

Impact Of Agricultural Practices On Soil Security In Sindhudurg

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Abstract:

This study evaluates the impact of agricultural practices on soil security in Sindhudurg using data from 50 sites, examining key dimensions of soil capability, condition, capital, connectivity, and codification. Findings reveal significant effects on soil health, sustainability, and ecosystem services, highlighting the need for improved soil management strategies.

Keywords: Soil security, agricultural practices, Sindhudurg, soil health, sustainability, soil quality, environmental impact, soil management, ecosystem protection, soil resources.

Introduction:

Soil health is fundamental to ecosystem functioning, influencing biodiversity, climate resilience, food production, and water management. Globally, land degradation affects nearly 30% of land, causing economic losses equivalent to 10% of global GDP and threatening the livelihoods of about 3.2 billion people due to declining biodiversity and ecosystem services (Alori et al., 2020). In Maharashtra, including Sindhudurg, these challenges necessitate improved land management to enhance soil fertility and mitigate climate-induced water stress (Purakayastha et al., 2024). Agricultural practices play a decisive role, with Conservation Agriculture enhancing soil structure and resilience (Tahat, Alananbeh, & Othman, 2020). Soil security is central to sustainability; as Norman Borlaug stated, “If you desire peace... cultivate the fields (soils) to produce more bread” (Pozza & Field, 2020). Strengthening soil security–agriculture linkages is therefore essential (Bertrand, 2023).

Objective Of The Study:

1. To assess the effects of modern agricultural practices on soil fertility.
2. To examine the role of traditional farming in maintaining soil health.
3. To evaluate the impact of pesticide, use on soil biological diversity.
4. To analyze soil erosion trends under different farming methods in Sindhudurg.
5. To explore sustainable agricultural practices for enhancing soil security.

Characteristics Of The Six Global Existential Environmental Challenges:

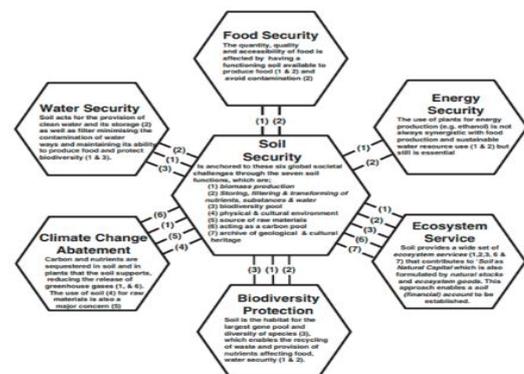


FIG.1 Aligning the established scientific concept of soil functions (CEC, 2006) as listed under Soil Security in order (read left to right,

or top to bottom) of their relative immediate impact for each of the major societal challenges.(McBratney et al., 2014)

The six global existential environmental challenges have been widely investigated, and their description and assessment rely on identifying shared characteristics that support soil security evaluation (Kumar et al., 2021). **Food security** is defined by availability, access, and utilisation, and depends on enhancing agricultural productivity through soil conservation, optimal management, and access to quality soils, while addressing nutrient constraints such as phosphorus (Gupta, 2019; Peng & Berry, 2018). **Water security** encompasses water quality, scarcity, and cooperation, with soils playing a critical role in water retention, filtration, and efficient use of both blue and green water (Singh, 2021; Ingrao et al., 2023). **Energy security** focuses on the affordability and availability of diverse, uninterrupted energy supplies, while balancing economic efficiency and environmental sustainability, placing increasing pressure on soil resources due to bioenergy demands (Sovacool &

Brown, 2011; Kim, 2024; Sovacool & Mukherjee, 2011). **Climate-change abatement** highlights soils as major carbon reservoirs capable of mitigating greenhouse gas emissions through carbon sequestration, while influencing productivity and resilience (Janzen et al., 2022; Lal & Uphoff, 2010). **Biodiversity protection** emphasises soil as a repository of genetic diversity essential for ecosystem functioning, nutrient cycling, and resilience (Anthony & Bender, 2023; Gougoulas et al., 2014). Finally, **ecosystem services** integrate supporting, provisioning, regulating, and cultural services, with soil natural capital forming a foundation for policy-relevant assessments of sustainability and soil health (S. Lele et al., 2013; Brevik et al., 2018; Schwilch et al., 2016).

Table.1 ‘Ecosystem services’ of soil refers to the fundamental necessities to support life encompassing human culture and its pursuits

Types of Services	Economic value
Supporting the physical stability and renewal of plants, as well as the retention and delivery of nutrients for the habitat and gene pool of plants	Production (9Yield) function for applied nutrient biodiversity, novel gene source from new cultivars
Regulating The regulation of the primary elemental cycle buffering, filtering, and moderating the hydrological cycle The disposal of decaying organic matter and waste	Freshwater processed per hectore, flood attenuation, and nutrient cycling values for carbon and nitrogen
Provisioning Building Materials	Materials, transportation, and storage expenses
Archaeological preserver of artefacts, cultural heritage sites	

Study Area:

The study was conducted in Sindhudurg district, located in the southern part of Maharashtra, India, between 73.4705°–73.9708° East longitude and 15.7551°–16.2703° North latitude. The district covers an area of approximately 5,207 km² and is bounded by the Arabian Sea to the west. Sindhudurg exhibits diverse physiography, including coastal plains, hills, and valleys, and experiences a humid subtropical climate with an average annual rainfall of about 3,500 mm (Mishra, 2014), which supports intensive agricultural activities. Major crops include rice, cashew nut, and coconut, with farmers predominantly relying on traditional agricultural practices. However, issues such as soil erosion, nutrient depletion, and declining soil fertility have emerged due to both natural factors and anthropogenic interventions (Rupa & Rejani, 2013). To assess the impact of agricultural practices on soil security, a survey of 50 respondents from various villages was conducted, focusing on farming methods, soil management,

chemical inputs, and irrigation practices (Parasnis, 2013).

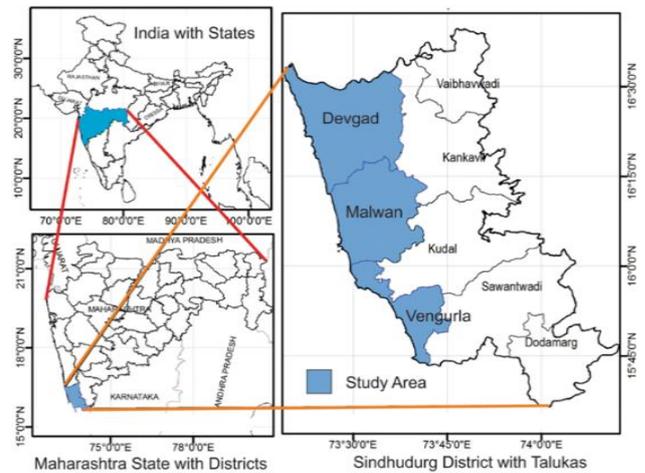


FIG.2 Study Area

1. Soil Types: Sindhudurg exhibits diverse soil types influencing soil security. Laterite soil (40%), rich in iron and aluminium, predominates, followed by red soil (30%) with high iron oxides. Sandy (15%), clay (10%), and fertile alluvial soils (5%) are also present, necessitating soil-specific agricultural management (Tahat et al., 2020).

TABLE.2 Sindudurg Soil Types

Soil Type	Description	Assumed Percentage (%)
Laterite Soil	Rich in iron and aluminum, commonly found in tropical regions.	40%
Red Soil	High in iron oxides, typically found in areas with moderate rainfall.	30%
Sandy Soil	Well-drained soil with larger particles, often found in coastal areas.	15%
Clay Soil	Heavy and nutrient-rich soil with fine particles, prone to waterlogging.	10%
Alluvial Soil	Fertile soil deposited by rivers, found in floodplains.	5%

Dimensions Of Soil Security:

Soil security in Sindhudurg necessitates a holistic, multidimensional approach that extends beyond biophysical attributes to incorporate economic, social, and policy considerations, aligning with principles of sustainable agricultural

development (McBratney et al., 2013). Conventional soil assessment frameworks, including soil quality assessment and land evaluation, primarily emphasize inherent and manageable soil properties, yet their outcomes are substantially shaped by economic, social, and

regulatory contexts (Minasny et al., 2012). Consequently, an integrated framework is required to differentiate between current and optimal soil states while reconciling scientific evaluation with societal priorities (Bünemann et al., 2018).

Contemporary discourse conceptualizes soil security through five interrelated dimensions—capability, condition, capital, connectivity, and codification—commonly referred to as the “five Cs” (Evangelista et al., 2024). Soil capability denotes the inherent potential of soil to perform functions relative to a reference condition, traditionally associated with biomass production and land-use planning (Alex et al., 2019). This capability is influenced by climate, management, and land use, necessitating optimized practices to sustain productivity and ecosystem services (U. Lele & Goswami, 2021; Hasanuzzaman, 2019; Salinas et al., 2020; Patel et al., 2020).

Soil condition, closely linked to soil health, reflects short-term management impacts and is assessed through physical, chemical, and biological indicators, with soil carbon increasingly recognized as an integrative metric (Doran & Parkin, 1996; Doran & Jones, 1996; Lehmann et al., 2020; Verhulst et al., 2018; Sharma et al., 2023). Soil capital frames soil as natural capital essential to ecosystem services and human well-being, despite challenges in economic valuation (Aronson, 2007; Robinson et al., 2009; Robinson & Lebron, 2010; Rani et al., 2019; Stromberger et al., 2015). Connectivity underscores interactions between soil, society, and knowledge systems, emphasizing tenure security, knowledge exchange, and public engagement (Berhanu Gebremedhin, 2003; Hou et al., 2020; Waller, 2019; Eric et al., 2017). Codification highlights the critical role of science-based policies and institutions in promoting soil security amid global challenges (Hannam & Boer, 2002; Mizuta & Grunwald, 2022; Talukdar et al., 2023; Prajapati, 2024)

TABLE. 3 ‘Natural stocks’ of soil refers to the compositional states of the soil that are intrinsic to determine its characteristics

Types of Services	Indicator	Economic Values
Mass Solid	Inorganic Material Mineral stock Nutrient stock Organic Materials Carbon Stocks Organisms	Cost of buildings materials Replacement costs of fertiliser Carbon offsets medicines
Liquid	Soil water content	Irrigation & freshwater supplies
Gas	Soil Air	
Thermal energy Biomass energy	Soil temperature Soil Biomass	In comparison to carbon, with a premium for diversity
Organisation Physico-chemical structure	Soil structure, biological population organisation, and physical-chemical organisation	The value of an enhanced water storage capacity

Impact of Agricultural Practices On Soil Security In Sindhudurg:

The influence of agricultural practices on soil security in Sindhudurg can be evaluated through indicators related to soil health, contamination, moisture status, and structural integrity. Soil health assessments revealed substantial spatial variability in key nutrients,

namely nitrogen (N), phosphorus (P), and potassium (K), across farming systems. Traditional practices generally maintained balanced nutrient levels, whereas intensive agriculture with excessive chemical fertilizer inputs resulted in nutrient imbalances, particularly elevated phosphorus and reduced nitrogen, indicating long-term sustainability risks.

TABLE.4 Impact of Agricultural Practices on Soil Security in Sindhudurg

Indicator	Chemical Fertilizer Use	Organic Farming	Conventional Tillage	Conservation Methods
Soil pH	5.6	6.2	5.8	6
Organic Matter Content	2.50%	4.00%	3.00%	3.80%
Soil Erosion Rate tons/ha/year	12	5	10	4
Nitrogen Level (kg/ha)	120	90	110	95
Phosphorus Level (kg/ha)	45	35	40	37
Potassium Level (kg/ha)	80	70	75	72
Soil Moisture Content (%)	20%	25%	22%	24%

Soil organic matter (SOM) varied significantly with management practices. Organic farming systems exhibited higher SOM levels (3–5%), while conventional systems frequently recorded values below 2%. Chemical fertilizer application was associated with lower organic matter (2.5%), whereas organic farming showed the highest SOM content (4%), supporting improved soil structure and nutrient availability.

Soil erosion posed a major concern in monoculture systems, with annual losses of approximately 20 t ha⁻¹, compared to about 10 t ha⁻¹ under diversified systems. Erosion rates were higher under chemical fertilizer use (12) and lowest under organic (5) and conservation practices (4).

Fertilizer type and tillage strongly influenced soil pH, with conventional systems

exhibiting acidification (pH < 5.5), while organic and conservation practices maintained near-neutral conditions (pH 6.2 and 6). Chemically managed plots showed elevated pesticide residues and higher cadmium (Cd) and lead (Pb) concentrations. Organic and conservation practices improved soil moisture (25%), aggregation, reduced compaction, and maintained balanced nutrients (N: 95 kg ha⁻¹, P: 37 kg ha⁻¹, K: 72 kg ha⁻¹), indicating enhanced soil security.

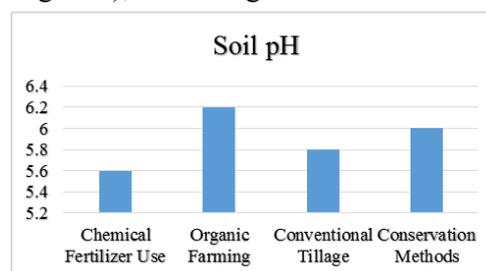


FIG.3 Soil PH

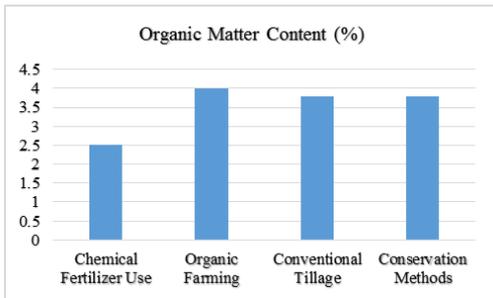


FIG.4 Organic Matter Content

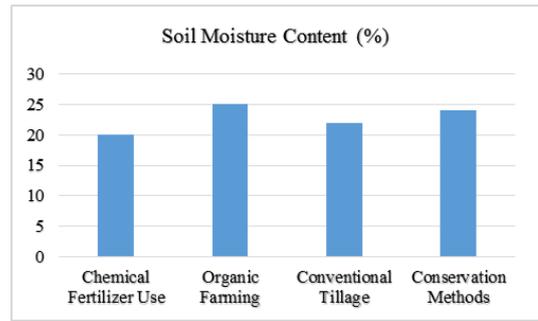


FIG.8 Soil Moisture Content

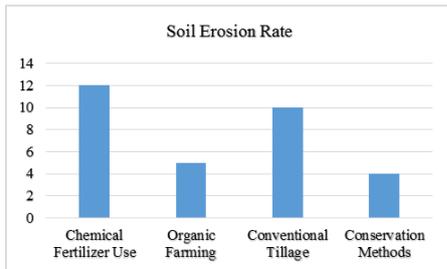


FIG. Soil Erosion Rate

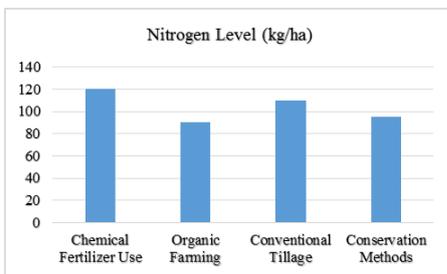


FIG.5 Nitrogen Level

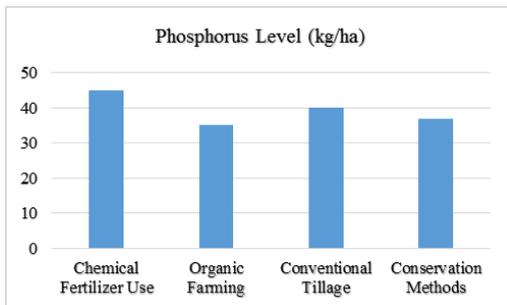


FIG.6 Phosphorous Level

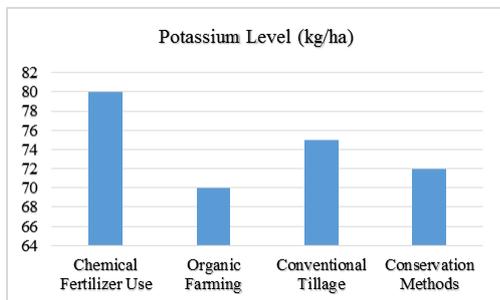


FIG.7 Potassium Level

6. Results And Discussion

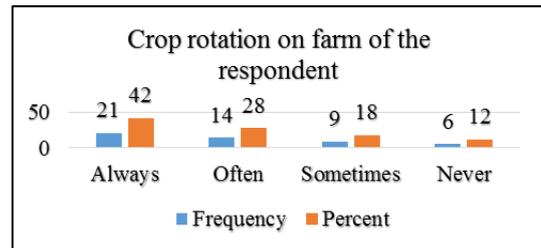


FIG.9 Crop Rotation On Farm of the Respondent

The results provide key insights into agricultural practices and soil management awareness among respondents. Crop rotation is widely adopted (Fig. 9), with 42% of farmers always practicing it and 28% using it frequently, indicating broad recognition of its benefits for soil fertility, pest management, and crop productivity. However, the 12% who never adopt crop rotation suggest persistent constraints that may compromise long-term soil health. Fertilizer use patterns (Fig. 10) show a strong dependence on chemical fertilizers, used exclusively by 42% of respondents, raising concerns about nutrient imbalance and soil degradation. Although 30% employ a combined approach and 22% rely solely on organic inputs, these trends indicate only a gradual transition toward sustainable nutrient management.

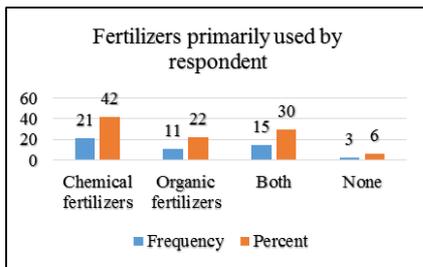


FIG.10 Fertilizers Primarily Used by Respondent

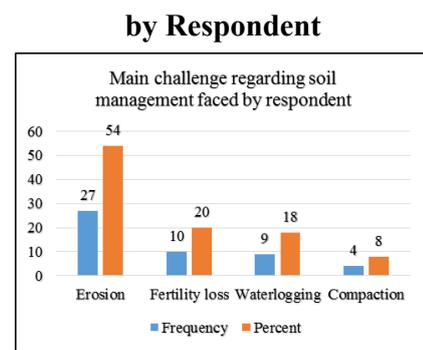


FIG.15 Main Challenge Regarding Soil Management

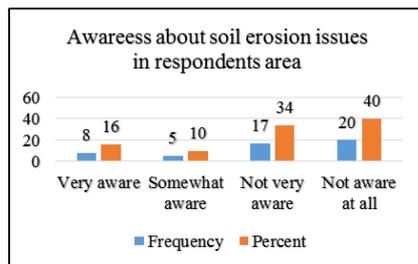


FIG.11 Awareness About Soil Erosion Issues in Respondent’s Area

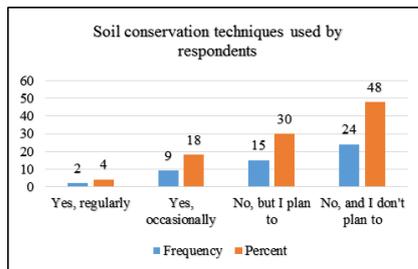


FIG.12 Soil Conservation Techniques Used by Respondents

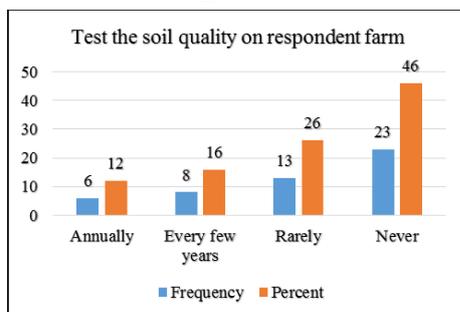


FIG.13 Test The Soil Quality On Respondent Farm

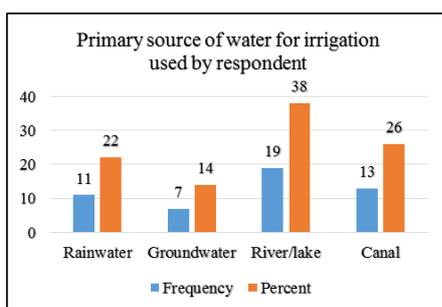


FIG.14 Primary Source of Water for Irrigation Used

Faced by Respondent: Awareness of soil erosion is notably low (Fig. 11), with 74% of respondents reporting minimal or no awareness, which likely limits the adoption of conservation measures. Consistently, soil conservation practices remain limited (Fig. 12), as only 4% use them regularly. Soil quality monitoring is inadequate (Fig. 13), with 46% never testing their soil, restricting informed management decisions. Irrigation practices (Fig. 14) reflect reliance on diverse water sources, while soil erosion remains the dominant challenge (Fig. 15), affecting 54% of respondents.

Conclusion:

Soil security is central to environmental sustainability, supporting ecosystem services, climate regulation, water security, and food production. This study demonstrates that agricultural practices in Sindhudurg strongly influence soil health and long-term productivity, highlighting the need for an integrated, risk-based soil security framework incorporating capability, condition, capital, connectivity, and codification to guide sustainable agricultural management

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