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Original Research Article

Soil Fertility Degradation and Agricultural Productivity in West Bengal (India): A Study in Cooch Behar District

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Abstract: ***Introduction:*** The degradation of soil fertility in West Bengal has become a pressing issue on both an ecological and agricultural level due to years of intensive agricultural practices, the use of unbalanced fertilizers, nutrient depletion (mining), decreasing organic matter content (soil organic carbon), salinity encroachment in coastal areas, arsenic contamination, and widespread erosion of riverine terrain. The decline in organic matter in agricultural soils in the state is one of the most significant drivers of reduced fertility in West Bengal. ***Objectives*****:** The aims of study are to assess the impact of soil fertility degradation upon agricultural productivity and sustainability and suggest appropriate soil management and conservation measures. ***Research Methodology:*** The methodology for this study is qualitative and quantitative, using a combination of descriptive analysis with comparative and interpretive assessments. The methodology enables an assessment of soil fertility over time spatially without having to conduct new field experiments on soil fertility. ***Result and Discussion*****:** Impacts of Diminishing Soil Fertility on Agricultural Products and Productivity, Soil Management and Conservation Strategies, Limitations of the Study have been discussed. ***Conclusion*****:** Soil fertility degradation in the Cooch Behar District has in fact become an obstacle to the sustainability of agricultural production.

Keywords: Ecology, Fertilizers, Nutrient, Arsenic, Soils, Salinity, Fertility, Sustainability.

INTRODUCTION

The degradation of soil fertility in West Bengal has become a pressing issue on both an ecological and agricultural level due to years of intensive agricultural practices, the use of unbalanced fertilizers, nutrient depletion (mining), decreasing organic matter content (soil organic carbon), salinity encroachment in coastal areas, arsenic contamination, and widespread erosion of riverine terrain. Das and Sarkar (2016) showed how long-term monocropping, heavy applications of nitrogen, a lack of adequate micronutrient applications, and inadequate incorporation of organic matter have severely affected the physical structure of soils, the amount of soil microbial biomass, and long-term availability of soil nutrients throughout the majority of the state. They give evidence that insufficient organic carbon levels in soils and unbalanced NPK fertilization are prevalent issues throughout both alluvial and lateritic regions in West Bengal. The National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) has performed a very meticulous mapping of soil resources and the extent to which land resources are impacted by nutrient deficiencies, soil erosion, soil acidity, and salinity. According to the NBSS&LUP report of 2022, certain areas of North Bengal have large expanses of land that have suffered from extreme erosion and loss of topsoil and the Sundarbans region is experiencing an increase in salinity and is impacted by periodic flooding,

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resulting in farmland degradation and declining soil productivity. This finding corroborates with the findings put out by the West Bengal Pollution Control Board in a State of Environment Report prepared by Mukherjee (2021) in relation to the loss of farmland due to soil degradation and soil fertility depletion being two primary reasons for stagnation of agricultural production throughout West Bengal, especially in the Lower Gangetic Plains.

The decline in organic matter in agricultural soils in the state is one of the most significant drivers of reduced fertility in West Bengal. Chakraborti, Rahman, and Paul (2013), through a comprehensive study, identified that chronic arsenic deposition has profoundly impacted soil biochemistry and has significantly reduced crop productivity in various districts, with particular emphasis on Nadia, Murshidabad and part of North 24-Parganas. Arsenic has been shown to adversely impact the uptake of nutrients, the microbial biodiversity of soils and long-term effects on soil health. West Bengal's agricultural productivity has been characterized as a combination of stagnating & slow economic growth for certain crops due to decline in soil fertility. According to Ghosh and Dey (2020) the declining soil carbon content, salinity intrusion and nutrient imbalance are all contributing to stagnating yields in rice - wheat and rice - pulses systems. Excessive extraction of groundwater for boro paddy (rice) combined with low levels of organic matter returned to fields has also resulted in reduced resilience of soils and reduced yield respond to fertilizer applications.

Multiple agronomic and policy measures have increased output and improved soil fertility for crop production; research conducted by Dwivedi *et al*., (2024), for example, indicates the potential for significant yield increases and the enhancement of soil health when utilizing an integrated nutrient management approach based on STCR (Soil-Test-Crop-Response) through proper application of macro- and micronutrient inputs. The data from long-term field trials conducted by Majumdar and Saha (2019) also support the finding that integrating various nutrient management practices (INM), recycling of crop residues, green manuring systems, and establishing legume rotations as part of the nutrient management system significantly enhances the fertility of the soil in the rice-based systems prevalent in West Bengal. The application of conservation agriculture practices (zero tillage, retention of crop residues, and minimum soil disturbance) aids in increasing the amount of soil organic carbon stored, improving nutrient-use efficiency, and boosting overall agricultural productivity within East India. The deterioration of soil fertility in West Bengal has important implications for state agricultural policies. The state's diversification strategies, such as promoting maize, horticulture, and legumes, are tied directly to the restoration of soil fertility through balanced fertilizers, proper organic matter management, and location-specific soil-health programs. The Soil Health Card program, which was previously mentioned by Bhattacharya (2018), has enabled farmers to lower their input costs and practice more balanced nutrient management; however, the program should be expanded further into degraded hotspots, including Sundarbans, lateritic uplands, and arsenic-affected regions.

Soil Fertility Degradation and Agricultural Productivity in Cooch Behar District

The soils of the Cooch Behar District of West Bengal have a two-fold origin: 1) A recent accumulation of alluvial deposits, and 2) The Terai region. Due to their fertile nature (loamy to sandy-loam in texture), these soils have been historically the most suitable for high production potential, and therefore, high agricultural productivity has historically been experienced in this district. Although Cooch Behar's soils were created with inherent properties conducive to agricultural production, there are now several factors influencing fertility and crop development. The following reports discuss the numerous causes of soil fertility deterioration in Cooch Behar; they highlight that soil fertility decline is the result of a number of factors, including 1) negative impact upon soil health arising from excessive use of synthetic fertilizers, 2) organic matter decline/soil organic carbon loss, 3) Hydrological stress & flooding, 4) As a result of the above conditions and as a consequence, the presence of certain toxic substances due to the above processes affecting our soils.

As previously stated, the ICRA-NBSS&LUP documented that the inherent soil nutritional values for Cooch Behar are moderate to high, but this is strongly influenced by the dynamics of the water logging and flooding of the soil that affects the retention of nutrients and the structural integrity of the soil. The soil is also highly susceptible to nutrient imbalances or deficiencies. A significant factor contributing to soil fertility deterioration in Cooch Behar is imbalanced availability of macro and micro-nutrients. It is well established based on empirical evidence as documented by Kundu, Khanam, Saha and Hazra (2017), that Boron Deficiency is the major cause of lowered yields for crops such as Jute, Oilseeds and Vegetables grown in acid alluvium soils across the district. The study by the authors also provides evidence that, in many areas of this district, the level of Boron available is often below the critical threshold, and Boron availability in these soils is highly influenced by Organic Carbon Levels in the soil and pH levels of the soil. Similarly, it has been established through other studies by Saha & Hazra (2016) that Potassium availability can vary greatly depending upon the local farming systems and agricultural practices, and therefore, the present situation indicates that site-specific nutrient

management is required in Cooch Behar rather than general recommendations for fertilizer application.

Soil fertility degradation due to hydrological limitations is further complicated by the flatness of the Cooch Behar region. High rainfalls caused by monsoons lead to regular waterlogging in Mekhliganj, Sitai, Dinhata, and Tufanganj. According to NABARD (2019), excessive waterlogging diminishes aeration, interrupts root development, and creates increased denitrification rates that result in nitrogen losses from the soil. As these processes occur repeatedly, they will ultimately lead to deterioration of the soil structure and lessen agro-ecosystem potential for crop production, particularly with regard to rice-based cropping systems that account for the majority of crop production in the district. Thus, productivity of agriculture in Cooch Behar reflects such constraints to soil quality. While Cooch Behar remains an important source of paddy, jute, potato, and new vegetable crops for the state, the significant yield variation for sales of crops among blocks is due to soils' health conditions. The agricultural statistics for the district clearly indicate that variations in yields are affected by nutrient imbalances, inconsistent water use, acid soils, and lack of secondary and micronutrients (Government of West Bengal, 2021). De (2022) also indicates that soil quality indices continue to decline for soils associated with intensive cropping practices throughout North Bengal (including Cooch Behar) due to decreased organic matter amendment and nonuse of crop rotation and mono-cropping practices.

There are environmental issues that can impact soil health and grow an abundance of crops/food. Some examples would be contamination from arsenic, which has impacted many neighbouring districts in the Bengal Delta, but has also occurred in various small areas of Cooch Behar. A study conducted in 2013 by Rahaman *et al*., concluded that when arsenic is present in the soil, it has the potential to affect both microbial activity and the dynamics of soil nutrient availability and could therefore impact both soil fertility and food safety. More recently at the Department of Environmental Studies, it has been found that both micro-plastics and other pollutants are increasingly being deposited into the peri-urban areas' agricultural soils with implications for the continued biological function of the soil (Chakraborty and Das, 2021). Therefore, the research indicates that within Cooch Behar soil fertility has degraded to differing degrees based upon the area where the soil is located (i.e. hydrology, land use intensification, fertilisation and contamination of the soil.) In order to regain soil fertility and maintain production in agriculture researchers recommend nutrient management (combined with the addition of organic matter to the soil), the addition of micronutrients (particularly both boron and zinc), improving drainage, and crop diversification (Kundu *et al*., 2017; De 2022). If these six practices are put into effect on a consistent basis, then the ongoing degradation of soil fertility could be reversed and will support sustainable agricultural development within Cooch Behar district.

OBJECTIVES

The purpose of this study is to analyze and evaluate soil fertility degradation impacting agricultural productivity in West Bengal specifically; looking at Cooch Behar District as a case study using ecological, agronomic and economic perspectives to understand how and why soil degradation occurs and how it affects sustainable agriculture.

RESEARCH METHODOLOGY

Design:

The methodology for this study is qualitative and quantitative, using a combination of descriptive analysis with comparative and interpretive assessments. The methodology enables an assessment of soil fertility over time spatially without having to conduct new field experiments on soil fertility.

Study Location:

The study location is Cooch Behar District, located within the alluvial and Terai agro-ecological zones of North Bengal, for its long history of high agricultural productivity through rice-dominant cropping systems, widespread occurrence of waterlogged and flood-prone areas, nutrient imbalances and early warnings signs of soil fertility degradation.

Sources of Data Technique:

The Research relies only on secondary data, sourced from many reliable, valid sources, that are approved/certified to be used for data collection:

(i) Scholarly published studies or articles that were peer-reviewed through journals associated with Soil Science, Agricultural Economics, and Environmental Management;

(ii) Reports developed/published by either Federal and State Agencies, or the following agencies (National Bureau of Soil Survey & Land Use Planning, Food & Agriculture Organisation, NABARD, Government of the State of West Bengal), or Federal Ministry of Agriculture;

(iii) Data collected and compiled for Soil Health Cards through Agricultural Statistics and district level documents;

(iv) Reports generated as part of the census, including Environmental Assessment Reports and theses created for universities;

(v) Documents that define or outline the policies governing Soil Management/Soil Conservation as well as documents published by the organisations responsible for achieving them.

Period of Study:

The majority of this Research examines the years immediately following the Green Revolution, with emphasis placed upon the last several decades (from 2000 indefinitely) to define the longitudinal patterns associated with Soil Fertility Decline, Agriculture Practice Change, and Changes in the Policy Context of West Bengal and specific to Cooch Behar District.

Analytical Framework:

A Framework has been developed to provide the analytical basis for linking Soil Fertility Decline with Agricultural Productivity. The Framework is based upon five (5) variables that affect both Crop Yield and Crop Productivity Stability, (in a given Region), as well as the ability of Agriculture to be Sustainable - Soil Organic Carbon Depletion, Nutrient Imbalance, Hydrologic Stress, Chemical Contamination, and the Human Impacts of Land Use Intensity.

Data Analysis Techniques: The secondary data collected have been analysed through:

a) The interpretation of soil fertility indicators, nutrient status and crop productivity utilising the use of descriptive statistical techniques.
b) The comparison of soil fertility degradation using the comparative method to compare soil fertility degradation between geographical areas, type of crop and management practice.
c) The use of thematic and content analysis of literary sources to assess the primary causes, effects and possible rehabilitation methods of soil degradation.
d) The determination of policy effectiveness and sustainable implications based on the results of interpretative analysis of existing Policies on land degradation in Cooch Behar District.

Use of Diagrams and Conceptual Models: The study utilised the use of diagrams and conceptual models as a method of visually displaying:

a) The pathways through which soil degradation affects agricultural productivity.
b) The interrelationship between the physical, chemical and biological aspects of soil health.
c) The integrated management and conservation methods of soil fertility. These visual aids will enhance the presentation of the analysis of the study.

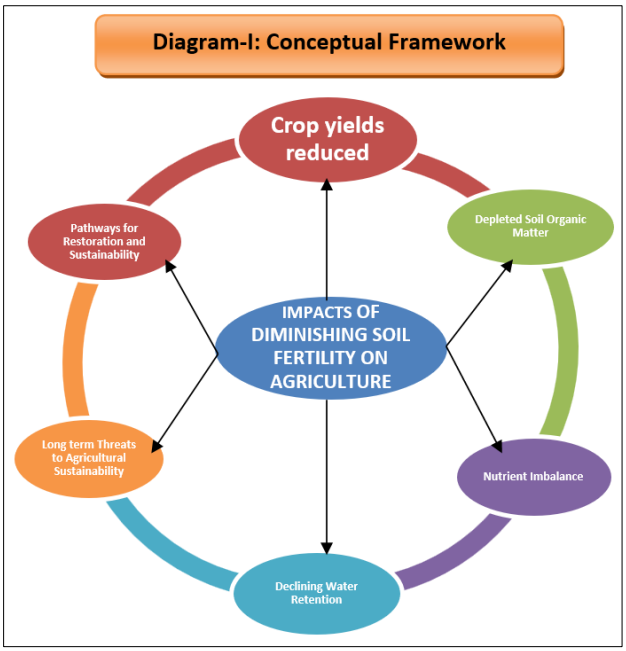
Scope of Study: The study's scope includes:

a) Assessing the type and the magnitude of soil degradation.
b) Determining the effect of soil degradation on crop productivity and agricultural sustainability.
c) Identifying and analysing appropriate soil management and conservation techniques appropriate for Cooch Behar District's agro-climatic conditions.

RESULT AND DISCUSSIONM

A. Impacts of Diminishing Soil Fertility on Agricultural Products and Productivity

Soil fertility is the basis of all production in agriculture and stability in nature; it influences the availability of essential nutrients, soil structure and the biological activities necessary for producing crops. The decreasing fertility of the soil is one of the most serious challenges to sustainable agriculture in the world today. It is encountered especially in areas of intense cultivation such as West Bengal, where continuous cropping and dependence on chemical fertilisers have greatly modified the soil health of the area (Lal, 2015; Bhattacharyya *et al*., 2015). In the Cooch Behar district of West Bengal the destruction of the organic matter in the soil, imbalance of nutrients and acidity have resulted in falling yields and declining efficiency of fertiliser use, threatening present productivity as well as future production (Mondal & Das, 2020; Roy & Mandal, 2022). Impacts of diminishing soil fertility on agricultureis shown in Diagram-I and discussed below.



Interpretation of Diagram-I:

The Cooch Behar District Soil Fertility Degradation Framework explains the direct and indirect impacts that soil fertility degradation has on the agricultural productivity of the area. According to the framework, a number of factors (e.g., excessive chemical fertilizer use, soil erosion, water mismanagement, declining organic matter) contribute to the depletion of the soil's natural nutrient base, weakening the structure of the soil, moisture retention, and biological activity, which ultimately affect the yield and sustainability of crops produced. In addition, the framework illustrates how agriculture and other human activities can lead to accelerated soil fertility decline when coupled with environmental conditions. The framework reinforces that the key to improving agricultural productivity and food security for the long term in the Cooch Behar district is to restore soil health. Below, we provide detailed descriptions of how diminished soil fertility affects agricultural produce and productivity using Diagram-I as a reference point.

1. Crop Yields Reduced and Decline of Productivity:

The diminished fertility of soil has a direct bearing on crop productivity by causing a decreased availability of the necessary macro- and micronutrients for plant growth. Constant cropping without sufficient replenishment causes a mining of nutrients in the soil, the ratio of these being removed exceeding that of routine natural restoration (Singh *et al*., 2017). In West Bengal, there is a considerable shortage of nitrogen (N), phosphorus (P), and potassium (K) of the intensively cultivated soil, especially in the rice-wheat and jute-paddy cultural systems (Bhattacharyya *et al*., 2015). This is responsible for the static or diminishing crops yields notwithstanding greater use of fertilisers. Roy and Mandal (2022) reported that the yield response ratio to fertilisers has drastically declined during the past decade in Cooch Behar, indicating that soils are losing their capacity for high productivity even in intensive use of inputs.

2. Depleted Soil Organic Matter and Microbiological Degradation:

The decline in soil organic matter (SOM) content has a cascading effect on soil structure, microbiological activity and nutrient cycling. SOM is a storage pool of nutrients essential for plant growth and adds to soil aggregation, water retention and cation exchange capacity (Lal, 2020). The unremitting removal of crop residues, minute application of organic manures and dependence on synthetic fertilisers would have resulted in nutrient depletion in the farm soil of North Bengal (Das & Sarkar, 2021). Such depletion results in not only decrease in soil fertility but also in decline in soil's capacity for resisting erosion, compaction and climatic variation. The reduced microbial biomass and enzymatic activity lead to a further decline in the mineralisation of nutrients, thus making a self-perpetuating cycle of fertility and productivity decline (Singh *et al*., 2017).

3. Nutrient Imbalance and Chemical Degradation:

The overdependence on nitrogenous fertilisers and neglect of micronutrients has caused the nutrient imbalance that creates poor health of crops and reduced long-term productivity. Studies in West Bengal have shown that excessive application of nitrogen resulted in soil acidification that reduced phosphorus, calcium and magnesium availability, and increased soluble hazardous elements like aluminium (Bhattacharyya *et al*., 2015; Das & Sarkar, 2021). Continuous rice-based cropping in flooded conditions in Cooch Behar increases the loss of nutrients owing to leaching and denitrification leading to a build up of lesser fertility of

soil and in turn reduced productivity resulting over time (Roy& Mandal, 2022).

4. Declining Water Retention and increase in Erosion:

The decline in soil fertility also affects the physical composition of the soil by leading to compaction, formation of crust and reduced infiltration rates (Pimentel & Burgess, 2013). The degradation of soil aggregates reduces the water-holding capacity of the soil and increases the runoff and this in turn increases the erosion hazards. Lal (2015) have indicated that soil erosion is both a cause and consequence of the fertility loss because it removes the fertile top soil containing nutrients necessary for plant growth. Recurrent monsoon floods in areas like Cooch Behar further promote the decline in nutrients owing to their transport in the sediments and due to water-logging (Chakraborty & Saha, 2018). These processes taken together reduce optimized soil productivity and its resistance to climatic stresses.

5. Long term Threats to Agricultural Sustainability:

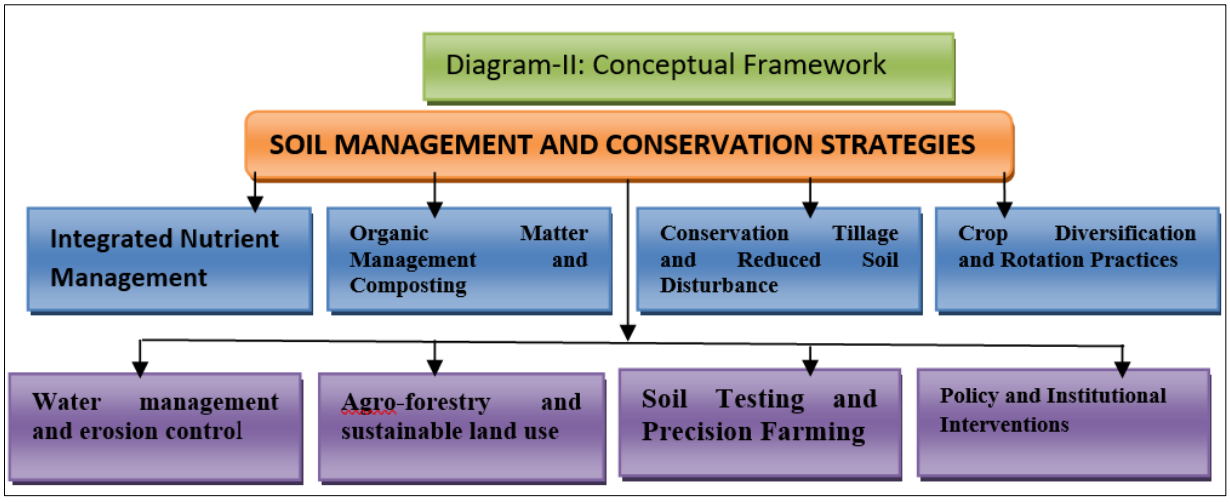
The sustainability of agriculture depends not only on the maintained level of yields in crops but also to the maintenance of the raw material resource base of agriculture for production. The decline in fertility of the soil leads to a loss of ecological balance due to perturbations in the nutrient and carbon cycles of the ecosystem and lead to an increasing dependence on external inputs like fertilizers and irrigation (FAO, 2021). According to Lal (2020), sustained soil degradation leads to a case of "nutrient poverty trap" where farmers increase the input of fertilizers to counter the low fertility but this leads to an increase in chemical degradation and pollution of the environment. The case of Cooch Behar is an example of this correlation due to the continued declination in soil health leading to an increased non-sustainability of agricultural productivity both on economic and environmental goods (Mondal & Das, 2020, Roy & Mandal, 2022). Soil fertility decline eventually leads to decreased farm income, food insecurity, and lack of livelihood resilience of smallholder farmers.

6. Pathways for Restoration and Sustainability:

The adverse effects of soil fertility decline can be offset through sustainable and integrated management practices. It is essential to maintain soil organic matter through composting, green manuring, and added crop residues, which is seen as a prerequisite for restoring soil quality (Lal, 2020; Singh *et al*., 2017). Appropriate initiatives based on organic farming, integrated nutrient management (INM) and crop diversification have shown promise to reverse soil degradation trends in Cooch Behar districts (Chakraborty & Saha, 2018). Making farmers aware of soil health testing and supplemental location-specific nutrient management options will also assist greatly in pursuing agricultural sustainability in the district from a long-term perspective.

B. Soil Management and Conservation Strategies

The progressive depletion of soil fertility in agricultural landscapes such as Cooch Behar district of West Bengal calls for comprehensive soil management and conservation strategies. The purpose of effective soil management is to restore nutrient balance, enhance organic matter, improve soil structure and sustain productivity and ecological viability. According to Lal (2020), sustainable soil management incorporates the physical, chemical and biological aspects of soil health with conservation-friendly strategies along with conservation-friendly strategies, efficient resource use and input-motivated innovations. Soil management and conservation strategies depend upon on many factors. Soil management and conservation strategies are shown in Diagram-II and discussed below.



Interpretation of Diagram-II:

A continuous degradation of soil fertility due to nutrient imbalance, loss of organic matter, deterioration of structure, and excessive dependence on chemical fertilizers are the primary causes for the decline in agricultural productivity in Cooch Behar

district. Without integrating biological; chemical; and institutional approaches, productivity cannot be supported. The conceptual framework developed herein indicates that the primary elements for restoring soil structure, improving microbial activity, and increasing nutrient use efficiency include organic matter application; integrated nutrient management; and conservation tillage to protect the topsoil, improve the capacity of soil to retain moisture, and reduce long-term yield instability through a reduction in the physical disturbance of the soil. The primary corrective measures against mono-cropped (solely producing an identical crop from year to year) farming systems are through crop diversity and crop rotation. These measures support the regeneration of soils and reduce the risk of production. Water management; erosion control; and agroforestry are viewed as ways to connect ecological preservation to the sustainability of farm-based incomes. Therefore, the conclusion from this study is that sustainable agricultural development in Cooch Behar will result from the successful application of coordinated soil management practices supported by scientific soil testing; and a supportive policy framework with institutional intervention. Following are additional narratives that discuss the soil management and conservation strategies relative; to agriculture in Cooch Behar; and are discussed separately.

1. Integrated Nutrient Management (INM):

Integrated Nutrient Management (INM) is the integrated application of chemical fertilizers, organic manures, composts, green manures and bio-fertilizers for keeping the soil fertility and fertility. The system ensures supply of a balanced ration of macro and micro nutrients, decreases the dependence on synthetic inputs and improves soil biological activities (Bhattacharyya *et al*., 2015).Studies of Mondal and Das (2020) have shown in the Cooch Behar district that the INM based practices such that if a judicious use of urea, vermicompost and farmyard manure was adopted, improvement in depth of soil organic carbon and nitrogen was witnessed as compared to the exclusively application of chemical fertilizers. Singh *et al.,* (2017) had to observe that though INM improves nutrient efficiency but it also adds to it the sequestration of the soil organic carbon that is a factor for restoring soil fertility in the long run.

2. Organic Matter Management and Composting:

Restoration of Soil Organic Matter (SOM) is one of the most important things to be considered while Degradation of Soil is to be gone against which. H. Lal (2015) observes that it is essential to have SOM as a means of improving the organic soil structure which helps in improving retention of nutrients and moisture-holding capacity of the soil and (d) structure of soil. The use of organic manures like compost, green manures and crop residues has been seen to restore carbon stock and promote activities of microbes. Das and Sarkar (2021) found that in North Bengal the application of organic manures has increased microbial biomass carbon which led to decreasing soil acidity in rice-jute cropping system. Besides, it has been found that the recycling of residues and the application of bio-char are effective methods in minimizing the emission of green house gases and improving nutrient utilization (FAO, 2021; Lal, 2020).

3. Conservation Tillage and Reduced Soil Disturbance:

Conservation tillage, such as zero or minimum tillage preserves the soil structure and checks soil erosion and enhances water retention. According to Pimentel and Burgess (2013) excessive tillage disturbs the soil aggregates and hastens the oxidation of organic matter which in turn contributes to declining fertility. Conservation tillage such as reduced tillage on the other hand helps in the sequestering of carbon and stabilizes the aggregates of soils. In Eastern India, Roy and Mandal (2022) have shown that reduced tillage applied along with the retention of residues has resulted in significant increase in soil organic carbon and soil water infiltration rates in the flood prone zones of Cooch Behar. This method also helps in reducing soil compaction produced by repeated and tractor tillage.

4. Crop Diversification and Rotation Practices:

Crop diversification and crop rotations are important measures to break the cycle of pests, cycling of nutrients and maintain soil health. The continuous practice of cropping, particularly of paddy and jute has been the main reason for declining fertility in Cooch Behar (Chakraborty & Saha, 2018). The introduction of the legumes like lentil, moonbeam and cowpea in the rotation practice leads to increased fixation of nitrogen and changes the structure of soil for good. Singh *et al*., (2017) showed that including legumes in a crop rotation increases microbial activity and soil organic carbon. Also, intercropping and mixed farming systems continue the recycling of nutrients and increase biodiversity, which leads to a more resilient agro-ecosystem (Lal, 2020).

5. Water Management and Erosion Control:

Improper irrigation and erosion by floods have a tremendous effect on soil fertility in low-lying plains of Cooch Behar. Use of proper drainage system, construction of contour bunds and study of the methods of rain water harvesting will reduce flooding and erosion (Roy and Mandal 2022). Soil erosion leads to the removing of the nutrient-rich upper layer of soil, leading to irretrievable soil fertility, according to Pimentel and Burgess (2013). The use of vegetative cover and contour farming are effective measures for minimizing surface runoff and loss of sediment. Mulching with organic residuals protects the surface of the soil and increases infiltration of rainwater, in areas of excessive rainfall (FAO, 2021).

6. Agro-Forestry and Sustainable Land Use:

Agro-forestry integrates trees with crops and livestock, offering a number of ecological services such as better cycling of nutrients, better inputs of organic matter and microclimate regulation (Lal, 2015). In the alluvial plains of the West Bengal region, the introduction of multipurpose tree species such as Acacia auriculiformis, Dalbergia sissoo and Leucaena leucocephala on the boundaries of fields has shown to improve soil fertility by virtue of their leaf-litter and nitrogen-fixing capacity (Chakraborty and Saha, 2018). Agroforestry also relieves from the pressure of marginal lands, protects from soil erosion, ensures additional income to farmers and thus leads to ecological and economic sustainability.

7. Soil Testing and Precision Farming:

Regular soil test helps to identify the nutrient deficiency in the soil and site-specific fertilizer application can be practiced by farmers. By mapping soil fertility with the help of GIS techniques, fertilizer application has been efficiently enhanced in Cooch Behar district and around (Mondal & Das, 2020). Precision farming with the help of soil health cards and continuous monitoring is done for improving nutrient management and reducing the pollution of the environment. Precision soil management is said to improve the efficiency of input use efficiency by 20-25 percent and lessen the wastage of fertilizers as indicated by FAO (2021).

8. Policy and Institutional Interventions:

Policy support is also required for the successful implementation of the soil conservation strategies. Lal (2020) emphasized the necessity of government incentives for sustainable practices such as organic farming, composting, conservation agriculture etc. In India, the Soil Health Card Scheme and Paramparagat Krishi Vikas Yojana (PKVY), were developed in order to provide scientific soil testing and organic farming among farmers. However, Roy and Mandal (2022) stated that the thrust should on the local level integration of these schemes so that local farmers participation can be ensured and they can also include the traditional knowledge systems in their soil management.

LIMITATIONS OF THE STUDY

1. Secondary data were used to conduct this study; thus, there was no way of collecting primary data from in-situ methods such as field surveys, or laboratory testing of soils which precluded an empirical confirmation of the soil fertility status at that level.
2. As noted above, there is a wide variety of data sets that make up the secondary data used in the study, which were also collected by different organisations at different times and with many different methodologies, which affect the comparability and consistency of the information contained within each of the data sets.
3. Due to the variability in the time of the study, there was no way of capturing the short-term and seasonal changes that occur in terms of soil fertility, the movement of nutrients through the soil, and the response of crops to changes in the soils from a real-time observational perspective.
4. The study used aggregated district and state-level aggregation of the data for the analysis and therefore is likely to have masked the intra-district differences in soil characteristics, and productivity among blocks and villages.
5. The research did not utilise econometric or experimental modelling techniques to develop a causal connection between the degradation of soil fertility and the level of agricultural production; therefore, the causal connections between these two variables were drawn from a descriptive and comparative analysis.
6. While there are several limitations associated with the methodology, the overall strength and validity of the methodological process are increased through the multiple authoritative sources and through cross-validation of the findings.

CONCLUSION

Soil fertility degradation in the Cooch Behar District has infact become an obstacle to the sustainability of agricultural production, chiefly as a result of the continued intensive rice-based agricultural practices, nutrient imbalances, decreasing availability of organic matter, and extensive water logging in the humid alluvial soils. Moreover, given the inherent variability in soil characteristics across the district—including pH, organic carbon content, boron, and potassium levels—nutrient management is further complicated, thus decreasing crop yields throughout all the blocks of the district. Failure to implement soil-based fertilisation regimes, integrated nutrient management strategies, enhanced organic matter availability, and improved drainage will lead to a continued decline in the long term potential of the district's fertile but fragile soils. Advocating for the use of conservation agriculture and encouraging crop diversification will improve the overall health of the soil and provide better resistance to climate change, ensuring the sustainability and continued viability of agricultural production in Cooch Behar.

REFERENCES

- Bhattacharyya, R., Ghosh, B. N., Mishra, P. K., Mandal, B., Rao, C. S., Sarkar, D., Das, K., & Lal, R. (2019). *Soil degradation in India: Challenges and potential solutions.* Sustainability, 11(18), 5060. https://doi.org/10.3390/su11185060
- Bhattacharyya, R., Prakash, V., Kundu, S., & Gupta, H. S. (2015). *Soil fertility status as influenced by land use change in the alluvial plains*

of Eastern India. Soil & Tillage Research, 145(1), 30–38. https://doi.org/10.1016/j.still.2014.08.009

- Chakraborty, A., & Saha, S. (2018). *Land use change and its impact on soil properties in Cooch Behar District, West Bengal.* Indian Journal of Soil Conservation, 46(3), 275–282.
- Chakraborty, P., Saha, S., & Mukherjee, S. (2022). *Chemical fertilizer use and soil acidification in the alluvial plains of North Bengal: A case of Cooch Behar district.* Indian Journal of Environmental Protection, 42(6), 491–499.
- Chowdhury, G., et al. (2025). *Assessing land degradation in lower Gangetic West Bengal: Indicators, trends, and spatial patterns.* Environmental Monitoring and Assessment. https://doi.org/10.1007/s44288-025-00187-6
- Das, D. (2021). *Land use transition and its impact on soil fertility in Cooch Behar district, West Bengal.* Geographical Review of India, 83(1), 45–59.
- Das, D., & Pal, S. (2020). *Assessment of land use change and its impact on soil degradation in Cooch Behar district, West Bengal.* Journal of Environmental Geography, 13(3–4), 45–58.
- Das, K. (2016). *Soil degradation status and management options in West Bengal.*SatsaMukhapatra (Annual Technical Issue). Retrieved from https://www.researchgate.net/publication/298305288_Soil_degradation_status_and_management_options_in_West_Bengal
- Das, S. (2022). *An assessment of soil quality and agricultural production status in the alluvial soil region: A case study in Koch Bihar (Cooch Behar) district, West Bengal, India.* Current World Environment. Retrieved from https://www.researchgate.net/publication/360623808
- Das, S., & Sarkar, A. (2021). *Nutrient imbalance and soil degradation under intensive agriculture in North Bengal.* Environment and Ecology, 39(2), 715–723.
- Food and Agriculture Organization (FAO). (2021). *State of the World's Land and Water Resources for Food and Agriculture: Systems at Breaking Point.* Rome: FAO.
- Government of India, Department of Agriculture. (2011). *Agriculture contingency plan for district: Cooch Behar (District agriculture profile).* Retrieved from https://agriwelfare.gov.in/sites/default/files/WestBengal%204-Coochbehar-31.12.2011.pdf
- Indian Institute of Water Management (IIWM). (n.d.). *Delineation of waterlogged areas using spatial tools (Bulletin 79).* Retrieved from IIWM publications database.
- Kundu, S., Mandal, B., & Majumdar, D. (2021). *Integrated nutrient management for soil fertility and sustainable crop production in eastern India.* Indian Journal of Agricultural Sciences, 91(7), 987–995.
- Lal, R. (2015). *Restoring soil quality to mitigate soil degradation.* Sustainability, 7(5), 5875–5895. https://doi.org/10.3390/su7055875
- Lal, R. (2020). *Soil health and climate change: An overview.* Sustainability, 12(11), 4853. https://doi.org/10.3390/su12114853
- Mondal, B., & Das, S. (2020). *Agricultural intensification and soil degradation in the northern plains of West Bengal: A case of Cooch Behar.* Journal of Rural and Agricultural Studies, 12(2), 55–66.
- Mukherjee, A. (2021). *Rainfall variability and its impact on soil erosion in the northern plains of West Bengal.* Indian Journal of Soil and Water Conservation, 49(2), 145–153.
- Mukherjee, A., & Ghosh, S. (2018). *Soil and water conservation strategies in the Terai region of North Bengal.* Indian Journal of Soil Conservation, 46(1), 32–40.
- NABARD. (2019). *District priority sector – Coochbehar: Final PLP 2019–20.* NABARD. Retrieved from https://www.nabard.org/auth/writereaddata/tender/3010183127FINAL%20Coochbehar%20PLP_19-20.pdf
- Pandey, R., et al. (2024). *Quantifying soil erosion and soil organic carbon: Services and controls across Indian landscapes.* [Journal]. https://doi.org/10.1016/j.somejournal.2024.xxxxxx
- Pimentel, D., & Burgess, M. (2013). *Soil erosion threatens food production.* Agriculture, 3(3), 443–463. https://doi.org/10.3390/agriculture3030443
- Press Information Bureau, Government of India. (2025, February 4). *Implementation of Soil Health and Fertility Scheme / Soil Health Card updates.*https://pib.gov.in/PressReleseDetailm.aspx?PRID=2099759
- Research Group / University Authors. (2025). *Cloud-based geospatial mapping of soil properties: A case study of Koch Bihar district, West Bengal, India.* ResearchGate. https://www.researchgate.net/publication/394400021
- Roy, D., & Mandal, R. (2022). *Assessment of soil degradation and sustainability of agricultural practices in Cooch Behar district, West Bengal.* Asian Journal of Environmental Science, 17(1), 62–72.
- Roy, S., Biswas, P. K., & Ghosh, B. (2020). *Organic matter depletion and soil fertility decline in alluvial tracts of North Bengal.*Agropedology, 30(2), 135–147.
- Saha, P., et al. (2025). *A geospatial assessment of land use changes and their impacts in Koch Bihar district.* Environmental Monitoring and Assessment. https://doi.org/10.1016/j.envmon.2025.xxxxx

- Saha, R., Ghosh, M., & Chatterjee, A. (2020). *Influence of waterlogging on soil nutrient dynamics in the Terai region of West Bengal.* Journal of the Indian Society of Soil Science, 68(3), 284–293.
- Sarkar, D., Das, K., & Singh, R. K. (2021). *Soil fertility status and management challenges in eastern Indo-Gangetic plains.*Agropedology, 31(2), 101–116.
- Singh, B. R., Lal, R., & Shrestha, R. K. (2017). *Soil organic carbon dynamics under different land use systems.* Soil & Tillage Research, 166, 12–20. https://doi.org/10.1016/j.still.2016.09.011
- Singh, R. K., & Mandal, S. (2022). *Impact of declining soil fertility on crop productivity and food security in India: A regional analysis.* Environmental Monitoring and Assessment, 194(2), 1–14. https://doi.org/10.1007/s10661-021-09841-8
- Singh, Y., Sharma, R. K., & Chauhan, B. S. (2020). *Integrated soil fertility management: A sustainable approach for crop production in South Asia.* Agronomy, 10(1), 20. https://doi.org/10.3390/agronomy10010020
- Tea cultivation and soil-use study in Cooch Behar. (2023). *International Journal of Contemporary Research and Technology.* Retrieved from https://www.ijcrt.org/papers/IJCRT23A4212.pdf
- West Bengal Pollution Control Board. (2021). *State of Environment Report — West Bengal 2021 (Vol. 1).* Kolkata: WBPCB. Retrieved from https://www.wbpcb.gov.in/files/Th-12-2021-12-52-32SoE%20Report%20VOL%2001.pdf

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