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Geological Study of Soil Quality Degradation in Jharkhand and Its Management

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ABSTRACT

Soil quality degradation is a significant environmental concern in Jharkhand, India, a region rich in mineral resources and diverse geological formations. The degradation of soil in this area is influenced by both natural geological processes and human activities, such as mining, agriculture, and deforestation. This study aims to explore the geological factors contributing to soil degradation and propose management strategies tailored to the region's unique geological context. The geological diversity of Jharkhand, which includes sedimentary, metamorphic, and igneous rock formations, plays a crucial role in shaping soil properties such as texture, fertility, and erosion susceptibility. This study examines the relationship between soil quality and geological factors such as mineral composition, weathering, erosion, and sedimentation. It highlights how these processes, when exacerbated by human intervention, lead to nutrient depletion, soil erosion, and the loss of soil fertility, thus reducing agricultural productivity. The findings suggest that soil management in Jharkhand must incorporate a geological perspective to address the specific challenges posed by the region's geological setting. The research advocates for geologically informed soil conservation practices, such as terracing, erosion control, and the use of locally appropriate soil amendments. The study emphasizes the importance of sustainable land management programs, including afforestation and community-driven conservation efforts.

Keywords : Geological Study, Soil Quality, Soil Degradation, Jharkhand.

Background of the Study: Jharkhand, located in eastern India, is known for its rich mineral resources and diverse geological formations, including sedimentary, metamorphic, and igneous rocks. This geological diversity significantly influences the region's soil properties, making it prone to varying degrees of soil quality degradation. Soil degradation in Jharkhand is a major environmental challenge, impacting agricultural productivity, water quality, and biodiversity. The region's agriculture heavily relies on soil fertility, and the degradation of soil poses a serious threat to food security and rural livelihoods. Soil quality degradation in Jharkhand

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occurs due to a combination of natural and anthropogenic factors. Naturally, the geological processes such as weathering of rocks, erosion due to the hilly terrain, and the high mineral content in the soil contribute to a depletion of nutrients. Additionally, excessive mining activities, deforestation, and unsustainable agricultural practices, such as monocropping and overuse of chemical fertilizers, exacerbate the degradation process. These human activities disturb the soil's natural balance and accelerate erosion, nutrient loss, and soil compaction. The impact of soil degradation is particularly acute in areas where the geology of the region leads to high susceptibility to erosion, such as in the plateau and hilly regions of the state. Moreover, the region's variable climate, with monsoonal rains followed by dry periods, further aggravates soil erosion and runoff. As a result, large parts of Jharkhand face severe soil erosion, reduced fertility, and a decline in agricultural yields.Despite the growing recognition of soil degradation, comprehensive studies focusing on the geological factors influencing soil quality in Jharkhand remain limited. Therefore, this study aims to investigate the relationship between geological processes and soil quality degradation, offering a framework for region-specific soil management strategies that take into account the unique geological characteristics of Jharkhand.

Soil Quality Degradation in Jharkhand : Soil degradation in India is estimated to be occurring on 147 million hectares (Mha) of land, including 94 Mha from water erosion, 16 Mha from acidification, 14 Mha from flooding, 9 Mha from wind erosion, 6 Mha from salinity, and 7 Mha from a combination of factors. This is extremely serious because India supports 18% of the world's human population and 15% of the world's livestock population, but has only 2.4% of the world's land area (Bhattacharyya et. al. 2015). Soil erosion is directly related to land degradation. Soil is a finite natural land resource created and degraded through both natural and human induced processes. Soil erosion is a naturally occurring process that results in degradation of landforms and particularly wipes out top soil by the natural physical forces such as water and wind (Mandal et. al. 2021). Similarly it is a major issue in Jharkhand a state of diverse geological features. Though geology of a region is directly linked with the soil distribution and quality over a space. Soil mechanics consists of the study of the physical and mechanical properties of uncemented deposits such as clays, silts and sands, and the application of these studies to the solution of civil engineering problems, soil mechanics is able to contribute toward a more complete understanding of certain geological phenomena (Skempton, 1953). Therefore it is very important to understand the geological charecterstics and soil types of this state.

Jharkhand's geology is diverse, with rock formations spanning from the Pre-Cambrian to the Cenozoic era. The region is primarily characterized by Archaean metamorphics, with the Chhotanagpur Gneissic Complex being a prominent feature. This complex includes rocks such as granite gneiss, talc chlorite schist, and calc magnesian schist, often intruded by pegmatite and quartz veins (Mahadevan, 2002). Jharkhand contains sedimentary formations from the Vindhyan and Gondwana Super Groups, along with some igneous rocks. The soil types in the region vary significantly based on geological conditions; red soil is common in the Damodar Valley and Rajmahal areas, while micaceous soil is found in Koderma, Jhumri Telaiya, Barkagaon, and around Mandar Hill. Sandy soil is present in Hazaribagh and Dhanbad, and black soil is found in the Rajmahal area. The state is also rich in mineral resources, with the only emerald deposits in India, as well as significant reserves of iron ore, apatite, cobalt ore, copper ore, granite, graphite, and silver ore. Geologically, the eastern part of the region is dominated by alluvial and Diara land, while the western part features hills, valleys, and undulating

terrain, with quartz and gneisses found in certain locations (Mondal, 2020). This geological diversity plays a crucial role in shaping the region's soil properties and its vulnerability to degradation, highlighting the need for geological consideration in soil management strategies.

Various study has been done in this regard which reveals direct association with the geological dimension of soil quality, soil quality degradation, its causes and interventions for sustainable management of soil in different part of Jharkhand, for example in a study Rai & Paul (2011) find out that Coal mining for an area is an economic activity but may lead to degradation of soil quality. Open-cast coal mining operations involved displacement of a large amount of overburden/rock mass materials to excavate the coal for many purposes. In mining areas, the soils are affected by various coal mining operations i.e. blasting, drilling, storage of overburden dump materials, clearing of land, construction of ancillary facilities and movement of vehicles. Various wastes such as heavy metals, inorganic substances, toxic materials and organic substances are released from different process of coal mining operations.

In a study of different agro climatic zone of Jharkhand Kumar et.al. (2012) have shown that the vertical distribution of physico-chemical properties in soils varies across different topographical zones. Soil pH and calcium carbonate (CaCO3) generally increase with soil depth, while organic carbon decreases with depth. Cation exchange capacity (CEC) tends to be higher in sub-surface layers, particularly where clay content is greater. Research has indicated that soil pH is positively correlated with CaCO3 and negatively with organic carbon. Furthermore, clay content shows a significant positive correlation with both CEC and electrical conductivity (EC). These findings highlight the complex interactions between soil properties in different agro-climatic zones.

In a study Nayak et.al. (2017), found that the cracking clay soils of the Rajmahal Trap, specifically the Jetkumarjari and Jirul Series, are deep, somewhat poorly to moderately well-drained, and silty clay in texture. These soils exhibit cracking characteristics, with pressure faces appearing in subsurface horizons. They are weakly acidic to slightly alkaline, with medium to high cation exchange capacity (CEC) and high base saturation. The mineralogical analysis revealed the dominant presence of low charge di-octahedral smectitic minerals, along with mica, kaolinite, and vermiculite. These soils are developed from the Rajmahal Trap and have a unique mineralogical composition, important for land use planning and soil health management.

Tirkey et al. (2013), studied that maximum soil loss contributed from agricultural lands of Daltonganj watershed of Jharkhand are 10 tonnes/ ha/yr, therefore in these regions soil conservation practices like bunding, terracing, crop rotation, agroforestry and other biological and physical structures must be adopted for mitigating the erosion.

Anthropogenic causes of soil quality degradation in Jharkhand are primarily driven by human activities such as mining, deforestation, agricultural practices, and urbanization. Jharkhand is rich in mineral resources, and extensive mining of coal, iron ore, and other minerals has led to severe soil erosion, loss of topsoil, and contamination from toxic substances like heavy metals. Deforestation, particularly in the hilly and forested areas, exacerbates soil erosion by removing vegetation that holds the soil in place. Unsustainable agricultural practices such as monocropping, excessive use of chemical fertilizers, and improper irrigation techniques have reduced soil fertility and increased salinity. The over-extraction of groundwater for irrigation has further contributed to soil salinization and compaction. Urbanization has led to the expansion of concrete structures, which reduces natural water infiltration, leading to soil

erosion and reduced moisture retention. These activities, when combined with the region's natural geological vulnerabilities, create a cycle of soil degradation that affects agricultural productivity, water quality, and local ecosystems, posing significant challenges to sustainable land use and development in Jharkhand.

Management Strategies : Management strategies for combating soil quality degradation in Jharkhand require a holistic, region-specific approach that integrates sustainable agricultural practices, conservation techniques, and restoration efforts. Firstly, promoting agroforestry and afforestation can help prevent soil erosion, enhance organic matter content, and improve moisture retention, especially in deforested and erosion-prone areas. Crop diversification and the adoption of organic farming practices, such as composting and green manuring, can restore soil fertility, reduce dependency on chemical fertilizers, and increase soil biodiversity. Conservation tillage methods, including minimum tillage and crop rotation, can minimize soil disturbance, prevent erosion, and preserve soil structure. The use of soil erosion control techniques, such as terracing, contour plowing, and check dams, can help stabilize sloped lands and prevent further loss of topsoil in hilly regions. The promotion of water-efficient irrigation techniques, like drip irrigation, would help reduce soil salinization caused by over-irrigation and excessive groundwater extraction. Soil testing and nutrient management programs should be encouraged to optimize fertilizer use and prevent over-application, ensuring that soils are not overburdened with chemicals that degrade their structure and health. In regions affected by mining, reclamation efforts such as re-vegetation, mine spoil treatment, and soil remediations are crucial for restoring soil productivity. Implementing proper waste disposal systems to prevent contamination from industrial effluents, along with strengthening local community involvement and awareness, will foster sustainable land management practices. These combined strategies can help mitigate soil degradation in Jharkhand, ensuring that its land resources are preserved for future generations while improving agricultural productivity and ecological sustainability.

Conclusion : The geological study of soil quality degradation in Jharkhand highlights the complex interaction between the region's diverse geological formations and soil properties. The findings show that natural geological factors such as rock weathering, erosion, and mineral composition significantly influence soil quality, particularly in hilly and mining-intensive areas. Human activities, including mining, deforestation, and unsustainable agricultural practices, exacerbate soil degradation, leading to nutrient depletion, erosion, and reduced agricultural productivity. The study emphasizes the importance of understanding the region's geological context when developing soil management strategies. Sustainable land management practices such as afforestation, erosion control, crop diversification, and the use of organic farming techniques can help restore soil fertility and prevent further degradation. Incorporating soil testing and region-specific reclamation efforts, especially in mining-affected areas, can improve soil health and ensure long-term sustainability. It is essential to integrate geological insights into soil conservation planning to address the challenges of soil degradation in Jharkhand effectively. Adopting a holistic approach that combines geological, agricultural, and environmental perspectives, Jharkhand can safeguard its soil resources, improve agricultural productivity, and enhance ecological sustainability for future generations.

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