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Review Article

Abiotic and biotic factors affecting formation of soil in the Earth

Gandhiv Kafle[1*]

[1]Faculty of Forestry, Agriculture and Forestry University, Hetauda, Nepal
[*]Correspondence: gkafle@afu.edu.np
[*]ORCIDs: https://orcid.org/0000-0001-5823-3454

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Abstract

The soil is formed and affected by a number of biotic and abiotic factors. The soil forming factors are climate, organisms, relief, parent material and time. A review on factors of soil formation was carried out with support from relevant literatures in this study. This review provides an overview of factors of soil formation with relevant research findings which could be useful to undergraduate and graduate students in agriculture and forestry sectors. Climate, organisms, relief, parent material and time are universally accepted factors of soil formation. Recently, 'human activities' has been discussed widely for its recognition as a soil forming factor. The soil forming factors are interacting and changing over time, so a system approach may be needed to understand their dynamics and impacts.

Keywords: Climate, organisms, relief, parent material, time, soil formation

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INTRODUCTION

Soils are complex natural entities, comprised of minerals, organic matter, water, and air, formed by the breakdown of rocks and organic materials. Essential to Earth's ecosystems, they support plant life, provide habitat for organisms, and underpin human survival by enabling agriculture and supplying vital resources (Brady & Weil, 2008). Plants rely on soil for nutrients and water, while it also hosts a vast array of organisms, fostering biodiversity and ecosystem health (Jenny, 1994). Ultimately, healthy soil sustains the plant-based food chains that support diverse animal populations and human society.

The transformation of rock or parent material into soil is called soil formation. Dokuchaev was the world's first person who suggested a "factorial" approach to soil formation. According to him, soil was formed by the combined effects of living and dead organisms, parent rock, climate, relief and age of the terrain (Dokuchaev, 1883).

Shaw (1930) recognized that soils are formed by the modification and partial destruction of the parent material by the action of water, air, temperature changes, and organic life. He expressed these "potent factors" in an equation:

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$S = M (C + V)^{T} + D$ ……………..(1)

Where, S= soil formed from the parent material (M) by the work of climatic factors (C) and vegetation (V) through a period of time (T). D is erosion or deposition.

Jenny (1941) presented a hypothesis that soil is formed as a result of the interaction of many variables, the most important of which are climate (cl), organisms (o), relief (r), parent material (p) and time (t). Jenny called these variables soil-forming factors that controlled the direction and speed of soil formation. In other terms, these factors are state factors that define the state of the soil system. It can be presented as follows:

Soil property (s) = f (cl,o,r,p,t) …………….(2)

Where, climate (cl), organisms (o), relief (r), parent material (p) and time (t)

These soil-forming factors are interdependent, each modifying the effectiveness of the others. Overall, the soil-forming factor equation has become a popular concept in pedology (Bockheim *et al.,* 2005). The state factor model as presented by Jenny (1941) has had more impact on pedogenic studies to understand soil formation than any other soil model published in the past 50 yrs.

Three of the eight epipedons are defined on the basis of parent material (folistic, histic, melanic), two from human activities (anthropic and plaggen), and two from the interaction of climate and vegetation (mollic and umbric). Of the 19 subsurface horizons, 11 originate from the interaction of climate and parent material. Soil Taxonomy uses the soil forming factors at all levels, including at high levels in the system (Bockheim *et al.,* 2014). Previous reviews on soil formation factors have consistently highlighted the interplay of five primary factors: parent material, climate, biota, topography, and time (Jenny, 1941; Buol *et al.,* 2011). While Jenny (1941) state factor equation provides a foundational framework, subsequent reviews emphasize the complex interactions and non-linear relationships between these factors (Schaetzl & Anderson, 2005; Dixon & Schulze, 1990). Several studies have explored the relative importance of each factor in different environmental contexts, revealing variations depending on geographical location and soil type (Birkeland, 1999; Johnson *et al.,* 2000). Furthermore, advancements in isotopic techniques and molecular biology have enabled more detailed investigations into soil organic matter dynamics and microbial community composition, refining our understanding of the biota's role in soil development (Schimel & Schaeffer, 2012; Bardgett & van der Putten, 2014). Despite these advancements, significant knowledge gaps remain regarding the additional factors, long-term effects of climate change on soil formation and the complex interactions between soil organisms and soil physicochemical properties. Effective environmental management, agriculture, and conservation depend on understanding soil formation. Soil develops through the intricate interplay of parent material, climate, organisms, topography, and time (Jenny, 1994), influencing key properties like fertility, structure, and ecological function. Reviewing these factors allows for better prediction of soil behavior, improved land use planning, and the development of sustainable agricultural practices (Brady & Weil, 2008). This updated knowledge is critical for mitigating soil degradation and climate change impacts, ensuring healthy and productive ecosystems long-term.

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This article provides an overview of factors of soil formation, supplemented with key findings of research scholars. It is expected that this study could be useful to students, teachers and researchers who are working in field of soil research.

METHODS

This review synthesizes current understanding of soil formation factors, integrating knowledge from diverse fields including pedology, geology, ecology, and microbiology. The literature search encompassed major scientific databases (e.g., Web of Science, Scopus, PubMed) using keywords such as "soil formation," "pedogenesis," "soil genesis," "soil forming factors," and combinations thereof, along with specific terms related to each factor (e.g., "climate," "parent material," "topography," "organisms," "time"). Studies published in English from 1980 onwards were prioritized to capture recent advancements, though seminal earlier works were also included where relevant. The review assesses existing models for understanding soil formation, focusing on the interactions between the five primary factors (parent material, climate, biota, topography, and time) and their relative importance in different soil environments. Emphasis is placed on identifying knowledge gaps and highlighting areas requiring further research.

RESULTS AND DISCUSSION

Factors of Formation of Soil

Abiotic factors of soil formation

Climate

Rainfall, temperature, humidity, wind, and aridity all have a direct and indirect impact on soil formation. Different climatic factors influence the creation of various soil groups, such as zonal, intrazonal, and azonal soils, and govern the various pedogenic processes. The production of lateritic soils, for instance, is favored by high temperatures and moderate to high rainfall because of the strong weathering and leaching of basic cations. Climate is a soil-forming factor but the climate is in turns affected by soils (Certini & Scalenghe, 2023). Soil climate is the most important factor in Soil Taxonomy. It is used at the highest level to define two of the 12 soil orders: Aridisols, the soils of the dry regions, and Gelisols, the permafrost-affected soils (Bockheim *et al.*, 2014). Moisture and temperature influence the speed of chemical reactions. It controls the rate of weathering of rocks and decomposition of dead organisms. It is a proven fact that the rate of chemical reaction is roughly doubled for each 10°C rise in temperature (Arrhenius, 1889). The development of soils is faster in warm and moist climates than in cold and arid ones. In wet climates, there is generally more precipitation than evaporation. So water continuously moves downward through the soil horizons. It results in leaching of soluble materials and translocating clay particles. In arid climates, evaporation is generally more than precipitation. So there is not leaching of salts downward. The factors of climate not only contribute directly to the processes of soil formation but also put a marked indirect effect through their effects on growth and development of vegetation. Reviews of climate's influence on soil formation consistently highlight its crucial role in determining soil properties and the types of soils that develop. Temperature and precipitation are the dominant climatic factors, influencing weathering rates, organic matter decomposition, and nutrient cycling (Jenny, 1941; Buol *et al.*, 2011). Warm, humid climates promote rapid weathering, leading to the development of deeply weathered soils with high clay content and potentially significant leaching of bases, resulting

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in acidic conditions (Schaetzl & Anderson, 2005; Wilding & Drees, 1971). In contrast, cold climates tend to have slower weathering rates, resulting in less developed soils with higher organic matter content due to slower decomposition. Arid and semi-arid climates are characterized by limited leaching and the potential accumulation of salts, leading to the formation of saline or sodic soils (Johnson *et al.,* 2000; Birkeland, 1999). The interplay of temperature and precipitation also influences vegetation patterns, which in turn significantly impact soil organic matter content and nutrient cycling. Therefore, climate acts as a master variable, shaping the overall trajectory of soil development and resulting in a wide range of soil types across different climatic zones.

Table 1: Review of factors of soil formation

Factors of soil formation	Description	Reference(s)
Parent material	Original geological material; influences initial texture, mineralogy, and chemistry.	Jenny (1941), Schaetzl & Anderson (2005)
Climate	Temperature and precipitation; dictates weathering rates, organic matter decomposition, and nutrient cycling. Includes aspects like freeze-thaw cycles and evapotranspiration.	Jenny (1941), Jobbágy & Jackson (2000), Lal (2015)
Organisms (biota)	Plants, animals, and microorganisms; influence soil structure, organic matter content, nutrient cycling, and decomposition. Includes interactions between different organisms.	Jenny (1941), Bardgett & van der Putten (2014), Fierer (2017)
Topography	Slope, aspect, and elevation; affects water movement, erosion rates, solar radiation, and soil temperature.	Jenny (1941), Hillel (2004), Wischmeier & Smith (1978)
Time	Duration of soil formation processes; allows for the cumulative effects of other factors to manifest. Soil age is a crucial factor.	Jenny (1941), Birkeland (1999)

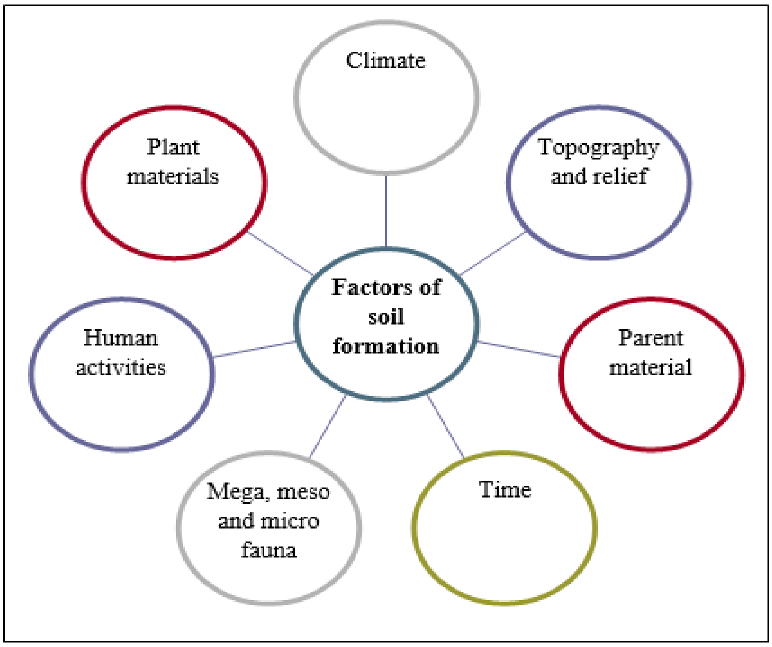

Figure 1: Factors of soil formation (this article)

Topography and Relief

Topography plays a role in the development of soil by influencing elements such as slope, configuration, and the geological structure of the elevation above sea level. Topography

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influences soil formation due to its controlling effect upon drainage, run-off, and erosion. The differences in soil properties with regard to topographical position are usually attributed to differences in runoff, erosion and deposition processes (Birkeland, 1984).A landscape location 1) has an elevation either above or below another part of the landscape, 2) has a distinct shape (convex, concave or linear), 3) faces a specific compass direction, and 4) is only one component of the landscape. These factors influence drainage, runoff, deposition, and erosion as well as the collection of solar energy. Soil profiles on steep slopes are usually not strongly developed. This stunting of soil development is due to (1) rapid normal erosion, (2) the reduced percolation of water through the soil, and (3) lack of water in the soil for the vigorous growth of plants responsible for soil formation. Flat valley bottoms along rivers are common landscapes with soils ranging from poorly to moderately well-drained, experiencing minimal runoff and frequent deposition during floods (reducing erosion concerns). Cold air drainage makes them cooler. Overgrazing by livestock can compact surface soils. South-facing slopes are warmer and drier due to increased solar radiation, accelerating chemical reactions and evaporation, leading to different vegetation than north-facing slopes. Topography significantly influences water dispersal: concave slopes concentrate water, increasing erosion and runoff, while convex slopes distribute it more evenly. Concave areas in flatter landscapes tend to be poorly drained with high water tables.

Seibert *et al.* (2007) studied topographic influences on soil properties on boreal forests in Sweden based on the Swedish National Forest Soil Inventory (NFSI) in total around 23,500 permanent plots. They found that the thickness of the organic layer increased with topographic wetness index and the thickness of the leached E-horizon increased with upslope area. Soil pH in the organic layer increased with topographic wetness index, while the C–N ratio decreased. Soil pH in the organic layer was also found to be higher for south facing slopes than for north facing slopes. The ratio between the divalent base cation (Ca and Mg) and the monovalent base cation (K and Na) concentrations in the O-horizon increased with topographic wetness index. These correlations confirmed the importance of topography on soil properties.

Reviews consistently demonstrate that topography and relief significantly influence soil formation and resulting soil types, primarily by affecting water and energy dynamics. Steeper slopes generally exhibit thinner soils due to increased erosion and reduced accumulation of organic matter (Schaetzl & Anderson, 2005; Birkeland, 1999). Water runoff is accelerated on slopes, leading to leaching of soluble nutrients and the development of shallower, less developed profiles. Conversely, flatter areas tend to accumulate thicker soils with better-developed horizons due to reduced erosion and increased deposition of sediment and organic matter (Johnson *et al.,* 2000; Buol *et al.,* 2011). Aspect (slope orientation) influences solar radiation and temperature, affecting vegetation patterns and soil moisture content. South-facing slopes in the Northern Hemisphere, for example, typically receive more solar radiation, leading to drier conditions and potentially different soil properties compared to north-facing slopes (Jenny, 1941; Wilding & Drees, 1971). Elevation also plays a role, with higher elevations often experiencing colder temperatures, increased precipitation, and potentially different vegetation, all influencing soil development. The interaction of these topographic factors creates complex soil patterns across landscapes, with variations in soil depth, drainage, and nutrient content reflecting the influence of relief on water movement and energy balance.

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Parent material

Parent material, the unconsolidated mineral or organic matter from which soil develops, profoundly influences soil properties and subsequent pedogenesis. Its mineralogical composition directly determines the initial nutrient pool and the rate of weathering, shaping the soil's chemical characteristics, including pH and cation exchange capacity (CEC). For example, basic igneous rocks weather slowly, yielding soils low in bases and often acidic (Busscher *et al.,* 2006; Dixon and Schulze, 1990), while sedimentary rocks, particularly those rich in carbonates, contribute to higher pH and base saturation (Chesworth, 2008; Buol *et al.*, 2011). The parent material's texture (particle size distribution) significantly affects soil drainage, aeration, and water retention, influencing soil structure and the types of vegetation that can establish (Schaetzl & Anderson, 2005; Jenny, 1941). This, in turn, affects organic matter accumulation and the development of soil horizons (Johnson *et al.*, 2000). The parent material's permeability and porosity influence water movement and the potential for leaching, impacting the distribution of soluble salts and nutrients within the soil profile (Wilding and Drees, 1971); McBratney *et al.*, 2003). Furthermore, the presence of specific minerals in the parent material can lead to the formation of unique soil features, such as the accumulation of iron oxides in lateritic soils (Ollier, 1984). Therefore, understanding the parent material's characteristics is crucial for predicting soil properties and interpreting soil landscape patterns.
Soil is formed by weathering of consolidated rock or unconsolidated deposits by different agents like ice, water, wind or gravity. Soils formed from granite have higher quartz content than those formed from basalt.

Parent material significantly influences resulting soil characteristics, determined by its composition, solubility, density, and susceptibility to modification by climate and vegetation. Earth's rocks are categorized as igneous, sedimentary, and metamorphic. Igneous rocks, formed from hardened lava, range from acidic (quartz-rich) to basic (high in iron, calcium, magnesium), with numerous variations in grain size and composition. Sedimentary rocks are consolidated or unconsolidated fragments deposited by water, ranging in texture from gravel to fine clay, including conglomerates, sandstones, clays/shales, and limestones. Metamorphic rocks result from the transformation of igneous and sedimentary rocks under intense heat and/or pressure, encompassing gneiss, quartzite, schist, talc, serpentine, slate, phyllite, and marble. Parent material is used to fully define two orders: Histosols and Andisols, and partially to define the suborders in the Entisol order (Fluvents, Psamments) (Bockheim *et al.*, 2014).

Reviews of the relationship between parent rock and resulting soil types highlight the strong influence of mineralogy and weathering characteristics. Igneous rocks, particularly basalts and granites, produce soils that reflect their mineral composition and weathering rates. Basaltic rocks, rich in mafic minerals, typically weather to form clay-rich soils with high base saturation and often dark colors (Busscher *et al.*, 2006; Wilding & Drees, 1971). In contrast, granitic rocks, with their felsic mineral content, tend to produce sandier soils that are often more acidic and lower in bases (Dixon & Schulze, 1990; Chesworth, 2008). Sedimentary rocks, including sandstones, shales, and limestones, yield soils with diverse properties depending on their composition. Sandstones often result in well-drained, sandy soils, while shales, rich in clay minerals, form heavy clay soils (Buol *et al.*, 2011; Schaetzl & Anderson, 2005). Limestones, due to their carbonate content, contribute to soils with high pH and base saturation (Johnson *et al.*, 2000). Metamorphic rocks, having undergone significant alteration, produce soils with properties reflecting their parent rock and the degree of metamorphism (Birkeland, 1999). However, it's crucial to note that these are generalizations,

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and other factors like climate, topography, and time significantly modify the soil properties derived from a given parent material.

Time

In practice, it is generally maintained that the larger the number of horizons and the greater their thickness and intensity the more mature is the soil. The rate of soil development is extremely variable, ranging from very rapid (several cm in 100 years or so) on volcanic ash in the tropics to very slow (1 cm per 5000 years) on Chalk weathering in a cool temperate environment. Time has important impact on soil formation. The value of the soil forming factor changes over time for example, climatic change, new parent material etc. The extent of pedogenic reactions depends on the time they have operated. Young soils are usually easy to recognize because they have little or weak soil horizon development and the horizons commonly are indistinct. An often-asked question is, "How long does it take to form an inch of topsoil?" This question has many different answers but most soil scientists agree that it takes at least 100 years and it varies depending on climate, vegetation, and other factors. In a wet, hot climate soil horizons will form fairly quickly compared to those in cold, dry environments. Therefore, soils in cold, dry climates develop rather slowly in comparison. It is not just the amount of time that determines the degree of soil development but also the parent material, climate, vegetation, and intensity of soil- forming factors during that time that ultimately determine soil development.

It is thought that about 70 to 75 % of the earth's crust is made up of sedimentary rocks and the remaining 25 to 30 %is made up of igneous rocks and glacial materials. Coarse-grained igneous rocks such as granite weather to sandy types of materials; thus, soils that formed from these kinds of rocks have a sandy texture. Fine- grained sedimentary rocks such as siltstone and shale weather to finer textured materials; thus, soils that formed from these types of rock are more clayey.

While the other soil-forming factors (parent material, climate, biota, topography) are considered state factors, time is a continuous process that allows for the progressive transformation of parent material into mature soils (Jenny, 1941; Schaetzl & Anderson, 2005). The length of time a soil has been developing significantly impacts the degree of weathering, horizon differentiation, and organic matter accumulation (Buol *et al.*, 2011; Johnson *et al.,* 2000). Young soils, formed relatively recently, exhibit less developed profiles with limited horizonation and often retain characteristics of their parent material. In contrast, older soils, given sufficient time, undergo extensive weathering, resulting in well-developed profiles with distinct horizons reflecting the cumulative effects of the other soil-forming factors (Birkeland, 1999). However, the rate of soil development varies considerably depending on the interacting effects of the other factors; a warm, humid climate will accelerate soil development compared to a cold, arid climate (Dixon & Schulze, 1990). Therefore, while time is essential for soil formation, its influence is intertwined with the other factors, making it difficult to isolate its effects completely.

Biotic factors of soil formation

Plant materials

Plants are the primary source of soil organic matter, contributing both aboveground (litter) and belowground (roots) material that decomposes into humus, improving soil structure, water retention, and nutrient availability (Brady & Weil, 2019). Higher plant diversity leads to more diverse organic matter, enhancing soil stability and nutrient richness. Plants actively cycle nutrients, with diverse communities exhibiting more efficient uptake and return through litter, exudates, and decomposition, improving fertility and reducing losses (Schimel, 1995). Plant roots physically bind soil particles, improving structure, porosity, water infiltration, and aeration (Six *et al.,* 2004). Diverse root systems enhance soil stability and reduce erosion. Finally, vegetation cover reduces runoff, regulates soil moisture, and protects against wind and water erosion (Hillel, 2004; Lal, 2001), with greater diversity leading to more effective erosion control. Rocks are cracked as they expand by the strong force of the roots of the plants. The roots release carbon dioxide and it reacts with water to form an acid that erodes rock. The succession of vegetation when reaching to climax community in a weathering rock surface has profound effect on the soil that is developed.

Human activities

Human activities mainly the removal of natural vegetation, the use of the soil for agriculture and the long-term accumulation of organic remains can have a significant impact on the soil, either positively or negatively. Human activities are often considered a sixth factor of soil formation (Bockheim *et al.,* 2017). Anthropogenic processes may not cause drastic changes in soil morphology, but modify some chemical, biological and physical properties which are significant for soil management. It is imperative that the anthropogenic processes be explicitly recognized as a fully-fledged soil forming factor. The effects and geographic distribution of the anthropogenic factor are very diverse as a result of considerable differences of human interventions in space and time (Dudal, 2005).Converting natural ecosystems to agricultural land or urban areas severely impacts soil formation. Vegetation removal increases erosion, topsoil loss, and reduced organic matter input, while intensive tillage degrades soil structure (Lal, 2008). Urban development further diminishes soil health through sealing, excavation, and contamination, disrupting water cycles and ecosystem services (Grimm *et al.,* 2008). Human activities, particularly deforestation, unsustainable agriculture, and grazing, dramatically accelerate erosion, reducing soil productivity and causing water body sedimentation (Pimentel *et al.,* 1995). These activities increase vulnerability to wind and water erosion, while intensive agriculture depletes nutrients (Vitousek, 1997), and irrigation can cause salinization (Flowers & Yeo, 1986). Finally, heavy machinery compacts soil, and industrial activities, waste disposal, and pesticide use contaminate it with harmful substances (Alloway, 2013), harming soil health, biodiversity, and human well-being.

Mega, meso and micro fauna

Organisms play a key role in soil development from a microscopic to the continental scale (Bockheim *et al.,* 2005). Animals burrow soil, microorganisms consume organic materials, and plant roots spread out in soil. They hasten the disintegration of big soil materials into smaller ones. Earthworms consume the litter and blend it with the small mineral particles. From this, they can create a layer of soil free of stones at the soil's surface. Termites have a significant role in the formation of soil because they transport water, dissolved salts and small particles from different depths of the soil to their termitaria on the surface. Termitaria rapidly deteriorate after being abandoned as a result of weathering and animal trampling, forming a thin mantle on the soil's surface. Soil compaction increases and infiltration rate decreases by large scale trampling of grazing animals and intensive use of heavy farm machines. It increases runoff and soil erosion, mainly on the sloping lands.

Soil formation is profoundly shaped by complex microbial interactions involving bacteria, fungi, archaea, and protists. Microbes drive organic matter decomposition, releasing nutrients

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through synergistic interactions and competition (Schimel & Schaeffer, 2012). They contribute to soil aggregation via extracellular polymeric substances (EPS), mycorrhizal fungi, and interactions with soil fauna (Six *et al.*, 2004). Microbial activity influences soil pH and redox potential, affecting nutrient availability and mineral transformation (Sparks, 2003). Microbes directly and indirectly influence mineral weathering, releasing nutrients for plants (Banfield & Nealson, 2003), and nitrogen-fixing bacteria convert atmospheric nitrogen into usable forms (Postgate, 1998). Finally, interactions between microbes and other soil organisms, such as fungi and fauna, are crucial for nutrient cycling, decomposition, and overall soil health (Bardgett & van der Putten, 2014).

Discussion and emerging concerns

Soil formation, or pedogenesis, is a complex process driven by the intricate interaction of five primary factors: parent material, climate, organisms, topography, and time (Jenny, 1941). While Jenny's model provides a foundational framework, understanding soil development requires acknowledging the dynamic and interconnected nature of these factors. Recent research highlights the limitations of viewing these factors in isolation and emphasizes the importance of considering their synergistic and antagonistic effects.

Parent material significantly influences initial soil properties, including texture, mineralogy, and nutrient content (Schaetzl & Anderson, 2005). However, the long-term impact of parent material is often mediated by other factors. For instance, a highly weathered parent material in a humid climate will produce a vastly different soil than the same material in an arid climate (Olson, 1963). Climate, particularly temperature and precipitation, profoundly affects rates of weathering, decomposition, and nutrient cycling (Jobbágy & Jackson, 2000). Increased temperatures and altered precipitation patterns associated with climate change are already impacting soil formation, accelerating erosion and altering soil organic matter dynamics (Lal, 2015; IPCC, 2022).

Organisms, including plants, animals, and microorganisms, play a crucial role in soil development. Plants influence soil structure through root growth and litter input, while microorganisms drive decomposition and nutrient cycling (Bardgett & van der Putten, 2014; Fierer, 2017). The composition and activity of soil microbial communities are increasingly recognized as critical factors influencing soil properties and ecosystem services (Philippot *et al.*, 2013). Furthermore, the impact of human activities on soil biota, including land use change and the use of pesticides, is a growing concern (Feller *et al.*, 2012).

Topography influences soil development through its effect on water movement and solar radiation. Slope angle and aspect affect erosion rates, water infiltration, and soil temperature, leading to variations in soil properties across landscapes (Hillel, 2004). Concave slopes, for example, tend to accumulate water, leading to poorly drained soils, while convex slopes experience higher erosion rates (Wischmeier & Smith, 1978).

Finally, time is an essential factor, representing the duration of soil development processes. Young soils retain characteristics of their parent material, while older soils exhibit more pronounced development reflecting the cumulative influence of all other factors (Birkeland, 1999). However, the rate of soil development can be significantly accelerated or decelerated by human activities, highlighting the considerable impact of anthropogenic influences on soil formation.

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Emerging concerns regarding soil formation increasingly center on the accelerating impacts of anthropogenic activities, particularly in the context of climate change and intensified land use. The accelerating rate of soil erosion due to extreme weather events linked to climate change poses a major threat to soil health and productivity, exceeding natural erosion rates significantly (e.g., Lal, 2015; IPCC, 2022). Changes in precipitation patterns and increased temperatures are altering soil organic matter dynamics, potentially leading to carbon losses and reduced soil fertility (Davidson & Janssens, 2006; Jobbágy & Jackson, 2000). Furthermore, the intensification of agriculture, including the widespread use of synthetic fertilizers and pesticides, is causing soil contamination and biodiversity loss, impacting soil structure and function (Feller *et al.,* 2012; Alloway, 2013). The expansion of urban areas is leading to significant soil sealing and habitat loss, further reducing the capacity of soils to provide ecosystem services (Grimm *et al.,* 2008). Finally, a growing understanding of the soil microbiome highlights the vulnerability of these complex communities to disruption from anthropogenic activities, potentially impacting nutrient cycling and soil stability (Fierer, 2017; Philippot *et al.,* 2013). These interconnected challenges necessitate a more holistic approach to soil management, integrating climate change mitigation and adaptation strategies with sustainable land use practices.

CONCLUSION

The soil forming factors are climate, topography and relief, parent material, time, plant materials, human activities and burrowing animals and insect-microbes. These abiotic and biotic factors control the direction and speed of soil formation. These factors are not as causes or forces but as independent variables. However, there is debate on quantification of relationship between soil properties and the soil forming factors or variables. These factors are interacting and changing over time. Soil formation is a complex, dynamic process characterized by the interplay of multiple interacting factors. While Jenny's model provides a valuable framework, modern research underscores the need to consider the intricate relationships between these factors, especially in the context of ongoing climate change and intensive land use. Future research should focus on integrating these factors within a holistic framework to better understand and manage soil resources sustainably.

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Author’s Contribution

The author reviews and writes the article.

Conflicts of Interest

There is no any conflict of interest regarding publication of this article.

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