RPD

PS 1/54

Prediction of Soil Depth for Marathwada Region Using Digital Soil Mapping

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Estimating soil depth across expansive regions offers crucial insights into its spatial distribution, which is essential for effective land resource management practices, agricultural planning, and ecosystem modelling. This research focused on evaluating the spatial variation of soil depth across the vast area of Marathwada region in Maharashtra spanning for 6272140 Hectares and comprising 8 districts viz. Aurangabad, Bid, Hingoli, Jalna, Latur, Nanded, Osmanabad and Parbhani. The research was conducted through digital soil mapping by incorporating 850 samples demarcated by Conditional Latin Hyper cube sampling (CLHS) strategy for building of prediction models. The environmental covariates used for generating the models can be broadly classified in three categories viz. Climate, organism and relief. The relief covariates derived from SRTM Digital elevation model (30m) were Multi-resolution valley bottom flatness index (MrVBF), Multi-resolution ridge top flatness index (MrRTF), Slope, Relative Slope position (RSP), Valley Depth, Channel network distance and Channel network base level. The associated covariates with Organism category were multi-spectral data for three cropping seasons over five years (2017-2022) from Landsat 8 satellite. Spectral bands viz. RED, GREEN and Near Infrared (NIR), Spectral indices viz. NDVI, EVI and SAVI in addition to Land surface temperature and fractional vegetation were derived from the multi- spectral dataset. Mean annual temperature and mean annual precipitation for the region of interest was acquired through WorldClim website. Quantile Random Forest (QRF), Support vector machine (SVM), XGBoost and multi-linear regression models were employed for demonstrating the soil depth variation. The models were calibrated using 80% of total collected samples and validated remaining 20% of samples which were split randomly. The results of the models were assessed through standard statistical parameters viz. coefficient of determination (R2), root mean square error (RMSE) and Lim's concordance correlation coefficient. The validation results showed that QRF outperformed all other models for the prediction of soil depth evident from the parameters R2=0.58, RMSE = 28cm and ccc=0.73. The most influential covariate affecting the model performance was found to be MrVBF for all the models, highlighting the dependence of soil variation on terrain characteristics instead of land use characteristics in the region. The same methodology has been replicated for generation of soil resources maps for the PoCRA (Project on climate resilient agriculture) project on 16 districts in Maharashtra and the results can be reproduced at other locations having similar type of geographic and climatic conditions.

Key words: Digital soil mapping, quantile random forest, soil depth, remote sensing

PS 1/55

DSM Approach of Soil Resource Inventorization of Harangul Village of Latur District, Maharashtra

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Soil survey using Digital Soil Mapping (DSM) approach was conducted during 2024 in the Harangul village of Latur district to characterize the soils for land use planning. Soils were dominantly developed over Deccan basalt with varying degree of alterations. Soil profiles were studied in very gently to gently sloping landforms representing to scarf slope and undulating upland (Profile P1-P4). Soils of profile P1 developed on scarf slope are moderately shallow, clay loam to sandy loam texture with presence of non-pedogenic carbonates (NPC) nodules in the subsurface horizon. Soils of profile P2 are moderately shallow, clay to sandy clay loam texture, calcareous with presence of both NPC and PC underlain by weathered murum. Soils of profile P3 developed over undulating uplands are very deep, clayey texture, calcareous with presence of NPC, PC and slickensides in soil control section, whereas, profile P4 developed on similar landform indicated moderately shallow, clay texture, non-calcareous with geogenic carbonate nodules. Slickensides are prominent and intersecting and have dimensions of over 10cm. They are the indicators of large volume of soils slide over another. Study indicated three types of magmatic crystallization and mixing of material representing to vesicular basalt (filled with well-developed zeolite minerals), hydrothermally altered basalt and massive basalt were observed in the profile section indicating the volcanic history of the area. Red colour soils of profile P1 indicate the climatic reversal in the area. Presence of large amount of gravel in the surface horizon indicates the differential weathering and solution movement. Analytical work is in progress.

Key words: Digital soil mapping, soil resource inventorization

PS 1/56

Standard Operating Protocol (SOP) for Land Resource Inventory (LRI) of Osmanabad District, Maharashtra

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Study was conducted to characterize land resources of the Osmanabad district following SOP guidelines. Landforms were delineated based on ALOS DEM (12.5m), Sentinal -2 data and Google Earth images. The slope derived from ALOS DEM (12.5m) and major LULC classes identified through analysis of Sentinal-2 were used to identify distinct TMUs. Soil sampling strategy was based on adoption of conditional Latin Hypercube Sampling (cLHS) model using primary and secondary terrain variable attributes. Soil profiles developed on different TMUs were validated with field traverses across the district. Soils were correlated based on their position in the landform, soil depth, carbonate content, physical and chemical characteristics and were selected based on their spatial distribution and accordingly 19 soil series (Linear Ridges-2; Narrow valley-1; Pediments-4; Subdued Plateau -2; Scarp slope-2; Undulating lowland-3; Undulating upland- 3; Valley floor -2) has been identified in the district. Soils are dominantly calcareous, deep to very deep, dominantly clayey in nature, with the development of slickenslides in the control section, and have Vertic property. Spectral reflectance study on SOC indicated that the accuracy level is up to nearly 70% and the results can be used for recommendations to the farmers.

Key words: Standard operating protocol, land resource inventory

PS 1/57

DSM Approach of Soil Resource Inventorization of Malwati Village of Latur District, Maharashtra

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Soil survey using Digital Soil Mapping (DSM) approach was conducted during 2024 in the Malwati village of Latur district to characterize the soils for their resource inventerization. Soils were dominantly developed over Deccan basalt with varying degree of alterations. Soil profiles were studied in very gently to gently sloping landforms representing to scarf slope, undulating upland and undulating low land. Soils of scarf slope are very shallow, clay loam texture with presence of non-pedogenic carbonate (NPC) nodules. Soils of undulating uplands are deep to very deep, clayey texture, presence of pedogenic carbonate (PC) and non-pedogenic carbonate (NPC) and slickensides in soil control section, whereas, soils of undulating lowland are very deep, clayey texture (g), non-calcareous with geogenic carbonate nodules and slickensides in soil control section. Slickensides are prominent and intersecting and have dimensions of over 15cm. They are the indicators of large volume of soils slide over another. Presence of gravely clay horizon in the undulating low land indicates that they are deposited by fluvial action in the past. Analytical work is in progress.

Key words: DSM approach, soil resource inventorization

PS 1/58

Enrichment of BHOOMI Geoportal Platform in the Context of National Geospatial Policy to Develop National Soil Resource Database Infrastructure

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In the 21st century, optimum utilization and sustainable management of soil resources assume a greater importance in the context of climate change, global food security, and achieve the Sustainable Development Goals like life on land, no poverty and zero hunger. Web-based Geoportal is essentially a master website, connected to a web server, it contains diversified thematic databases derived from various sources and field surveys with metadata information about the geographic data and services. Across the globe, the emerging geoportal platforms have redefined the efficient planning, monitoring and sustainable management of soil resources. ICAR-National Bureau of Soil Survey and Land Use Planning has designed and developed the BHOOMI Geoportal platform to provide various thematic services of soil and allied resources as Web Map Services to visualize, access, query and disseminate information to the users. Web Map Services like terrain, soil resources on various scales, agro-ecology, land degradation, and vegetation dynamics derived from earth observation datasets and crop suitability have been developed on BHOOMI. The BHOOMI Geoportal platform facilitates the users to visualize and query various web map services and cross-domain applications in soil and allied resources. The National Geospatial Policy-2022 aimed to develop robust National Geospatial infrastructure, standards, promote innovation and strengthen the National Geospatial infrastructure of identified fourteen thematic sectors that include a soil resource database. The National Geospatial Policy-2022 identified ICAR-NBSS&LUP under the Department of Agricultural Research and Education (DARE) as a nodal agency for soil resource data assimilation, management and dissemination. In this context, the major current challenges to be addressed are the development of robust Geoportal with advanced functionalities, assimilation of national soil resource databases, development of thematic applications, online geospatial data analysis, enhanced semantic search engines and dynamic visualization tools. To realize the core aims of the National Geospatial Policy-2022, the BHOOMI Geoportal platform could be strengthened to assimilate, manage, visualize and develop various cross-domain applications for sustainable management of soil resources in agricultural planning in India.

Key words: BHOOMI geoportal, GIS, national geospatial policy, remote sensing, soil resources

PS 1/59

Design and Development of Framework for LRI Data Assimilation on BHOOMI Geoportal

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The BHOOMI Geoportal represents an advanced approach to sharing geospatial data publicly. Its primary purpose is to facilitate the digitization of agricultural and geographical data. Land Resource Inventory system provides data assimilation at the block level, operating on a 1:10K scale. Researchers and scientists collect data for specific blocks or areas through field surveys or satellite observations. Once collected, the data undergoes validation by experts. Validated information is then uploaded to the GeoServer, accompanied by a Styled Layer Descriptor (SLD). The data is made accessible through the BHOOMI Geoportal via Web Map Services (WMS) and Web Feature Services (WFS). Users can explore fully digitized data, complete with metadata. The platform supports both raster and vector data formats, allowing users to access and analyze information in a variety of ways. If data is available for specific parameters, it is highlighted for users. For the remaining parameters, data awaits publication as researchers and scientists contribute further information. In summary, this enhanced system empowers users to view, analyze, and extract valuable insights from geospatial data, tailored to their specific requirements.

Key words: Geoportal, GeoServer, LRI, SLD, WFS, WMS

PS 1/60

Development of Online Soil Survey Data Collection System

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The Online Soil Survey Data Collection System Mobile App has been developed at ICAR-National Bureau of Soil Survey & Land Use Planning for online soil survey data collection. The app streamlines data collection, management, and analysis, catering to the needs of modern surveyors. Installation is straightforward, with a direct download link provided for Android devices. The app's interface presents essential information on the home screen, including Profile ID, horizons, distance, and location coordinates, facilitating efficient survey progress tracking. The app's significance lies in its ability to enhance surveyors' fieldwork, allowing for the systematic capture and storage of vital data, including site and profile characteristics. Its streamlined interface ensures data integrity through mandatory fields, fostering precision in data collection. The app enables seamless data updates and modifications, enhancing adaptability to changing conditions. Features like the horizon list and profile characteristics enrich user experience, ensuring comprehensive soil data collection. The Online Soil Survey Data Collection System Mobile App modernizes soil survey methodologies. Its user-friendly interface and robust data management capabilities empower surveyors to collect, update, and analyze soil data effectively, aiding informed decision-making in agriculture and land use planning. Technologies used in the development include Android Studio with Java for the mobile application, PHP for backend development, Postman for API testing, and MySQL DB for data storage and management, among others.

Key words: Soil survey, data collection mobile app, remote sensing, MySQL DB, android studio, java, PHP

PS 1/61

An Integrated Framework for Digital Soil Data Management: From Acquisition to Dissemination

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The ICAR-National Bureau of Soil Survey and Land Use Planning has been engaged in carrying out soil resource survey and mapping at various scales, digital soil mapping, quantitative assessment of soil properties through soil spectroscopy, mapping land degradation and monitoring of the soil health for viable land use planning. The research activities of have resulted in identifying the soil potentials and problems, and the various applications of the soil surveys with the ultimate objective of sustainable agricultural development. A digital framework has been designed and developed for survey data acquisition, sample and data storage, creation of soil spectral libraries, and dissemination of the soil information and suggested land use planning options through various geo-portals and mobile apps. A mobile app named "Soil Survey Data Collection & management System" has been developed to assist the soil surveyors to collect the soil profile information and transfer the data in real time to the central server. The QR coded physical soil samples and database on soil-site characteristics and the soil morphology collected through the app are then assimilated in the "National Soil Archives" updated with analytical data obtained from the laboratory analysis and soil spectra obtained through spectroscopy. The soil spectra and the national soil archive database forms the base of development of "Indian Soil Spectral Library" which stores the spectral soil libraries of different types of soils such as salt affected soils, black soils, red soils, etc.. These spectral libraries are then utilized in developing "Online Soil Spectroscopy" portal -- a rapid and low-cost complement to traditional wet chemical analyses -- which predicts the soil properties based on the best fit model. The other digital portal named "National Soil Grid" has been developed for disseminating the digital soil mapping products where, the user can identify the depth wise soil properties at any given pixel. All these geo-portals are linked to the "BHOOMI Geo-portal" which apart from hosting these portals also works as a repository of all the legacy data on soils, land degradation, agro-ecological regions/ sub-region, land resource inventory, land Use planning options, land suitability, etc. It also serves as a tool for digital data acquisition on soils and land use planning. The integrated digital initiative aims to collect, store, update, analyze, and share essential soil information and land use planning options with stakeholders, promoting sustainable agriculture and environmental management.

Key words: National soil archive, national soil grid, soil spectral library, online soil spectroscopy, soil survey app, BHOOMI geoportal

PS 1/62

Characterization and Evaluation of Soils of Rahuri Tehsil of Ahmednagar District, Maharashtra for Alternate Land Use Planning

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Based on variation in landforms and soils five pedons namely, Vambori (P1), Dambori khurd (P2), Brahmani (P3), Kendal khurd (P4) and Pimpri (P5) in Rahuri tehsil of Ahmadnagar district of Maharashtra were characterized for their physical and chemical characteristics. These pedons are very shallow (P3), moderately shallow (P1) and others are very deep. The soils have Munsell colour notation in 7.5YR/10YR hue with value 3 to 4 and chroma 2 to 4. The dominant structure is moderate, medium and sub angular blocky type, but angular blocky structure is common feature in slickenside zone of Vertisols. Almost all soils are clayey in texture and bulk density ranges from 1.22 to 1.86 Mg m-3. Relatively high smectite content resulted in higher moisture content at -33 and -1500 kPa suctions. These soils are moderately to strongly alkaline in reaction and their ECE varied from 32 to 62 cmol (p+)kg-1. The surface soil layers had relatively higher organic carbon content than underlying horizons. Calcium and magnesium were found to be dominant cations on the exchange complex however the soils of lowland and valley floor had Na+ as the dominant cation on the exchange complex. The available N, P, and K content ranged from 25.0 to 150.5, 6.0 to 51.0 and 134.4 to 963.2 Kg ha-1respectively. The DTPA extractable-Fe, Mn, Zn and Cu ranged from 8.3 to 20.3, 2.5 to 34.7, 0.01 to 0.6 and 0.08 to 5.9 mg kg-1 respectively. These pedons were classified as Typic Haplustepts (P1 and P5), Sodic Haplusterts (P2 and P4) and Lithic Ustorthents (P3). The dominant cropping system in Ahmednagar district are sugarcane-based cropping systems, hence the soils were evaluated for sugarcane suitability. As per Sys et al. (1993) the soil of pedon P3 are not suitable for sugarcane, soil of pedon P1are marginally suitable and the soils of pedon P2, P3 and P4 are moderate to marginally suitable for sugarcane cultivation due to the problem of soil sodicity.

Key words: Vertisols, sodic soils, land suitability

PS 1/63

Significance of Soil-Biophysical Properties in Ecosystem Services

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Ecosystems play a crucial role in providing various goods and services essential for human well-being. Soil, a key component, contributes significantly to ecosystem services through diverse functions. However, many studies tend to overlook soil, focusing predominantly on other services like provisioning, supporting, regulating, and cultural services. Recognizing this gap, experts have emphasized the necessity of assessing soil ecosystem services to inform land resource policies and management decisions. Despite the vital role soils play in providing ecosystem services, they are often inadequately highlighted by soil and crop scientists in decision-making processes. Recent efforts have aimed to underscore the significance of soil functions and their contribution to ecosystem services in maintaining and enhancing overall ecosystem health, including soil and crop productivity. Scientific soil resource management can effectively address various challenges such as climate change mitigation, urbanization regulation, improved agricultural production for food security, recreational services, and reliable water supplies. In India, tropical soils have historically been perceived as agriculturally poor, hindering sustainable productivity. Indian soil scientists have, however, made strides in the last decade by providing comprehensive information on tropical soils, emphasizing their role in determining the country's economic status. Despite these efforts, managing Indian tropical soils for sustained productivity remains challenging due to unique bio-physical properties that are not explicitly linked to soil ecosystem services. Previous research has failed to pinpoint specific bio-physical properties causing low crop productivity in semi-arid tropical (SAT) climates. Recent research at ICAR-NBSS&LUP, Nagpur, has made progress in linking some bio-physical properties to crop productivity in SAT environments. Soil properties modified by regressive pedogenic processes in SAT areas contribute to low productivity by hindering soil organic carbon accumulation, restricting air and rainwater entry, and minimizing soil moisture retention-release during crop growth. The Division of Soil Resource Studies (SRS) at ICAR-NBSS-LUP has undertaken high-quality research highlighting causative factors of natural soil degradation due to Holocene climate change, adversely affecting crop production in the SAT region of India. Researchers at the Bureau have emphasized the significance of soil organic and inorganic carbon stock in soil drainage, particularly in SAT regions. They propose effective management interventions to plough back inorganic carbon into organic-rich and better-drained soils, addressing challenges in rainfed agriculture. Through various research projects, ICAR-NBSS&LUP has generated substantial datasets on soil-bio-physical factors, illustrating their importance in soil and crop productivity. This research has successfully established a connection between bio-physical properties and soil/crop productivity, enhancing our understanding of the critical role of soils in providing ecosystem services in tropical environments.

Key words: Ecosystem services, sustainable development goals, tropical soils, bio-physical properties, soil productivity

PS 1/64

Contrasting Ecosystem Services of the Palygorskite Containing Shrink-Swell Soils

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Managing the productivity of Indian tropical soils has always been challenging due to unique soil and clay properties not explicitly linked to soil ecosystem services. Recognizing the importance of the ecosystem's goods and services for human welfare, there is a need for a comprehensive document on the significance of clay and other minerals in Indian soils and their overall influence on ecosystem services. Four major groups of ecosystem services, including lower-level services such as food, fiber, water supply, and aesthetic values, are crucial for human well-being. Recent studies on benchmark soils underscore the vital role of soil and clay properties in lower-level ecosystem services of Indian tropical soils. This research focuses on the divergent ecosystem services of palygorskite in influencing the soil hydraulic properties of semi-arid tropical (SAT) shrink-swell soils in the Indian peninsular region. Soil hydraulic properties, regulating water and nutrient availability to plants, contribute to the provisioning and regulating services of the ecosystem. Palygorskite, a magnesium-rich mineral with a fibrous morphology, differs structurally from typical 1:1 and 2:1-layer structures. It impairs soil hydraulic properties by releasing Mg2+ ions during irrigation, leading to high exchangeable magnesium and dispersion of clay colloids, ultimately clogging soil pores and making subsoils impermeable to air and water. This scenario results in a significant reduction in yields of deep-rooted crops, with cotton crops experiencing nearly a 50% reduction in yields in the SAT areas of Rajasthan, Maharashtra, and Gujarat. However, contrasting situations are observed in palygorskite Vertisols (Typic Haplusterts) in the sub-humid dry (SHD) bioclimatic environment of the Chhattisgarh basin in central India. Here, poor soil drainage due to hydraulic properties at non-alkaline chemical conditions contributes to successful rain-fed cultivation of long-duration rice through a direct-seeded method, despite the essential requirement of standing rainwater on the soil surface for rice cultivation. This success is comparable to the reclamation measures in sodic soils of the north-western Indo-Gangetic Plain, where rice is cultivated after gypsum addition, ensuring standing water availability at a specific exchangeable sodium percentage (ESP) around 40-45. The unique soil ecosystem services (SES) of palygorskitic shrink-swell soils (Vertisols) emphasize the need for clay mineralogical research in evaluating the SES of Indian tropical soils. It also underscores the importance of alerting pedologists, soil mappers, and natural resource managers about the presence of palygorskite in poorly drained, non-sodic soils to effectively manage them for enhanced productivity, considering the mineral's severe drainage problems.

Key words: SAT soils, Palygorskite mineral, vertisols, sub-humid dry, hydraulic properties, exchangeable Mg

PS 1/65

Efficiency of Cotton Production Across Major Producing States in India

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Cotton is an important commercial crop predominantly grown across the western, central and Southern Indian States in an area of 13 million ha producing 33.66 million bales with a productivity of 442.62 kg lint/ha. India needs to produce 50 million bales by 2030 to meet the growing demand. As increasing the cotton acreage is unlikely, the only other option is to increase the productivity. Using Relative Spread Index (RSI) and Relative Yield Index (RYI) in tandem, this study mapped the production efficiency of major cotton producing districts across 10 States in India viz. Punjab, Haryana, Rajasthan, Madhya Pradesh, Gujarat, Maharashtra, Telangana, Andhra Pradesh, Karnataka and Tamil Nadu. Having large acreage under cotton and realizing higher yield than national average, 23 districts covering 20% of area were found relatively most efficient in cotton cultivation. By realizing higher yield from lesser area, 45 districts covering 13% area were efficient. By realizing lesser yield in spite of cultivating in larger area, 41 districts covering 55% area were less efficient. With less area and yield, 44 districts covering 12% area were inefficient. Most of the districts in Punjab, Haryana, Rajasthan and Gujarat are efficiently cultivating cotton, thanks to the developed irrigation infrastructure, whereas most of the districts in other States are not efficient in cotton cultivation. While the cotton in inefficient districts should be replaced with other remunerative crops, irrigation infrastructure should be improved in the less efficient districts to support technological interventions viz. sprinkler irrigation, mechanization, soil amendments.

Key words: Cotton, productivity, relative spread index, relative yield index, efficiency mapping

Theme 2

Soil Ecosystem Services for Sustainable Agriculture to Ensure Food and Nutritional Security

SESSA 2024

PS 2/1

Fractionation of Copper in a Long-Term Fertilizer Experiment within a Soybean-Safflower Cropping Sequence in Vertisols

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The research was conducted during the period 2021-22 at the Long-Term Fertilizer Experiment Research Farm, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. Employing a Randomized Block Design (RBD), the experiment comprised 12 treatments replicated four times. Soil samples were collected at depths of 0-15 cm after the safflower harvest in the soybean-safflower cropping sequence. The experiment involved various treatments: T1 - 50% NPK, T2 - 100% NPK, T3 - 150% NPK, T4 - 100% NPK with hand weeding, T5 - 100% NPK + $ZnSO_4$, T6 - 100% NP, T7 - 100% N, T8 - 100% NPK + FYM @ 5 t ha^{-1}, T9 - 100% NPK-Sulphur, T10 - Only FYM @ 10 t ha^{-1}, T11 - Absolute control, and T12 - Fallow. The investigation revealed that the various fractions of copper (available copper, water-soluble copper, exchangeable copper, reducible copper, total copper, and residual copper) were significantly highest with the combined application of inorganic fertilizers and organic manures, specifically with 100% NPK + FYM @ 5 t ha^{-1}, followed by 150% NPK and 100% NPK + $ZnSO_4$. Conversely, the lowest copper fractions were observed in the absolute control treatment, followed by treatments involving only 100% N and fallow conditions. Correlation coefficients between different copper fractions and various physico-chemical soil properties indicated a negative correlation with pH, calcium carbonate, and bulk density, while positive and significant relationships were established with available nitrogen, phosphorous, potassium, sulphur, and DTPA-Fe, Zn, and Mn. The study concludes that the combined application of inorganic fertilizers and organic manures, particularly 100% NPK + FYM @ 5 t ha^{-1}, enhances various fractions of copper in Vertisols within a soybean-safflower cropping sequence, while correlation analysis indicates significant relationships between copper fractions and key soil properties.

Key words: Available copper, exchangeable copper, Vertisol, water-soluble copper

PS 2/2

Nutrient Release Dynamics of Humic Acid-Fortified Fertilizer Briquettes in Brinjal (*Solanum melongena* L.) Cultivation on Lateritic Soils

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Lateritic soils, characterized by their red Ferro-magnesium composition, are prone to leaching losses and exhibit poor nutrient holding capacity. Macronutrient use efficiency is hindered by factors like volatilization, denitrification, surface runoff, leaching, and fixation. Achieving optimal yield potential in brinjal crops necessitates balanced fertilizer management, particularly when supplemented with organic sources. To address nutrient losses and meet crop demands, humic acid-fortified briquettes were employed. Humic acid acted as a chelating agent, facilitating the controlled release of fertilizers in accordance with crop requirements. In a pot culture experiment, the nutrient release patterns and soil properties of various treatment combinations were examined. Observations were conducted periodically during both investigation years. Results indicated that straight fertilizer application led to higher releases of ammoniacal-N, nitrate-N, phosphorus, and potassium ions at 30 days after transplanting, gradually decreasing from 60 days after transplanting up to harvest. Konkan Annapurna Briquette and UB-DAP exhibited intermediate release patterns, while UB-10:26:26 consistently released nutrients throughout the growth period up to harvest. Soil reaction and organic carbon content showed no significant differences across treatments during most observations (30, 60, 90 DAT, and harvest) in both investigation years. Electrical conductivity was elevated with Konkan Annapurna Briquette application, accompanied by sodium and potassium humic acid. Available nitrogen, phosphorus, and potassium content increased from 30 to 60 days after transplanting and gradually decreased from 90 days after transplanting up to harvest. UB-10:26:26, followed by UB-DAP with potassium humic acid, exhibited higher available primary nutrients and plant height. In conclusion, the study indicated that ammoniacal and nitrate nitrogen release was more pronounced with straight fertilizers, while UB-10:26:26 provided a slow, constant nutrient release. Phosphorus release was higher with UB-DAP, and UB-10:26:26 showed consistent release up to harvest. Straight fertilizer application led to higher potassium ion release, while UB-10:26:26 exhibited a slower, optimal nutrient release throughout the crop's growth period.

Key words: Lateritic soils, Nutrient management, humic acid-fortified briquettes, nutrient release patterns, brinjal crop

PS 2/3

Chitosan-Mediated Response to Water Stress on Lablab Bean (*Lablab purpureus* L.) Yield in Lateritic Soils of the Coastal Konkan Region, Maharashtra

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The lateritic soils of the Konkan region in Maharashtra are inherently acidic and exhibit very low water holding capacity, despite receiving an annual rainfall of 3500 mm. Lablab bean (Lablab purpureus L.), a crucial pulse crop in this region grown under residual moisture, locally known as Wal, faces challenges due to erratic rainfall patterns and climatic anomalies. Protected irrigation for lablab bean is challenging under these circumstances. This study, conducted at the University's Botany Farm, aimed to evaluate the impact of chitosan on lablab bean performance under water stress conditions. Two factors were considered: seed priming with chitosan at the time of sowing (0.0%, 1.0%, and 2.0%) and foliar application of chitosan (0 ppm, 100 ppm, and 200 ppm). Nine treatment combinations were tested under irrigated and non-irrigated conditions in lateritic soil. Various physiological, biochemical, and yield-related parameters were recorded. Chitosan application exhibited significant effects in all parameters under moisture stress conditions. Both seed priming and foliar application of chitosan positively influenced lablab bean compared to the control treatment under both irrigated and non-irrigated conditions. The plant height (97.29 cm) at harvest was significantly influenced by the foliar application of 200 ppm chitosan without seed priming. Chlorophyll content in the leaves showed an increasing trend up to 60 DAS with chitosan application. The foliar application of 200 ppm chitosan with 2% seed priming demonstrated significantly superior chlorophyll content (1.38 mg g-1) compared to other treatments. The treatment P2F2, where seeds were primed with 2% chitosan and 200 ppm chitosan was sprayed at 30, 60, and 90 DSA, recorded the maximum number of pods (17.80) under water stress conditions. In terms of seed yield per plant, P2F2 also reported the highest seed yield (11.60 g), while the control (P0F0) recorded the minimum yield (7.89 g) under water stress conditions. In conclusion, lablab bean seed primed with 2% chitosan and foliar application of 200 ppm chitosan at 30, 60, and 90 DAS exhibited better performance across all parameters under water stress conditions in the lateritic soils of the Konkan region in Maharashtra. The study concludes that the application of 2% chitosan through seed priming and foliar application of 200 ppm chitosan at specific growth stages enhances lablab bean performance, including plant height, chlorophyll content, pod formation, and seed yield, under water stress conditions in the lateritic soils of the Konkan region, Maharashtra.

Key words: Lateritic soils, lablab bean, chitosan, water stress, crop performance

PS 2/4

Fertilizer Briquettes Fortified with Humic Acid: Boon to Increase Brinjal Productivity in Lateritic Soils of Konkan

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Addressing the challenge of nutrient use efficiency in Indian soils is crucial, particularly in the lateritic soils of the Konkan, characterized by red Ferro-magnesium composition and susceptibility to leaching losses. This study aimed to optimize fertilizer management for brinjal crops by utilizing humic acid-fortified briquettes, acting as chelating agents for controlled nutrient release. The research encompassed field experiments and pot culture studies, employing a factorial randomized block design with 15 treatment combinations. Various fertilizer briquettes, including Konkan Annapurna Briquette, UB-10:26:26, UB-DAP, and straight fertilizer applications, combined with different humic acids (sodium and potassium humic acid) and an absolute control, were applied in three splits during the rabi seasons of 2021-22 and 2022-23. The investigation assessed the impact on brinjal growth, yield, nutrient uptake, quality parameters, nutrient use efficiency, and soil properties. In the pot culture experiment, nutrient release patterns and soil properties were observed. Soil reaction gradually decreased, while electrical conductivity exhibited no significant differences. Available nitrogen, phosphorus, and potassium content increased from 30 to 60 days after transplanting and decreased gradually from 90 DAT up to harvest. Cation exchange capacity was significantly highest with UB-10:26:26 and potassium humic acid application. The study highlighted that UB-10:26:26 fortified with potassium humic acid positively influenced brinjal growth, yield, nutrient content, nutrient uptake, and quality, contributing to sustained soil fertility. The highest fruit yield of brinjal occurred with the conjunctive use of UB-10:26:26 fortified with potassium humic acid, reaching 31.37 t ha-1 in 2021-22 and 32.87 t ha-1 in 2022-23. Nitrogen use efficiency increased by 23 to 24 percent using briquettes compared to straight fertilizers. In conclusion, the application of UB-10:26:26 along with potassium humic acid can significantly enhance brinjal production, increase nutrient use efficiency, and improve the properties of lateritic soils in the Konkan region. The study recommends this approach for achieving optimal net returns with a higher benefit-to-cost ratio in brinjal cultivation.

Key words: Nutrient use efficiency, humic acid-fortified briquettes, brinjal crops, fertilizer management, lateritic soils

PS 2/5

Land Use Dynamics in Karnataka: District Level Study

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The study investigates land use dynamics in Karnataka by analyzing the changes in the share of net sown area, permanent pasture, grazing land, barren and unculturable land, fallow lands, culturable wasteland, and land under miscellaneous tree crops and groves over the period 2000-01 to 2020-21. Using district-level data obtained from the Directorate of Economics and Statistics of the Government of Karnataka, a panel data regression is employed to empirically establish relationships, particularly focusing on non-agricultural land, barren land, and arable land. The findings reveal an increase in the share of net area sown from 54.65% in 2000-01 to 60.12% in 2020-21, while permanent pasture, grazing land, barren and unculturable land, fallow lands, culturable wasteland, and land under miscellaneous tree crops and groves experience a decline in their share compared to 2000-01. The share of land under non-agricultural purposes has risen from 6.89% to 7.96% during the same period, while forest area remains constant. The study employs panel data regression to understand the tendencies and reasons for these land use changes. The analysis includes the rate of urbanization and land use change for each district, offering insights into the direction of land use changes in Karnataka. The study's policy implications underscore the need for well-planned and monitored land use policies, especially in response to rapid population growth impacting non-agricultural, arable, and barren land areas at the district level. Such insights are crucial for ensuring sustainable land use practices in the state.

Key words: Panel data regression; Land use change; urbanisation; arable land; non-agricultural land; barren land

PS 2/6

Challenges and Opportunities in Sugarcane Farming for Improving Soil Fertility

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The sugar industry plays a pivotal role in India, influencing the livelihoods of approximately 50 million sugarcane farmers and around 5 lakh workers directly employed in sugar mills. India alone contributes 17% to the total global sugar production. Projections indicate that by 2030, India will need around 520 million tonnes of sugarcane to meet the escalating demands for sugar and ethanol. Given limited scope for expanding cultivation areas, achieving the required yield increase of 100-110 tonnes per hectare by 2030 poses a substantial challenge. Climate change adds another layer of complexity to agriculture, with erratic rainfall, extreme events, and unseasonal rains adversely affecting sugarcane production. Urgent measures are needed to develop climate-resilient crop varieties, cropping patterns, and management practices. Managing water, a potentially scarce resource in the twenty-first century, is currently a top priority in sugarcane farming. Diversification into value-added streams such as cogeneration, ethanol, industrial and potable alcohol, and animal feed presents substantial opportunities. This creates a demand for increased sugarcane production, fostering potential research and development interventions to elevate production frontiers. Sugarcane is recognized as a champion crop for carbon sequestration, contributing to mitigating the effects of global warming. Additionally, by-products of the sugar mill, like press mud and post-bio-methanated spent wash from distillery, hold economic importance. Press mud cake, with its nutrient-rich composition, has the potential to enhance soil properties, and distillery effluent can be converted into a humus-rich organic manure. This sustainable approach not only addresses waste management but also reduces the reliance on chemical fertilizers. Furthermore, the utilization of spent wash powder as a potash fertilizer offers a strategic solution to the shortage of potash fertilizers in India. The integration of chemical, organic, and biofertilizers is essential for sustainable sugarcane production, ensuring nutrient use efficiency and maintaining soil health. Overall, these holistic nutrient management strategies, involving sugar industry by-products, are crucial for increasing crop productivity and sustaining soil fertility.

Key words: Sugarcane Industry, Climate Resilience, Agricultural Diversification, Carbon Sequestration, Nutrient Management

PS 2/7

Is Land Use Affects Preferential Flow Characteristic and Flow Types: A Case Study from Semi-Arid Watershed, India

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Preferential flow of water in a soil is a concept of soil hydrology, and a common form of soil water movement. Increasing attention has been paid to preferential flow in recent years due it's influences on solute transport and hydrological response. In recent years, the effects of land use on hydrological responses were hot spots in hydrology, soil science and environmental perspectives. Land use affects hydrological system in a great way. Different land-use types affect development of the soil structure as well as distribution and characteristics of the preferential flow paths in its own way. Based on the above statements, this study was proposed to investigate the role of preferential flow, as affected by different land use, taking a micro-watershed as a unit. Its effect on bio-physico-chemical properties of soil, quantification of preferential flow parameters by image analysis under different elevation and assessment of different preferential flow types flow under different land use and elevation was also carried out for better understanding of the whole process. Total of 20 profiles were dug to study the preferential flow with the help of Brilliant Blue dye at different land use and elevations. Ten representative soil profiles under different land use (Planted Forest, Plantation crop, fallow land and cropped land at three elevation) were randomly selected for image analysis and further processing. The characteristic and flow types of preferential flow were estimated by combining multi-index method and preferential flow classification. Wilcoxon signed-rank test-Significance at 0.05 level was done with the hypothesis that there is no change in preferential flow parameters with elevation and land use. The hypothesis was rejected with significance at upper reach by 0.002** middle reach by 0.008** and at lower reach by 0.008** (*$p<0.01$). Based on preferential flow fraction and length index and other preferential flow parameters compared under different elevations, the preferential flow advantage of forestland was more evident than that of fallow land.

Key words: Preferential flow, land use, hydrological response, soil structure, image analysis

PS 2/8

Effect of Chelated Micronutrient on Summer Groundnut and Their Relationship with other Nutritional and Yield Parameters

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The present investigation was undertaken during the summer 2022-23 at Oilseed Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in Factorial Randomized Block Design (FRBD) with two factors (Soil application and Foliar spray of chelated micronutrients (ZnEDTA and FeEDDHA) replicated three times. The objectives were to study the effect of Soil application and foliar spray of chelated micronutrients (iron and zinc) on growth, yield, quality and soil properties of summer groundnut. The soil of the experimental site was moderately alkaline in nature. The fertility status of soil indicated that the soil was low in nitrogen and high in potassium and low in phosphorus content. The results of the present investigation revealed that, the yield (Pod and Haulm) of summer groundnut was significantly highest with Soil application of chelated iron and zinc S3 (100% RDF + Zn EDTA @ 1.5 kg ha-1 + FeEDDHA @ 1.5 kg ha-1) along with foliar spray of chelated iron and zinc F3 (Zn EDTA @ 0.5 % + FeEDDHA @ 1.0% at 35 and 65 DAS). Similarly, the growth parameters like plant height of summer groundnut, number of branches of summer groundnut, Chlorophyll content index, 100 kernel weight and shelling percentage, harvest index, leaf area index, number of one, two and three kernel and number of nodules were numerically highest with soil application of chelated iron and zinc S3 (100% RDF + Zn EDTA @ 1.5 kg ha-1 + FeEDDHA @ 1.5 kg ha-1) along with foliar spray of chelated iron and zinc F3 (Zn EDTA @ 0.5% + FeEDDHA @ 1.0% at 35 and 65 DAS). The quality parameters viz. protein content and oil content were highest with soil application of chelated iron and zinc S3 (100% RDF + Zn EDTA @ 1.5 kg ha-1 + FeEDDHA @ 1.5 kg ha-1) along with foliar spray of chelated iron and zinc F3 (Zn EDTA @ 0.5 % + FeEDDHA @ 1.0% at 35 and 65 DAS).The uptake of N, P, K, Zn, Cu, Fe and Mn were also significantly improved in kernel and straw of summer groundnut. Soil application of chelated iron and zinc S3 (100% RDF + Zn EDTA @ 1.5 kg ha-1 + FeEDDHA @ 1.5 kg ha-1) along with foliar spray of chelated iron and zinc F3 (Zn EDTA @ 0.5 % + FeEDDHA @ 1.0% at 35 and 65 DAS). The improvement in fertility status of soil for major nutrients and for micronutrients at harvest of summer groundnut was found with the soil application of chelated iron and zinc S3 (100% RDF + Zn EDTA @ 1.5 kg ha-1 + FeEDDHA @ 1.5 kg ha-1) along with foliar spray of chelated iron and zinc F3 (Zn EDTA @ 0.5 % + FeEDDHA @ 1.0% at 35 and 65 DAS).

Key words: Micronutrient management, summer groundnut, chelated iron and zinc, growth parameters, soil fertility

PS 2/9

Agronomic Fortification of Zinc in Pigeonpea Genotypes Grown on Swell-Shrink Soil

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The study conducted during the Kharif season 2022-23 at the Pigeonpea Breeding Unit, CRS, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola utilized a Split-Plot Design with fifteen treatment combinations, involving five pigeonpea genotypes (AKTE 1905, AKTE 1904, AKTE 16-12, AKTE 19-01, and AKT 8811) and three zinc levels. The treatments included Recommended Dose of Fertilizer (RDF), RDF with Soil application of Zn at 5 kg Zn ha-1 during sowing, and RDF with Foliar spraying of ZnSO4 at 0.5% during branching and flowering stages. The investigation aimed to assess zinc content in pigeonpea seeds, study soil nutrient status at harvest, and evaluate the interaction between genotypes and zinc levels on seed yield. AKTE 1905 and AKTE 16-12 exhibited superiority in yield attributes, yield, nutrient content, and nutrient uptake. Pigeonpea genotypes demonstrated significantly increased seed and straw yield with soil application of Zn at 5 kg ha-1 through ZnSO4 during sowing. Quality parameters, such as test weight, protein content, protein yield, and nutrient uptake, were highest with soil application of Zn at 5 kg ha-1 during sowing, followed by two foliar sprayings of 0.5% ZnSO4 at branching and flowering stages. The interaction effect between genotypes and zinc levels significantly influenced pigeonpea seed yield, with the best combination observed in genotype AKTE 1905 with soil application of Zn at 5 kg ha-1 during sowing. AKTE 1905 also recorded the highest zinc content in seeds (35.42 mg kg-1). The study concludes that soil application of Zn at 5 kg ha-1 during sowing in AKTE 1905 and AKTE 16-12 enhances zinc content, nutrient uptake, seed yield, and quality parameters in pigeonpea genotypes.

Key words: Pigeonpea genotypes, Zinc levels, Soil application, Foliar spraying, Seed yield

PS 2/10

Dynamics of Iron Fractions Rice Soil as Influenced by Different Biochar Application and Moisture Regimes

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An investigation conducted in 2022 at the Department of Soil Sciences, Assam Agricultural University, Jorhat, focused on the "Dynamics of iron and manganese influenced by biochar application on rice soil." The study involved an adsorption isotherm study to understand the iron (Fe) adsorption characteristics of biochar. Additionally, an incubation experiment was carried out to examine the impact of different biochar types (rice husk biochar (RHB) and bamboo biochar (BB)) and levels (0, 3, and 5% (w/w)) on the dynamics of Fe in soil under a selected phytotoxic level (250 mg kg-1) at two moisture regimes (continuously waterlogging (CW) and continuous saturation (CS)).Twelve treatment combinations under spiked Fe concentration, along with one control, were utilized and replicated thrice, employing a factorial completely randomized design with a single control. Adsorption isotherm data fit well with both Langmuir's and Freundlich isotherm models. Rice husk biochar exhibited a maximum adsorption capacity (Gmax) of 39.90 for Fe2+, while bamboo biochar had 24.33 mmol kg-1 for Fe2+. In the equilibrium state, rice husk biochar and bamboo biochar demonstrated removal efficiencies of 84% and 72%, respectively, for Fe2+.In the incubation experiment, the application of bamboo biochar, continuous waterlogged moisture regime, and 5% biochar level recorded significantly higher soil pH at different incubation intervals. Rice husk biochar application, regardless of the incubation interval, resulted in significantly higher adsorbed and dissolved Si. Furthermore, bamboo biochar application, continuous saturation, and 5% biochar level recorded significantly lower DTPA-Fe. Among different treatment interactions, the application of 5% bamboo biochar in continuous saturation moisture regime recorded significantly lower DTPA-Fe in soil. Regarding the fraction of Fe, different moisture regimes, biochar types, and levels significantly decreased soluble + exchangeable and oxide-bound Fe fractions, while increasing carbonate and organic matter-bound Fe fractions under spiked Fe concentration. However, the residual fraction of Fe remained unaffected by biochar application and moisture regime. The application of rice husk biochar at a 5% level in continuous saturation moisture regime, under spiked Fe concentration, significantly decreased DTPA-Fe and Mn, soluble plus exchangeable, oxide-bound, and residual fractions of Fe and Mn. Simultaneously, it significantly increased carbonate-bound and organic matter-bound fractions of Fe and Mn in the soil. These findings suggest that continuous saturation with rice husk biochar application at a 5% level in Fe-contaminated soil significantly decreases the availability of Fe in soil and different solid phases. This approach holds promise as a farm-level viable technique for managing Fe toxicity in lowland rice cultivation.

Key words: Biochar application, iron and manganese dynamics, soil adsorption isotherms, moisture regime impact, Fe toxicity management

PS 2/11

Towards Sustainable Nitrogen Management: Unveiling the Potential of Urease and Nitrification Inhibitors to mitigate Greenhouse Gases and Ammonia Emission in Indian Agriculture

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Ranked as the fourth-largest contributor to greenhouse gas (GHG) emissions, India has set an ambitious target of achieving net zero emissions by 2070. In India, agriculture stands as the second largest GHG emitter following the energy sector. Synthetic nitrogen (N) fertilizers contribute significantly, constituting 8.3% of agricultural emissions. Although adoption of neem coated urea (NCU) is mandatory since 2015, its efficacy remains inferior to synthetic nitrification inhibitors (NIs). Moreover, use of NIs often lead to increased ammonia (NH_3) volatilization. Therefore, to assess alternative nitrogen management strategies for mitigating GHGs emission and NH_3 volatilization, a laboratory incubation experiment was conducted with six modified nitrogenous fertilizers (including a control) and two residue management methods (CRR: crop residue removal, and CRI: crop residue incorporation) in a 6×2 factorial completely randomized design. The study utilized soil from a 10-year residue management field experiment in the rice-wheat cropping system of northern India. The fertilizer treatments comprised NCU (Neem coated urea), U (standard urea), UAS (urea ammonium sulfate), and two novel inhibitor-coated fertilizers - UUI (urea + urease inhibitor N-(n-butyl) thiophosphoric triamide, NBPT) and UUINI (urea + NBPT + nitrification inhibitor 3, 4-dimethyl-1H-pyrazol-1-yl succinic acid, DMPSA). The effects of fertilizers on global warming potential (GWP) and ammonia volatilization were contingent on residue treatment. Compared to standard urea, NCU reduced GWP by 11% in CRI, but insignificantly in CRR. Conversely, UAS decreased GWP by 12% in CRR, but insignificantly in CRI. UUI and UUINI demonstrated consistent GWP reduction in both residue treatments, with greater effectiveness in CRI (21% and 26%) than in CRR (15% and 14%). Regarding ammonia volatilization, relative to standard urea, NCU increased it by 8% in CRI, but insignificantly in CRR. UUI exhibited the most substantial reduction (40% in CRI and 37% in CRR), while UUINI and UAS reduced it by 28-29% and 12-15%, respectively. In summary, urease inhibitors, either individually or in combination with nitrification inhibitors, proved more effective in mitigating greenhouse gas and ammonia emissions compared to NCU. Nevertheless, the validation of these findings requires field testing beyond the controlled laboratory experiment.

Key words: Ammonia volatilization, nitrous oxide emission, global warming potential, urease inhibitor, dual inhibitor, residue incorporation, rice-wheat

PS 2/12

Zinc Adsorption Desorption Behaviour and Sequential Extractable Pools in Sugarcane-Based Cropping Systems of Western Indo-Gangetic Plain

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The fractionation of Zn and its adsorption at soil matrix are crucial for careful management to attain the sustainability in Western Indo Gangetic Plain (IGP) region. Soils from three depths (15, 30, 45cm) were collected from the farmers field in 2021-22 from five different cropping systems (sugarcane - ratoon – wheat, sugarcane - ratoon - wheat - rice, sugarcane + mustard - ratoon - rice, sugarcane + cucumber - ratoon, sugarcane - ratoon – potato) who has been practicing the same cropping sequence since last 10-12 years and a reference soil which was uncultivated from last 50 years. The pH and EC revealed neutral to moderate alkaline, low to medium organic carbon (0.59mg/kg), medium to high Olsen's phosphorous (30.14mg/kg) and low to sufficient DTPA-Zn (1.82mg/kg). Sugarcane - ratoon - wheat among cropping system revealed highest total (86.94mg/kg), residual (67.95mg/kg) and sequentially extractable Zn (19mg/kg) fractions which implies that Zn is retained and released for longer duration. The retention of Zn at the soil matrix were further clarified by sorption mechanism which invoked maximum %Zn sorption occurs at sugarcane - ratoon – wheat (49.17%). The sorption phenomena of Zn on soil is spontaneous (ΔG is negative) and is physically adsorbed (E <8kJ/mol). Monolayered Zn sorption depicted from Langmuir Isotherm constants (Q_o = 8.67μg/gm, K_L = 0.25ml/μg) occurs at silt (r^2 = 0.813*) and calcium carbonate surface (r^2 = 0.943*) of top soil while at sub-surface multilayered sorption from Freundlich Isotherm constant (K_F = 3.07μg/gm, n = 6.27gm/ml) is pH-dependent (r^2 = 0.910*) and occurs at clay surface (r^2 = 0.812*).The study highlights the crucial role of Zn fractionation and adsorption in soil matrix for sustainable management in the Western Indo Gangetic Plain, with sugarcane-ratoon-wheat cropping system exhibiting the highest Zn retention and release, influenced by specific sorption mechanisms at different soil depths and surfaces.

Key words: Sugarcane, Zn, adsorption, Zn-fractions

PS 2/13

Effect of Urban Compost on Soil Quality, Yield and Quality of Seasonal-Sugarcane in Vertic Inceptisol

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Field experiment was conducted during the year January 2020-21 at Post Graduate Institute Farm, Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.) to study the effect of urban compost on soil quality, yield and quality of *seasonal*-sugarcane in *Vertic Inceptisol.* The field experiment was laid out in randomized block design three replications and eight treatments. There were five levels of nitrogen 0, 25, 50, 75 and 100% of recommended dose of nutrients (RDF) with 100% P_2O_5, 100% K_2O along with organic manures *viz.*, FYM and urban compost. The application of 75% N through urban compost and remaining 25% N through urea, with recommended dose 115 kg P_2O_5 and 115 kg K_2O ha^{-1} in *seasonal*-sugarcane significantly increased cane and CCS yield followed by GRDF, 100% N through Urban compost and 50 % N through Urban Compost + 50% N through Urea. Total uptake of nitrogen, phosphorus, potassium, micro nutrients and yield attributing characters viz., no. of tillers, total cane height, millable cane height, no. of millable canes, girth and length of internodes, Apparent Nitrogen Recovery Efficiency, yield of cane and CCS were significantly higher in 75% N through urban compost + 25% N through urea (T6) treatment. However, Actual Nitrogen status and actual gain of nitrogen were highest in treatment of GRDF (250:115:115::N:P_2O_5:K_2O + FYM@20 t ha^{-1}). B:C ratio was found significantly highest (3.62) in 25% N through urban compost and 75% N through urea treatment (T_8). In view of the economics, Application of 75% nitrogen through urban compost and remaining 25% nitrogen through urea along with recommended dose of phosphorus@115 kg ha^{-1} + potassium@115 kg ha^{-1} to *seasonal* -sugarcane found beneficial for increase in growth parameters (millable cane height, total plant height, tillers, No. of millable cane, number, length and girth of internodes), uptake of macro & micro nutrients, nutrient use efficiency, net returns and yield of sugarcane grown in *Vertic Inceptisol*. However, the treatment of 25-50%N through urban compost and remaining 75-50% N through urea along with recommended dose of P and K to *seasonal* -sugarcane found beneficial for increased in agronomic efficiency and B:C ratio of *seasonal* –sugarcane.

Key words: Urban compost, Seasonal-sugarcane, Nutrient management, Crop yield, Soil quality

PS 2/14

Mineralization of Phosphorus as Influenced by Different Sources of Phosphorus in Calcareous Soil

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Managing phosphorus in calcareous soil is challenging due to carbonate phosphorus fixation, limiting plant availability. Organic manure enhances P mobilization through organic acids during decomposition, stimulating microbial activity or blocking P-fixing sites. The study aimed to assess the impact of different phosphorus sources on calcareous soil mineralization. A 90 days incubation study was carried out at Division of SSAC, RCSM, College of Agriculture, Kolhapur, (M.S.) during the year 2021- 2022. The experiment was laid out in factorial completely randomized design having three replications. The treatmentsconsisting of SSP and DAP as inorganic sources of P and farm yard manure (FYM), vermicompost (VC), poultry manure (POL) and press mud compost (PMC) as organic sources of P and combinations of both the organic and inorganic source of P. The fertilizer dose phosphorus for pot culture was used 50 kg P_20_5 ha^{-1} and the chemical fertilizer dose phosphorus was applied as 100% *i.e.* 50 kg P_20_5 ha^{-1} as 75% (37.5 kg P_20_5 ha^{-1}) through inorganic and 25% (12.5 kg P_20_5 ha^{-1}) through organic in combined treatments. The results revealed that the application of phosphorus through DAP recorded significantly superior P release over SSP during incubation period while among the sole organic treatments PMC was found to be superior. Among the combination treatments wherein, DAP is used as inorganic P source, it was observed that during initial incubation period *i.e.* at 0 DAI to 30 DAI, conjunct use of DAP+VC resulted in higher P release while at 45 DAI and 60 DAI, combine use of DAP+POL emerged as better combination in terms of P release. After 75 days of incubation period, DAP+PMC recorded highest P release as compared to othercombination whereas it was at par with DAP+POL. The combination treatments of DAP and different organic manures suggested that the in-case DAP is inorganic source of P, either PMC or POL should be used conjointly for higher P availability and improvement in soil properties. In conclusion, the application of phosphorus through DAP proved to be the most effective source for higher phosphorus release compared to SSP. Among the organic sources, POL and PMC both outperformed VC and FYM in phosphorus release. Utilizing, DAP or SSP in combination with POL or PMC not only enhanced phosphorus availability but also contributed to the overall improvement in the fertility status of calcareous soil.

Key words: Phosphorus management, Calcareous soil, Organic manure, Phosphorus release, Soil fertility

PS 2/15

Effect of Nitrogen Level and Irrigation Regimes on Plant Growth, Yield and Storage Quality of Onion

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The field experiment was conducted to study the effect of nitrogen fertilizers and irrigation regimes on plant growth, yield, and total storage losses of onion during 2021-2022. The experiment was designed on strip plot design and each treatment was replicated four times. Factor A consisted of irrigations methods namely drip, sprinkler and flood irrigation system, and Factor B consisted of four levels of nitrogen fertilizers (0, 50, 100 and 150% of recommended nitrogen). Twenty percent nitrogen fertilizer was applied as a basal at transplanting and remaining N dose was applied in three equal splits as side dressing at 15, 30 and 45 days after transplanting to all the treatments. In addition, onion bulb harvested from this experiment were stored for four months. The results showed that the treatment received 100% N (110 kg /ha) and 150% N (165 kg/ha) and irrigation through sprinkler system showed significantly higher chlorophyll concentration and leaf area index in comparison to the treatment received 100% N and 150% N through drip fertigation. However, the treatment received 100% N and 150% N and sprinkler irrigation showed the plant height comparable with the treatment received 100% N and 150% N through drip fertigation. However, application 100% N through drip and sprinkler irrigation system produced significantly higher onion yield compared to the treatment received 100% and irrigation through flooding system. N, P, K and S concentration were also higher in treatment received sprinkler irrigation and 100% N and 150% N compared to the treatment received 100% N through drip fertigation. Whereas, the quantity of A grade bulbs (bulb size bigger than 50mm) was higher in treatment received 100% N and 150% N through drip fertigation. In addition, equatorial diameter (57.8 mm) and polar diameter (51.5 mm) of the bulbs were higher in the treatments received 100% N through drip compared to the treatment received 100% N and irrigation through sprinkler (51.7 mm ED and 47.9 mm PD). Production of uniform and bigger bulb size and higher onion yield in this treatment may be due to the application of N through drip as per the crop requirement on the root zone. In addition, 100% N and 150% N applied treatments through sprinkler irrigation showed higher neck thickness of onion bulbs compared flood and drip irrigation system. The storage losses of onion were the highest in the control plots and the lowest in 100% and 150% N applied treatments in all three irrigation methods. However, 150% N application through drip showed 30.2% higher total storage losses compared to 100% N application through drip. The total storage losses in sprinkler and flood irrigation system were higher compared to that of drip irrigation system. This result indicated that 100% recommended N through drip as per crop requirement increased plant height, bulb size, produced uniform bulbs (bulb size >50 mm diameter), and onion yield and showed less total storage losses.

Key words: Nitrogen, Irrigation regimes, Chlorophyll, Onion yield, Total storage losses

PS 2/16

Impact of Nitrogen Sources and Levels on Wheat Yield and Soil Fertility under Saline Conditions

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This research investigates the influence of different nitrogen levels and sources on wheat yield and soil fertility in saline conditions. The field experiment was conducted at the Agricultural Research Station, K. Digraj, Dist. Sangli (M.S.), focusing on the wheat cultivar Tryambak. The experiment utilized a randomized block design with three replications and ten treatment combinations, including various nitrogen sources and levels (ranging from 100% to 150%). The recommended doses of P_2O_5 and K_2O were applied through SSP and MOP, respectively. The experimental soil exhibited saline characteristics (pH 8.17, EC 2.25 dS m^{-1}) with low available nitrogen (185 kg ha^{-1}), phosphorus (10.25 kg ha^{-1}), and high potassium (495 kg ha^{-1}). Soil analyses were conducted initially and after harvest. The results demonstrated that the application of 150% N- calcium nitrate significantly increased wheat grain yield (32.73 q ha^{-1}) compared to other treatments, with similar effects observed in treatments with 150% N- ammonium sulphate (31.60 q ha^{-1}), 125% N- ammonium sulphate (31.13 q ha^{-1}), 125% N- calcium nitrate (30.91 q ha^{-1}), and 100% N- calcium nitrate (29.57 q ha^{-1}). Additionally, straw yield was significantly higher with 150% N- calcium nitrate (40.28 q ha^{-1}). The nitrogen uptake by wheat was notably higher with 150% N- calcium nitrate (98.12 kg ha^{-1}), while phosphorus (23.88 kg ha^{-1}) and potassium (67.89 kg ha^{-1}) uptake were also maximized with this treatment. The treatment with 150% N- ammonium sulphate recorded the highest available nitrogen (217 kg ha^{-1}) and phosphorus (11.79 kg ha^{-1}). The application of 150% N- calcium nitrate resulted in the highest soil pH (8.15) and electrical conductivity (2.09 dS m^{-1}). Furthermore, the study observed improvements in soil fertility levels, excluding the absolute control. The highest net monetary returns (Rs.27,830 ha^{-1}) and B: C ratio (1.74) was recorded with the application of 150% N through urea. In conclusion, the application of 150% N- calcium nitrate to wheat exhibited superior outcomes in terms of yield, quality parameters, and nutrient uptake under saline conditions.

Key words: Nitrogen Levels, Wheat Yield, Soil Fertility, Calcium Nitrate, Saline Conditions

PS 2/17

Effect of Bioinoculants with Phosphorus Levels on Yield, Nutrient Uptake, Phosphorus Use Efficiency and Microbial Count in Soybean on Inceptisol

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A field experiment was conducted to study the Effect of bio-inoculants with phosphorus levels on yield, nutrient uptake, phosphorus use efficiency and microbial count in soybean on Inceptisol during *kharif* in 2018 at Post Graduate Institute Research Farm, Department of Soil Science, MPKV, Rahuri (MS). The experimental field was medium deep black (*Inceptisol*) family *Vertic Haplustept*. The experiment was laid out in factorial randomized block design with three sources of bio-inoculants and four levels of phosphorus and three replications. Soil is moderately alkaline in reaction with high calcium carbonate content and moderate in organic carbon content. The available nitrogen and available phosphorus were low and very high in available potassium. The treatments comprised of absolute control, PSB, PSB + 25 kg P_2O_5 ha^{-1}, PSB + 50 kg P_2O_5 ha^{-1}, PSB + 75 kg P_2O_5 ha^{-1}, VAM, VAM + 25 kg P_2O_5 ha^{-1}, VAM + 50 kg P_2O_5 ha^{-1}, VAM + 75 kg P_2O_5 ha^{-1}, PSB + VAM, PSB + VAM + 25 kg P_2O_5 ha^{-1}, PSB + VAM + 50 kg P_2O_5 ha^{-1}, PSB + VAM + 75 kg P_2O_5 ha^{-1}. Farm yard manure (5 t ha^{-1}), nitrogen (50 kg ha^{-1}) and potassium (45 kg ha^{-1}) applied to all treatment except absolute control as per recommended dose of soybean. Application of phosphorus level @75 kg ha^{-1} $P_2O_5$with seed treatment of arbuscular mycorrhizae and phosphate solubilizing bacteria along with recommended dose of nutrient (50: 45 kg ha^{-1} N: K_2O + 5 t ha^{-1}FYM) to soybean was found beneficial to increase grain (22.78 q ha^{-1}) and straw yield (29.11 q ha^{-1}) of soybean, total uptake of nitrogen (98.00 kg ha^{-1}), phosphorus (19.77 kg ha^{-1}), potassium (73.85 kg ha^{-1}) of soybean grown on Inceptisol. Agronomic phosphorus use efficiency (16.84 kg grain kg^{-1} P_2O_5) and apparent phosphorus recovery (32.76 %) were higher in 25 kg ha^{-1} $P_2O_5$with seed treatment of arbuscular mycorrhizae and phosphate solubilizing bacteria. The PSB + VAM with 50 kg ha^{-1} P_2O_5found beneficial for increase in PSB population at 30 DAS (55.81 cfu x $10^{-4}g^{-1}$soil), at 60 DAS (81 cfu x $10^{-4}g^{-1}$ soil) and at 90 DAS (66.55 cfu x $10^{-4}g^{-1}$ soil) and VAM root colony.

Key words: soybean, phosphorus levels, PSB and VAM source of bioinoculants.

PS 2/18

Fertigation Impact on Leaf Nutrient Content and Soil Fertility in Post-Harvest Nagpur Mandarin Orchards with High-Density Planting

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This research investigates the impact of different fertigation levels on leaf nutrient content and soil fertility after the harvest of 10-year-old Nagpur mandarin in high-density planting. Conducted in Hatla village, Taluka Katol, District Nagpur, the field experiment comprises five fertigation treatments (85%, 100%, 115%, 130%, and 145% of recommended NPK dose). Employing a Randomized Block Design with four replications across eighteen splits, the study analyzes leaf nutrients and soil properties. Leaf nutrient analysis revealed higher concentrations of total nitrogen (2.59%), total phosphorus (0.17%), total potassium (1.54%), and total sulfur (0.13%) in the treatment with 145% of recommended dose. Micronutrients, including iron (78.05 mg kg^{-1}), zinc (17.93 mg kg^{-1}), manganese (64.28 mg kg^{-1}), and copper (13.80 mg kg^{-1}), were also elevated in the 145% RDF treatment. Soil analysis indicated a slightly acidic to slightly alkaline soil reaction, consistent electrical conductivity across treatments, and non-saline soil conditions. Organic carbon content ranged from medium to high, and calcium carbonate content varied from slightly calcareous to calcareous. The treatment with 145% RDF exhibited the highest available nitrogen (231.63 kg ha^{-1}), available phosphorus (18.39 kg ha^{-1}), available potassium (419.37 kg ha^{-1}), and available sulfur (13.50 mg kg^{-1}). Moreover, soil micronutrients, including Fe (4.67 mg kg^{-1}), Zn (0.63 mg kg^{-1}), Mn (9.79 mg kg^{-1}), and Cu (1.38 mg kg^{-1}), were found to be highest in the 145% RDF treatment. Overall, this study provides insights into the influence of fertigation levels on leaf nutrient content and soil fertility, offering valuable information for optimizing nutrient management practices in high-density Nagpur mandarin orchards.

Key words: Nagpur mandarin, leaf and soil nutrients, fertility status, fertigation, high density planting

PS 2/19

Synthesis and Characterization of Nano Zinc Oxide for Linseed: Assessing the Impact of Nano Zinc Oxide on Growth, Yield, and Nutrient Uptake by Linseed

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This study delves into the evaluation of nano zinc oxide's influence on growth, yield, and soil fertility post-linseed harvest during the 2019-20 rabi season at AICRP Linseed Farm, College of Agriculture, Nagpur. Employing a Randomized Block Design with seven treatments replicated three times, the research encompasses the synthesis of zinc oxide nanoparticles through direct precipitation, characterized by FTIR and Dynamic Light Scattering. Nano ZnO particle size, ranging from 45.18 to 48.50 nm, demonstrated consistent dispersion (Polydispersity Index 0.224 to 0.250), with zeta potential values of -27.2 ± 7.6 mV, indicating stability in aqueous suspension. Treating linseed seeds with 1000 ppm nano ZnO resulted in an outstanding germination rate of 88%, accompanied by improvements in various plant attributes, including plant stand, branches, capsules, and significant seed yield. Noteworthy changes in soil parameters were observed, particularly with a treatment involving ZnSO4 at 15 kg/ha and foliar spray of nano ZnO at 0.25%. These interventions led to increased soil pH, enhanced nutrient availability (nitrogen, potassium, sulfur), improved electrical conductivity, heightened zinc availability, and a positive impact on soil organic carbon and phosphorus content. The findings highlight the multifaceted effects of nano zinc oxide on both plant and soil dynamics, providing valuable insights for sustainable agricultural practices.

Key words: Nano ZnO, growth, yield, linseed, nutrient uptake

PS 2/20

Effect of Integrated Nutrient Management on Yield of Nagpur Mandarin in Vertisol

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The present investigation was conducted during the year 2021-22 and 2022-23 to study the response of nutrients on yield, soil nutrient status and carbon fractions under Nagpur mandarin at the Regional Fruit Research Station of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Katol, Nagpur. The experiment was laid out in a randomized block design (RBD) with nine treatments replicated three times. The treatments comprise T_1- Only FYM @ 50 kg tree^{-1} + Biofertilizers, T_2- 100 % Recommended dose of NPK, T_3- 100 % Recommended dose of N only + FYM @ 50 kg tree^{-1} + Biofertilizers, T_4- 100 % Recommended dose of N and P + FYM @ 50 kg tree^{-1} + Biofertilizers, T_5- 100 % NPK+ FYM @ 50 kg tree^{-1} + Biofertilizers, T_6-100 % NPK+ FYM @ 50 kg tree^{-1} + Biofertilizers + S, T_7- 100 % NPK+ FYM @ 50 kg tree^{-1} + Biofertilizers + S + Zn, T_8- 100 % NPK + FYM @ 50 kg tree^{-1} + Biofertilizers + S + Zn + Fe, T_9- 100 % NPK + FYM @ 50 kg tree^{-1} + Biofertilizers + S + Zn + Fe + B. The results indicated that, maximum fruit yield can be harnessed through balanced nutrition using integrated nutrient management i.e. highest in application of 100 % NPK + FYM @ 50 kg tree^{-1} + Biofertilizers + S + Zn + Fe + B was found optimum for sustaining a higher fruit yield. Also, all integrated nutrient management treatments showed good results. This approach also improved quality parameters in Nagpur mandarin, such as juice recovery percentage, total soluble solids and TSS: acid ratio, compared to using only chemical fertilizers. In conclusion, the study suggests that consistent adoption of an integrated nutrient management approach involving the use of FYM, biofertilizers and inorganic fertilizers, along with foliar micronutrient spray, can enhance Ambia Bahar Nagpur mandarin yield and fruit quality.

Key words: Integrated nutrient management, Nagpur mandarin, fruit yield, soil nutrient status, carbon fractions

PS 2/21

Yield and Biochemical Metabolites of Brinjal as influenced by Compost and Foliar spray of Humic acid

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The experiment on effect of compost and foliar spray of humic acid on growth, yield and biochemical metabolites of brinjal was conducted at Department of Horticulture, and laboratory analysis was carried out at Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during Rabi, 2021-22. The experiment was laid out in randomized block design with nine treatments and three replications. The treatments comprised of foliar sprays of @ 0.5%, 1% and 1.5% of humic acid in combination with FYM and NPS compost along with recommended dose of fertilizers. The results indicated the number of fruits, fruit length and fruit weight of brinjal were found to be significantly influenced with the application of organics and foliar spray of humic acid. The highest fruit weight and fruit length were recorded with the application of 100% RDF + NPS compost @ 2.5 t ha^{-1} + 4 sprays of humic acid @ 1.5%. Higher number of fruits were recorded from the application of 100% RDF + NPS compost @ 2.5 t ha^{-1} + 4 sprays of humic acid @ 1%. Quality parameters viz. ascorbic acid and chlorophyll content were significantly influenced by the application of organics and foliar spray of humic acid. Application of 100% RDF + FYM @ 5 t ha^{-1} + 4 sprays of humic acid @ 1% recorded significantly higher ascorbic acid content whereas application of 100% RDF + NPS compost @ 2.5 t ha^{-1} + 4 sprays of humic acid @ 1% recorded higher chlorophyll index. Flavonoid, anthocyanin and Nitrogen Balance Index (NBI) was higher with the application of 100% RDF + NPS compost @ 2.5 t ha^{-1} + 4 sprays of HA @ 1.5 %. The experiment concludes that the application of 100% RDF + NPS compost @ 2.5 t ha-1 + 4 sprays of humic acid @ 1.5% resulted in the highest fruit weight, fruit length, and quality parameters of brinjal, highlighting the positive impact of organic and humic acid treatments on growth, yield, and biochemical metabolites.

Key words: Compost, foliar spray, brinjal, humic acid, growth

PS 2/22

Effect of Biochar as Amendment on Soil Properties and Yield of Maize Grown in Vertisols

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The field study was conducted on the Research Farm, Department of Agronomy, Dr. PDKV, Akola during Kharif, 2022-23. The experiment was laid out in Randomized Block Design (RBD) with eight treatments and three replications. The treatment comprised of control, various levels of nitrogen and their combinations with 2.5 and 5.0 t ha^{-1} biochar. On the basis of results obtained, Soil physical, chemical and biological properties like bulk density water holding capacity, organic carbon,available nitrogen , phosphorus and potassium in soil after harvest of maize were recorded significantly higher with the application of 125 % RDN + Biochar 5 t ha^{-1} , However, the biological properties like SMBC and DHA in soil at tasseling stage of maize were recorded significantly higher with the application of 125 % RDN + Biochar 5 t ha^{-1},whereas highest soil CO_2 evolution (52.49 mg CO_2) in soil at tasseling stage of maize was observed with the application of 100 % RDN . Whereas, pH and EC of soil were found non-significant by the various treatment. Higher application rates of biochar showed slight increase in micronutrients (Zn, Cu, Fe and Mn) but, statistically were found non-significant by the various treatments in the biochar applied soil. Higher the dose of biochar applied higher the SOC stock was recorded. Significantly higher grain and straw yield of maize were recorded with the application of 125% RDN + Biochar 5.0 t ha^{-1}. Higher the dose of biochar applied, higher the nutrient (N, P and K) use efficiency was recorded. From the present investigation, it can be concluded that, the soil application of 100 % RDN + Biochar 5 t ha^{-1} improved the soil properties, SOC stocks and favourably influenced the yield of maize.

Key words: Biochar, Vertisols, chemical properties, physical properties, biological properties

PS 2/23

Impact of Crop Residue Recycling under Cotton based Intercropping Systems on Soil Health and Productivity of Cotton in Vertisols

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The efficient use of chemical fertilizers requires an optimum level of organic matter in the soil that can be achieved by integrated use of chemical and organic fertilizers including composts.It is a promising approach in preserving soil biological activities, which will ultimately show positive impacts on different soil physicochemical properties and nutrient uptake by cotton crop. In this regard the, the present investigation was conducted at Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, (MH), during year 2017-18 and 2018-19. The experiment was laid out in split plot design with three replications. The main plot treatments comprised of nutrient management viz., INM (75 % RDF + compensation through NPS compost) and Organic (100 % NPK dose through NPS compost). Sub plot treatments consisted of cotton based intercropping systems viz., Cotton + dhaincha (1:1), Cotton + sunhemp (1:1), Cotton + greengram (1:1), Cotton + blackgram (1:1) and Sole cotton. Results revealed that, the use of 75 % RDF + compensation through NPS compost recorded highest cotton yield and improved the soil physical, chemical and biological properties. Build-up of the total organic carbon, soil carbon pools and carbon pools indices viz. Lability of SOC, LI, CPI and CMI was recordedwith the adoption of INM (75 % RDF + NPS compost) and Organic (100 % NPK dose through NPS compost) with intercropping of cotton + dhaincha (1:1) which was at par with cotton + sunhump (1:1) followed by cotton + greengram (1:1) and cotton + blackgram (1:1) as compared with sole cotton.The magnitude of various carbon pools in respective of the treatments were in order non labile > very labile > less labile > labile, indicating dominance of non-labile portion of carbon pools in Vertisol.

Key words: Integrated nutrient management, organic-inorganic fertilizer combination, cotton intercropping systems, soil carbon pools, soil health improvement

PS 2/24

Effect of Integration of VAM, Organic Resources and Chemical Fertilizers on Root Characteristics and Yield of *Kharif* Sorghum in Swell-Shrink Soils of Maharashtra

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A field experiment was conducted to assess the effect of Integration of VAM, Organic Resources and Chemical Fertilizers on Root Characteristics and yield of *kharif* Sorghum in Swell-Shrink Soils of Maharashtra at Dr. PDKV, Akola during 2022-23. The experiment was laid out in RBD with eight treatments replicated thrice. The treatments comprised of absolute control, 100 % RDF, 100 % RDF + VAM @ 5 kg ha^{-1}, 75 % RDF + VAM @ 5 kg ha^{-1} and 75 % RDF + VAM @ 5 kg ha^{-1} with and without FYM @ 5 t ha^{-1} and vermicompost @ 2.5 t ha^{-1}. The experimental soil was clay in texture, moderately alkaline in reaction, low in available N and P and high in available potassium and classified as Typic Haplusterts. The plot wise soil samples were collected and analyzed as per standard methods. The results revealed that the application of 75 % RDF + vermicompost @ 2.5 t ha^{-1} along with VAM @ 5 kg ha^{-1} recorded significantly highest highest root acid phosphatase activity, root volume and yield of sorghum followed by application of 75 % RDF + FYM @ 5 t ha^{-1} along with VAM @ 5 kg ha^{-1} which was at par with each other. While, significantly highest root length was registered with the application of 75 % RDF + FYM @ 5 t ha^{-1} along with VAM @ 5 kg ha$^{-1.}$ The significantly highest soil organic carbon and residual soil fertility status was observed with the application of 75 % RDF + vermicompost @ 2.5 t ha^{-1} along with VAM @ 5 kg ha^{-1} which was at par with application of 75 % RDF + FYM @ 5 t ha^{-1} along with VAM @ 5 kg ha^{-1}. Hence, it can be concluded that application of 75 % RDF + VAM @ 5 kg ha^{-1} along with vermicompost @ 2.5 t ha^{-1} or FYM @ 5 t ha^{-1} was found beneficial for improvement in root characteristics and yield of sorghum as well as improvement in soil fertility status of swell-shrink soils in Maharashtra.

Key words: VAM (Vesicular Arbuscular Mycorrhiza), organic-inorganic fertilizer integration, root characteristics, sorghum yield, swell-shrink soils

PS 2/25

Effect of Salinity and Sodicity on Reduction of Sugarcane (*Saccharum Officinarum*) Yield

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Sugarcane is grown in India in about 5.0 million hectares, and one fourth of the acreage is affected by salinity and alkalinity. Sugarcane is the major cash crop and the larger area is under sugarcane crop in canal command of Godavari River. The study was conducted under the command area of right bank of Godavari cannel (Dy. No. 6) to study the effect of salinity and sodicity on the yield of sugarcane. The soil suitability criteria for sugarcane were modified and the new criteria were developed based on local experience and available literature for the command area. The soil and site characteristics of the different soil units were compared with the requirements and the overall soil suitability were determined. The soils in general, in upland and mid land of the command were found to be moderately to marginally suitable, while most of the soils in the low land were not suitable for sugarcane. About 43 per cent area shows severe problems for growing sugarcane. Most of the command area observed unsuitable for sugarcane due to the severe limitations of soil in respect of effective soil depth, texture, hydraulic conductivity, pH, salinity and sodicity. The soils in the upland were found unsuitable due to the limitations of soil depth. The low land soils were found unsuitable due to limitations of EC*e* and ESP. The optimum cane and sugar yields, salinity level should be kept below 2.0 dSm^{-1} and threshold EC*e* value seems to be 4.0 dSm^{-1}. The growth of sugarcane ceases at EC*e*8.6 dSm^{-1}. The critical ESP level beyond which reduction in the yield of cane noticed is 15 per cent with exchangeable sodium 10 per cent. It thus appears that EC*e*4.0 $dSm^{-1}$and ESP6.0 per cent are the threshold values of these diagnostic parameters for valley soils beyond which the sugarcane crops suffer from salinity and sodicity hazards under present conditions. The yield data of sugarcane on different soil units was evaluated in relation to the ECe and ESP and it was observed that there was up to 45 per cent yield reduction due to ESP beyond 6.0per cent and ECe >4.0 dSm^{-1}, suggesting that the threshold level of EC*e* and ESP was> 4.0 dSm^{-1} and >6.0 per cent, respectively, which may be considered as the critical level of salinity and sodicity for sugarcane in black clayey soils of cannel command areas in Maharashtra.

Key words: ECe, ESP, salinity, sodicity

PS 2/26

Assessing the Impact of Organic Farming Practices on Soybean Growth, Yield and Soil Properties in Vertisol

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The field experiment was conducted during *kharif* season 2021-22at ongoing long term organic farming experiment during third cycle at Organic Farming Research and Training Centre (OFRTC)with thirteen treatments and three replications in randomized block design to study the effect of organic farming on physical, chemical and microbiological properties of soybean grown Vertisols and also the effect of organic farming on growth parameters, yield attributing characters and yield of soybean. The application of RDF+ 5 t FYM ha^{-1} significantly improved the plant height, number of pods $plant^{-1}$, seed weight $plant^{-1}$, pod weight $plant^{-1}$, seed index of soybean crop, availability of NPK, and maximum monitoring return and B: C and followed by treatment T_3 (33% FYM + 33% Vermicompost + 33% Neem cake) of organic sources of nutrients. Whereas the application of 100 % RDN through 33% FYM + 33% Vermicompost + 33% Neem cake enhanced DTPA extractable micronutrients, microbial population and enzymatic activity in soybean grown Vertisol. Among organic treatment, application of 100 % RDN through 33% FYM + 33% Vermicompost + 33% Neem cake recorded highest soybean yield, gross monetary returns, net monetary returns and B: C ratio. The study revealed that organic manure application improved the supplying capacity of all the essential nutrients in balanced proportion. The use of organic manure *viz*, FYM, Vermicompost, neem cake, improve organic carbon, microbial population and availability of micronutrients in Vertisol under soybean which promotes organic farming under rainfed condition.

Key words: Organics, soybean, FYM, neem cake, vermicompost, yield

PS 2/27

Evaluation and Utilization of Municipal Biowaste Compost using Microbial Inoculants to Enhance the Growth and Yield of Amaranthus Crop

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To mitigate the accumulation of municipal solid waste (MSW) and promote sustainable waste management, this study aimed to optimize composting techniques for various microconsumers in MSW compost (MSWC) production. Utilizing diverse sources such as sawdust balls impregnated with Panchakavya, TNAU Biomineralizer, PUSA decomposer, Effective Microorganisms (EM) solution, RCOF Waste decomposer, and novel microbial consortia, the research focused on achieving rapid and efficient biowaste compost production. Results revealed that the PUSA decomposer significantly reduced the composting period to 32 days, while enhancing nutrient content, including a balanced C:N ratio (13:1), total N (1.14%), total P (0.39%), and total K (0.94%). Furthermore, the prepared compost was enriched with rock phosphate at a rate of 30 kg per ton of MSWC. To assess the impact on crop yield, Amaranthus was selected as a test crop for a field experiment using the enriched MSWC. The application of enriched MSWC at a rate of 5 tons per hectare along with 75% NPK fertilizer demonstrated superior biomass production, yielding 27.84 tons per hectare. This was notably higher than the control and 100% NPK treatments, which produced 59.7% and 49.9% less biomass, respectively. The study highlighted the efficacy of proper microbial inoculation in reducing composting time, and the combined application of MSWC and inorganic fertilizers not only saved 30% to 50% of fertilizer dosage but also improved soil quality and crop yield. This eco-friendly waste disposal approach provides a promising solution to address the challenges associated with MSW accumulation and underscores the importance of sustainable waste management practices.

Key words: Municipal biowaste compost, PUSA decomposer, biomass yield

PS 2/28

Nutrient Content, Quality and Yield of Yam Bean as Affected by Different Levels of Inorganic and Organic Manure in Coastal Region of Maharashtra

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The effect of combine application of inorganic fertilizers and FYM on nutrient content i.e., nitrogen, phosphorous and potassium as well as quality parameters such as reducing sugars, non-reducing sugars, starch, crude fiber, protein, moisture content and shelf life of yam bean (*Pachyr rhizuserosus* L.) tuber was investigated in Alfisols of Konkan region. The field experiment was conducted during *Kharif 2020* at research farm of Central Experiment Station, Wakawali, Dr.Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri. The experiment comprised of different levels of nitrogen (80,100,120 kg ha^{-1}), phosphorous (40, 60, 80 kg ha^{-1}), a constant dose of potassium (100 kg ha^{-1}) alone and in combination with different levels of farm yard manure (10, 15, 20 t ha^{-1}), was laid out in thirteen treatment combinations consisting one absolute control which was replicated thrice in randomized block design.The nutrient content of yam bean leaves and yam bean tubers were observed to be highest in treatments receiving higher dose of nitrogen, phosphorus and FYM as compared to sole application of inorganic sources and absolute control. The highest NPK content of tuber recorded was 0.61 per cent, 0.24 per cent and 0.24 per cent, respectively. The quality parameters such as reducing, non-reducing sugar, starch, ascorbic acid, crude fibre, protein, and moisture were significantly improved due to various treatments receiving combined application of inorganic fertilizers and organic manures over control treatment. The total yam bean tuber yield (23.02 t ha^{-1}) recorded was significantly highest under treatment consisting 120:80:100 N, P_2O_5, K_2O kg ha^{-1} + 20 t FYM ha^{-1}. The study further concluded that integrated nutrient application significantly improves quality as well as quantity of yam bean in lateritic soils of Konkan region of Maharashtra.

Key words: Alfisols, inorganic-organic manures, nutrient content, quality parameters, Yam bean

PS 2/29

Effect of Zeolite on Potassium Use Efficiency of Maize Crop Grown in an Inceptisol

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An experiment entitled "Effect of zeolite on potassium use efficiency of maize crop grown in an Inceptisol" was undertaken during summer 2022, at Department of Soil Science and Agricultural Chemistry, M.P.K.V., Rahuri, with an objective to access the effect of zeolite on nutrient use efficiency of potassium. The experiment was laid out in a randomized block design with three replication and ten treatments comprised of T_1- Absolute control, T_2 - GRDF (120:60:40 N, P_2O_5, K_2O kg ha^{-1} + FYM 10 t ha^{-1}), T_3- Zeolite @400 kgha^{-1}, T_4 - Zeolite @600 kgha^{-1}, T_5 - Zeolite @ 400 kg ha^{-1} + 50% K_2O of RDF (20 kg ha^{-1} K_2O), T_6 - Zeolite @ 400 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O), T_7 - Zeolite @ 400 kg ha^{-1} + 100% K_2O of RDF (40 kg ha^{-1} K_2O), T_8 - Zeolite @600 kgha^{-1}+50%K_2O of RDF(20 kg$ha^{-1}$$K_2O$), T_9 -Zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kgha^{-1} K_2O), T_{10} -Zeolite @ 600 kgha^{-1}+100% K_2O of RDF(40 kg$ha^{-1}$$K_2O$). From the findings it was observed that the significantly highest uptake of N, P, K (213.30, 23.16 and 140.24 kg ha^{-1}) and micronutrients viz., Fe, Mn, Zn and Cu (2548.83, 1210.53, 913.27 and 141.87 mg kg^{-1}) was in treatment T_{10}over rest of treatments exceptT_9which was at par with T_{10} in respect to nitrogen and phosphorus uptake but in case of potassium uptake treatment T_7 is found to be at par with treatment T_{10}. The potassium use efficiency was significantly influenced by the application of different levels of zeolite and potassium after harvest of maize. The highest potassium use efficiency (92.50%) was observed in treatment T_{10}i.e., Zeolite @ 600 kg ha^{-1}+100% K_2O of RDF(40 kg ha^{-1} K_2O)over rest of the treatments except T_9 i.e., Zeolite @ 600 kg ha^{-1} + 75% K_2O of RDF (30 kg ha^{-1} K_2O)with potassium use efficiency (91.66%) was statistically at par with treatment T10.The experiment concluded that the application of Zeolite @ 600 kg ha^{-1} + 100% K_2O of RDF significantly enhanced nutrient uptake, particularly potassium, in maize crops, leading to the highest potassium use efficiency of 92.50%, emphasizing the potential of zeolite in improving nutrient management strategies.

Key words: Zeolite, potassium use efficiency, maize crop, nutrient uptake, Inceptisol

PS 2/30

Nutrient Management in Sustainable Vegetable Production

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Vegetable crops are known for their high nutrient demand, prompting increased fertilizer application to enhance productivity. Farmers often apply higher quantities of mineral fertilizers and frequent irrigation to stimulate crop growth and achieve higher yields. However, in India, fertilizer application is primarily confined to nitrogen (N), phosphorus (P), and potassium (K) fertilizers, with the bias towards N followed by P and K, leading to an unbalanced fertilizer application. Additionally, these essential nutrients are typically applied at the time of planting or sowing without considering the specific crop nutrient demands. Furthermore, the continuous addition of mineral fertilizers alone over the years has led to a decline in soil organic carbon and soil fertility status, and resulted in multi-nutrient deficiencies that contributed to reduced yields in various vegetable crops. Excessive and untimely application of nitrogen has reduced shelf life, while an excess of phosphorus has led to the buildup of phosphorus in soils, a common issue in vegetable cultivation areas.Application of organic manure or naturally occurring sources enhances soil health, but does not directly improve productivity due to the relatively low major nutrient content. However, organic manures provide sufficient micronutrients essential for crops. In addition, the release of nutrients from organic manures often does not synchronize with crop nutrient demand.Therefore, integrating both organic and inorganic sources of plant nutrients becomes crucial for sustainable production while preserving the natural resource base essential for long-term sustainability. The assessment of nutrient demands during crop growth stages of many vegetable crops reveals that about 10-15% of the total NPKS uptake occurs during the initial 30 days of plant growth. Peak nutrient uptake commences at 15 days after planting or sowing, reaches its maximum uptake during the peak vegetative growth stage. The total NPKS uptake during the vegetative growth stage accounts for about 75-85% of the total NPKS uptake. At the maturity stage, the crop only extracts 5-10% from the soil.Despite this, farmers often apply a substantial quantity of fertilizers during sowing or transplanting, which might not match the crop's requirements. To optimize efficiency and yield, it's crucial to time fertilizer applications to synchronize with the nutrient demands of the crop. Applying NPKS fertilizers through drip systems according to crop requirements, coupled with the application of necessary organic manures, has shown a 25-30% increase in crop yield compared to traditional methods.Drip fertigation not only enhances yield but also improves nutrient use efficiency, water productivity, and the benefit-cost ratio compared to the broadcast method of fertilizer application. Microbial inoculation further improves nutrient uptake and crop yields. Although progress has been made, there is potential to increase nutrient use efficiency and yields in vegetable crops. Precision agriculture, employing soil moisture and NPK sensors, along with early detection of nutrient deficiencies through unmanned aerial vehicles (Drones) during the initial crop growth stage, could contribute in improving nutrient use efficiency and crop yield. Furthermore, developing cultivars with higher N, P, and K use efficiency is imperative. Research initiatives addressing these aspects are currently underway at ICAR-Directorate of Onion and Garlic Research in Pune, with a specific focus on onion and garlic. By employing onion and garlic cultivars with improved nutrient use efficiency and adopting precision irrigation and fertilizer application technologies, higher nutrient use efficiency and yields can be achieved.

Key words: Organic farming, chemical fertilizers, integrated nutrient management, Micronutrient, Fertigation

PS 2/31

Effect of Silicon and Nitrogen Levels on Nutrient status of soil and Nutrient uptake by Sorghum (*Sorghum bicolor* L. Moench)

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The field experiment was conducted on effect of silicon and nitrogen levels on soil nutrient dynamics, yield and quality of sorghum (*Sorghum bicolor* L. Moench) Under Inceptisol during *Rabi* 2019-20 at Research Farm of College of Agriculture, Latur. The experiment was laid out in FRBD with two factors *viz.*, four levels of Silicon (S_0- control, $S_{0.25}$- silicon @0.25 % foliar spray, $S_{0.5}$- silicon @0.5 % foliar spray and $S_{1.0}$- silicon @1 % foliar spray) and four levels of nitrogen (N_0- control, N_{40}- N @40 kg ha^{-1}, N_{80}- N @80 kg ha^{-1} and N_{120}- N @120 kg ha^{-1}) with three replications and SPV-2407 (Parbhani super moti) as test crop. The results of field study indicated that the nutrient uptake by sorghum was significantly influenced by silicon and nitrogen application. The available N, P_2O_5 and K_2O in soil were not significantly influenced due to combined application of silicon and nitrogen but the uptake of nutrients *viz.*, N, P and K by crop were significantly increased due to foliar application of silicon @1 % in combination with soil application of nitrogen @120 kg ha^{-1} over rest of the treatments. Thus, it can be concluded that the combined application of silicon and nitrogen was found to be superior in increasing nutrient uptake by sorghum over separate application of silicon and nitrogen.

Key words: Silicon, nitrogen, uptake, nutrient and sorghum

PS 2/32

Effect of sewage water disseminated on micronutrients in soil and fodder for Sustainable Agriculture

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The study pertaining to Effect of sewage water disseminated on micronutrients in soil and fodder for Sustainable Agriculture near Cattle cross breeding project, VNMKV, Parbhani. The soil samples were collected from area surrounding to Pingal gad nala in *Kharif* and *Rabi* season 20 samples in each season. Fodder (Marvel grass, Lucerne grass and Berseem grass) samples were collected from respective area 20 marvel grass samples in *Kharif* and 20 samples of Lucerne and Berseem in *Rabi* (10 samples of each grass) respectively. The positive effect of sewage on DTPA extractable iron, copper and manganese were observed as compared normal water and recorded higher values in *Rabi* season as compared to *Kharif* season. DTPA extractable zinc found deficient in all samples. DTPA extractable heavy metals of survey area viz. lead (Pb), nickel (Ni) and cobalt (Co) had shown significance of sewage water in Rabi season as compared to Kharif season.

Key words: Sewage water impact, micronutrient levels, sustainable agriculture, cattle crossbreeding, VNMKV Parbhani

PS 2/33

Influence of Organic Inputs with Bio-enhancer on Nutrient Availability, Humic Substances and Yield of Wheat in Vertisol

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Field investigation was conducted during r*abi* season during 2019-20 to 2022-2023 at College of Agriculture, Nagpur with the objective to study the soil phosphorus availability at physiological growth stages of wheat (*Triticum aestivum* L.) as influenced by management practices of integrated nutrient. Before sowing of wheat, in-situ burying of sunhemp 30 DAS along-with the addition of Ghanjivamrut (combination of FYM and jivamruit) @ 5 t ha^{-1} and apply seed treatment of Azophos means Azotobacter + PSB @ 25 g kg^{-1} each of seed. Jivamruit was prepared with cow dung 10 kg + cow urine 10 lit.+ Jaggary 2 kg + gram flour 2 kg and half kg organic rich soil with 100 lit water and diluted 10 lit of jivamrut with 100 lit water and applied @ 500 lit ha^{-1}. Soils was slightly alkaline in soil reaction 7.55 with medium in organic carbon, low in available N P and high in K.Pooled result revealed that, significantly influence the grain yield of wheat 28.93 q ha^{-1} with the incorporation of sunhemp green manuring (GM) +Ghanajivamrut 5 t ha^{-1}+ 50% RD of NP through inorganic fertilizers+2 foliar spray of jivamrut @ 500 lit ha^{-1} (1:10 ratio) at tillering and jointing stage and also resulted slowly released of phosphorus and maintained the amount of soil available phosphorus at latter stage of crop due to solubility of phosphorus and better functioning of microbial activity due to secretion of organic acids and ultimately slightly enhanced the amount of P in soil and reduced 50 per cent inorganic fertilizers of NP and 100 per cent K. Maintain the available phosphorus in soil at tillering stage (19.01 kg ha^{-1}) and flowering (20.88 kg ha^{-1}). Humic acid, fulvic acid and humin per cent in soil after harvest of wheat was obtained from 1.25 to 2.25, 3.50 to 4.75 and 93.25 to 95.00 % with mean value 1.67, 4.07 and 94.26 %, respectively with the application of various organic sources, bio-fertilizers and green manure. On the basis of three-year data result concluded that yield of wheat was enhanced due to increase in nutrient availability as the humic substances increases with the combination of in-situ burying of sunhemp 30 DAS along-with the addition of Ghanjivamrut before sowing of wheat + seed treatment of Azophos + 50% RD of NP through inorganic fertilizers + 2 foliar sprays of jivamrut at tillering and jointing stage.

Key words: Wheat growth stages, integrated nutrient management, green manuring, soil phosphorus availability, organic farming practices

PS 2/34

Evaluation of Manurial doses on Cotton + pigeon pea and soybean + pigeon pea intercropping system in rotation under rainfed condition

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A long-term experiment on evaluation of permanent manurial doses on cotton + pigeon pea and soybean + pigeon pea intercropping system in rotation under rainfed condition was conducted on fixed site on experimental field of All India Coordinated Research Project on Dryland Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The various nutrient levels of recommended dose of fertilizer and combination of RDF and FYM were evaluated for both the intercropping systems. The long-term data revealed that Soybean + pigeon pea intercropping system recorded higher yield than cotton + pigeon pea intercropping system. The intercropping system of soybean + pigeon pea recorded significantly higher cotton equivalent yield (1540 kg/ha). The Nutrient level of FYM 5 t/ha + RDF 75 per cent (N3) recorded significantly higher cotton equivalent yield (1750 kg/ha) than rest of the nutrient levels. Whereas the intercropping system of Soybean + pigeon pea with the nutrient level of FYM 5 t/ha + 75 per cent RDF recorded significantly higher cotton equivalent yield (1460 kg/ha). The gross monetary return and net monetary return under soybean+ pigeon pea intercropping system were found to be Rs. 68073/ha and Rs. 45140/ha respectively. The BC ratio (2.71) was found higher under soybean + pigeon pea intercropping system with higher RWUE of 3.16. Under nutrient levels, the treatment of FYM 5 t/ha+ 75% RDF (cotton) and FYM 5 t/ha + 75 % RDF (soybean) recorded higher equivalent yield of 1750 kg/ha with GMR and NMR of Rs. 76715 and Rs. 47422 /ha. The higher BC ratio of 2.50 and RWUE of 3.52 was also recorded under this treatment.

Key words: Intercropping systems, permanent manurial doses, rainfed agriculture, nutrient management, economic returns

PS 2/35

Effect of Liquid Organic Manures on Yield of Green Gram-Aerobic Rice-Onion and Bio-Chemical Prosperities of Soil

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The field experiment carried out by department of Soil Science and Agricultural Chemistry, N. M. College of Agriculture, Navsari, Navsari Agricultural University Navsari, Gujarat, during the year of 2020-2021 and 2021-2022 (Summer, *Kharif* and *Rabi* seasons). The field experiment was conducted on green gram, aerobic rice and onion using the RBD with 17 treatments and four replications. The treatments were as follows: T1: T16+0 day conditioned jivamrut @ 500 l/ha, T2: T16+7 days conditioned jivamrut @ 500 l/ha, T3: T16+14 days conditioned jivamrut @ 500 l/ha, T4: T16+21 days conditioned jivamrut @ 500 l/ha, T5: T16+28 days conditioned jivamrut @ 500 l/ha, T6: T16+0 day conditioned amritpani @ 500 l/ha, T7: T16+7days conditioned amritpani @ 500 l/ha, T8: T16+14 days conditioned amritpani 500 l/ha, T9: T16+21 days conditioned amritpani @ 500 l/ha, T10: T16+28 days conditioned amritpani @ 500 l/ha, T11: T16+0 day conditioned panchgavya @ 50 l/ha, T12: T16+7 days conditioned panchgavya @ 50 l/ha, T13: T16+14 days conditioned panchgavya @ 50 l/ha, T14: T16+21days conditioned panchgavya @ 50 l/ha, T15: T16+28 days conditioned panchgavya @ 50 l/ha, T16: NADEP compost @ 1 t/ha for green gram and @ 3 t /ha for rice and onion and T17: Absolute control. The effect of different treatment of liquid organic manures on yield of green gram was non-significant but its effect on aerobic rice grain and onion bulb yield was significant. The treatments were remained at par with majority of the organic treatments including sole application of NADEP compost but recorded higher yield as compared to control. More or less similar trend of treatment effect was observed on green gram equivalent yield and biological yield of green gram, rice and onion. The Soil pH, EC, available N, P_2O_5, K_2O, S, Fe, Mn, Zn and Cu after harvest of green gram, rice and onion were manurial treatments remained at par with each other but recorded higher value than control. Similarly, population of bacteria, fungi and actinomycetes and PGPR (*Azotobacter*, *Rhizobium*, P and K-solubilizing microbes) recorded after harvest of green gram, rice and onion, population were increased by addition of liquid organic manures along with NADEP compost. Higher total microbial population and PGPR population was observed in treatment of NADEP compost + panchgavya.

Key words: Liquid organic manures, aerobic rice, green gram, NADEP compost, soil microbial population

PS 2/36

Characterization and Valorization of Indian Glauconitic Shale as Slow-Release K Fertilizer

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The glauconite beneficiation techniques so far reported are not cost-effective. Therefore, to find out an alternative way for the utilization of glauconite as K fertilizer is an important area of the study to reduce import dependency. Considering this,the detailed characterization of glauconite and K release studies were performed to understand the release kinetics and Ksupplying capacity by using physical, chemical, and biological approaches in contrasting soils. The strata wise (1‑5) analysis of glauconite showed that total K_2Oranged from 7.1 to 12.6%. The total elemental composition of glauconite showed that it was rich in Si, Al, Fe, Ca, and Mg. The X-ray diffraction (XRD) analysis and scanning electron microscope (SEM) images showed that glauconite falls under highly evolved stage of evolution. The results of study showed that no single technique was effective in enhancing K release from glauconite. However, the integrated approach of the calcined glauconite (CG), farmyard manure (FYM), and microbial inoculation (MI) showed significantly highest improvement in NH_4OAc-K by average3.50 and 1.48-fold and water soluble-K (WS-K) by 5.13 and 2.22-fold over glauconite in Alfisol and Vertisol, respectively. Similarly, the integration of glauconite, FYM, and MI was also found effective in enhancing K status of both the soils. Therelease of K from glauconite was more pronounced in Alfisol than Vertisol. Release kinetics proved that K release from glauconite was diffusion control phenomenon. The study confirmed that the integration of CG, FYM, and MI was the best technique for agricultural utilization of glauconite as K fertilizer for crop production.

Key words: Glauconite, K-fertilizer, FYM, microbial inoculation

PS 2/37

Optimizing Sulphur and Boron Fertilizers for Enhancing Sesame Yield and Oil Content

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The mesonutrient sulfur (S) plays a crucial role in the nutrition of sesame, serving as a vital element necessary for synthesizing S-containing amino acids such as cysteine, cystine, and methionine. This contribution is pivotal in forming the polypeptide chain in proteins. Similarly, the micronutrient boron (B) is essential for enhancing pollen tube growth, pollen germination, and increasing pollen grain viability in sesame. Despite the importance of these nutrients, the management of S and B combinations remains limited. Consequently, a field experiment employing a randomized block design was conducted to evaluate the impact of S as a soil application and foliar spray of B combinations on the yield and oil content of the Gujarat Til-3 variety of sesame (*Sesamum indicum* L.) in sandy loam soil. The experiment involved three levels of S as basal doses (10, 20, 30 kg/ha) and three levels of B (1000, 1250, 1500 mg/L) applied as a foliar spray at 25 days after sowing. The recommended dose of fertilizers (RDF) served as the control treatment, and the experiment was replicated three times. The results revealed significant improvements in yield attributing characters, including capsules per plant, seeds per capsule, test weight, seed yield, and oil content, showing increments of 14%, 19%, 7%, 11%, and 5%, respectively. Additionally, the application of 30 kg/ha of S and B at 1500 mg/L led to a reduction of 3 days in the time to 50% flowering compared to the control. The synergistic effect of S and B was evident in enhancing both yield parameters and oil content. The study suggests that the application of S enhances protein synthesis, resulting in increased production of photosynthates, ultimately leading to the formation of oblong capsules and bold seeds. Adequate S supply also contributes to enhanced glutathione production, a compound pivotal in oil synthesis. Furthermore, the application of B promotes tissue differentiation from somatic to reproductive activity, initiating floral primordia and improving flower production, ultimately resulting in increased seed setting. The positive correlation observed between capsules per plant, seeds per capsule, and test weight highlights the role of B in augmenting seed yield. In conclusion, the combined application of S at 30 kg/ha and B at 1500 mg/L demonstrates significant potential to improve seed yield and oil content in sesame.

Key words: Basal sulphur, foliar boron, oil content, sesame, yield

PS 2/38

Effect of Irrigation Regimes and Hydrogel on Yield and Yield Attributes of Upland Paddy (*Oryza sativa)*

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The irrigation management in upland paddy is a big challenge. To address this issue, a field experiment was conducted on clay loam soils at Agricultural Research Station, Banswara during *kharif* season *2022*. The experiment consisted of 12 treatment combinations having three irrigation regimes (0.8, 1.0 and 1.2 IW/CPE) in main plots and four hydrogel levels (control, 10, 15 and 20 kg ha^{-1}) in sub plots evaluated under Split Plot Design (SPD) with three replications. The variety tested under this experiment was *Mahi Sugandha*. The impact of irrigation regimes and application of hydrogel on paddy yield was found significant. The maximum plant height, number of tillers per clump, paddy yield, straw yield and biological yield was found under irrigation regime I_3 (1.2 IW/CPE) followed by I_2 (1.0 IW/CPE). Further, the above yield attributes and yield parameters were found statistically at par under I_3 (1.2 IW/CPE) and I_2 (1.0 IW/CPE) irrigation regimes except plant height. The higher water use efficiency was recorded under lower levels of irrigation. Among the different hydrogel doses, H_{20}(20 kg hydrogel per hectare) demonstrated the higher plant height, number of tillers per clump, paddy yield, straw yield and biological yield but these parameters remained statistically at par with H_{15} level of hydrogel except number of tillers. The soil parameters were remained non-significant with irrigations regimes but the hydrogel application reduced the soil pH and increased soil moisture and organic carbon content significantly.

Key words: Irrigation regimes, hydrogel, yield, upland paddy

PS 2/39

Soil Based Sustainable Planning for Major Crops in Dhanpatganj Block: A Case Study from Middle Indo-Gangetic Plains

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Dhanpatganj block (Sultanpur district, Uttar Pradesh) is a part of Middle Indo-Gangetic Plains. MIGP is bestowed with favourable climate, soil and water resources but characterized by low crop productivity, profitability and livelihood security. The challenge of increasing crop productivity and farm income requires sustainable utilization of natural resources especially soil and water resources. Sustainable utilization of soil resource requires cultivation of crops and adoption technology based productive potential, suitability domain and location specific constraints. Therefore, comprehensive land resource (on 1:10, 000 scale) database of Dhanpatganj block has been interpreted for soil potential, constraints and evaluated for soil site suitability for selected crops (rice, wheat, maize, pearl millet, sugarcane, mustard and Pigeonpea). Soils of the block classified into Inceptisols and Entisols, and mapped into 11 soil series and 19 soil phases. Block classified into 4 land capability classes with maximum area covered by land capability class IIIes (37.4%). Soil site suitability for crops indicates that about 23.3%, 19.8% 8.9% and 8.9%, area is highly suitable for mustard, pearl millet, wheat and maize, respectively. Moderately suitable area is 32.9%, 51.8%, 51.8%, 40.9%, 60.6%, 60.4% and 40% for rice, wheat, maize, pearlmillet, sugarcane, pigeon pea and mustard, respectively. Among major crops, about 48.1%, 32.4%, 32.4%, 20.5% and 11% area is marginally suitable for rice, wheat, pigeon pea, sugarcane and mustard respectively. Soil pH, poor fertility, poor drainage, sodicity, soil erosion and $CaCO_3$ concretions/layer limits the successful crop production and needs to be taken into consideration for soil centric sustainable planning for crop selection and diversification.

Key words: Soil resources; middle Indo-Gangetic plains; land use planning, sustainable planning

PS 2/40

Nutrient Status and Nutrient Index values in Dharni Tehsil of Melghat Region

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A detailed soil survey was carried out in a t tribal area in Dharni tehsil of Melghat region during the year 2017-2019 to study the nutrient status and nutrient index of different land use systems. The study covered the tribal area of Melghat region to identify different landform units and soil heterogeneity as well as the present land use. Twenty-four (24) representative soil profiles were selected as per soil survey manual (Soil Survey Division Staff, 2000) for sampling and analyzed for pH, electrical conductivity, organic carbon, available nitrogen, phosphorous and potassium and available micronutrient viz. Zn, Mn, Fe and Cu by using standard methods. The soils were neutral to moderately alkaline in nature (pH 7.81) and free from soluble salt hazards (EC 0.24 dSm^{-1}). Soils were medium in organic carbon (0.70 %). Nutritionally, soils in this high rainfall region showed lower content of available N (273.7 kgha^{-1}) and available P (19.82kgha^{-1}) and higher in available K (459.4kgha^{-1}), however, medium to higher in available micronutrient status viz. Fe (5.66 mg kg^{-1}, Mn (7.57 mg kg^{-1}), Zn (0.69 mg kg^{-1}) and Cu (1.56 mg kg^{-1}). Nutrient index values showed that available N (1.18) and available P (0.89) were in low category, OC (2.02), $CaCO_3$ (1.77), available Zn (1.35) and Fe (1.43) were moderately high, available Mn (2.31) was in a higher category, however, available K (2.77) and Cu (2.85) were very high. Thus, the study highlights the need for location-specific nutrient indexes for proper land use planning and sustainable management of natural resources.

Key words: Nutrient indexing, available nutrients status, Melghat region

PS 2/41

Effect of Phosphorus Rich Organic Manure on Growth and Yield of Wheat in Calcareous Soil

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Effect of phosphorus rich organic manure (PROM) on growth and yield of Wheat in calcareous soil was studied by producing PROM and conducting field experiment at Division of Soil Science, College of Agriculture, Pune during June 2022 to April 2023. In the first phase composition of PROM was assessed by using three levels of rock phosphate @ 100, 200 and 300 kg mixed in each ton of partially decomposed rain tree litter compost. The twelve treatments in field experiment was consisted absolute control; GRDF (120:60:40 kg ha^{-1} N P_2O_5 and K_2O + 10 t ha^{-1} FYM) ; 100% P_2O_5 : DAP ; 75% P_2O_5: DAP; 100% P_2O_5: RTLC; 75% P_2O_5 : RTLC; 100% P_2O_5 through PROM : 100 kg rock phosphate; 100% P_2O_5 :PROM : 200 kg rock phosphate; 100% P_2O_5 :PROM : 300 kg rock phosphate; 75% P_2O_5 :PROM : 100 kg rock phosphate; 75% P_2O_5 :PROM : 200 kg rock phosphate; 75% P_2O_5 :PROM : 300 kg rock phosphate; replicated thrice in Randomized Block Design in calcareous soil for wheat. The object of this experiment was to assess the composition of PROM as influenced by rock phosphate and tree litter compost. Another objective of this field experiment was to study the effect of phosphorus application through PROM and DAP on growth and yield of in calcareous soil. The content of nitrogen and potassium in PROM were reported increasing trend with addition of 100, 200 and 300 kg rock phosphate mixed in per ton of rain tree litter compost. Blending of 100, 200 and 300 kg rock phosphate in one ton of each partially decomposed compost of rain tree litter reported increasing trend for P_2O_5 @ 261.54, 446.15 and 643.07% in the PROM prepared in 100 days respectively. Data of field experiment revealed that application of either 75 or 100% P_2O_5 through PROM prepared by using 300 kg rock phosphate with one ton of partially decomposed compost of rain tree litter reported significantly higher fresh root weight, plant height, chlorophyll content in wheat at 50% flowering which was found to be statistically at par with the application of either 75 or 100% P_2O_5 through PROM prepared by using 200 kg rock phosphate. Incorporation of P_2O_5 @ 100% through PROM either prepared by using 300 or 200 kg rock phosphate along with PSB and partially decomposed compost of rain tree litter recorded significantly higher and statistically at par results for grain (47.15 and 46.31 q ha^{-1}) and straw (67.89 and 66.64 q ha^{-1}) yield of wheat in calcareous soil.

Key words: PROM, raintree litter, rock phosphate, wheat, calcareous soils.

PS 2/42

Effect of Fertigation Levels on Leaf Nutrient Content and Fertility Status of Soil after Harvest of Nagpur Mandarin in High Density Planting

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The present investigation in relation to "Effect of fertigation levels on leaf nutrient content and fertility status of soil after harvest of Nagpur mandarin in high density planting" The field experiment was carried out in Hatla village on farmers field, Taluka Katol, District Nagpur on 10 years old Nagpur mandarin. There are five fertigation treatments i.e. 85, 100, 115, 130 and 145 per cent of recommended dose NPK of fertilizers. The experiment was laid out in Randomized Block Design with four replications through eighteen splits. Leaf nutrient viz. total nitrogen (2.59 %), total phosphorus (0.17%), total potassium (1.54%) and total sulphur (0.13%) observed higher in treatment fertigation with 145 % of RDF. According to result, total micronutrients such as iron (78.05 mg kg^{-1}), zinc (17.93 mg kg^{-1}), manganese (64.28 mg kg^{-1}) and copper (13.80 mg kg^{-1}) observed higher in treatment fertigation with 145% of RDF. The result revealed that, soil reaction of study area exhibited slightly acidic to slightly alkaline in nature. In all treatments, there were no much variation in electrical conductivity of soil and these soils were non-saline in nature. Soils were medium to high for organic carbon content and slightly calcareous to calcareous for calcium carbonate content. The higher available nitrogen (231.63 kg ha^{-1}), available phosphorus (18.39 kg ha^{-1}), available potassium (419.37 kg ha^{-1}) and available sulphur (13.50 mg kg^{-1}) found in treatment fertigation with 145 % of RDF. Also, result revealed that, soil micronutrients such as Fe, Zn, Mn and Cu found higher in treatment fertigation with 145% of RDF (4.67 mg kg^{-1}), (0.63 mg kg^{-1}), (9.79 mg kg^{-1}) and (1.38 mg kg^{-1}) respectively.

Key words: Nagpur mandarin, leaf and soil nutrients, fertility status

PS 2/43

Enhancing Nitrogen use Efficiency by using Nano-Urea and Urea for Maize (Fodder) in Inceptisol

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A study was undertaken to enhance the nitrogen use efficiency in maize (fodder) crop by soil application of urea and foliar sprays of nano-urea synthesized at College of Agriculture, Pune (COAP) in comparison with commercially available IFFCO nano-urea on Inceptisol during *rabi* 21-22. The nitrogen through urea was applied as 0, 50 and 75 per cent of recommended dose of nitrogen of maize (fodder) crop and this was combined with foliar application of water, COAP nano-urea with 50, 100, 150 and 200 ppm concentration, IFFCO nano-urea 160 ppm and urea with 10000 ppm (1%) at 30 and 40 days after sowing of the crop. The average size of COAP and IFFCO nano-urea was 22.419 nm and 22.773 nm. The optimum uptake of major nutrients and micronutrients was recorded higher due to combined application of 75 per cent urea and foliar application of COAP nano urea @200 ppm. The soil chemical properties *viz.* pH, electrical conductivity, organic carbon and calcium carbonate were not influenced significantly due to application of nitrogen either through soil or by foliar. The major nutrients *viz.* nitrogen (245.22 kg ha^{-1}) phosphorus (24.02 kg ha^{-1}) and potassium (589.74 kg ha^{-1}) were improved due to soil application of urea and foliar application of COAP nano urea @200 ppm. The micronutrient of the soil was improved due to soil application of nitrogen @75 per cent along with foliar application of urea @10000 ppm. The application of 75 per cent nitrogen through soil combined with foliar spray of urea @10000 ppm resulted into higher green fodder yield (846.37 g pot^{-1}) of the maize crop which was at par with foliar application of COAP nano urea @200 ppm. As regards the quality of maize crop, the crude protein (12.88 %) was recorded due to application of COAP nano-urea @200 ppm. The nutrient use efficiency (34.75 %) was higher due to the application of 75% RDN over other treatments while in foliar spray treatments, application of IFFCO nano urea @ 160 ppm recorded significantly higher nutrient use efficiency (33.42 %). Significantly higher nitrogen use efficiency (82.98 %) was observed when combination of 75 % RDN along with foliar spray of IFFCO nano urea @160ppm was applied.

Key words: Nano-urea, urea, nitrogen use efficiency, maize, soil nutrient status

PS 2/44

Influence of Organic Inputs with Bio-enhancer and Integrated Nutrient Management on Soil Properties and Yield of Nagpur Mandarin Grown on Farmers Field in Vertisol

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Field investigation was carried out on farmer's field of Katol tehsil during the year 2017 with the objective to evaluate the soil properties, quality and yield of Nagpur mandarin under practices of bio-stimulant with organic alone and integrated nutrient management.Five locations viz., Fetri, Katol local, Katol (RFRS), Wandaliwagh and Hatla were selected for considering management practices of organic verses integrated nutrient system.Dasparni extract prepared with neem leaves + nirguli + maharukh + custurd apple + wild tulasi + castor leaves + karanj leaves 2 kg each, 1 kg cow dung, 2 lit cow urine and 200 lit water. Jivamrut prepared with 10 kg cow dung+ 10 lit cow urine + 2 kg jaggary+2 kg gram flour with half kg of organic rich soil in 200 lit water. Organic liquid applied as foliar spray every month from June to January. Results revealed that soil reaction under moderately alkaline and moderately calcareous in nature. Organic carbon was observed 7.6 g kg $^{-1}$ and 6.2 g kg $^{-1}$ with orchards age eight treated with use of 20 kg FYM + 332:140:83 g NPK tree^{1} and organic inputs alone, respectively.Fertility status of soilswas maintaining with the combination of organic liquid extract+FYM and integrated nutrient source. Use of FYM@15-20 kg tree^{-1}, combination of organic source with manurial liquid found useful for maintaining the available micro-nutrient status of soil under Nagpur mandarin. However 44.3 per cent farmers field found deficient Zn status under practices of organic alone and integrated nutrient management.The data on exchangeable cations follow order of Ca^{2++}>Mg^{2++}>Na^{+}>K^{+}. CEC of soil ranging from 49.2 to 62.2 Cmol (p^{+}) kg^{-1} among the locations. Quality parameters of Nagpur mandarin viz. juice recovery %, TSS, fruit weight and ascorbic acid found maximum with the application of FYM 15-20 kg tree^{-1}coupled with balanced inorganic fertilizers. Yield of Nagpur mandarin recorded 17-20 t ha^{-1} with the practices of FYM @20 kg tree^{-1} along witheight foliar spray of manurial liquid whereas 22-0- 25.0 t ha^{-1} was obtained with the combined application of 20 kg FYM + N: P: K :Mg: S- 450:70:150:25:50 g tree^{-1}.Micronutrients played supportive role in augmenting the fruit yield of Nagpur mandarin. On the basis of results, it can be concluded that the soils of Nagpur mandarin orchards age of eight year provides sufficient amount of organic coupled with liquid inputs alone or balanced amount of integrated nutrient management on farmers field enhanced the fertility status of soil, sustaining the yield and quality of Nagpur mandarin.

Key words: Nagpur Mandarin, INM, bio-enhancer, foliar spray

PS 2/45

Effect of Tuberose Genotypes to Gibberellic Acid for Yield and Quality

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An experiment entitled, "Influence of tuberose genotypes to GA_3 for growth, flowering, yield and flower quality" carried out during July 2015-16 and July 2016-17 at Horticulture Section farm, College of Agriculture, Nagpur with the objectives to study the performance of different genotypes of tuberose and to find out the suitable genotypes and concentration of GA_3 for better growth, flowering regulation and quality flower yield of tuberose. The trial was laid out in split plot design with twenty treatment combinations replicated thrice. The treatments comprised of tuberose genotypes *viz.*, Prajwal, Shringar, NT-01, NT-06 and NT-09 and foliar application of GA_3 *viz.*, GA_3 50 ppm, GA_3 100 ppm, GA_3 150 ppm and control treatment were given at 30 and 60 days after planting. The result of the present investigation revealed that, in respect spike yield and quality parameters of tuberose such as number of spikes plant^{-1}, length and weight of spike, diameter of spike and florets spike^{-1} were found to be the maximum in tuberose genotype Prajwal and foliar application of GA_3 100 ppm. However, number of bulb and weight of bulb plant^{-1} were maximum in the same treatment combination.

Key words: Tuberose, genotypes, gibberellic acid

PS 2/46

Effect of Nano Zinc Oxide on Growth, Yield and Uptake of Major Nutrients by Wheat under Salt Affected Soils

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A pot culture study was conducted during Rabi 2022-2023 at Dept. of Soil Science and Agricultural chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experimental soil which was collected from saline tract of purnavally was saline in nature, medium in organic carbon, moderately calcareous in nature, low in available N, and medium in available P, very high in available K, marginal in available S and sufficient in micronutrients but deficient in Zn. The experiment was laid out in Completely Randomized Design with nine treatments replicated thrice. Significantly higher germination percentage (85%), number of tillers per plant (6.80), plant height (50.03 cm) was recorded under T_4: RDF + seed treatment with nano ZnO 1000 ppm @ 8 ml per kg of seed. Maximum spike length (9.29 cm) was recorded in RDF + foliar spray with of nanoZnO 1000 ppm @ 2 ml per litter. In case of chemical properties of soil i.e., pHs, ECe, organic carbon and available N, P, K, S and Zn content, the slight changes in pHs, ECe, OC, N, P and K due to application of nano ZnO were non-significant. The highest N and K content in soil were recorded due to RDF + seed treatment with nano ZnO 1000 ppm @ 8 ml per kg of seed. The highest P content in soil was recorded due to RDF + seed treatment with nano ZnO 1000 ppm @ 8 ml per kg of seed. In respect of content and uptake of N, P, K by wheat were significantly found highest at seed treatment with RDF + seed treatment with nano ZnO 1000 ppm @ 8 ml per kg of seed which is at par with RDF + foliar spray with nano ZnO 1000 ppm @ 2 ml per liter at 30 and 45 DAS. In respect of content and uptake of Zn by wheat were significantly found highest at RDF + seed treatment with nano ZnO 1000 ppm @ 8 ml per kg of seed.

Key words: Nano zinc, salt affected soils, germination, wheat

PS 2/47

Sustaining Crop Productivity with Water and Nutrient Management Strategies Under Changing Climate Scenario

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Continuous intensive agriculture without adequate attention on rational soil management poses serious threat to the sustainability of agro-ecosystems. One of the consequences of irrational soil management under intensive cropping is the decline in soil fertility and low productivity. Low crop productivity associated with high production costs is a great concern in agriculture. Additional stresses come from climate disruption, variability and change, resulting in impacts on water availability and temperature regimes over time and space.This paper describes about the Best Management Practices (BMPs) available over time and space. To assess climate change related impacts on crop suitability and agro-ecologically attainable yield, the study applied the Agro Ecological Zonation (AEZ) methodology, which is jointly developed by Food and Agriculture Organization (FAO)and the International Institute for Applied Systems Analysis (IIASA). Range of scenarios for crop productivity for years 2041–2070 (2050s) and 2071–2100 (2080s) using the climatic condition based on four RCPs (2.6, 4.5, 6.0, and 8.5) as well as new Shared Socioeconomic Pathway (SSP) adopted by the Intergovernmental Panel on Climate Change (IPCC) were generated using AEZ simulation modeling based the datasets as well as satellite products. Major crops grown in Kerala are coconut, arecanut, rubber, black pepper, coffee, tea, cardamom, paddy, tapioca, cashew andvegetables. The AEZ analysis for these crops showed that for ensemble mean of RCM outputs, under rain-fed conditions, yields of banana, arecanut, rubber, coffee, and black pepper show declines between 2.89 and 74.18 %. In the case of coconut and rice, it showed very minor increases of 3.17 and 0.99 % respectively. Under irrigated conditions, yields of coconut, arecanut, coffee, and black pepper show a decline between 3.83 and 86.18 %. However, if we look at all the models and different RCPs and SSPs, results show that with few exceptions in most of the cases yields tend to decline with climate change for future scenarios. Drip fertigation was chosen as one of the BMPs and it was demonstrated across Kerala. Results from the project showed that the application of nutrients through drip fertigation improved the crop yield of all the demonstration plots and the increase in yield over control. Investments in climate smart agriculture, micro-irrigation practices especially drip fertigation, improved water conservation practices, development and management of natural resources through watershed and afforestation activities, conservation of crop biodiversity, etc. needs to be given focus to improve the production from farms. Besides, strategies need to be adopted for improving the water and nutrient use efficiency were also discussed.

Key words: Intensive agriculture, soil fertility, climate change impacts, agro ecological zonation, drip fertigation

PS 2/48

Effect of Micronutrients on Yield and Quality of Groundnut (*Arachis Hypogaea* L.) in Calcareous Soil

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An experiment entitled, "Yield and quality of groundnut (*Arachis hypogaea* L.) as influenced by application of micronutrients in calcareous soil" was conducted during summer, 2022 at PG Research Farm, RCSM, College of Agriculture, Kolhapur with an objective to study the effect of micronutrient fertilizers on growth, nutrient uptake and yield parameters of summer groundnut. The experiment was laid out in randomized block design with three replications and ten treatments in calcareous soil (11.55 % $CaCO_3$). The soil application of 20 kg $FeSO_4.7H_2O$ + 15 kg $ZnSO_4.7H_2O$ + 5 kg Borax ha^{-1} along with GRDF had recorded the highest values of all growth and yield contributing characters like plant height (34.40 cm), number of pods (35.82), test weight (52.33), shelling percentage (72.97) as compared to all other treatments. The same treatment was found to be significantly superior for dry pod yield (36.54 q ha^{-1}), haulm yield (44.83 q ha^{-1}) and protein content (27.70 %).

Key words: Foliar spray, micronutrients, groundnut, yield and quality, calcareous soil

PS 2/49

Effect of Integrated Phosphorus Management on Yield and Quality of Mustard (*Brassica juncea* L.) and Residual Soil Fertility

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Field experiments were conducted for two consecutive years during *rabi* 2016-17 and 2017-18 at Rajasthan College of Agriculture, Udaipur (Rajasthan) to study the effect of integrated phosphorus management on yield and quality of mustard and residual soil fertility. The experiment was laid out in split plot design with four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}), two levels of FYM (0 and 5 t ha^{-1}) and four levels of microbial inoculum (no inoculum, PSB, VAM and PSB + VAM). Seed, straw and oil yield of mustard was significantly enhanced up to 40 kg P_2O_5 ha^{-1}, 5 t FYM ha^{-1} and PSB + VAM inoculation over respective control treatments. Significantly higher available N, P and K content in soil after harvest of mustard was reported with application of 40 kg P_2O_5 ha^{-1}, 5 t FYM ha^{-1} and PSB + VAM inoculation over control. Integrated application of 40 kg P_2O_5 ha^{-1} + 5 t FYM ha^{-1} reported significantly higher seed yield, straw yield, oil yield and available P after harvest of mustard. Application of 5 t FYM ha^{-1} along with dual inoculation of PSB + VAM reported significantly higher available P after harvest of mustard.

Key words: Mustard, phosphorus, FYM, PSB, VAM, biofertilizer

PS 2/50

The Need of Natural Farming in Context with Soil and Human Health

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The Green Revolution (GR) undoubtedly, contributed to reduce widespread poverty, averted hunger for millions of people, and saved thousands of hectares of land to be converted into agricultural cultivation to feed the corresponding increase in the world's population in the 20th century. But the post-GR, unintended increase in utilization of inputs especially fertilizers, pesticides and number of irrigations posed the negative consequences on long term and contamination of these inputs moved away from the target plants, resulting in not only soil environmental damage but simultaneously serious impact on human health issues, directly and indirectly through toxins to enter the food chain via vegetables, cereals and water. Excessive use instead on the basis of soil health card reports, has hardened the soil, reduced fertility, strengthened the use of insecticides, polluted air and water, and emitted greenhouse gases, creating health and environmental risks and destructed the soil biodiversity. Soil, water, and air pollution, as well as damage to non-target creatures such as plants, birds, mammals, fish, and crops, are the main environmental problems associated with pesticides. Thus, it linked to a variety of human health problems via producing harmful compounds called free radicals which are usually destroyed by our body's natural antioxidant system. In addition, climate change has also impacted on enhanced usage of pesticides. In the areas surveyed for land resource inventories, farmers were interviewed and it was found that fertilizers and pesticides are being recommended by the input-dealers without the scientific interventions. As a result, the farming community rarely adoption rate of integrated nutrient and pest management is very slow. The recommendations as per soil health card and proceed to apply full dose. About Almost 40 per cent of agricultural GHG emissions and contaminants in fertilizers might have adverse impacts on the soil quality and health through toxic trace elements found in fertilizers (include mercury, cadmium, arsenic and lead). About 40% of the world's agricultural land is severely diminished in quality because of erosion and the use of chemical fertilizers, which prevent land from regenerating. The decline in soil quality as a result of agricultural chemical fertilizers also further leads to water and land pollution thereby lowering the land's worth on earth. In this context, the need of natural and organic farming emerged as the better concepts involving the betterment of nature, protecting the soil-cover and its tilth, well supported by farm-biodiversity, integration and symbiotic farm components. It is environmentally sustainable food production systems as generally observed in tribal areas. During the survey in Hingoli district near watershed area, farmers reported the above constraints and few of the farmers started adopting the natural farming by using beejamrit for seed treatment as well as jivamrit for nutrition management and prepared dashparni ark, brahmastra, neemastra and agniastra for controlling sucking pests. These practices are being demonstrated amongst farming community. But in true sense it is a farming where least possible damage to soil-ecosystem is observed. Natural farming provides benefits to the surrounding environment but organic impacts the environmental ecosystems.

Key words: Natural farming, fertilizers, pesticide, soil health

PS 2/51

Diversification of Land Use in Cotton Growing Areas of Marathwada Region

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In the last few decades, increasing agricultural production and ensuring food security was the major concern for agricultural development to feed the increasing population in India. The period 1990 witnessed the emergence of agrarian distress of low level of absolute income and deteriorating disparity between income of a farmer and non-agricultural worker, which turned even more serious in recent years. Later, the conceptual goal of setting double farmers' income by 2022-23 might play a crucial role in promoting farmers welfare, reduce agrarian distress and bring parity between income of farmers and non-agricultural work force. The government emphasised the improvement in productivity, resource use efficiency of reducing cost of production, intensifying cropping pattern, diversification towards high value crops etc. For optimal and sustainable land use, the task of development is now more complex with fewer opportunities to enhance area under irrigation. Under such situation, the need for crop diversification becomes a major step towards sustainability in today's scenario. Now attentions are required to be implemented towards intensification and diversification by matching land use more closely with land qualities emphasizing soil-site suitability analysis that helps in choosing crops to be taken up matching to the location specific soil units for optimizing crop productivity. During the survey carried out for land resource inventory in Hingoli, Marathwada region indicated that the region accounts for nearly 75 per cent for small (32.56%) and marginal (43.85%) farming community. Hingoli district is a hot and dry Deccan plateau with black cotton. In this district in the year 2021-22, cotton was the major crop and being practiced as sole or / cotton-pigeon pea in addition to chickpea and turmeric. At present, the area under cotton has declined significantly due to high cost of cultivation, non-availability of labour, cumbersome spraying for pests, season-long crop, less irrigation facilities but ease in cultivating other crops like sorghum, safflower, and turmeric. It was reported by the farmer that Rs. 70,000/- (approx.) is needed to cultivate one hectare of cotton. The resource poor small and marginal farmers do not have sufficient investment capacity. Persistent low level of farmers' income can cause serious adverse effect on the future of agriculture in the country. Hence, they prefer crops with less investment with ease of cultivation. This combined with the above three reasons makes the farmers to prefer other crops which are comparatively easy to cultivate. It was recorded that the cotton crop has been replaced due to above reasons and on the other hand, area under turmeric, safflower and rabi sorghum has increased due to their minimum support price to the tune of Rs. 3180/- (2023-24) for sorghum Hybrid and Rs. 3225/- for Maldandi with the increase of 12.90 and 14.48 per cent as compared to 2021-22. Crops such as safflower, chickpea and turmeric have significant suitability to the soils of Hingoli and factors such as cost of cultivation and minimum support price played a important role in diversifying the crops in the region. To secure the future of agricultural resource poor farming community, adequate attention needs to be given for raising the agricultural income. There is a need to identify crops and varieties that may suit as per soil site suitability to a range of environments and farmers' preferences. Crop diversification provides better conditions for food security and enables farmers to grow surplus and to gain access the markets and increase the profitability.

Key words: Crop diversification, cotton, sorghum, soil suitability

PS 2/52

Identification of Efficient Cropping Zones for Suitable Crops in Marathwada Region

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In Marathwada region, the productivity level of crops has to be enhanced and sustained and this is possible only when efficient locations have been identified for the crops. A methodological study was made to identify the potential districts for cultivation of cotton, soybean, pigeon pea, wheat, chickpea and sorghum in Marathwada region covering eight districts namely Parbhani, Jalna, Hingoli, Beed, Latur, Osmanabad, Aurangabad and Nanded. The data on area, and productivity of study crops for 2021-22 were collected and indices such as Relative Spread Index (RSI) and Relative Yield Index (RYI) were computed to identify the potential cropping districts for the above crops. In Marathwada region, Hingoli, Beed, Jalna, Osamanabad and Aurangabad districts are the most efficient cropping zone (MECZ) for all the study crops beside few districts are required to expand the area. In soybean, wheat and chickpea, all the districts of the region are although potential and efficient but are required to expand the area under crop with few scientific interventions. During the survey, it was recorded that farmers have adopted other crops like sorghum looking to the minimum support price (MSP). In case of pigeon pea, all the districts are most efficient beside few districts are growing on hills and escarpments to make better utilization of available lands with farming community as the small and marginal farming communities are inhabited nearby hilly and escarpments parts of the districts. Where RYI and RSI have most efficient cropping zone (MECZ), the reasons accredited for superior RSI and RYI values in identified districts might be the irrigation facilities, prevailing favorable conditions and marketing facility which are highly pronounced in the districts identified. This information helps to replace the uneconomical crop in the identified areas and provides an opportunity to utilize the available natural resources to the maximum extent possible without any degradation. The uneconomical crops, if any, will be replaced by the crops with good potential to achieve the sustainability and self-sufficiency. Recently, the area under cotton crop is declining significantly due to higher cost of cultivation, crop diversification, livelihood requirement and high labour cost. In addition, efficient cropping zones (ECZ) are required to expand area under these crops. For MECZ and ECZ, good agricultural practices as per the crops may be introduced for higher productivity. The best management practices to enhance crop productivity low yielding areas of Marathwada region.

Key words: Relative yield index, relative spread index, Marathwada region, potential areas

PS 2/53

Dynamics of Crop Residue Compost Characteristics during Various Decomposition Intervals

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The study was conducted for the preparation and chemical characterization of enriched compost at the Research Farm of the Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during 2018-19. The experiment was laid out in Completely Randomized Design with six treatments replicated four times. The treatments comprised wheat straw, shredded cotton stalks, Gliricidia leaves and sorghum stubbles along with rock phosphate, elemental sulphur, urea, as well as PDKV decomposer and cow dung slurry were mixed with different proportion to study the Chemical and biological changes during decomposition of crop residues. The compost samples were collected treatment wise at 15, 30, 60, 90 and 120 days of decomposition, respectively, and analyzed for properties. The moisture content of compost was maintained at 60 to 70%. The pH was decreased as the decomposition progressed. The significantly highest pH was recorded at 15 days decomposition stage in (T2), 100% Shredded cotton stalk. Whereas, least was recorded at final stage of decomposition in (T6), 25% Wheat straw +25 % Shredded cotton stalk +25% Gliricidia Leaf + 25 % sorghum stubbles. The total organic carbon was decreased with time decomposition. The higher value was recorded for (T1), 100 % wheat straw at 15 days stage. Lowest organic carbon content was noted in T6 at the end of composting. The total N was increased as decomposition period increased. The total N was observed lowest in T2 as compared to other treatments throughout decomposition period. However, significantly highest total N was recorded in T6 followed by in T5, 30% WS + 30% SCS + 20% Gliricidia Leaves + 20% Sorghum Stubbles. It is clearly evident that C:N ratio was continuously declined with increase in period of composting in all treatment. Finally, the compost recorded the lowest C:N ratio from T6 followed by T5 while, the highest C:N ratio was recorded in T2. Among the crop residues used for preparation of compost the combination of crop residues in equal proportion i.e. 25% wheat straw + 25% shredded cotton stalks + 25% Gliricidia leaves + 25% sorghum stubbles were found beneficial for increasing microbial biomass carbon.

Key words: Wheat straw, shredded cotton stalk, *Gliricidia* leaf, sorghum stubbles, rock phosphate, elemental sulphur

PS 2/54

Assessment and Control of Mycoflora in Pigeon Pea: Implications for Yield Enhancement

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Pigeon pea production is amenable for many biotic and abiotic constraints. Among biotic constraints leaf blight disease caused by Alternaria alternata is one of the yield limiting factors in pigeon pea. Losses upto 20-80 percent in yield due to Alternaria blight were recorded in pigeon pea. Therefore, it is highly imperative to develop an effective management strategy for enhancing the yield potential of the pigeon pea. Therefore, an experiment was conducted to study the soilborne and seedborne mycoflora associated with 5 different varieties of pigeon pea. The seed samples were taken from BDN-711, BDN-716, phule-12, PDKV-TARA and ICP-8863 varieties. Single row of each variety was cultivated in the field plot of Dr. PDKV, Akola, also the seedborne mycoflora were detected by using ISTA techniques viz. Standard blotter paper method and Agar plate method. Various mycoflora were detected from field and invitro method, predominantly found mycoflora were Alternaria alternata, Fusarium moniliforme, Asperegillus niger, Curvularia lunata and Cladosporium cladosporioides. The highest yield loss causing mycoflora in pigeon pea is Alternaria alternata (causing leaf blight) and Fusarium sp. (causing wilt) where isolated using invitro poisoned food techniques. Different fungicides (carboxin 37.5% + thiram 37.5% 75WP @ 0.25%, tebuconazole 25% WG @0.2%, carbendazim 50%WP@ 0.1%, carbendazim 12% + mancozeb 63% 75WP @0.25%) where used to control the isolated mycoflora. The most effective fungicide for Alternaria alternata is carboxin 37.5%+thiram 37.5% 75WP followed by Tebuconazole 25%WG and for Fusarium sp. is Carbendazim 50%WP followed by Tebuconazole 25%WG among selected fungicides in pigeon pea crop.

Key words: Pigeon pea, mycoflora, standard blotter paper method, agar plate method, fungicides

PS 2/55

Influence of Water-Soluble Fertilizer and Humic Acid on Yield and Quality of Rose Under Protected Conditions

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A field investigation entitled "Effect of water-soluble fertilizer and humic acid on rose under protected conditions." was carried out at College of Agriculture, Nagpur (MS.), Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Akola. Dist. Akola during rabi season in year 2021-2022. The experiment was laid out in Factorial Randomized Block Design with four levels of 19:19:19 water soluble fertilizer [Control, 200 g 19:19:19, 300 g 19:19:19 and 400 g 19:19:19] and three levels of humic acid [Control, 500 ppm humic acid, 750 ppm humic acid] with twelve treatment combinations replicated thrice. The result of the present investigation revealed that, highest flowers yield plant-1 and flowers plot-1 were found significantly maximum with the treatment combination 300 gm 19:19:19 water soluble fertilizer with 750 ppm humic acid. In respect of quality parameters like diameter of flower stalk, length of flower stalk at bud initiation, diameter of bud, length of bud, diameter of flower, length of stalk after opening of flower, number of petals flower-1, longevity and vase life were found significantly maximum were recorded in the application of 400 g 19:19:19 water soluble fertilizer with 750 ppm humic acid. The interaction effect of 19:19:19 water soluble fertilizer and humic acid were found non-significant on quality parameters like diameter of bud, length of stalk after opening of flower, number of petals flower-1.

Key word: Rose, water soluble fertilizer, protected condition

Theme 3

Soil ecosystem services, conservation and management

SESSA
2024

PS 3/1

Sustaining Productivity of Soybean- Safflower Cropping System by Long Term Fertilization through Carbon Biomass Management under Vertisol

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A field experiment was conducted during the kharif season of 2018-2019 at the research farm of the Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The objective was to investigate the long-term fertilization carbon biomass management in Vertisol. The soybean-safflower cropping sequence experiment comprised twelve treatments, including different levels of NPK, zinc sulfate at 25 kg ha-1, hand weeding, sole N application, NP application, and organic manure application at rates of 5 t ha-1 and 10 t ha-1. The experimental design followed a completely randomized block layout, with four replications. Results revealed that the highest grain and straw yields were obtained with 100% NPK + FYM at 5 t ha-1 in soybean (20.62, 27.81 Kg ha-1) and safflower (17.84, 43.87 Kg ha-1), followed by 150% NPK (19.34, 27.00 and 17.24, 43.20 Kg ha-1) for soybean and safflower, respectively. The maximum organic carbon content was observed with only FYM at 10 t ha-1 (6.87 g kg-1), while the lowest organic carbon content was recorded in the absolute control (5.55 g kg-1). In terms of above and below biomass carbon, carbon input and output ratio, and carbon credit, the soybean-safflower cropping sequence exhibited significantly higher values in the 100% NPK + FYM at 5 t ha-1 treatment, followed by 150% NPK. These findings emphasize the potential of integrated nutrient management for enhancing productivity and carbon sequestration in Vertisols under soybean-safflower cropping systems.

Key words: Grain yield, carbon biomass, carbon credits, soybean-safflower

PS 3/2

Vertical Distribution and Influencing Factors of Deep Soil Organic Carbon Stocks in a Tropical Humid Region, India

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A comprehensive understanding of organic carbon distribution throughout the entire soil profile, beyond the conventionally studied upper 1 m layer, is essential for a holistic assessment of soil health. This study estimates soil organic carbon stocks in 12 master pedons from both upland and lowland areas of the Elamdesam block in the tropical humid region of India. Pedotransfer functions were employed to determine bulk density. Surface clay percentage varied from 11.37% to 63.52%, while subsurface clay percentage ranged from 8.95% to 44.51%. Bulk density increased with depth, ranging from 1.17 to 1.42 Mg m-3 in the surface to 1.17 to 1.63 Mg m-3 in the subsurface. Organic carbon content ranged from 11.90 to 33.90 g kg-1 in the surface to 3.60 to 32.30 g kg-1 in the subsurface. Soil organic carbon stock (SOCS) exhibited variations, ranging from 1.86 to 6.0 kg m-2 in the surface and 1.36 to 6.16 kg m-2 in the subsurface. SOCS positively correlated with clay (r=0.137) and organic matter (r=0.646) but negatively correlated with bulk density (r= -0.657). However, organic matter negatively correlated with bulk density (r= -0.973). Among the 12 pedons studied, 8 recorded SOCS between 3-6 kg m-2, indicating low land quality, while the remaining 4 exhibited very low land quality. SOCS decreased with depth in deep soil profiles, whereas subsurface values were higher than surface values in shallow soil profiles.Very low land quality was associated with low organic carbon status due to factors such as high erosion, steep slope, and light soil texture. In contrast, low land quality was attributed to dense rubber cultivation and the practice of leaving leaf litter and biomass in situ, promoting decomposition with reduced erosion. This underscores the significant influence of soil properties on the formation and transformation of SOCS along the soil profile, with strong variations observed with soil depth. SOCS is influenced by vegetation cover, management practices, fertilizer application, and soil type.

Key words: Soil carbon stock, vertical distribution, landform, soil depth, land quality

PS 3/3

Economic Valuation of Soil Carbon Stock in Different Agro-Climatic Zones of Karnataka, India

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Soil carbon assessment is crucial for evaluating land productivity and formulating effective land-use policies. This study focuses on quantifying soil organic carbon (SOC) stocks and assessing their economic value for carbon sequestration in Karnataka's croplands using 200 soil profile datasets from the Sujala-III project. The replacement cost method was employed for economic valuation, considering current market prices in India. Replacement costs for SOC and soil inorganic carbon (SIC) were determined at 0-30 cm, 30-100 cm, and 100 cm depth intervals. The cost for 10,000 kg C was ₹120,182 (approximately ₹12,000 t–1) or ₹3,270 CO2 t–1 (1 gram of carbon releases 3.67 grams of CO2). SOC stock estimates at 0-30 cm depth were 13.3 t ha-1 (low organic carbon), 23.1 t ha-1 (medium), 30.5 t ha-1 (high), and 40.5 t ha-1 (very high).Zonal-wise values for the total quantity and economic value of SOC stock (0-30 cm) per hectare revealed the highest values in the Northern Dry Zone (1.19 tg, ₹1,425,593 million), followed by the Central Dry Zone (0.48 tg, ₹581,327 million), North Eastern Dry Zone (0.42 tg, ₹498,747 million), Eastern Dry Zone (0.41 tg, ₹495,315 million), Southern Dry Zone (0.36 tg, ₹431,357 million), North Eastern Transition Zone (0.25 tg, ₹300,339 million), and Northern Transition Zone (0.23 tg, ₹275,517 million).The returns per rupee of investment were higher in areas with high SOC stock compared to those with low to medium SOC stock. To achieve the government's goal of doubling farmer income, policies should focus on increasing soil organic carbon stock and promoting best land management practices. Subsidies for organic fertilizers, farmer training on compost manure preparation from farm waste, incentives for retailers selling organic fertilizers, and promoting integrated nutrient management approaches for agro-ecological farming are recommended government interventions.

Key words: Soil carbon assessment, soil organic carbon stocks, economic valuation, carbon sequestration, land-use policies

PS 3/4

Impact of Soil and Water conservation practices on Vegetable Productivity in Selected Clusters in Nagpur District

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Land degradation and water scarcity are the major challenges in Nagpur district that adversely affect the soil fertility and crop productivity. Farmers mainly doing rainfed agriculture in kharif season. To increase the soil fertility, crop productivity and employment generation through off season vegetable cultivation with micro irrigation system (MIS) with implementation of need-based soil and water conservation practices, the present study has been carried out in Kalmeshwar, Parseoni, Savner and Umrer talukas with the target of 160 farmers. Data were collected and compared farmer's conventional practices with NBSS&LUP recommended package of practices. Compared yield and economic performance of vegetables in different soil depths. Suggested management practices to the farmers are vegetable cultivation, preferably in sandy loam soils for good yields and good returns. At the time of soil preparation, application of organic matters, compost and farm yard manures in soils. Planting of seeds in a proper depth (1 to 2 inches) and ensuring proper drainage and moisture availability in soil. The results of the study showed that the percentage change in NBSS recommended vegetable cultivation practices under drip irrigation system in shallow depth (12 to 16 inches) soils gave 43% higher yield of spinach, 36% higher yield of fenugreek, 28% higher yield of cluster bean, 27% higher yield of coriander leaves, 19% higher yield of amaranth, 16% higher yield of okra, 10% higher yield of chilli and cowpea over the farmer's conventional practices. The study further revealed that the net returns realized by the farmers were 111% higher in spinach, 83% higher in fenugreek, 60% higher in coriander leaves, 56% higher in cluster bean, 41% higher in amaranth, 33% higher in okra, 23% higher in chilli and 21% higher in cowpea cultivation in shallow depth soils with MIS system over the farmer's conventional practices. The BC ratio increased by 44% higher in spinach, 36% higher in fenugreek, 27% higher in coriander leaves and cluster bean, 19% higher in amaranth, 16% higher in okra, 11% higher in cowpea and 10% higher in chilli in shallow depth soils with MIS system over the farmer's conventional practices. The average water use efficiency increased by 54% in all crops. Additional employment of 70 to 80 days has been generated in summer due to huge demand of vegetables in summer season with cultivation of vegetables with micro irrigation structures. Thus, the implementation of need-based soil and water conservation practices, combined with off-season vegetable cultivation using a micro-irrigation system, significantly improved yield, economic performance, and water use efficiency in shallow-depth soils in Nagpur district, emphasizing the potential for sustainable agricultural practices and enhanced livelihoods.

Key words: Conservation, economics, production, soil, vegetable, water

PS 3/5

Economics of Soil and Water Conservation Practices Used for Field Crops Cultivation in Selected Clusters of Nagpur District

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Loss of productive soils and rain water is the major concern in farmer's fields due to lack of proper management of these scarce resources. The present study conducted in Kalmeshwar, Parseoni, Savner and Umrer talukas of Nagpur district with the target of 160 farmers.Economics of demonstrated kharif (cotton, pigeon pea, sorghum) and rabi (wheat, chickpea) field crops has been compared with the farmer's traditional practices in different soils such as shallow black and deep to medium deep black soils under rain-fed and irrigated conditions in three treatments, T1 : Farmer's traditional practice under shallow black soils in rainfed conditions, T2 : Demonstrated crops under deep to medium deep black soils in rain fed conditions and T3 : Demonstrated crops under deep to medium deep black soils using micro irrigation system (MIS). To increase the resource use efficiency with implementation of need-based soil and water conservation practices, data collected on inputs used, land and water used, returns on investment etc. has been collected and compared economics in abovementioned three treatments. Results of the study showed that the impact of improved soil and water management practices gave higher yields and net returns in treatment 2 and 3 as compared to farmer's traditional practice under shallow black soils in rainfed conditions (T-1). The cost of cultivation in cotton increased by 16 and 18 % in T-2 and T-3 respectively. The yield of cotton increased by 48 and 60 % in T-2 and T-3 respectively as compared to farmer's traditional practices. The net return increased by 96% in T-2 and almost double in T-3 with BC ratio increased by 22% to 40% in T-2 and T-3 respectively. The cost of cultivation in pigeonpea increased by 22 and 25% in T-2 and T-3 respectively. The yield of pigeonpea increased by 39 and 45 % in T-2 and T-3 respectively as compared to farmer's traditional practices. The net return increased by 52% in T-2 and 65% in T-3 with BC ratio increased by 16% to 19% in T-2 and T-3 respectively. The cost of cultivation in sorghum increased by 18 % in T-2 and yield of sorghum increased by 25% in T-2 as compared to farmer's traditional practices. The sorghum net return increased by 38% in T-2 with BC ratio increased by 16%. The cost of cultivation in chickpea increased by 15 and 16 % in T-2 and T-3 respectively. The yield of chickpea increased by 30 and 50 % in T-2 and T-3 respectively as compared to farmer's traditional practices. The net return increased by 58% in T-2 and 96% in T-3 with BC ratio increased by 10% to 30% in T-2 and T-3 respectively. The cost of cultivation in wheat increased by 05 and 10 % in T-2 and T-3 respectively. The yield of wheat increased by 30 and 75 % in T-2 and T-3 respectively as compared to farmer's traditional practices. The net return increased by 70% in T-2 and 75% in T-3 with BC ratio increased by 50% to 68% in T-2 and T-3 respectively. The overall impact on resources use efficiency showed that the cultivated area i9ncreased by 2%, the average yields of all crops increased by 35%, net returns increased by 55%, employment in agricultural activities increased by 2% and water use efficiency increased by 6% in study area. The improved need-based soil and water management practices created positive impact in study area over the farmer's traditional practices.

Key words: Conservation, economics, production, soil, traditional, water

PS 3/6

Alleviation of Soil Moisture Deficit Stress in Banana (*Musa sp.*)

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Water stress poses a significant challenge to banana growth and development, impacting productivity. This field experiment, conducted at the Banana Research Station in Jalgaon from 2017 to 2021, aimed to mitigate the adverse effects of soil moisture deficit stress in banana through biochemical priming at critical phenological stages. The experiment followed a Randomized Block Design (RBD) with five treatments and four replications, including irrigated control, soil moisture stress at the floral primordial initiation stage (5 MAP), foliar priming with acetyl salicylic acid (0.1mM) at the floral primordial initiation stage + soil moisture stress, and foliar priming with acetyl salicylic acid (0.1mM) at flowering + soil moisture stress. Foliar priming occurred two days before imposing soil moisture stress, targeting a soil moisture level at field capacity. The acetyl salicylic acid-primed plants exhibited higher relative water content compared to non-primed plants. At harvest, finger length and girth decreased by 17.02% and 21.14%, respectively. Bunch weight decreased in all soil moisture-stressed plants compared to the control, with the lowest recorded in soil moisture stress at the floral primordial initiation stage (5 MAP), resulting in a yield decrease of 47.54%. Among the stressed treatments, acetyl salicylic acid-primed plants showed higher yields compared to non-primed plants.

Key words: Banana, soil moisture stress, biochemical priming, acetyl salicylic acid, phenological stages

PS 3/7

Microbial, Enzymatic Properties and Nutrient Availability of Soil as Influence by Consortia of Inoculants

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Microbial consortia play a vital role in soil management and nutrient mobilization. Microbial consortia are importance for solubilize the Macro and micro nutrient for plant and improved the plant growth and soil health and important in disease prevention and management stress tolerance. The present experiment was conducted to application of different microbial consortia through rhizomes treatment of Turmeric. Field experiment was undertaken at vegetable Research center, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhaani during *Kharif* season 2022.Ten different treatment combinations were used in the experiment which includes different microbial consortia *Azotophos* inoculation (Consortia-I), *Azotobacter* + KSB inoculation (Consortia-II), *Azotobacter*+ SSB (Consortia-III), *Azotobacter*+ ZnSB (Consortia-IV),*Azotophos*+ KSB (Consortia-V), *Azotophos*+ SSB (Consortia-VI), *Azotophos*+ ZnSB (Consortia-VII). Rhizomes treatment of turmeric was done with microbial consortia @1000 ml in 100 liter of water for one acre and application at the time of sowing with recommended dose of fertilizers. Microbial population count higher in all treatment of microbial consortia. Significantly higher microbial count of bacteria, fungi and actinomycetes in *Azotophos* + SSB (Consortia-VI and *Azotophos* inoculation (Consortia-I). Significantly higher enzymatic activity is higher in treatment of microbial consortia. Significantly higher Dehydrogenase activity, Acid phosphatase activity and alkaline phosphatase activity at tillering stage, flowring stage and after harvest in *Azotophos* + KSB (Consortia-V) and*Azotophos* + ZnSB (Consortia-VII). Microbial consortia are importance for mobilization of nutrients. Essential nutrient higher in all treatment of microbial consortia. Available Nitrogen, Phosphorus, Potassium, Fe, Cu, Mn, Zn and Organic Carbon are significantly higher in *Azotophos* + KSB (Consortia-V), *Azotophos* + SSB (Consortia-VI), *Azotophos* + ZnSB (Consortia-VII).

Key words: Microbial consortia, rhizomes treatment, turmeric, soil health, nutrient mobilization

PS 3/8

Assessment of Carbon Sequestration under Different Agroforestry Tree Species

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The study in relation to Assessment of carbon sequestration under different agro-forestry tree species was conducted during 2020-21. The different agro-forestry plantation was selected, the soil samples were taken from 0-15 cm (surface) and 15-30cm (sub-surface) depth from plantation of Maharukh (Ailanthus excels), Babhul (Federbia albida), Teak (Tectona grandis), Karanj (Millettia pinnata), Amla (Phyllanthus emblica L.), Sisoo (Dalbergia Sisoo L.) and one sample was taken from adjacent fallow land (control) for the comparison of the study from the Agroforestry farm and was analyzed for different physico-chemical properties, carbon fractions and carbon sequestration. The bulk density of soils varied from 1.27 to 1.45 Mg m-3 in surface soil and 1.36 to 1.49 Mg m-3 in sub-surface soil. Hydraulic conductivity of the soil ranges between 0.91 to 1.34 cm hr-1 (surface) and 0.69 to 1.21 cm hr-1 in (sub-surface). The soil pH was varied from 7.23 to 7.75 (surface) and 7.36 to 7.82 (sub-surface). Soil organic carbon highest in Millettia pinnata plantation and was found lowest in fallow land. It ranges from 4.83 to 11.93 g kg-1 (surface) and 3.85 to 10.15 g kg-1(sub-surface). The free CaCO3 content of all these soils was found moderately high to high calcareous in nature. The available N content ranges from 209.09 to 425.83 kgha-1 (surface) and 165.22 to 397.03 kg ha-1 (sub-surface), low to medium in available Pas it ranges from 12.11 to 19.80 kg ha-1 (surface) and 10.57 to 18.65 kg ha-1(sub-surface) and high to very high in available K as it ranges between 286.12 to 350.18 kg ha-1 (surface) and 260.06 to 334.84 kg ha-1(sub-surface).The Readily oxidizable carbon (ROC), Cold water extractable carbon (CWOC), Hot water extractable carbon (HWOC), and Acid hydrolysable carbon (AHC)SOC fractions were highest in Millettia pinnata plantation and was found lowest in fallow land. The ROC ranges between 115.90 to 193.50 mg kg-1 (surface) and 114.55 to 191.48 mg kg-1 (sub-surface), CWOC ranges between 28.24 to 52.38 mg kg-1 (surface) and 27.19 to 51.31 mg kg-1(sub-surface), HWOC ranges between 47.52 to 63.28 mg kg-1 (surface) and 46.23 to 62.34mg kg-1 (sub-surface) and AHC ranges between 1509 to 3728 mg kg-1 (surface) and1203 to 3172 mg kg-1 (sub-surface).The carbon stock in the soil ranges between 11.76to 23.49 Mg ha-1 (surface) and10.19 to 21.62 mg ha-1 (sub-surface), the soil carbon stock was highest in Millettia pinnata plantation amongst all plantations and was found lowest in fallow land.

Key words: Carbon sequestration, agro-forestry tree species, physico-chemical properties, carbon stock, etc.

PS 3/9

Quantification Heavy Metals in Waste Water Irrigated Soil and their Bioaccumulation in Different Vegetable Species

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The presence of heavy metals (HMs) in agricultural soil has drawn attention from the environmental world due to their abundance, persistence, and harmful effects on living organisms. The present study was conducted to assess the level of HM contamination in the agricultural waste water irrigated soils of peri-urban areas of Amravati district, Maharashtra. The evaluation was done using different indices including the geo-accumulation index (Igeo), pollution index (PI), pollution load index (PLI), enrichment factor (EF) and potential ecological risk index (PERI). With this, bioaccumulation of HMs in vegetables also analysed. In this study, five specific locations were selected along the Amba Nala drainage channel, where sewage effluent is used for crop irrigation (Spinach, Cabbage, Brinjal, and Fenugreek), as contaminated sites. Additionally, three areas that are irrigated with tube-well water (TW) were chosen as control sites. All the soil, water and vegetables samples from contaminated sites showed significantly high concentration of heavy metals as compared to control sites. On an average, pH was decreased due to long-term sewage irrigation, while EC and organic carbon content were increased. As per EF index Cu, Cr and Co showed slight enrichment in soil and PLI showed deterioration of soil quality in the study area. Igeo index values represents no or less metal accumulation in soil and PERI represents slight ecolological risk. The levels of HMs in vegetable samples were found in the Fe > Mn > Cu > Zn > Cr > Ni > Cd order. All the heavy metals were observed below permissible range with the exception of Mn, Cr, and Cd. Bio-Concentration Factor (BCF) values shows higher uptake of Fe, Ni in Spinach and Fe in Fenugreek. Therefore, it is concluded that a prolonged application of contaminated water would probably lead to an increase in the metal accumulation in soil and vegetables, which might be harmful to living things.

Key words: Heavy metals, agricultural soil, contamination indices, bioaccumulation, ecological risk

PS 3/10

Effect of Organic Sources of Nutrients on Organic Carbon Pools and Productivity of Rainfed Cotton in Vertisols

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This research, titled "Effect of organic sources of nutrients on organic carbon pools and productivity of rainfed cotton in Vertisols," was conducted during the kharif season of 2021-22 at the Research field of AICRP for Dryland Agriculture, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. The experimental site featured Vertisol with a moderately alkaline reaction, low available nitrogen, medium available phosphorus, and high available potassium.The study employed a randomized block design with nine treatments replicated three times, including 100% RDF (60:30:30 NPK kg ha-1), FYM 12 t ha-1, *Gliricidia* 8 t ha-1, vermicompost 3.0 t ha-1, 50% N through FYM/vermicompost + 50% N through *Gliricidia* /vermicompost, and 25% N through FYM/*Gliricidia* + 25% N through vermicompost + 50% N through *Gliricidia*.The results revealed that significantly higher cotton yield was achieved with 100% RDF, and it was comparable to most of the integrated organic treatments. Moreover, the integrated application of 50% N through FYM/vermicompost + 50% N through *Gliricidia* demonstrated improvements in soil fertility and soil organic carbon pools. Consequently, the study concludes that the integrated application of 50% N through FYM/vermicompost + 50% N through *Gliricidia* not only enhances soil fertility and organic carbon pools but also increases the yield of cotton in Vertisols under rainfed conditions.

Key words: Organic sources of nutrients, organic carbon pools, Vertisols, *Gliricidia*

PS 3/11

C and N Mineralization and Soil Enzyme Activities under Different Cropping Systems in Inceptisol

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Studies of biological activities in soils are important as they indicate the potential of soil to support biochemical processes which are essential for the maintenance of soil fertility. Cropping systems, including crop diversification, crop rotation and intercropping, impact soil health and quality from various spatial and temporal aspects. The present study therefore, designed to assess the effects of different cropping systems on mineralization pattern and enzyme activities.A field experiment was conducted at AICRP on Integrated Farming system, Mahatma Phule Krishi Vidyapeeth, Rahuriand laid out in randomized block design with three replication and ten cropping systems as treatments.The different cropping systems includes viz., T_1: Soybean-Onion, T_2: Soybean-Wheat, T_3: Groundnut-Chickpea, T_4- Soybean-Chickpea, T_5: Maize + Green Gram-Groundnut, T_6: Pearl millet- Chickpea, T_7: Cowpea (F)-Rabi Sorghum (F), T_8: Cotton-Onion, T_9: Maize (F)- Berseem (F) andT_{10}:Pigeon pea-Okra. The soil samples were collected at start, at harvest of *kharif* crops and at the end of cropping systems and analyzed for physical, chemical and biological properties of soil.At the end of cropping systems, significantly highest C mineralization (20.87µg C g^{-1} soil d^{-1}) and soil microbial biomass carbon (203.48 µg C g^{-1} soil) were recorded under treatment T_4- Soybean-Chickpea followed by treatment T_2- Soybean-Wheat. While, at the end of cropping systems, significantly highest N mineralization (5.37 µg N g^{-1} soil d^{-1}) and soil microbial biomass nitrogen (28.60 µg N g^{-1} soil) were recorded under treatment T_4- Soybean-Chickpea followed by treatment T_3- Groundnut-Chickpea. The fungal, actinomycetes and bacterial populations were significantly increased from start to end of the all cropping systems. However, at the end ofcropping systems, significantly maximum fungal (34 cfu × 10^4 g^{-1} soil), bacterial (55 cfu × 10^7 g^{-1} soil) and actinomycetes population (43 cfu × 10^6 g^{-1} soil) were recorded with treatment T_4- Soybean-Chickpea followed by treatmentT_2- Soybean-Wheat. Significantly, maximum dehydrogenase (55.39 µg TPF g^{-1} soil 24 hr^{-1}), alkaline phosphatase (55.39 µg PNP g^{-1} soil 24 hr^{-1}) and urease enzyme (55.39 mg NH_4-N g^{-1} soil 24 hr^{-1}) activities were noted under treatment T_4- Soybean-Chickpea and were gradually increased up to the end of all cropping systems. From the results, it is concluded that significantly, maximum carbon mineralization was recorded with Soybean-Chickpea followed by Soybean-Wheat cropping. While, the highest nitrogen mineralization was observed under Soybean-Chickpea followed by Groundnut-Chickpea cropping system. Overall enhancement in soil biological properties might be attributed to the inclusion of cereal, pulse, legume crops in cropping systems.

Key words: Cropping systems, soil biological activities, carbon mineralization, nitrogen mineralization, enzyme activities

PS 3/12

Carbon Evolution and Characteristics of Vermicompost Prepared from Various Biomass at Different Locations

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This research, conducted at Central Campus, Mahatma Phule Krishi Vidyapeeth, Rahuri, focuses on vermicompost preparation from diverse locations encompassing research schemes, farms, and hostel premises. Various biomass materials are utilized to fill vermicompost beds at these locations, serving agricultural and horticultural purposes. The study aims to quantify CO_2 evolution from these beds and analyze changes in their characteristics during the vermicomposting process. The experiment, implemented in the year 2022-2023, employed a randomized block design with eight treatments representing different locations, each replicated three times. Sampling intervals of 15 days, specifically at 15, 30, 45, and 60 days during the vermicomposting period, were selected for CO_2 evolution and characterization analyses. Results indicate a gradual increase in carbon dioxide evolution up to 45 days, followed by a decline at 60 days. The Integrated Farming System, utilizing FYM + Goat manure + Animal feed waste, exhibited the highest CO_2 evolution (68.93 to 156.20 mg CO_2 day-1), followed by the Organic Farm location (60.60 to 145.20 mg CO_2 day-1). Approximately, CO_2 evolved from studied beds at Central Campus, MPKV, Rahuri ranged from 308.93 to 472.96 mg CO_2 day-1 during the vermicomposting period. At 60 days of vermicomposting, the Organic Farm location demonstrated the highest total N (1.54%), total P (0.89%), and total K (1.74%), paralleled by the Integrated Farming System. Maximum humic acid (3.78 g $100g^{-1}$) and fulvic acid (14.28 g $100g^{-1}$) contents were recorded in vermicompost beds at the Organic Farm location. The highest organic carbon contents (22.13%, 21.81%, and 21.34%) were found at locations Cotton Research Project, Irrigation Water Management, and Integrated Farming System, respectively. The lowest C:N ratio (13.05 and 14.27), E4/E6 ratio of humic acid (1.73 and 1.86), and fulvic acid (4.86 and 4.97) were recorded in vermicompost from Organic Farm and Integrated Farming System. At maturity, the maximum micronutrient contents (Fe, Cu, Mn, and Zn) and microbial counts were observed at the Organic Farm location, followed by the Integrated Farming System. Heavy metal (Ni, Cd, Cr, and Pb) contents in vermicompost met acceptable limits across different biomasses and locations.

Key words: Vermicompost, CO_2 evolution, biomass utilization, characterization analysis, integrated farming system

PS 3/13

Assessment of Groundwater Potential Zones using GIS and Remote Sensing Techniques: A Case Study of Sawangi Watershed of Yavatmal District, Maharashtra

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Groundwater is a crucial source of water supply due to its continuous availability, reasonable natural quality, and being easily diverted directly to the poor community more cheaply and quickly. Were studies from 2008 to 2017 in Sawangi Watershed of Yavatmal District, Maharashtra. This study uses to remote sensing data and geographic information system techniques to evaluate the groundwater potential of the study area. The parameters affecting of groundwater potential (thematic maps of LULC, soil, TWI, slope, rainfall, drainage density and geomorphology) were prepared and classified into defined raster classes. The weighted overlay analysis technique was deputed to develop groundwater potential map. "High" GWP zone (501.87 ha) is located around the drainage channels and water bodies. The "Poor" GWP zone (1216.08 ha) is located mostly in the hilly region. More than 80% (10056.66 ha) of the watershed area was observed to have a "Moderate" potential zone. From (2008 to 2017) the mean irrigated area per well was in the order of 2.21 ha in high (H) > 2.12 ha in moderate (M) > 0.36 ha in poor (P) GWP zone. The well enumeration data indicated that in the Sawangi watershed total number of wells was 728, of which 332 functional wells irrigated 696.0 ha area and 396 wells became defunct in 2017 and the average area irrigated per well was highest at 1.45 ha. While the average area irrigated per well was the lowest at 1.13 ha in 2008. The groundwater potential map could substantially help in decisions related to investment in direct recharge of abandoned open wells and is also useful for policymakers.

Key words: Groundwater potential assessment; GIS; remote sensing; weight overlay analysis

PS 3/14

Assessment and Management of Soil Degradation in the Mula Right Bank Canal Command Area using GIS and Remote Sensing

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The present investigation on “Soil Management Strategies Under Special Reference to GIS and Remote Sensing in Minor of Mula Right Bank Canal Command Area” was conducted at M.P.K.V., Rahuri during the year 2018-20. The geo-referenced 152 soil and 90 well water samples were collected from Mula right bank canal minor No.2 by using Global Positioning System (GPS). The soils were analyzed as per standard procedure for assessing physical, chemical, microbiological and saturation paste extract properties. The texture of soils of study area are clay and the soils of area were medium deep to deep. The colour of soils of area ranged from 10YR 3/3 to 10YR 5/2 (dark brown to greyish brown), while bulk density ranged from 1.21 to 1.55 Mg $^{-3}$ and porosity ranging from 41.51 to 62.64 per cent. The pH of soil varied from 7.75 to 9.34 while; EC varied from 0.10 to 3.42 dSm^{-1}. The organic carbon and calcium carbonate content in soil varied from 0.12 to 1.35 percent and 4.25 to 20 per cent, respectively. The available nitrogen, phosphorus and potassium ranged from 87.81 to 188.16, 2.32 to 39.84 and 224 to 694 kg ha^{-1} respectively. Soils of study area were very low to low in available nitrogen, low to high in available phosphorus and high to very high in available potassium. The available iron, manganese, zinc and copper varied from 2.0 to 5.98, 1.22 to 7.30, 0.24 to 1.86 and 1.09 to 4.42 mg kg^{-1} respectively. Soils of area were very low to low in available iron, moderate to moderately high in available manganese, low to moderate in available zinc and high available copper in the study area. Soil fertility status of various locations of area was delineated by the maps and supported by the soil data generated. The saturation pastes extract of soil pHs ranged between 7.25 to 8.95 indicating the slight to strongly alkaline nature. ECe of saturation paste extract ranged from 1.0 to 3.46 dSm^{-1}, which is not the desirable sign for soil fertility. Among the cations, Na was dominant followed by Ca, Mg and K. Among the anions, SO_4^{2-} was dominant followed by Cl^-, HCO_3^- and CO_3^{2-}. Soluble Sodium Percentage (SSP) of saturation paste extract of samples showed higher values. SAR, RSC and ESP ranged between 3.59 to 9.31, 0.15 to 7.85 meL^{-1} and 13.43 to 17.79, respectively. Soils of study area were classified as moderately saline alkaline soil. In general, it is concluded that the soils in the area of MRBC are getting deteriorated to a great extent and getting converted to saline sodic to sodic in nature. Therefore, there is a need to manage the soils by through subsurface drainage along with suitable land use planning.

Key words: Soil management strategies, GIS and Remote Sensing, Mula Right Bank Canal, soil fertility, saline sodic soil

PS 3/15

Water Quality Management in the Mula Right Bank Canal Command Area: Insights from GIS and Remote Sensing

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The research conducted at M.P.K.V., Rahuri, during 2018-20, focuses on water quality management in Mula Right Bank Canal Minor No.2 using GIS and Remote Sensing. Geo-referenced soil and well water samples (152 and 90, respectively) were collected with GPS, revealing alkaline well water with pH ranging from 7.15 to 8.41. The dominant cation in water was Na, with a corresponding high Soluble Sodium Percentage (SSP). SAR analysis categorized 31.11% as low sodium, 23.33% as medium saline, 17.77% as high sodium, and 27.77% as very high sodium. The average irrigation water, belonging to C3S3 suitability class, is unsuitable for all soils due to restricted drainage. Maps generated through GIS delineated the irrigation water quality status, providing valuable information for decision-making. Pedon analysis showed lower pH, EC, CaCO3, and available K content in upper soil, predominantly in the soil of the lower piedmont. Pedons developed on basaltic parent material exhibited color variance from black to dark brown. The well waters in the Mula Right Bank Canal area are deteriorating, turning saline-sodic to sodic, emphasizing the need for soil management through subsurface drainage and suitable land use planning. Judicious use of canal water is crucial for sustaining soil health. This study underscores the significance of GIS and Remote Sensing in comprehensively assessing and managing water quality in agricultural ecosystems.

Key words: Water quality management, GIS and Remote Sensing, irrigation water suitability, soluble sodium percentage (SSP), soil health and management

PS 3/16

Influence of Teak Leaf Litter Incorporation on Soil Microbiota

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Investigation into the Influence of Teak Leaf Litter Incorporation on Soil Microbial Communities: A Field Study at an Agroforestry Research Farm in Nagpur. A randomized block design with ten treatments, each replicated thrice, was implemented in the kharif season at the College of Agriculture, Nagpur. The treatments were T_1 - Absolute control, T_2 -Teak leaf litter @ 2.5 t ha^{-1}, T_3 Teak leaf litter @ 5 t ha^{-1}, T_4 - Teak leaf litter @ 7.5 t ha^{-1}, T_5 - Teak leaf litter @ 2.5 t ha^{-1}+ cow dung slurry 50% of teak leaf litter + bio decomposer, T_6 - Teak leaf litter @ 2.5 t ha^{-1} + cow dung slurry 50% of teak leaf litter, T_7 - Teak leaf litter @ 5 t ha^{-1}+ cow dung slurry 50% of teak leaf litter + bio- decomposer, T_8 - Teak leaf litter @ 5 t ha^{-1} + + cow dung slurry 50% of teak leaf litter, T_9 - Teak leaf litter @ 7.5 t ha^{-1} + cow dung slurry 50% of teak leaf litter + bio- decomposer, T_{10} - Teak leaf litter @ 7.5 t ha^{-1} + cow dung slurry 50% of teak leaf litter. The study revealed significant effects of teak leaf litter addition on the soil microbial population. Actinomycetes populations, post-crop harvest, varied between 22.36 × 10^{4}cfu g^{-1} soil and 24.94 × 10^{4}cfu g^{-1}, with the highest colonies observed in treatment T_9. The increased actinomycetes in T_9 could be attributed to the ample organic matter enhancing temperature and multiplication conditions. Bacterial counts ranged from 84.36 × 10^{6}cfu g^{-1} soil to 86.88 × 10^{6}cfu g^{-1} soil, with T_7 exhibiting the highest count, likely due to accelerated decomposition from organic matter incorporation. Fungal populations ranged from 11.49 × 10^{5}cfu g^{-1} to 15.18 × 10^{5}cfu g^{-1}, with the maximum in T_{10}. The control plot, devoid of nutrient sources, exhibited the lowest microbial communities. Overall, litter treatment significantly influenced the composition of soil microbial communities in terms of actinomycetes, bacteria, and fungi counts.

Key words: Teak leaf litter, soil, actinomycetes, bacteria, and fungi

PS 3/17

Effect of different Organic Manures on Physical, Chemical and Biological Properties of Inceptisols under Incubation Study

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A laboratory incubation experiment of 60 days was carried out at Department of Soil Science, PGI, MPKV, Rahuri, during 2020-21 to study the effect of organic manures on physico-chemical and biological properties of soil. The experiment was laid out in a complete randomized block design (CRD) with three replications and seven treatments. The treatments comprised of (T_1) soil + FYM @ 10 t ha^{-1}, (T_2) soil + Vermicompost @ 5 t ha^{-1}, (T_3) soil + Poultry manure @ 5 t ha^{-1}, (T_4) soil + Press mud compost @ 5 t ha^{-1}, (T_5) soil + Goat manure @ 5 t ha^{-1}, (T_6) soil + Urban compost @ 10 t ha^{-1} and (T_7) absolute control. The effects of organic manures on soil varied with manure type and incubation period. The application of FYM @ 10t ha^{-1}significantly improved the MWD and AWC (0.90 mm and 13.44% respectively) also recorded significantly lower pH (7.73). Significantly highest EC was recorded with the application of press mud compost @ 5 t ha^{-1} (1.22 dS m^{-1}). The application of poultry manures significantly improved soil available N (173 Kg ha^{-1}), available P (29 Kg ha^{-1}) and available K (375 Kg ha^{-1}) content. The highest OC (0.68% at 15 days of incubation) and highest Fe and Zn content (4.55 mg kg^{-1} and 0.71mg kg^{-1} respectively) was observed with application of FYM @ 10 t ha^{-1}. The Mn content was improved with the application of poultry manure @ 5 t ha^{-1} (10.32mg kg^{-1}) and application of urban compost @ 10 t ha^{-1}recorded significantly highest Cu content (0.81 mg kg^{-1}). The application of press mud compost @ 5 t ha^{-1} recorded the highest bacterial, fungi and actinomycetes population (52.52 cfu × 10^7 g^{-1} soil, 43.46 cfu × 10^4 g^{-1} soil and 39.88cfu × 10^6 g^{-1} soil, respectively). In general, physico-chemical properties of Inceptisols were improved with application of FYM @ 10 t ha-1. However, being a higher initial content of nutrients in poultry manure resulted an increment in available nutrient status of soil with 5 t ha^{-1} application, whereas significant improvement in soil biological properties was observed under press mud compost @ 5 t ha^{-1}.

Key words: Organic manures, physical, chemical and biological properties, incubation study, Inceptisols

PS 3/18

Comparative Analysis of Annual and Perennial Alley Cropping Systems on Soil Health and Yield of Organic Cotton in Vertisols

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In the pursuit of sustainable agriculture, understanding the impact of diverse farming practices on soil health and crop productivity was crucial. The study conducted a comparative analysis of Annual (AC_{an}) and Perennial (AC_{pe}) Alley Cropping Systems initiated in 2011-12 at the bioRe research farm in Dist. Khargone (M.P.), with a focus on their impact on soil fertility and yield of organic cotton in 2019-20. The treatment included perennial rows of Gliricidia and leucaena, with annual rows of pigeonpea and chillies forming an alley, and in between the rows, cotton & soybean as kharif crops in rotation followed by rabi wheat was grown. To meet nutritional needs, perennial alleys were regularly cut and incorporated, while compost @ 5 t acre^{-1} was annually applied to the annual alleys. A detailed analysis of findings was presented from On-Farm Research (POR) in India. The study revealed that the perennial (AC_{pe}) system showed higher benefit as regards to total nitrogen (0.33 to 0.35%), available nitrogen (134 to 171 kg ha^{-1}), zinc (1.39 to 1.46 ppm), and iron (8.6 to 6.76 ppm). Conversely, the annual (AC_{an}) system positively influenced soil pH (7.89 to 7.86) total phosphorus (343 to 581 ppm), available phosphorus (23.64 to 16.05 kg ha^{-1}), total potassium (11913 to 12706 ppm), available potassium (445 to 715 kg ha^{-1}), manganese (17.3 to 13.37 ppm), and copper (3.81 to 3.42 ppm) over the initial status in surface soils. After long-term experimentation under the intensive cotton-wheat cropping system, continuous addition of organic matter from both alley cropping systems led to a spontaneous increase in soil organic carbon (AC_{pe} 0.69%, AC_{an} 0.64%) over the initial SOC (0.47%) in surface soils. Intense competition within the soil food web resulted in meticulous mining of available P, Fe, Mn, and Cu. Cultivation of organic cotton/soybean in the alternate kharif season followed by rabi wheat was nutritionally stabilizing after the 4th cycle of experimentation, reflecting improved organic cotton yield performance. Ultimately, the annual system excelled in terms of organic seed cotton yield, achieving a substantial 7.75 quintals per hectare, while the perennial system yielded a comparatively modest 5.76 quintals per hectare of organic cotton.

Key words: Sustainable agriculture, alley cropping systems, soil fertility, organic cotton

PS 3/19

Water Pollution Intensity Analysis of *Mula* River in Pune on Basis of BOD, COD and Heavy Metal Concentration

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The present study entitled "Water pollution intensity analysis of *Mula* river in Pune on the basis of BOD, COD and heavy metal concentration" was conducted in 2021-2022. For the experiment,40 samples were collected along the Mula river stretch starting from origin of Mula river in Pune district of Maharashtra i.e. Mulshi Dam to Sangamwadi area where the river merges with Mutha river. The sampling point's latitude and longitude were also recorded. The collected river water samples were analysed in laboratory of Division of Soil Science and Agricultural Chemistry, College of Agriculture, Pune. Intensity of water pollution in Mula river was analysed on the basis of biological oxygen demand (BOD), Chemical oxygen demand (COD) and heavy metal concentration. From the data, it was observed that all 40 river water samples had BOD values within suitable range according to the CPCB limits. Although an increasing trend was observed in BOD values from Mulshi dam to Sangamwadi area. This might be due to increase in organic pollution by variety of sources of pollution, including the addition of wastewater through nalas and the disposal of industrial and medical waste in the stream. Similarly in case of COD, all 40 samples were within suitable range of CPCB limits but showed consistent increase in COD values which might be due to presence of untreated or partially treated sewage in river water. In case of heavy metal concentration, all 40 samples had below permissible limit concentration of nickel, cadmium and chromium. From the data, it was concluded that as the Mula River flows into more heavily populated and industrialised areas and merges with the Mutha River, the quality of the water degrades from its source of origin.

Key words: BOD, COD, CPCB, Mula, WHO.

PS 3/20

Soil Carbon Stock and Carbon Sequestration Potential under Different Crop Research Schemes VNMKV, Parbhani

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The present investigation was conducted during 2022-23. For conducting the experiment representative soil samples were collected from nine major field crops of crop research stations of VNMKV, Parbhani. These soil samples were analyzed for physico-chemical, biological properties and carbon fractions. The main objective of this study was to quantify organic and inorganic carbon content in major field crop soils. The GPS based soil samples were collected at a depth of 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm from a cotton, sugarcane, soybean, safflower, bajra, sorghum, wheat & maize, soybean –safflower cropping sequence and pigeon pea field crops of crop research stations of VNMKV, Parbhani. The results showed that soil organic carbon stock is more under sugarcane field crop soil sample followed by wheat & maize cropping pattern and soil inorganic carbon stock is more under bajra field crop soil sample followed by wheat & maize than the other field crop soils. The highest carbon sequestration potential was observed at pigeon pea followed by sugarcane, maize and wheat (0.052, -0.17, and -0.22 respectively). The highest change in SOCC was observed in the cereals cropping pattern followed by pigeon pea and the lowest change in SOCC was found in soybean cropping pattern after ten year. However also observed that the highest soil organic carbon, total organic carbon, labile carbon found in sugarcane field crop as compared to other cropping pattern may be due to addition of high amount of biomass.

Key words: organic carbon, inorganic carbon, soil carbon stocks, cropping patterns, carbon sequestration

PS 3/21

Carbon Sequestration and Soil Carbon Fraction under Different Age of Bamboo Plantation

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The research conducted during 2019-20 at the Agro-forestry farm, College of Agriculture, Nagpur, focuses on "Carbon Sequestration and Soil Carbon Fraction under Different Ages of Bamboo Plantation." The study assessed carbon stock variations in the surface (13.52 to 22.97 Mg ha^{-1}) and sub-surface (12.44 to 22.34 Mg ha^{-1}) soils across different bamboo plantation ages, ranging from 1990 to 2014. Results indicated the highest soil carbon stock in the 1990 bamboo plantation year, while fallow land exhibited the lowest. Carbon sequestration potential followed an increasing trend corresponding to the years 2014, 2008, 1997, 1994, 1992, and 1990, with the highest potential observed in the oldest bamboo plantation (1990) and the lowest in fallow land. The study underscores the positive correlation between carbon sequestration potential and the age of bamboo plantation, emphasizing higher potential in older bamboo plantations compared to fallow land. Additionally, soil organic carbon fractions, including Readily Oxidizable Carbon (ROC), Cold Water Extractable Carbon (CWOC), Hot Water Extractable Carbon (HWOC), and Acid Hydrolysable Carbon (AHC), exhibited their highest values in the 1990 bamboo plantation year, showcasing the influence of plantation age on these carbon fractions. This research provides valuable insights into the dynamic relationship between bamboo plantation age, soil carbon stock, and carbon sequestration potential, contributing to our understanding of the role of bamboo agro-forestry systems in promoting carbon sequestration and soil health.

Key words: Carbon sequestration, carbon stock, SOC fraction, organic carbon and bamboo

PS 3/22

Soil Carbon Sequestration and Dynamics under Temperate Orchards of Western Himalayas Region

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Soil degradation is prevalent on a significant scale within the Western Himalayan region, promoted by factors such as the absence of vegetation (uncultivated land), inadequate agricultural management, and anthropogenic activities. Within this region, diverse categories of temperate fruit orchards demonstrate distinct abilities to sequester soil carbon, thereby contributing to the preservation of soil health and mitigating degradation. In the current investigation, the spatial assessment of five prominent orchard plantations (apple, almond, apricot, walnut, and peach), alongside uncultivated land (control) in the region, was conducted at two soil depths (0-20 and 20-60 cm) to evaluate the influence of diverse orchard systems on soil carbon fractions, pools, and their stocks.The findings indicate that, at both soil depths, apricot and walnut soils exhibited significantly higher levels of total carbon and total organic carbon contents, as well as their respective stocks, compared to the other orchard systems, while the lowest values were observed in uncultivated land.The transformation of uncultivated land into differentorchards led to a significant increase in total carbon content by 24-44% at surface and 17-38% at subsurface depths. Conversely, the walnut and plum systems recorded the highest levels of soil inorganic carbon. The soil planted with apricots displayed the highest values of active carbon pool at surface (10.1 g kg^{-1}) and subsurface (4.9 g kg^{-1}) depth. In contrast, the passive C pools were more prominent in the walnut orchard, especially in the surface layer (5.8 g kg^{-1}). TheC sequestration rate was observed maximum in apricot (0.54 and 0.45 Mg C ha^{-1} yr^{-1}) and walnut orchard systems (0.53 and 0.43 Mg C ha^{-1} yr^{-1}) in 0-20 and 20-60 cm soil, respectively. In a nutshell, the higher C sequestration, soil carbon fractions and their stocks were noticed with the apricot and walnut system, which may be more preferable option for soil conservation of the region.

Key words: Soil degradation, Western Himalayan region, orchard plantations, soil carbon fractions, C sequestration rate

PS 3/23

Assessment of Carbon Storage and Sequestration Potential in Marathwada Region, Maharashtra, Across Various Land Uses

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The study assessed soil characteristics under various land uses, including fallow land, Glyricidia, grape, soybean, sorghum, pigeon pea, and cotton in the Marathwada region of Maharashtra, specifically in Latur, Osmanabad, and Beed districts. The highest soil organic carbon (SOC) at the surface (0-15cm) was observed under Glyricidia. Additionally, SOC showed significant positive correlations with organic carbon (OC), clay, and cation exchange capacity (CEC) (r=0.544, r=0.564, and r=0.558, respectively). Soil inorganic carbon (SIC) ranged from 1.16 to 85.06 t ha^{-1}, with the minimum under Glyricidia (4.2 to 10.86 t ha^{-1}) and the maximum under sorghum (19.44 to 85.06 t ha^{-1}). SIC also exhibited a significant positive correlation with calcium carbonate (CaCO3) content (r=0.536). Total soil carbon stock (TSCS) varied, with sorghum showing the maximum (50.04 to 61.73 t ha^{-1}) and grape the minimum (20.7 to 22.7 t ha^{-1}). TSCS correlated significantly with SOC and SIC (r=0.747 and r=0.691), indicating an increase with higher SOC and SIC. Carbon sequestration potential ranged from 0.21 to 1.8 t ha-1 year-1, with Glyricidiaexhibiting the maximum potential (1.6 to 1.8 t ha^{-1} $year^{-1}$), followed by soybean, pigeon pea, sorghum, cotton, grape, and fallow land. This indicated that Glyricidia, followed by leguminous, cereal, cash, and horticultural crops, holds the highest SOC stock and carbon sequestration potential. This also highlights the importance of implementation of effective management practices in agronomic and horticultural land uses to enhance carbon stock restoration.

Key words: Marathwada region, soil characteristics, soil organic carbon, carbon sequestration potential, land use patterns

PS 3/24

Can LRI Data be Mapped as Soil Degradation Indicator using Carbon Management Index Concept as Soil Ecosystem Services

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Soil is a reservoir of natural capital that provides several ecosystem services, ensuring human well-being and sustainable socioeconomic development. Many researchers nevertheless argue that there is no consensus on practical indicators to assess soil ecosystem services (SES).As many policy decisions rely on metrics and indicators to communicate concise and relevant information, an assessment of ecosystem service indicators can help identifying gaps hindering policy makers from more fully adopting ecosystem service approaches. Mostly complex models are used for assessing ESS which requires huge number of data set. The aim of this study was to develop a method to quantitatively evaluate six SES using a single indicator derived carbon management index (CMI). The evaluation was carried out in conservation agriculture slopping plot and found significant correlation not only with wheat equivalent yield, soil degradation parameters but also with soil quality index. First soil maps have been prepared based on data set of details soil survey following LRI method. Then, derived CMI values considering different pools of carbon on different land use, climate and mineralogy was super imposed. The map developed will help for land use planning based on ecosystem services of soils.

Key words: Soil ecosystem services, carbon management index, conservation agriculture, soil degradation, land use planning

PS 3/25

Factors Influencing Key Soil Microbial Properties under Different Land Uses in Eastern Himalayas, India: A Machine Learning Algorithm Approach

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Soil microbial biomass carbon (SMBC) and dehydrogenase activity (DHA) controlled by several factors viz., climate, terrain, edaphic and land use types (LUTs) were used as bio-indicators for prediction of soil quality (health) towards environmental monitoring. Nevertheless, comprehensive information and knowledge regarding interactions among the stated factors and their effects on SMBC and DHA are not explicit in the Eastern Himalayas, India. In such context, the present investigation is an attempt to identify the key factors influencing the soil microbial properties under different land uses using machine learning algorithm approach. Accordingly, 174 soil samples were collected from four transects covering higher to lower elevation under different LUTs (viz., forest, cinchona, and horticulture), and analysed for soil physical, chemical, and biological properties. Results revealed that significant variation ($p<0.05$) of SMBC and DHA under various LUTs in the order: forest> cinchona> horticulture. Random Forest model indicated channel distance network (CND) and soil organic carbon (SOC) as the most important predictor variables at 0□15cm depth and CND at 15□30 cm depth affecting SMBC and DHA. Structural equation model revealed LUTs to be the most determinant factor having direct influence on SMBC and DHA at 0□15 cm depth. Soil and terrain attributes equally affected SMBC whereas, soil variables influenced DHA at 15□30 cm depth. Pedotransfer functions for both SMBC and DHA were also developed for surface as well as subsurface by estimating the parameters obtained from multiple linear regression models. Furthermore, the study also delineated three elevational gradients (EGs) based modified partition entropy and fuzzy performance index and result revealed that SOC, SMBC, and DHA are significantly higher in EG1 as compared to EG2 and EG3. In conclusion, our results provide the first evidence of factors influencing on SMBC and DHA directly and indirectly in different LUTs on both surface and subsurface soil in Eastern Himalayas.

Key words: Land use types; soil microbial properties; influencing factors; structural equation model, pedotransfer functions; elevational gradient

PS 3/26

Soil Carbon Stabilization and Organic Matter Interactions: A Key Factor in Climate Change Mitigation and Sustainable Soil Management

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In recent times, concerns about climate change have escalated, prompting the research community to focus on mitigation measures such as soil, which has garnered attention as a reservoir for storing atmospheric carbon dioxide (CO_2). Soil organic carbon (SOC) stabilization mechanisms have become a focal point due to their importance in regulating the global carbon (C) cycle. The objective of this chapter is to review the current understanding of soil organic matter (SOM) dynamics, with particular emphasis on the contribution of clay mineralogy to the retention and stabilization of organic C in soil. A comprehensive understanding of SOC stabilization mechanisms would facilitate the implementation of optimal management practices for SOC storage, improvement of soil structure, and ultimately, mitigation of greenhouse gas emissions. This chapter discusses the relationships between SOC dynamics, its sources and sinks, factors influencing SOC sequestration, and various mechanisms involved in SOC stabilization. The studies examining soil, its management, and the environmental factors influencing soil organic carbon (SOC) stabilization, with a specific focus on clay mineralogy, are provided. The term "climate change" was formally introduced by the United Nations Framework Convention on Climate Change (UNFCCC) to denote alterations in the climate resulting from human activities that affect the composition of the atmosphere globally, as well as long-term variations in climate patterns. The Intergovernmental Panel on Climate Change (IPCC) describes climate change as any significant alteration in climate patterns over time, which may arise from natural variability or human intervention.SOC, a crucial component of soil organic matter, consists mainly of plant-derived material, with a smaller fraction originating from mineral matter. It plays a vital role in soil health and contributes to both climate change mitigation and adaptation, aligning with sustainable development goals (SDGs). SOC also promotes soil structure stability by facilitating aggregate formation, thereby ensuring adequate aeration and water infiltration for plant growth. Optimal SOC levels support soil water filtration, contributing to clean water resources. However, excessive mineralization of SOC can lead to greenhouse gas (GHG) emissions from the soil, impacting the atmosphere. The proportion of active SOC relative to the total SOC significantly influences carbon sequestration in soil and soil health.

Key words: Climate change, soil organic carbon (SOC), soil management, clay mineralogy, sustainable development goals (SDGs)

PS 3/27

Identification of Suitable Sites for Soil and Water Conservation Measures using a GIS-Based Multi-Criteria Approach in the Andaman Ecosystem

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In recent years, the Andaman ecosystem has suffereda decline in crop acreage and a water crisis during the summer season even for domestic use. To make the Indian tropical Islands i.e., Andaman ecosystem a self-sufficient food and water supply system, suitable ‘soil and water conservation/harvesting measures’ are to be adopted wherever needed. Therefore, in this study, a multi-criteria approach is used to identify suitable sites for planning various soil conservation and water harvesting measures in the Andaman ecosystem. Various thematic maps such as rainfall, runoff, slope, soil texture, stream order, land use land cover, proximity to roads and buildings, etc. were generated and integrated into the geographical information system to map the identified locations for soil conservation and water harvesting measures using the weighted overlay method. The results of this study indicate that only 0.02% of the study area is considered highly suitable and 2.59, 12.26,61.76, and 21.1% are rated as moderately suitable, marginally suitable, less suitable, and not suitable for water harvesting measures, respectively. It is also found that about 33.1% and 4% of water resources development was taken part in the Andaman Islands in terms of farm ponds and check dams, respectively for water supply. However, there is scope for more water resource development (63%) in the Andaman Islands to address the water scarcity issues during the summer season, to augment groundwater recharge, and to improve the irrigation-based infrastructure for year-round cultivation practices. Similarly, about 25% of the area is identified as suitable for practising the soil conservation measures to bring out more area under agriculture using contour/graded bunding, terracing, and broad bed and furrow in the Islands. The identified areas were validated using visual interpretations, ground truth, and recorded data. This study concludes that with the proposed soil and water conservation measures, the water demand for both the local and tourist populations can be met and crop acreage can also be doubled. These findings aim to assist decision-makers, planners, and managers in finding sites, investing in water resource measures, and using rainwater harvesting as an alternative water source.

Key words: Conservation, soil, water, islands, land use, multi-criteria, Andaman

PS 3/28

Comparative Evaluation of Carbon Sequestration Potential of Various Bamboo Species in Entisols of Sub-Montane Zone of Maharashtra

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Bamboo with the vigorous growth and its ability to thrive in varied climatic conditions probably can replace woods in sequestering carbon. A field experiment on the carbon sequestration potential of various bamboo species was initiated at Zonal Agricultural Research Station, Kolhapur, Sub-montane Zone Maharashtra during 2022-23. The present investigation was initiated with an objective to evaluate the comparative carbon sequestration potential of different bamboo species after 12 years of plantation. The experiment comprised of six bamboo species *viz. Bambusa tulda, Bambusa balcooa, Bambusa bambos, Dendrocalamus asper, Dendrocalamus strictus, Melocanna baccifera* with four replications and tested using RBD design. The soil bulk density and maximum water holding capacity (MWHC) and soil pH, EC and $CaCO_3$ was not affected by different bamboo species in both the soil depths *i.e.* 0-15 cm and 15-30 cm. Notwithstanding, the available N, P and K content in soil varied significantly. The significant highest available N, P and K were observed in *Dendrocalamus strictus* plot in both the layers. The soil organic carbon was found to be non-significant within different species. However, slight numerical increment in organic carbon was observed in *Dendrocalamusstrictus* plot. The significant highest dehydrogenase, acid and alkaline phosphatase activities were observed in plot under *Dendrocalamus strictus* species. The total above ground biomass comprising of component biomass *viz.*, culm (89.48 t ha^{-1}), branches (27.90 t ha^{-1}), and leaves (1.34 t ha^{-1}) biomass was found to be significantly highest in *Dendrocalamus strictus* over respective bamboo components biomass of all the other species. Similarly, the below ground biomass (32.05 t ha^{-1}) was also found to be significantly superior in *Dendrocalamus strictus*. In context of soil carbon density, *Dendrocalamus strictus* recorded highest though non-significant value of 21.13 t C ha^{-1}. In most of the total carbon stock contributing parameter the bamboo species *Bambusatulda* emerged as second-best species. The summation of total biomass carbon stock and soil carbon density implied that the bamboo species *Dendrocalamus strictus* is most proficient species of bamboo that can thrive well in the prevailing climatic condition of sub-montane region and emerged as the most potential bamboo species in sequestrating carbon by recording significantly highest total carbon stock to the tune of 90.90 t C ha^{-1} over all the other bamboo species. It is therefore concluded that the species *Dendrocalamus strictus* planted on shallow, sloppy Entisols of Sub-montane zone of Maharashtra can comparatively thrive well and sequester more atmospheric carbon.

Key words: Bamboo, carbon sequestration, *dendrocalamus strictus*, soil carbon density, biomass carbon stock

PS 3/29

Evaluation of Tillage and Weed Management on Soil Properties and Yield of Wheat in Incpetisols

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The present investigation was conducted during the year 2020-21 to study the "Evaluation of tillage and weed management on soil properties and yield of Wheat in Incpetisols, " at Research Farm of All India Coordinated Research Project (AICRP) on Weed Management, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The five weed control practices were superimposed in four different strips of tillage and randomized in strip plot design with three replications. The tillage operations consist of conventional tillage, reduced tillage, minimum tillage and zero tillage, while weed management practices includes application of post emergence weedicides, WM_1 (Sulfosulfuron + Metsulfuron), WM_2 (mesosulfuron + Iodosulfuron), WM_3 (Clodinafop + Metsulfuron), hand weeding and weedy check. The soils of the experimental plot were alkaline having low to medium organic carbon. The biological properties were estimated after eight and thirty days of spraying of weedicide (8 & 30 DAS). During this study, the individual and interaction effect of tillage and weedicide was evaluated. Based on the results generated, thetillage and weed management has significant effect on various biological properties. DHA (25.05 & 34.05 μ g TPF g^{-1} 24 hr^{-1}), urease (43.14& 58.98 mg NH_4 kg^{-1} 24 hr^{-1}) and alkaline phosphatase (81.27 & 125.52 μ p-nitrophenol g^{-1} 24 hr^{-1}) was registered with minimum tillage that is treatment T_3. In concern to weed management, the highest DHA (27.67 & 38.26 μ g TPF g^{-1} 24 hr^{-1}), urease (45.94 & 59.57 mg NH_4 kg^{-1} 24 hr^{-1}) and alkaline phosphatase (82.51& 128.50 μ p-nitrophenol g^{-1} 24 hr^{-1}) were noted in weedy check treatment where weeds were allowed to grow. The application weedicide may have temporary adverse impact on soil biology. It was observed that, the bulk density of soil was influenced and the lower bulk density (1.42 Mg m^{-3}) was noticed with minimum tillage, however the highest bulk density was registered with zero tillage (1.46 Mg m^{-3}). While in respect of weed management the highest bulk density (1.45 Mg m^{-3}) was noted where weeds were allowed to grow (weedy check). The maximum grain yield (36.22 q ha^{-1}) of wheat was recorded with conventional tillage while at the same time under weed management practices it was registered (38.74 q ha^{-1}) with adoption of hand weeding. The minimum disturbance to soil through various tillage practices and adoption of hand weeding as against application of weedicide has evolved promising findings towards long term sustainability of soil. Therefore, the adoption of minimum tillage and hand weeding is the most convenient way to maintain soil biodiversity and productivity of wheat under rainfed agricultural system.

Key words: Conservation tillage, enzyme activity, Inceptisol, wheat yield

PS 3/30

Adoption of IPNS and Conservation Tillage for Efficient Land Use and Sustainable Cotton Productivity

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An investigation on "Adoption of IPNS and conservation tillage for efficient land use and sustainable cotton productivity" was conducted at experimental field, Department of Soil Science, Dr. PDKV, Akola during 2016 to 2022with an object to study the effect of tillage and IPNS on soil properties and yield of Cotton. The experiment was carried out with main plot comprises two treatments i.e. conservation tillage and conventional tillage and eight sub plot treatments of integrated plant nutrient system consisting of control, 100 per cent RDF and use of chemical fertilizer along with organic source of nutrient in which 50 per cent N applied through organic sources (FYM, wheat straw, glyricidia leaf manuring (GLM), composted cotton straw, vermicompost and phosphocompost) and remaining N was applied through chemical fertilizers. The experiment was run for six years since the year 2016. However, at the same site sole cotton was sown for four years since the year 2011. The soils of the experimental site were alkaline having low organic carbon, available nitrogen and phosphorus and high available potassium. Based on the results generated, it was noted that the significantly highest seed cotton yield (15.05 qha^{-1}) was observed with the application of 50 % N through FYM + remaining RD through chemical fertilizer followed by 100 % P through phosphocompost+ remaining N & K through chemical fertilizer and 50 % N through Vermicompost + remaining RD through chemical fertilizer. The similar trend of results was also observed in respect of carbon stock (13.09 $Mgha^{-1}$) and soil quality index (1.73). The residual fertility in respect of major nutrients were also remarkably improved with conservation tillage. Therefore, FYM, Phosphocompost, Vermicompost and green leaf manuring shown enhancement in cotton productivity, soil quality and residual nutrient status over conventional tillage. The adoption of integrated nutrient management system involving conservation tillage practice found to be useful for better land use planning under changing climatic conditions.

Key words: Cotton yield, conservation tillage, land use, organic carbon

PS 3/31

Orange Peel (*Citrus sinensis*) as an Eco-Friendly Adsorbent for Crystal Violet Dye Remediation

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Numerous industries utilize a variety of dyes to enhance their products, often discharging untreated waste into water bodies. Consequently, it is imperative to mitigate or eliminate their concentrations prior to release into aquatic environments, aiming to mitigate associated health risks and environmental harm. Crystal violet (CV) synthetic dyes, prevalent in the dyeing industry, pose significant health and environmental hazards due to their toxic nature. While various physical and chemical methods exist for wastewater dye removal, adsorption stands out for its efficiency and affordability. This study focuses on employing orange peel material as a low-cost, environmentally friendly adsorbent for removing crystal violet from aqueous solutions. Batch adsorption experiments were conducted to assess the impact of contact time, pH, adsorbent dose, and dye concentration on the removal process. Optimal removal efficiency (98.6%) was achieved with a 0.2 g dose of orange peel in a 2 mgL^{-1} solution, with pH manipulation using sodium hydroxide (NaOH - 98.2%) or sulphuric acid (H_2SO_4 - 97.4%) enhancing removal. Dye removal per unit mass of orange peel increased with prolonged contact time, reaching a peak removal efficiency of 84% at 50 minutes and achieving 91% efficiency within 180 minutes at ambient temperature. Equilibrium adsorption data fitted well with the langmuir isotherm model (R^2 = 0.97). Thermodynamic analysis indicated the process to be spontaneous and endothermic. These findings suggest that orange peel holds promise as a cost-effective, eco-friendly adsorbent for treating wastewater contaminated with organic crystal violet dye.

Key words: Adsorption, orange peel crystal violet, waste water, eco-friendly

PS 3/32

Effect of Different Sources of Phosphorus and Phosphorus Solubilizing Microorganisms on Yield and Phosphorus availability in Lowland Paddy

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A field experiment was conducted at the Zonal Agricultural Research Station, MPKV, Igatpuri during 2019, 2021 and 2022. The experiment was laid out in Randomized Block Design with ten treatments which are replicated trice. The rice variety used in the experiment was *Indrayani*. Treatment consist of absolute Control (T_1), GRDF 100:50:50 ($N:P_2O_5:K_2O$) kg ha^{-1} + 10 t ha^{-1} FYM(T_2), RDP through DAP + Phosphorus Solubilizing Bacteria + AMF(T_3), RDP through DAP + *Aspergillus awamori*+ AMF (T_4), RDP through SSP + Phosphorus Solubilizing Bacteria+ AMF(T_5), RDP through SSP + *Aspergillus awamori* + AMF(T_6), RDP through rock phosphate + Phosphorus Solubilizing Bacteria + AMF(T_7), RDP through rock phosphate + *Aspergillus awamori* + AMF (T_8), RDP through steamed bone meal + Phosphorus Solubilizing Bacteria +AMF(T_9), RDP through steamed bone meal + *Aspergillus awamori* + AMF(T_{10}). The initial soil status of available N and K low and P medium in soil.The effect of different sources of phosphorus and phosphorus solubilizing micro-organisms data of three year of experiment noticed that application of RDP through SSP + *Aspergillus awamori* + AMF (T_6)on higher grain (44.94 q ha^{-1}) and straw yield (53.67 q ha^{-1}), highest nitrogen uptake (104.97 kg ha^{-1}), phosphorus uptake (18.45 kg ha^{-1}) and potassium uptake (78.22 kg ha^{-1}),higher available phosphorus (19.6 kg ha^{-1})and Phosphorus use efficiency(20.21%)of lowland paddy.

Key words: Phosphorus solubilizing microorganisms**,** yield, nutrient uptake, available P and phosphorus use efficiency

PS 3/33

Phytoaccumulation of Heavy Metals and Micronutrients in Different Plants at Sewage Effluent Phytorid Bed in Nagpur

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The present investigation entitled " Phytoaccumulation of heavy metals and micronutrients in different plants at sewage effluent phytorid bed in Nagpur " was conducted at College of Agriculture, Nagpur during 2022-2023. Sixteen different plant species from banks of Nag River were collected, separated into root, stem and leaf and analysed for heavy metals and micronutrients. The results revealed the mean accumulation for Fe (14199.83), Zn (231.87), Mn (5014.43), and Cd (2.23) was highest in *E.crassipes* while *I.carnea* showed maximum accumulation for Cu (153.53), Pb (56.75), and Ni(202.12). Typha showed maximum accumulation for Cr (72.63), and *C. alternifolius* for Cobalt (36.93). Different patterns of accumulation were observed for different plant species and elements. Different plants show different patterns of accumulation for heavy metals and micronutrients. Micronutrients like iron and manganese primarily showed Leaf > Root > Stem in species viz., *A. mexicana*, *C. tinctoria*, *A.viridis* and *B.juncea.* Zinc and copper predominantly showed Root > Stem > Leaf pattern in species like *C.esculenta.* Among heavy metals, chromium and nickel primarily observed Leaf > Root > Stem in plants like *A.mexicana*, *A. viridis*, *C. album.* Cobalt and Cadmium chiefly followed the trend Root > Leaf > Stem in plants like *C.indica.*

Key words: Phytoaccumulation, heavy metal, sewage effluent, Nagpur

PS 3/34

Identification of Suitable Sites for Soil and Water Conservation Measures using Geospatial Technologies

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Identification of suitable sites for soil and water conservation measures in watershed required information such as soil characteristics, land use and land cover, terrain parameters etc. apart from the climatic data. Spatial generation of this information required more time, however using geospatial technologies with satellite data can be used for reliable and quick generation of different spatial information for planning of various conservation measures in a watershed. In this study, suitable sites for different soil and water conservation measures were identified for Dhanora block, Seoni district, Madhya Pradesh using GIS environment. The total geographical area of the block is 550.00 km^2. Linear Imaging Self Scanner (LISS-IV) satellite data, soil information (1:10000 scale) and Cartoset DEM (10m resolution) were used for generation different thematic maps like land use/land cover, slopes, landform and other maps required for selection of suitable sites for soil and water conservation. The conceptual framework for site specific suitability plan for different soil and water conservation measures are developed and subsequently, this information was integrated with other thematic information generated using geospatial technologies and area of different measures are computed. The area of suitable sites for farm pond is 8300 ha, bench terrace is 36 ha, vegetative barrier is 1480 ha, field bund/contour bund is 26500 ha, graded bund is 1943 ha, length of silt detention trench is 422 km with catchment area of 2152 ha, staggered contour trench is 11219 ha are identified in the study area. This information will be useful for implementation of different soil and water conservation measures in the study area.

Key words: Geospatial technologies, satellite data, soil and water conservation, watershed

PS 3/35

Effect of Different Bamboo Species on Soil Carbon Content and Microbial Indices Grown on Entisol of Semiarid Climate of Maharashtra

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A long-term field experiment "Performance of different bamboo species on growth and yield of bamboo" was initiated in the year 2018-19 at National Agricultural Research Project (NARP), Dryland Sub-Centre (Agroforestry), Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar. The same field experiment was selected for conduct of present study entitled, "Quantification of soil carbon pools and carbon sequestration rate as influenced by bamboo plantation grown on entisol of semiarid climate of Maharashtra" during the year 2020-21. The field experiment was laid out in randomized block design comprising three replications and seven treatments of bamboo species *viz.*, *Dendrocalamus brandisii* (T_1), *Bambusa nutans* (T_2), *Bambus abalcooa* (T_3), *Dendrocalamus strictus* (T_4), *Bambusa tulda* (T_5), *Bambusa bamboos* (T_6) and *Dendrocalamus asper (*T_7). The experimental site belongs to sandy clay texture. The initial soil of experimental field was slightly alkaline in reaction (pH 8.01), had low EC (0.21 dSm^{-1}) and CaCO3 content (3.37%), was medium in SOC (6.70 g kg^{-1}), low in available N (178.70 kg ha^{-1}), very low in available P (6.10 kg ha^{-1}) and very high in available K (403.20 kg ha^{-1}) content. The average depth of experimental soil is up to 45 cm. The control plot next to the experimental field free from the effect of bamboo species had a BD of 1.51 Mg m^{-3}. After the 2nd year of bamboo plantation, the soil under *Bambusa nutans* (T_2) recorded highest Soil Organic Carbon (8.07 g SOC kg^{-1}) and Total Organic Carbon (12.9 g TOC kg^{-1}) content. The soil labile carbon fractions *viz.*, Water Soluble Carbon (14.08 mg WSC kg^{-1}), Soil Microbial Biomass Carbon (181.7 mg SMBC kg^{-1}) andParticulate Organic Matter Carbon (1.90 g POMC kg^{-1}) was recorded highest under *Bambus atulda* (T_5), whereas, soil under *Bambusa nutans* (T_2) recorded highest Permanganate Oxidizable Soil Carbon (0.666 g POXC kg^{-1}) content over rest of bamboo species after 2nd year of bamboo species on Entisol of semi-arid climate.

Key words: Entisol, bamboo, agroforestry, soil carbon

PS 3/36

Ecological Niche Modeling of Disease Vector: Preliminary Observations of a Study to Map the Distribution of a Cattle Tick Vector from Maharashtra

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Use of ecosystem services for disease epidemiology has gained a substantial recognition as the emergence of user-friendly geospatial technologies being introduced in recent times. Yet its adoption in Indian perspective is minimal. The current study is such a pilot approach to model a distribution of an arthropod vector of livestock diseases *i.e. Rhipicephalus microlpus*, a cattle tick in the state of Maharashtra through ecological niche modelling. To achieve this the primary data collected through field visits during the year 2023 was used and bioclimatic and remote sensing variables *viz*. NDVI, Topographic Wetness Index (TWI), annual mean temperature (Bio1), annual precipitation (Bio12), slope, elevation, cattle population density and land cover classes were included as predictor variables. The maximum Entropy (MaxEnt) modeling was used to predict the potential distribution of the tick within the geographical boundary of Maharashtra State. The resultant Max Ent model gave satisfactory results as the final model's AUC mean over 10 iterations was 0.839 and standard deviation as 0.015 which demonstrates strong functionality and great prediction accuracy of the final model. Slope, elevation and land cover classes are most important predictors of *R. microplus* distribution, as these factors had highest influence on the model with contributions of 30.9%, 12.9% and 10.3% respectively. Low sloppy areas are much suitable for these species than high slope terrains. The probability of occurrence of *R. microplus* increased with an increase in annual mean temperature; however, the suitability of habitat for this species decreased with the increase in annual precipitation. *R. microplus* increased their distribution in suitable habitat within medium ranges of minNDVI, meanNDVI and maxNDVI. TWI has a significant impact on its distribution as higher values of this index increases probability of *R.microplus* distribution. As far as land cover classes are concerned, the most influential factor for habitat suitability for *R.microplus*was found to be urban built up areas followed by grasslands and croplands. The potential distribution of this tick in the state included areas from central part comprising area from Marathwada and north Maharashtra, areas from south western Maharashtra and a part of eastern Vidarbha region however moderate suitability is noted across the state. The observations from current study can form useful evidence for preparation of control programs and surveillance priorities of tick-borne diseases which are primarily dependent on estimating suitable areas where a vector may occur. This approach can also be used more profoundly for other livestock diseases by integrating more suitable environmental predictors and even be useful to predict the areas at risk in future for certain pathogens and factors responsible for such a risk.

Key words: NDVI, cattle tick vector, entropy, TWI

PS 3/37

Assessing Land Degradation Vulnerability using GIS and Analytical Hierarchy Process Approach- A Case Study from Arid Region of Karnataka

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The land degradation vulnerability (LDV) is loss of production potential of a land due to various factors like soil properties, landform, climatic and vegetation. The aim of the present study is to assess the land degradation vulnerability of Hire-Wankalkunta Sub-watershed located in Yelburga Taluk of Koppal District, Karnataka, India using analytical hierarchy process (AHP) integrated with Geological information system. Various factors composing vegetation attributes (Land-use and land cover (LULC) and Normalized Difference Vegetative Index (NDVI)), climate variables (Rainfall), topographic parameters (Slope, Terrain Ruggedness Index (TRI), and Multi-Resolution index of valley bottom flatness (MrVBF)) and pedological attributes (Soil texture, Drainage, Soil Depth and Soil Organic Carbon (SOC)) were considered for assessing land degradation vulnerability. Weightages and scores of the criteria (factors) and sub-criteria influencing land degradation were assigned through AHP and they were used for weighted overlay analysis in GIS interface. Rainfall, Slope, Soil texture and TRI are found to be the most influencing factors of land degradation with significant weightages of 0.25, 0.19, 0.19 and 0.11, respectively. The weighted overlay analysis demonstrates that about 45 per cent area falls under the category of high and very high land degradation vulnerability. The area identified as very highly and highly vulnerable for land degradation could be managed cautiously with proper land management options viz., suitable crops cultivation, surface covering with vegetation and mulches and soil and water conservation measures interventions (contours bunding). This study would definitely help in taking optimal action plan to improve agricultural sustainability as well as farmers' livelihood in Hire-Wankalkunte sub-watershed.

Key words: land degradation vulnerability, topographic factors, normalized difference vegetation index, analytical hierarchy process, weighted overlay

PS 3/38

Soil Organic Carbon Fractions Impacted by Land Use in the Brahmaputra Plains of Assam

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Land use and its management exerts an impact on soil organic carbon (SOC) dynamics; however, the impact varies with climate, soils, and management practices. Therefore, an in-depth understanding of changes in SOC pools and its fractions is imperative to understand the status of soil health and carbon (C) emissions, so that, effective land use can be adopted for sustainable soil management in the Brahmaputra Plains of Assam. In the present study, soils were sampled at 0-15 cm depth to assess the impact of four dominant land uses (natural forest, tea plantation, arecanut plantation, and agriculture) on SOC (Walkley Black, 1934) density, its fractions and soil dehydrogenase activity. The results demonstrated that forest soil had the highest organic carbon (OC, 33.15 Mg ha^{-1}), active C (AC, 20.37 Mg ha^{-1}), passive C, (PC, 13.42 Mg ha^{-1}) pools followed by tea plantation (30.89 Mg OC ha^{-1}, 19.48 Mg AC ha^{-1}, and 10.29 Mg PC ha^{-1}).The soils under forest had a higher share of the labile C (LC) fractions followed by very labile C (VLC) and non-labile C (NLC) fraction whereas in tea plantation, areca nut plantation, and agricultureland uses have higher share of VLC fraction followed by NLC fraction. The AC/PC ratio and lability index was least in forest. The dehydrogenase activity was highest in forest (2.39 µg TPF g^{-1}d^{-1}) and lowest under tea plantation (0.26 µg TPF g^{-1}d^{-1}) which might be due to increased soil acidity under tea plantation. This indicates higher microbial activity in forest soils compared to other land uses. Cultivation resulted in reduced SOC and soil quality. Therefore, it is important to adopt best management practices which reduces carbon loss and improves SOC level. The study suggests that knowledge of soil organic carbon and its fractions is vital to suggest suitable long term and short-term land use plan not only to preserve SOC and enhance soil fertility, but also to reduce carbon emissions from terrestrial systems.

Key words: Active carbon, land uses, passive carbon, soil organic carbon, tea plantation

PS 3/39

Assessment of Soil Erosion by RUSLE Model Using Remote Sensing and GIS: A Case Study of Vemgal Hobli of Kolar District, Karnataka

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The soil erosion status increased due to intensive agricultural practices and other human activities all leads the severe deterioration of land. The deterioration of land notification of Erosion-Prone areas is the most important factor for agricultural planning and effective land management. The present study is carried out in Vemgal Hobli in Kolar Taluk of Kolar District in Karnataka, having an area of 13948.0 ha. In this study, the Universal Soil Loss Equation (USLE) model, with Geographic Information System (GIS) and Remote Sensing (RS) have been used to quantify the soil loss in the Vemgal Hobli. The USLE model required the integration of thematic factors' maps (layers) which are rainfall intensity, length and steepness of the slope, vegetation cover, soil erodibility, and erosion control practices. All of these layers have been prepared in GIS and RS platform using various data sources and data preparation methods. In these studies, DEM and LISS satellite data have been used. The rainfall data (2015-2021) obtained from KSNMDC have been used to predict the R factor. Soil erodibility (K) factor is estimated from LRI data of the study area and it ranges from 0.13 to 0.18. The results showed that about 40.12% of the total geographical area (TGA) in the study area is to very slight (0-5 t ha^{-1} yr^{-1}) and slight (5-10 t ha^{-1} yr^{-1}) soil erosion and 29.51% of the area will come under severe (15-20 t ha^{-1} yr^{-1}) and very severe (>20 t ha^{-1} yr^{-1}) probability zone. The result can certainly assist in the implementation of soil management and conservation practices to reduce soil erosion in the study area.

Key words: Soil erosion, agricultural practices, erosion-prone areas, universal soil loss equation, geographic information system

PS 3/40

Factors Controlling Soil Organic Carbon Sequestration in Coastal Soils

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Factors controlling organic carbon (OC) sequestration in coastal soils vary due to the variability in the climate - land use – soil dynamics of coastal regions. A temporal data set consisting 30 soil profiles studied during 1990 and 2020 was used in the study to model the effect of climatic variables and land use type (LUT) on OC sequestration in coastal soils of Gujarat. Random Forest Regression (RFREG) was used to analyse the factors influencing OC sequestration. The results indicated that climate significantly ($p<0.05$) influenced SOC only up to 20 cm depth, during 1990. RFREG showed that intrinsic soil properties such as clay, cation exchange capacity (CEC), and base saturation-controlled OC in the topsoil and climatic variables and land use were weak predictors of OC. After 30 years (2020), both climate ($p<0.001$) and LUT ($p<0.01$) showed significant influence on OC in all soil depth classes, indicating the effect of land use change on OC sequestration. The OC was lower in soils under cotton and higher in soils under plantation crops. Soils under sugarcane, rice and grassland had similar OC content up to 50 cm. RFREG results showed that climate and land-use interaction controlled the OC sequestration in soils during 2020. Further, the effect of intrinsic soil properties such as clay and CEC were weak in predicting OC sequestration. The study indicated that change in LUT and climatic variables in the west coast region of India significantly increased the OC content in the soils.

Key words: Organic carbon sequestration, coastal soils, land use change, climate variability, random forest regression

PS 3/41

Pools of Carbon as Influenced by Long term Manuring and Fertilization under Sorghum-Wheat cropping sequence in Vertisol

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The present investigation was undertaken on existing AICRP Long Term Fertilizer Experiment initiated during 1988-89. The twelve treatments replicated four times in a randomized block design comprising various nutrient management practices. The treatment were various nutrient management practices replicated four times in randomized block design. The results of the present experiment revealed that the application of 100% RDF along with FYM @ 5 t ha-1 recorded higher value of very labile carbon in 0-20 and 20-40 cm depth, while it was higher with the application of FYM @ 10 t ha-1 in 40-60 cm depth. The application of balanced fertilization (100 % NPK, 100 % NPK + Zn, 100 % NPK + S) found equally beneficial for obtaining higher value of very labile pool in 0-20, 20-40 and 40-60 cm depths. The labile carbon (LC) pool is the fraction with the most rapid turnover rates and greatly influences the nutrient cycling in soil. The application of FYM @ 10 t ha-1 resulted improvement in the labile carbon pool in 0-20 cm and 40-60 cm depth. Non-labile carbon pool was noted significantly higher in treatment where farmyard manure applied alone, in combination with 100%RDF and 75% RDF in 0-20, 20-40 and 40-600 cm depths. The lower value of non-labile pool was noted with the treatment of control and 50% RDF.

Key Words: Carbon pools, AICRP, non-labile C, labile C, Vertisol

PS 3/42

Fallow Land Mapping in Gaya District, Bihar using Remote Sensing and GIS

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Identification of fallow lands is important for sustainable land use planning. In the study spatial distribution of fallow lands in Gaya district, Bihar mapped by using the spectral signature of normalized difference vegetation index (NDVI) derived from Sentinel-2 satellite data for the period of 2018 to 2022. Google Earth Engine platform, QGIS and ArcMap software were used to collect, process and extract the best pixel-based long-term dataset of NDVI. Feature extraction and edge correction were done using unsupervised and supervised classification. Seasonal False Color Composite and Google hybrid basemap were used for the edge correction. Summarising the area statistics of fallow lands, barren lands and brick kilns, it was observed that about 2.6 per cent of the total geographical area (TGA) of the district. At several places, water logging was observed. The south and southeastern region of the Falgu River consists of more fallow lands. The eastern part of the Sherghati subdivision and the south-eastern part of the Bathani subdivision displayed more fallow lands compared to other parts of the respective subdivisions. Among the four subdivisions, the Tekari subdivision had the least fallow lands. The incorporation of cadastral and forest area boundaries can reduce edge correction efforts. The developed methodology can be used to identify seasonal as well as permanent fallow lands in the rest of the state.

Key words: Fallow land, FCC, feature extraction, GIS, NDVI, remote sensing, Sentinel-2, spectral signature

PS 3/43

Impact of Ground Water Quality on Soil Properties

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The investigation was conducted in Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. To assess the effect of irrigation on soil properties in Pentakali command area of Buldhana district of Maharashtra the water samples from forty open wells were collected in three different seasons viz. pre monsoon (summer), monsoon (rainy) and post monsoon (winter). The ground water samples from fourty open wells were collected from nine village's in Pentakali command area. This result showed that the pHs varied from 7.10 to 7.81 and 7.15 to 7.95 during before and after irrigation respectively. Whereas Ece 0.48 to 0.87 dSm-1 and 0.60 to 0.98 dSm-1 during before and after irrigation respectively. While among the cations the concentration of sodium is dominated among all the cations in between 2.02 to 3.56 meL-1 and 2.16 to 3.73 during before and after irrigation season respectively, whereas Ca2+ and Mg2+ dominant after sodium during before and after irrigation season. The concentration of K+ very less during two season and among the anion HCO3-, Cl-, SO4 2- was dominant during after irrigation as compared to before irrigation. In the context of serious soil health decline, imbalanced use of fertilizers, multicurrent deficiency in soils, higher costs of chemical fertilizers, scarcity of organics etc. which necessitate exploration of possibility of utilizing various nutrient sources and ensuring balanced nutrient supply to the crops, the nutrient addition through irrigation needs to be taken into account. The quality of irrigation water also affects the physical properties of soil up to certain extent which needs to be study.

Key words: Pentakali command area, before irrigation, after irrigation, saturation paste, permissible limit, soluble sodium percentage

PS 3/44

Impact of Land-use Types and Topographic Positions on Soil Organic Carbon and Total Nitrogen Stocks in a Degraded Landscape: A Case Study in Eastern Ghats Highlands, India

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In landscapes degraded by shifting cultivation, soil organic carbon (SOC) and total nitrogen (TN) serve as crucial indicators of soil quality. This study delves into the impact of land-use types and topographic positions on SOC and TN stocks to enhance the understanding of ecological processes in such degraded landscapes. Conducted in the Eastern Ghats Highland region of India, a watershed affected by shifting cultivation, the study sampled 144 sites based on land use and slope, employing transects and grid surveys. The eight major land-use types studied included forest, degraded forest, scrub, plantation, fallow, agriculture, grazing land, and shifting cultivation. Additionally, three topographic positions—upper, middle, and lower—were considered. Sampling was conducted at a depth of 45 cm, with three layers (0–15, 15-30, and 30–45 cm). The results revealed significant variations in SOC and TN stocks among different land uses and topographic positions. Forest land exhibited notably higher SOC (105.3 Mg ha^{-1}) and TN (9.1 Mg ha^{-1}) stocks, while shifting cultivated areas displayed the lowest stocks (60.3 and 4.4 Mg ha^{-1}). The observed disparities were attributed to unmanaged tree cutting and extensive erosion in shifting cultivated areas. Lower carbon and nitrogen stocks in croplands were linked to heavy ploughing, excessive biomass removal, and soil erosion, while plantations exhibited lower stocks due to poor undergrowth and overexploitation for charcoal and firewood production. The study underscored the significance of land use as a key factor influencing SOC and TN stocks, with the impact of topographic position also pronounced in varying levels of SOC and TN stocks. Notably, the middle and lower topographic areas, characterized by prolonged cultivation and unsustainable human activities, emphasized the urgency of land management interventions, particularly targeting croplands. In contrast, in the uplands, the forested areas exhibited better C and N stocks. The study highlights the necessity for urgent conservation measures in areas dominated by shifting cultivation. Ultimately, in the heterogeneous environment of the Eastern Ghats Highlands of India, a comprehensive understanding of the interactions between land use and topographic position proves crucial for designing effective soil management practices.

Key words: Degraded landscape, land-use types, soil organic carbon, topographic positions, total nitrogen

PS 3/45

Erosional Intensity Assessment of the Trans Himalayan River Basins (upper Teesta and upper Chenab) Using Comparative Morphometric Analysis

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The water resources in the Himalayan region are under stress due to varied factors like climate change, increasing population, and land-use changes. The Trans Himalayan River basins in particular are the most susceptible to climate change. Therefore, it's important to have an assessment of the water resources of the region for better understanding and management. The morphometric parameters play an important role in hydrological processes and are significant in determining the runoff reaction to intense rainfall, especially in the case of ungauged, flash flood-prone basins. In this study, the comparative morphometric assessment was carried out for the upper Teesta and upper Chenab basins located in the Trans Himalayan region on the eastern and western sides respectively. Quantitative morphometry of the basins was done using Aster DEM (30m) on Arc GIS using the standard methods. Both river basins were compared using morphometric parameters of 4th order sub-watersheds. The study revealed that both the basins have gentle slopes, fine coarse drainage texture, and are more prone to flooding as both the basins are oval in shape. The intensity of erosion in the Upper Teesta basin is a little higher than in the Upper Chenab basin. This comparative study clearly indicates that among the basins Upper Chenab basin has higher chances of floods as it has a higher discharge, is hydrologically more active, and has a shorter time lag for peak flow under the similar environmental conditions and will need more management in case of adverse conditions whereas the Upper Teesta basin has higher erosional intensity and it needs more management in handling the higher sediment load this river will pass down.

Key words: Trans Himalaya, Teesta River, Chenab River, Remote sensing and GIS, river morphometry, erosion intensity

PS 3/46

Assessment of soil erosion by RUSLE model using remote sensing and GIS A Case Study of Vemgal Hobli of Kolar District, Karnataka

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The soil erosion status increased due to intensive agricultural practices and other human activities all leads the severe deterioration of land. The deterioration of land notification of Erosion-Prone areas is the most important factor for agricultural planning and effective land management. The present study is carried out in Vemgal Hobli in Kolar Taluk of Kolar District in Karnataka, having an area of 13948.0 ha. In this study, the Universal Soil Loss Equation (USLE) model, with Geographic Information System (GIS) and Remote Sensing (RS) have been used to quantify the soil loss in the Vemgal Hobli. The USLE model required the integration of thematic factors' maps (layers) which are rainfall intensity, length and steepness of the slope, vegetation cover, soil erodibility, and erosion control practices. All of these layers have been prepared in GIS and RS platform using various data sources and data preparation methods. In these studies, DEM and LISS satellite data have been used. The rainfall data (2015-2021) obtained from KSNMDC have been used to predict the R factor. Soil erodibility (K) factor is estimated from LRI data of the study area and it ranges from 0.13 to 0.18. The results showed that about 40.12% of the total geographical area (TGA) in the study area is to very slight (0-5 t $ha^{-1}yr^{-1}$) and slight (5-10 t $ha^{-1}yr^{-1}$) soil erosion and 29.51% of the area will come under severe (15-20 t $ha^{-1}yr^{-1}$) and very severe (>20 t $ha^{-1}yr^{-1}$) probability zone. The result can certainly assist in the implementation of soil management and conservation practices to reduce soil erosion in the study area.

Key words: Soil erosion, land degradation, geographic information system, remote sensing, universal soil loss equation

PS 3/47

Characterization of Soil Resources Using Geospatial Technologies for Sustainable Agricultural Land Use Planning in Lesser Himalayas

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A systematic and scientific appraisal of land resource is essential to know its potential and problems. It helps to a great extent in working out efficient management strategies to optimize land use. Chamba Block (30°8'52"N to 30°24'32"N latitudes and 78°15'22"E to 78°36'21"E longitudes) covering about 16256 ha area represents very strongly hillside slopes to moderate hillside slopes climatically, varies from cold temperate, tropical to sub-tropical with mean annual temp 21oC and mean annual rainfall of 1067.48 mm has been selected for land resource inventory on 1:10,000 scale. The area qualified for Kumaon Himalayas, warm to hot dry to moist sub-humid ecosystem. Modern tools and techniques of remote sensing and GIS are main pillars of the flagship programme of Land Resource Inventory. The high-resolution Remote sensing data (5.8 m) products of the IRS-R2, LISS-IV and Cartosat-1 digital merged data were used for generation of slope, landform, land use /land cover and landscape ecological units which is used as base map for soil survey work in the field. The study area is divided in to upper hill side slopes, lower hill side slopes and river terraces or intermountain valleys. Ten landscape ecological units have been identified. The soils resources of the block are mapped into 2 orders, 3 sub orders, 3 great groups, 5 subgroups, 4 soil families, 9 soil series and 17 mapping units or soil phases. Entisols and Inceptisols, covers about 75 and 19 per cent area respectively. Soils of upper hillside slopes are excessively drained and comprises of Gunogi, Jaledi, Birogi and Nakot soil series. Soils of lower hillside slopes are well drained to excessively drained and comprises of Arakot, Hadam and Kot soil series. Soils of river terraces or intermountain valleys are moderately well drained to somewhat excessively drained comprises of Nagni and Lamkot soil series. Jaledi, Birogi, Arakot and Hadam soil series occupied 77% area of the block. Among the soil families, loamy covers 37.6 per cent area of the block followed by loamy skeletal (36.7 %) and fine loamy (19.3%). Excessively drained soils occupy 47.32 percent area of the block followed by well drained (26.28 %) and somewhat excessively drained (20.51 %) soils. Most of the area (49.39 %) of the block is under severe erosion followed by moderate (41.29 %) and very severe (3.12 %). Majority of soils are high in organic carbon (75 %), medium in available nitrogen (69.48 %), medium in available phosphorus class (57.03%) and medium in available potassium (49.54%). Thus, the LRI study carried out in Chamba block may be able to address the local level problems and also to explore the potential for suggestion of a particular kind of land use at specific site. However, the study represents block area i.e., Chamba block of Tehri Garhwal but it can be extrapolated at large scale under similar agro-climate and agro-ecological conditions.

Key words: Land resource inventory, Kumaon Himalayas, remote sensing, GIS

PS 3/48

Delineation of Landscape Ecological Units for Soil resource Mapping in the Hill and Mountain Ecosystem

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Soil resources play a vital role in agriculture development and sustainable production. Satellite data and GIS tools are helpful in soil survey, soil resource mapping and assessment of land degradation. Satellite image is found to be very useful in capturing the soil resources variability. Using geospatial techniques, a case study was planned in the Bhimtal block (29°13’34”N to 29°26’18”N and 79°19’47”E to 79°41’19”E) of Nainital district, Uttarakhand to study the land resources of the area, where land degradation along with decreasing land resources availability renders the land as well as agriculture less productive. The area represents the diverse climate and physiography in the southern part of Kumaun division of Uttarakhand and span over an area of 11064 hectare. The block is selected for land resource inventory for land use planning so that the area under agriculture can be increased and land resources can be improved. The main objective of the study is to prepare Landscape Ecological Units (LEU) that serves as base map for land resource characterization. For this study, high resolution remote sensing data (Sentinel-2 and SRTM DEM) downloaded from USGS. Visual and digital interpretation of RS data carried out for delineation of slope, landform and LULC in ARC-GIS software. Results of interpretation revealed four slope classes (moderately sloping, moderately steeply sloping, steeply sloping, and strongly sloping), 4 landform classes (high hills, moderate hills, low hills and intermountain valleys) under lesser Himalayas and 6 land use classes viz.,forest, terrace cultivation, degraded land, pasture/grazing land, habitation and others, and water bodies have been delineated. Results of further interpretation revealed that majority of the area found to be under forest (85%) and degraded land (2%). About 9% areas come under terrace cultivation. Based on slope, landform and LULC, 21 LEUs have been delineated.

Key words: Soil resources, satellite data, geographic information system, land degradation, remote sensing

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Integration of Real Time Nitrogen, Precision Irrigation Management and Conservation Agriculture for Sustainable Agricultural Production

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Feeding the growing population within changing climate conditions and limited resources poses a pressing challenge. Considering the sustainability issues associated with the green revolution, such as low nitrogen (N) use efficiency (generally 30-45%), declining water tables, crop residue burning, stagnant crop productivity and multi-nutrient deficiencies etc., it is imperative that we seek alternatives to provide solutions. These alternatives should not only efficiently feed the growing population but also optimize the use of agricultural inputs while conserving natural resources for future generations. Hence, we designed an experiment, integrated real-time N management, precision irrigation, and conservation agriculture (CA), and compared the results with conventional practices. In CA, we directed tillage only in the row zone, as opposed to intensive tillage. Additionally, instead of burning crop residue, we retained the crop residue between crop rows. N application was tailored to the crop's needs, as measured by GreenSeeker. Regarding irrigation, we applied water at 25% depletion of available soil moisture to maintain water levels near field capacity, with the help of evapotranspiration and crop coefficient data, and volume of water applied was measured through water meter. The integrated approach demonstrated significant improvements in grain yield (t/ha), net returns (₹/ha), apparent N recovery (%), and microbial biomass carbon (μg C/g soil), transitioning from 5.26, 63378.0, 35.0, and 439 under conventional practices to 7.4, 97927.0, 56.9, and 609.0, respectively. This approach not only saved 16 kg of N and 1.25 lakh litre/ha water but also resulted in lower NO3-N content (10.8 mg/kg) compared to CT (13.0 mg/kg) at a soil depth of 30-45 cm, indicating a reduction in groundwater pollution due to N leaching. The successful integration of real-time N management, precision irrigation, and CA principles serves as a promising model for sustainable intensification in soil-ecosystems. It addresses green revolution issues, resource limitations, and lays the foundation for resilient, sustainable agricultural practices, promising to meet global food demands while conserving natural resources for future generations.

Key words: Conservation agriculture, green seeker, microbial biomass carbon, sustainable agricultural production

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Soil Health Management for improving Climate Resilience

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Soil Health is critical for global food security, clean water, maintenance of biodiversity, carbon sequestration, and other ecosystem services, but is threatened by soil degradation processes, including erosion, soil organic matter loss, nutrient imbalances, salinization, acidification and soil biodiversity loss. India is ranked fourth among the list of countries most affected by climate change in 2015. India emits about 3 giga tonnes (Gt) CO2 and greenhouse gases each year; about two and a half tons per person, which is less than the world average. The country emits 7% of global emissions, despite having 17% of the world population. India is one of the low per capita greenhouse gas emission countries. The climate-related hazards for India that are most relevant to agricultural production are droughts; the effects of extreme rainfall (flooding, erosion, landslides); high maximum temperatures and pest conditions. Healthy soil is critical for global food security and other essential ecosystem services but is threatened by processes of soil degradation, drought, salinity, flooding, erosion and soil acidity. Climate-resilient soil management practices, including the importance of developing moisture holding capacity, managing nutrient availability and soil nutrient-based fertilizer application.

Key words: Soil health, climate change, India, greenhouse gas emissions, soil degradation

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Effect of Organically Extracted Humic Acids on Growth, Dry Matter Accumulation and Rooting Properties During Hardening of Banana Plantlets

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The humic acids were prepared from composts and organics and were analysed for total elemental (total carbon, N, P, K, S), functional group and FTIR analysis. The efficacy of the extracted bio stimulants was tested to optimize the use of bio stimulants based on the total elemental and functional group analysis. Banana plantlets were used as test crop to assess the impact of bio stimulants on growth, yield, quality and nutrient uptake. The significant improvement in growth parameters of root and shoots, conc. of N and K, uptake of N, P and K and available N, P and K in the growth media was recorded with the foliar spray of bio stimulant extracted from vermicompost. Whereas, application of drenching of bio stimulant extracted from vermicompost resulted in maximum enhancement in the growth parameters of root and content of Nitrogen in banana plantlet. The drenching of bio stimulant extracted from FYM found beneficial in enhancement of growth parameters of shoot, concentration of K, and uptake of N and K. However, significantly higher available N, P and K concentrations and its uptake was observed with drenching of bio stimulants extracted from NPS compost. The higher E4/E6 ratio (colour ratio) was noted in bio stimulants extracted from vermicompost (4.81) followed by FYM (4.22). The higher carboxylic and total acidity was recorded in the bio stimulants extracted from vermicompost and the higher phenolic group was observed in the bio stimulant extracted from FYM.

Key Words: Humic acids, bio stimulants, vermicompost, E4/E6 ratio, total acidity

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