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Progress research on pedological investigation of the volcanic landform in the western part of the Ring of Fire: A review

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Abstract

Pedological investigations in volcanic landscapes represent a critical area of study due to the significant influence of volcanism on soil formation and development. However, research on this topic in the western part of the Ring of Fire remains relatively limited and fragmented. This study aims to analyze the progress and development of pedological research in volcanic environments across this region and examine the relationship between volcanic characteristics and soil properties. Data were collected through a systematic review of published literature in the Scopus database using specific keywords related to pedological investigation and volcanic landforms, resulting in the identification of 23 relevant articles published between 1968 and 2024. Analysis was conducted using bibliometric methods and VOSviewer software to identify research trends, contributing authors, and keyword patterns, complemented by qualitative content analysis to categorize studies into key themes. Results reveal that research in this field has evolved through five distinct stages, with three main themes emerging: the influence of soil-forming factors on pedogenesis, soil properties, and the dynamics of soil development processes. Japan and Indonesia emerge as the leading contributors to this research area. This study provides a comprehensive overview of soil development under volcanic influence in the western Ring of Fire and identifies significant gaps that warrant further investigation.

Keywords: Pedogenesis; Volcanic soils; Soil development; Soil geography

Introduction

Soil is one of the most essential parts of the Earth's surface. This is because soil covers a large area of the Earth's surface and is a dynamic system (Egli & Dahms, 2023). Moreover, the soil has extensive benefits in supporting human life, especially as a medium for growing plants in agricultural efforts to meet food needs. In this regard, soil is said to be one of the most critical natural resources (Arbogast, 2011; Bhattacharyya & Pal, 2016). Soil even provides ecosystem

services to sustain life on Earth (Adhikari et al., 2024). In this regard, many soil studies have been conducted worldwide. Soils on the Earth's surface vary significantly due to the influence of the complex soil-forming factors of climate, organisms, parent material, relief, time, and local factors. Volcanism is a crucial natural local factor affecting soil development under specific conditions (Delmelle et al., 2015; Sartohadi et al., 2016).

On the Earth's surface lies the Pacific Ring of Fire, a zone covered by volcanic masses and the most prominent volcanic region. The western side of the Ring of Fire, from Japan in the north to the Philippines, Indonesia, and Papua New Guinea, is a high-density volcanic area. Indonesia, Japan, Papua New Guinea, and the Philippines are among the top ten countries with the most significant number of volcanoes in the world, both those that have been active in history and the last 10,000 years (Ashari & Purwantara, 2022). The large number of active volcanoes in the region certainly plays an essential role in soil development. Massive volcanism in number and activity is a determining factor that contributes significantly to soil formation and development.

Pedological investigations in this area have indeed been conducted. The results of these studies have been published in world-renowned and highly reputable journals. However, further studies are still needed to summarise the results of these studies so that they can provide a comprehensive description of the regional scope. In addition, the progress and development of studies on pedogenesis and soil characteristics in volcanic environments, especially on the western side of the Ring of Fire, is still not covered in the previous literature. Thus, two issues underlie the need for further pedological investigation in this region. First, studies are needed to inform the characteristics of volcanism and its influence on soil formation and characteristics. Second, the profile of the soil study that has been conducted so far reflects future studies.

In this paper, we present the result of a systematic literature review of previous studies on pedogenesis and soil characteristics under volcanic influence on the western side of the Ring of Fire. Concerning the two issues raised, this paper has two more specific objectives. First, we present a description of the progress of previous studies, including the profile of study results in various journals indexed in the Scopus database, as well as trends in topics and approaches in studies. Second, we present the results of analyses on the relationship between the characteristics of volcanism in the western Ring of Fire region and pedogenesis and soil properties. This paper provides alternative information about pedological investigations in countries located on the west side of the Pacific. Also, this paper offers new insight into the influence of volcanic activity in the Ring of Fire area on its soil conditions.

This paper is a systematic literature review (SLR) organized using the PRISMA approach. Search keywords were determined using the PCC method. The documents reviewed were obtained from the Scopus database. The search criteria were research articles in English, published in journals or conference proceedings, and territory/area on the western side of the Ring of Fire, which is between Japan, the Philippines, Indonesia, and Papua New Guinea. One hundred and one documents were obtained using search keywords and criteria as filters. Among the documents collected, 23 articles fulfilled the criteria based on the selection through the extraction process, so they continued to the review stage. The findings of this study show that relatively little previous research on soil formation and development on volcanic landscapes or under the influence of active volcanism has been conducted on the western side of the Ring of Fire.

Method

This study employs the systematic literature review (SLR) method. The initial stage of the SLR method is to develop a research question using the PCC framework, namely: 'What is the progress of studies on pedogenesis and soil characteristics concerning volcanism activity on the

western side of the Ring of Fire?'. Referring to the PCC framework, the research question includes population, concept, and context (Table 1).

Table 1. PCC framework for identifying the main concepts of the scoping review study.

PCC Element	Definition
Population	Western part of the Ring of Fire: the area between Japan, the Philippines, Indonesia, and Papua New Guinea
Concept	Pedogenesis and soil characteristics under the influence of volcanic activity
Context	Research articles published in English

The next step is to search for documents on the Scopus database. This stage is carried out by referring to the keywords identified in the preparation of research problems and the PCC framework that has been developed. The keywords used in this study are (1) soil, (2) soil properties, (3) soil development, (4) volcano, (5) volcanic, (6) volcanic landform, (7) Southeast Asia, (8) Indonesia, (9) Philippines, (10) Japan, (11) Papua New Guinea. From these keywords, boolean operators were determined for searching in the Scopus database, namely: 'soil' OR 'soil properties' OR 'soil development' AND 'volcano' OR 'volcanic' OR 'volcanic landform' AND 'Southeast Asia' OR 'Indonesia' OR 'Philippines' OR 'Japan' OR 'Papua New Guinea'.

After collecting the documents, the next step was screening to determine which documents were suitable for the review. Based on the inclusion and exclusion criteria, the articles included in the provisions are (1) research articles, (2) English language, (3) published in Journal or Conference Proceedings, and (4) country/territory limited to the area between Japan, the Philippines, Indonesia, and Papua New Guinea. The articles are categorized as irrelevant reports if they do not meet these criteria. There are two stages in the screening process. Completely irrelevant articles are no longer used from this first stage. Some reasons for being completely irrelevant are because they discuss irrelevant topics or the study area outside the specified region. In the second stage, there is a possibility that the article is not included in the selection because the discussion does not match the expected criteria. This kind of article will be categorized as excluded with reasons. The review procedure was conducted using the PRISMA method, as shown in Figure 1.

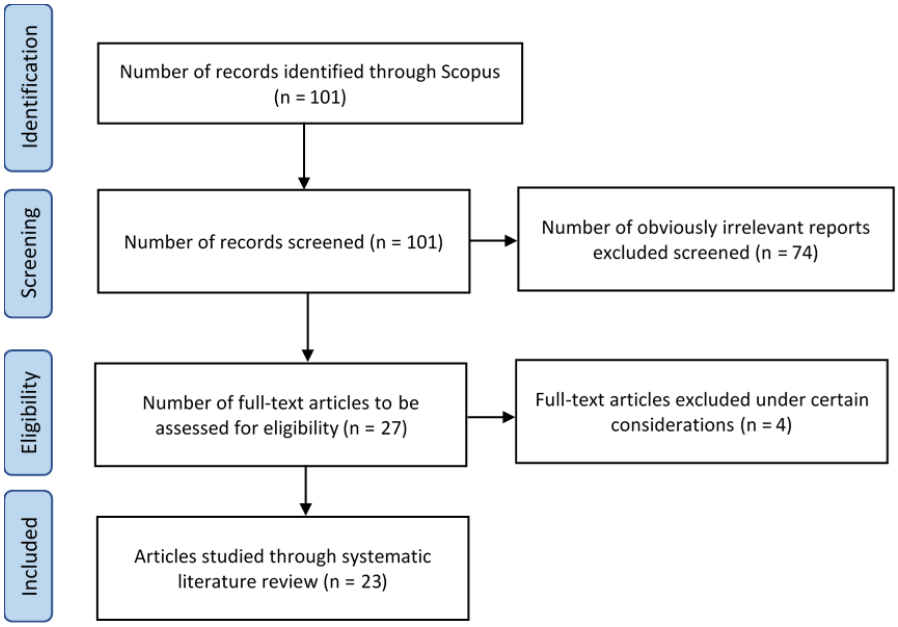

Figure 1. PRISMA flow diagram of the systematic literature review according to Pollock and Berge (2018)

Result

Progress research on pedological investigation of the volcanic landform in the study area

In this section, we present the results of an analysis of the progress and achievements of previous research on pedogenesis and soil characteristics in the volcanic landform or under volcanic influence of the Western Part of the Ring of Fire. In general, relatively few studies related to pedological investigation of the volcanic landform in the region are indexed in the Scopus database. This study found only 101 documents with the search keywords applied to the Scopus database. Of these 101 documents, only 23 articles met the criteria for further research following the theme to be discussed. Although the number of articles is relatively tiny, studies in this field have been conducted for more than five decades.

The publications in this theme span from 1968 to August 2024. However, there were not always publications published every year during that period. In 1968, 1987, 1990, 1999, 2002, 2007, 2009, 2014, 2015, 2016, 2017, 2019, there was one publication document in one year. Furthermore, in 2020 and 2021, there were three articles, then in 2022 and 2023, there were two articles each, and in 2024 until August, there was one article. 2020 showed an insignificant increase in publications, which continued into 2021. After 2021, the number of publications has also not increased sharply, thus indicating that this topic is still relatively little studied and published in various reputable journals. However, publications appear to have always been produced in the last six years.

In the 23 documents studied, there were 92 contributing authors. Among the 92 authors, two main contributors produced two articles, namely Setiyo Purwanto and Erna Suryani from Universitas Sebelas Maret, Indonesia. There were 15 affiliations of origin of the first author contributing to this study, four of which contributed to more than one published article, namely Tohoku University, Japan, which contributed to 4 articles, and three institutions that contributed two articles each, namely Iwate University, Japan; Ghent University, Belgium; and Universitas Sebelas Maret, Indonesia (Figure 2).

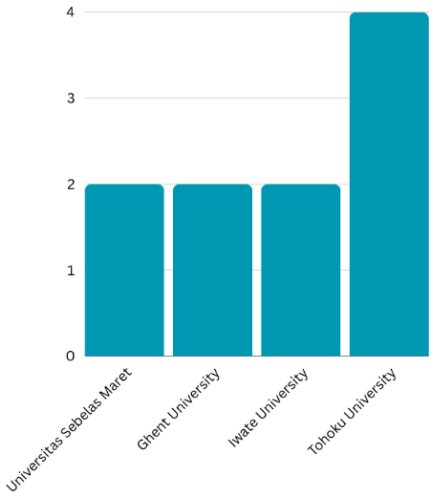

Figure 2. Top four institutions contributing to the pedological investigation of the volcanic landform in the western part of the Ring of Fire (Source: Scopus Database, 2024)

There are four countries of origin of the first author: Japan, Indonesia, Belgium, and Australia. Japan is the most significant contributor with 13 articles, followed by Indonesia with seven articles, Belgium with two, and Australia with 1 (Figure 3). In addition, there are also four countries where the study was conducted, namely Japan, the Philippines, Indonesia, and Papua New Guinea. In

addition to being the most significant contributor, Japan has the most study locations. Various articles resulting from the study were published in 17 different journals. Four journals published more than one article, namely Soil Science and Plant Nutrition, which published three articles, and three journals published two articles, namely Geoderma, Soil Science, and Soil Science and Agroclimatology (Figure 4).

Keyword analysis using VOSviewer showed that the various keywords in the published articles formed two clusters (Figure 5). These clusters are not large, indicating that the number of publications produced is insignificant. The distance between the clusters is relatively far, suggesting a weak connection between the clusters. The first cluster discusses volcanoes, volcanic soils, soil properties, and Indonesia; the second discusses Japan, pedogenesis, and weathering. Based on the keywords, it turns out that many published articles discuss volcanic geomorphology, but very few mention pedogenesis and soil characteristics. The discussion on the soil itself is still relatively little done.

Figure 3. Distribution map of the country of the first author (Source: Scopus Database, 2024)

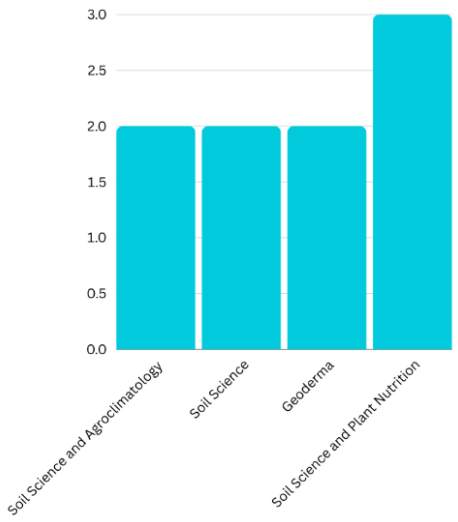

Figure 4. Top four journals that published articles in this study (Source: Scopus Database, 2024)

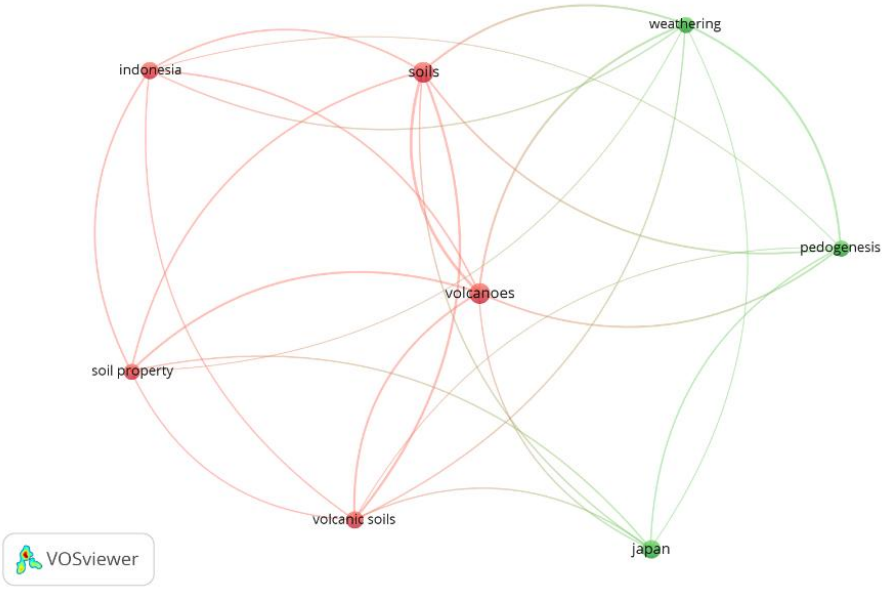

Figure 5. Clusters of keywords in the study of pedological investigation in the western part of the Ring of Fire (Source: VOS Viewer Analysis, 2024)

Visualization with density shows that several keywords are widely used, including volcanoes, volcanic soils, soils, pedogenesis, soil property, weathering, Indonesia, and Japan (Figure 6). Some keywords related to soil, such as pedogenesis, soil development, and soil properties, were not even used in previous publications. From this, it can be seen that the topic in these studies is more focused on soil property and development in Indonesia and Japan. In the last decade, many keywords have been used (Figure 7). Keywords such as pedogenesis and Indonesia are used in the early decade. Then, in the middle of the decade, keywords widely used were weathering and soil properties. In recent years, the keywords used are soils, volcanoes, volcanic soils, and Japan. This shows that the recent trend of studies on this topic tends to shift to volcanic soils focused on Japan.

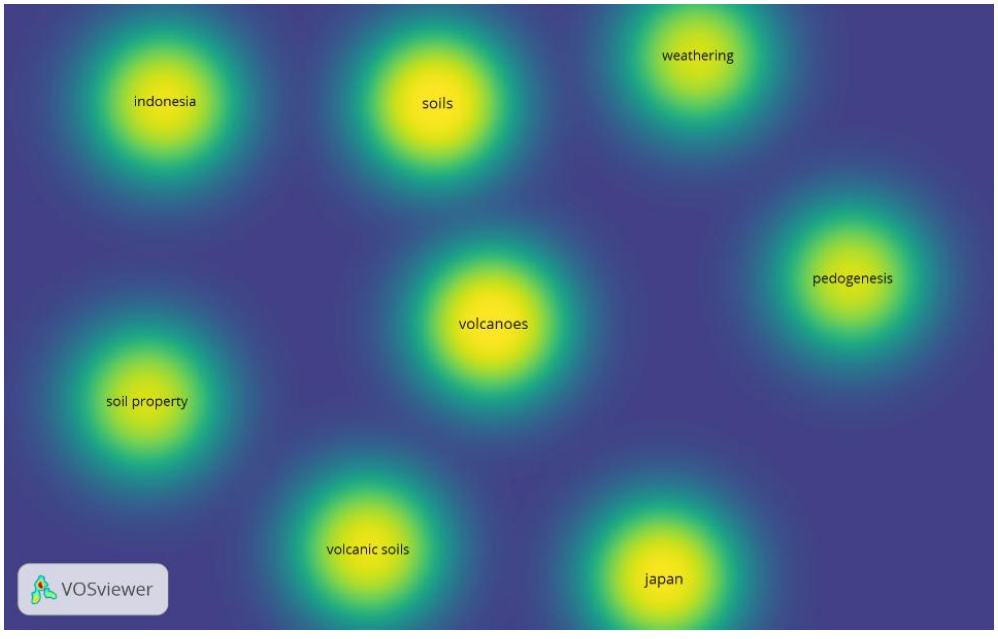

Figure 6. Publication keywords by intensity of use (Source: VOS Viewer Analysis, 2024)

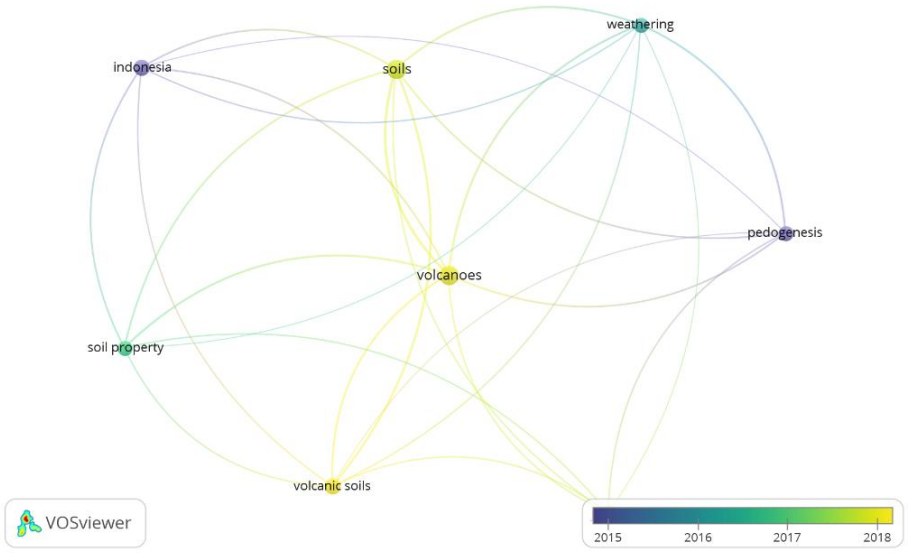

Figure 7. Publication keywords used in the last decade (Source: VOS Viewer Analysis, 2024)

A review of all articles published between 1968 and 2024 found that pedological investigations in the Western Part of the Ring of Fire generally consist of three main themes: the influence of soil-forming factors on pedogenesis, soil properties, and the dynamics of soil development processes. Soil properties are the most discussed theme of soil physical, chemical, and biological properties. The progress of studies in pedological investigation consists of five stages. The first stage covers the period 1968-1987, the second stage 1990-2002, the third stage 2007-2015, the fourth stage 2017-2019, and the fifth stage 2020-2024 (Figure 8). The time of each stage is not the same because it depends on the similarity of the study topic and the results obtained. Relatively similar discussions mark one stage of development, while different talks indicate that the progress of this study has entered another stage.

The discussion of the influence of soil-forming factors in pedogenesis started from the first stage. This theme is the only one discussed in the first stage. Studies at this time found that soil parent material from volcanic ash was dominant in influencing the nature of the soil formed. The discussion of this theme continued to the second stage, which focused more on the influence of dominant climatic factors. A strong climate in leaching can cause differences in soil characteristics even though it develops from the same parent material. Furthermore, in the third stage, the discussion is further developed by looking at the combination of influences among soil-forming factors. The study on the impact of soil-forming factors in pedogenesis ends at this third stage but inspires studies on other themes at later stages (see Fig 8).

The theme of soil properties first emerged in the second stage, even at the end of the second stage between 1999-2002. The study found that soils from volcanic parent materials have distinctive characteristics, different from soils mixed with other parent materials, even though they are located nearby. In the third stage, the discussion expanded to include an investigation of a broader range of soil physical and chemical characteristics due to the influence of various soil-forming factors. Furthermore, in the fourth stage, the impact of local factors, namely human activities, on soil development in volcanic environments was discussed. Human activities in tilling the soil that has been going on for more than a century have led to the formation of specific characteristics in andosol soils. Finally, in the fifth stage, the study of soil characteristics developed again by finding variations in soil characteristics between regions even though they both developed from volcanic parent material. This is inseparable from the influence of soil-forming factors that also vary (see Fig 8).

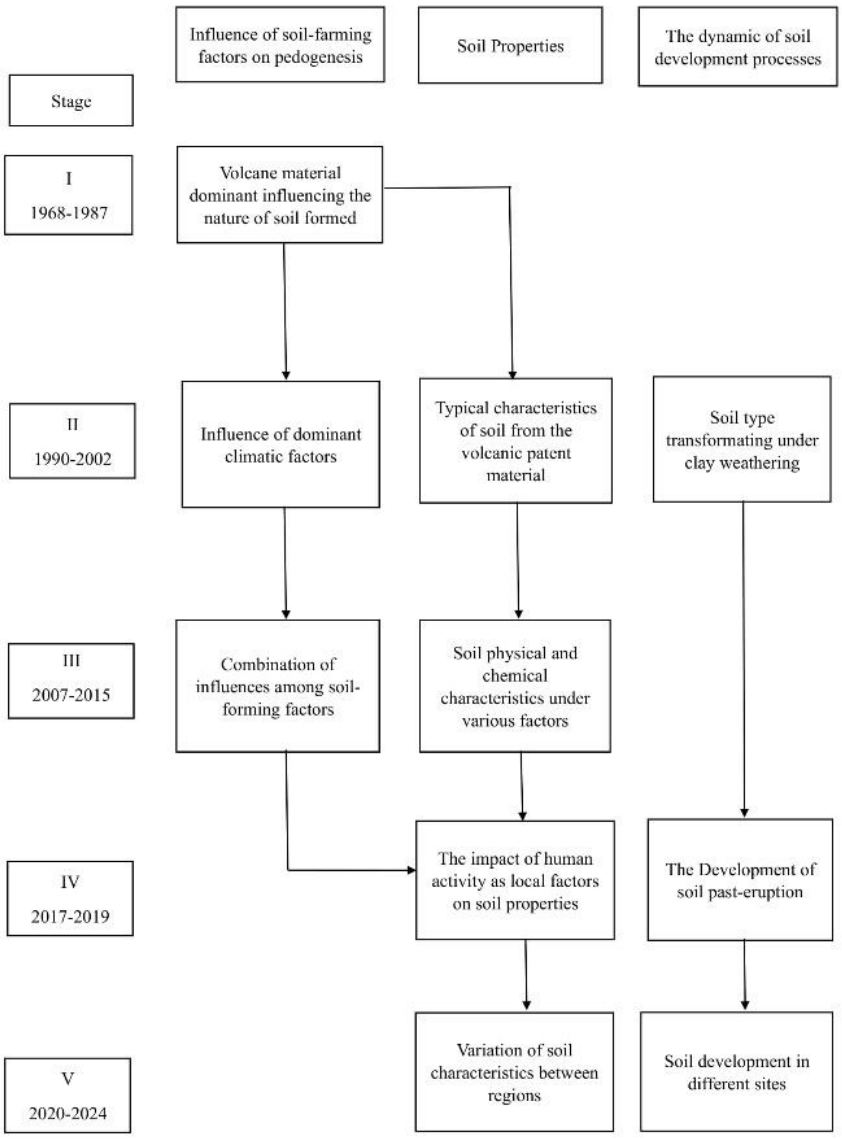

Figure 8. Development and progress study on pedological investigation of the volcanic landform in the western part of the Ring of Fire

Pedogenesis and soil properties under volcanic influence

Reviewing all articles published over six decades also provides new knowledge of soil development on volcanic landscapes. This is because volcanism itself produces specific parent materials, which are dominant in determining the characteristics of the soil formed. In further development, soil characteristics will be modified by the role of various soil-forming factors. Therefore, soils developed from volcanic parent material can have varying characteristics when the climatic environment, topography, and time of formation are different. Moreover, anthropogenic activities also play a role in determining soil development at a later stage. It is not uncommon for these developed soil characteristics to change soil type, for example, from Andisols to Mollisols.

Soil parent materials from volcanic materials generally form andisols. These soils are formed from weathering volcanic materials such as ash, lava, and lapilli. These materials, ejected during volcanic eruptions, settle in the vicinity and act as soil parent material. The weathering of these volcanic materials and the accumulation of organic matter from the growing vegetation results in soils rich in minerals and humus. Black soils formed from andosols have distinctive

physical and chemical properties, such as high fertility and good water retention capacity, thanks to the influence of these two components. This is shown by the research conducted by Yamaya and Sengoku (1968) in the Kitakami Massif, northern Japan, focusing on black soils on Mount Hashikami that consist of granitic rocks and volcanic materials. The soil was classified as Ando soil, with a typical profile comprised of a black surface layer, a dark brown transition layer, and a brown subsoil. The results show that the parent material of the black soil is volcanic material deposited on top of weathered granitic material, with generally compact, weakly acidic soil characteristics and deficient in exchangeable bases. This finding is reinforced by Wood (1987), who explains that these soils have a distinctive appearance and properties due to the nature of the parent material (volcanic ash) and not the climate. However, climatic factors are essential in regulating soil processes and the effects of cultivation on soil properties.

The type of tephra rock affects the concentration of elements in Andisols by determining the mineral composition and reactivity of the soil. Tephra rocks, such as basaltic ash, rich in silica, magnesium, and iron, can increase the availability of essential elements and soil fertility. In contrast, tephra from andesitic rocks richer in alumina and silica can affect the soil mineral profile differently. In addition, alkaline tephra can raise soil pH, involving the dissolution of elements and the availability of nutrients to plants. According to Nanzyo et al. (2007) principal component study, the degree of weathering and the type of parent tephra rock are essential factors in the variation of elemental concentrations, with three main rock types identified: dacite, andesite, and basaltic-andesite. Oxalate-extractable Si, Al, and Fe contents were used as indices of Andisol development, and a strong correlation was found between elemental concentrations and weathering indices in andesite samples, suggesting that certain elements enriched in Andisols are related to total weight loss during soil formation.

Research conducted by Van Ranst et al. (2002) on Java Island showed that soil pH and exchangeable calcium decreased from East Java to West Java as volcanic ash became more acidic from east to west. However, Si, Al, and Fe contents and the amount of allophane and ferrihydrite increased from east to west, indicating the development of active forms of Al and Fe favored by the robust leaching environment. Soils in East Java can store more base cations and are less likely to be deficient in Ca and Mg when treated with acidified nitrogen fertilizer each year. As is well known, soil pH is an essential chemical property as it indicates the acidity or basicity of the soil, which affects nutrient availability and plant health. Exchangeable calcium is the form of calcium available for exchange with other ions in the soil solution and is essential for plant health and soil structure. The relationship between the two is that soil pH can affect the availability of exchangeable calcium. Highly acidic soils often have lower calcium, which can be addressed by adjusting the soil pH by adding certain materials.

Andisols consisting of a mixture of tephras and eolian dust have different characteristics and classifications than soils formed purely from tephra. Soils dominated by tephras, which is volcanic material, generally have a more neutral to slightly acidic pH and are rich in minerals that favor soil fertility. In contrast, soils containing more eolian dust often have a lower pH and more variable mineral content, which can negatively affect soil fertility if not balanced with organic matter. These differences affect soil structure, water retention capacity, and fertility and require different soil management approaches for agricultural optimization. This was the finding of Adjadeh and Inoue (1999) in their study of Andisol soils in the Kitakami mountains derived from a mixture of tephras and eolian dust, with differences in soil classification between the north/central and southern parts of the mountains. Soils in the north and center of the hills were classified as Typic Kuroboku with a pH of 5.1-6.7 and high Al+FeO content, while soils in the south, influenced by eolian dust, had a pH of 4.3-5.7 and lower Al+FeO content, but still met the criteria of Andisols with volcanic glass content in the sand fraction. Soils in the north are mostly Typic Hapludands

with moderate organic C content. In contrast, soils in the south show a broader spectrum of Andisols with high trends in Alic and Typic Fulvudands and Alic and Typic Melanudands.

Andosols and Udands soils with andosolization as the dominant process indicate that they are formed from volcanic materials with typical characteristics such as high mineral content and variable pH. Andosolization involves the accumulation of volcanic materials that affect soil structure and fertility. Weak podsolization in the uplands indicates the presence of weathering processes that produce podsolic horizons. However, the effect is not very strong, affecting soil quality and its use. According to Nishiue et al. (2014), soil classification in the Lake Kuwanuma region, eastern slopes of Mount Funagata, northeastern Japan, based on morphological, chemical, and mineralogical properties, using CSCSJ, ST, and WRB. All pedons were classified as Andosols in CSCSJ and WRB and Udands in ST, with andosolization as the dominant process and significant modification due to forest vegetation. The study also shows indications of weak podsolization in the uplands and recommends the development of a podsolic subgroup in the soil classification system to reflect soil properties in the area more precisely.

Soils with low phosphate retention and weak neutral pH can be challenging for agriculture. The use of green manure can help improve soil fertility. In addition, utilizing older soils with high clay content can improve farmland productivity. Myoga et al. (2017) conducted a study of soil properties on Suwanose Island, which had recovered from a volcanic eruption in 1813, focusing on agricultural land, grazing land, bamboo forest, and volcanic deposits. Soils on the island are mainly classified as “tephric Regosols” and “vitric Andosols,” with soil chemistry showing a weakly neutral pH and low phosphate retention, which supports potential agricultural land use. However, volcanic activity may inhibit the formation of typical Andosols. The analysis shows that soil amendment with green manure can improve fertility, and using 200-600-year-old buried soils with high CEC and clay content can expand agricultural areas on the island.

Andisols are formed under various climatic conditions, influenced by volcanic materials as parent materials. Although the transition from Andisols to other soil types, such as Mollisols, is influenced by climate and vegetation, the exact transition between these two soil orders has not been documented. Both have similar properties, such as thick surface horizons, high organic content, and large porosity, so the transition is thought to be related to the development of weathering. In the lowland Abashiri region of Hokkaido, Northern Japan, volcanic ash soils from the Holocene and Pleistocene periods show signs of change from Andisols to Mollisols. Shoji et al. (1990) , in his research, studied the properties and classification of four volcanic ash soils from Abashiri Hokkaido and discussed the transition from Andisols to Mollisols. Two of the four pedons showed properties consistent with Andisols in Japan, while the others had different properties. The change in andic soil properties and the transition to Mollisols are closely related to clay weathering, especially the transformation of non-crystalline clay materials to halloysite, with one of the pedons showing transitional characteristics between Andisols and Mollisols.

In contrast to andisols, ultisols on volcanic landscapes have low pH and poor fertility, often requiring liming and fertilization for improvement. However, research on the parent material of Ultisols soils is still limited. Further understanding of these parent materials is essential to optimize Ultisols soil management. With more in-depth research, soil management techniques can be more effective and sustainable. This follows the statement made by Purwanto et al. (2021) that Ultisols soils have low pH and soil fertility problems, which are usually overcome by liming and fertilization. However, research on Ultisols parent material is still rarely done. This study examined the characteristics of Ultisols from andesite and basaltic andesite parent materials in five pedons of 19 soil samples. The results showed variations in chemical and mineralogical properties in Ultisols based on the parent material, with some pedons showing very low to very high mineral reserves, which are essential for agricultural development on Ultisols land.

Inceptisols on volcanic soils have properties influenced by the basaltic andesite parent material. Analysis showed variations in soil color, texture, and cation exchange capacity. Base saturation also varies, reflecting the different soil conditions in various locations. These differences are essential for formulating region-specific soil management strategies. This follows research conducted by Muslim et al. (2021) characterizing Inceptisols on volcanic landforms from basaltic andesite parent material in six locations in Indonesia, with physical, chemical, and mineral analysis of 23 soil samples from each horizon of six pedons. The results showed variations in soil color from yellowish brown to dark brown with varying base saturation and cation exchange capacity and soil texture dominated by clay. Easily weathered minerals dominate pedons on Java Island. In contrast, pedons on Sumatra Island are dominated by resistant minerals such as quartz and calcite, which can serve as a reference for soil management recommendations.

Volcanism as a local factor in pedogenesis

Various factors influence soil formation. In addition to the five factors described by Hans Jenny (1941), namely climate, organisms, parent material, relief, and time, there are local factors whose role in soil formation is also crucial. One of the regional factors is volcanism (Sartohadi et al., 2016). It is proven that soil development occurs specifically in volcanic environments. A study conducted at Sinabung Volcano by Lubis et al. (2021) found that soil pH ranged from very acidic to neutral, with total nitrogen and organic carbon levels varying from low to very high, as well as high exchangeable base cations and cation exchange capacity (CEC). Research revealed that volcanic ash from eruptions provides benefits by enriching the soil through nutrient addition, improving overall soil properties.

At Tambora Volcano, the volcanic landscape from the eruption some 200 years ago shows soil formation influenced by the soil's unique mineralogical composition, physical properties, and chemistry. This massive eruption released volcanic materials such as ash and lava containing new minerals, such as olivine and feldspar, which contributed to the formation of mineral-rich soils. The physical properties of these soils are generally porous, with textures varying from sand to clay. In contrast, chemically, these soils have a pH that can vary depending on the acidity of the volcanic ash. Nutrient reserves in volcanic soils tend to be high, especially in elements such as potassium, calcium, and magnesium, which come from the burning and weathering of volcanic minerals. However, the rate of soil development can be slow at first because new volcanic material takes time to decompose and integrate with older organic matter. Anda (2023) explained in your research that easily weathered minerals dominate the soil and have high nutrient reserve potential, with rapid solum development (22 to 107 cm) and significant accumulation of organic carbon (SOC) and organic nitrogen (SON) stocks. Chemical weathering and base depletion indices showed an accumulation of Al oxides and a decrease in base cations with horizon depth, indicating rapid recovery of soil function and support for agricultural production.

A study conducted in Japan by Tateno et al. (2019) showed that in the first three years of soil development over volcanic ash in various climates in Japan, carbon (C) and nitrogen (N) accumulation began to show an exponential relationship with temperature at 36 months, especially in the upper 2 cm layer. This acceleration was related to denser moss cover in warmer climates, while microbial abundance showed no significant increase or relationship with temperature. The effect of temperature on the buildup of moss cover may substantially control soil development in volcanic ash. Each island has different geochemical characteristics despite being affected by the same eruption due to variations in bedrock composition, local geologic conditions, and different magmatism processes at each site. Volcanic eruptions can produce magma with varying compositions depending on the depth and type of material involved in the magma process. In addition, interactions between magma and subsurface rocks and the effects of erosion and

sedimentation can enrich or alter the chemical elements present on each island. These factors lead to differences in the mineralogy and chemical composition of the volcanic materials, ultimately forming geochemical characteristics unique to each island.

A relatively similar study was conducted on the Krakatau Volcano by Fiantis (2021). The study characterized the morphology, chemistry, and geochemistry of soils from the Krakatau archipelago and found that each island had different geochemical characteristics despite being affected by the same eruption. The analysis showed significant differences, with soils on Anak Krakatau distinguished by Mahalanobis distance and the most considerable base cation loss occurring on Sebesi. The study concludes that the unique geochemical characteristics of volcanic materials on the islands can be used to assess weathering processes and pedogenesis.

As a fellow local factor, human activity also determines soil development and volcanism. Several studies found this. The age of deposition and 30-50 years of land use management significantly impact the geochemical properties of tropical volcanic soils. During this period, natural weathering changes the mineral composition of the soil, reducing the native nutrient content and increasing the concentration of secondary minerals such as kaolinite and iron oxides, which can affect pH and soil fertility. Land management, such as intensive agriculture, can accelerate the weathering process and reduce soil organic carbon content due to increased erosion and decomposition of organic matter. This interaction between weathering and land use causes changes in soil structure and nutrient cycling, decreasing soil quality and carbon storage potential. Good management practices, such as organic matter and crop rotation, can help maintain soil fertility and increase the soil's ability to store carbon. According to Anindita (2022), pine forest soils were weathered more intensively, while agricultural land use increased pH, base cations, base saturation, and organic carbon stocks, with agricultural soils qualifying as “eutric” WRB. Positive correlations were found between amorphous materials, Al oxides, and organic carbon, with increased base cation retention and decreased acidification in agricultural soils, suggesting carbon stabilization by non-crystalline materials.

Soil compaction in no-till farming systems can have a significant impact on productivity in two different locations. Compaction can reduce aeration and water percolation on sites with heavy textured soils, such as clays, resulting in inhibited root growth and reduced crop yields. In contrast, compaction may have less impact on sites with sandy soils as sandy soils tend to be easier to decompose and have better drainage capacity. However, compaction may reduce the effective use of water and nutrients. In both locations, compaction can reduce root penetration and disrupt air circulation in the soil, ultimately affecting plant health and the efficiency of no-till farming systems. Ishak (2024) suggested a linear relationship exists between soil compaction and sand fraction, soil organic matter, phosphate solubilizing bacteria, and phosphorus availability. Still, no linear relationship was found with total nitrogen. These findings confirm the importance of soil compaction management to improve soil health, especially with low soil carbon, and point to further research to understand the inconsistent relationships between soil compaction and chemical-biological properties.

Andesite rock mining can significantly alter the morphology of the land as this activity results in the excavation and removal of material from convex hills. This process changes the initial contours of the land from curved to sloping zones, depressions, and flat areas. Excavation removes layers of rock and soil, causing changes in the shape of the land surface and creating depressions and flat areas where they were previously. In addition, mining can accelerate erosion and sedimentation processes, activating new geomorphic processes such as weathering, erosion, and sedimentation that form new landscapes according to the dynamics of the surrounding environment. Juhadi (2022) explained in his research that mining causes the soil to return to an early stage of development with altered genetic horizons and high base saturation levels but low

C-organic and N-total contents, which do not support vegetation growth. Recommendations for rehabilitation include proper surface morphology design, extra soil surface protection, and increased organic matter to support vegetation growth in post-mining areas.

Conclusion

Various factors, including local factors, influence soil development. Volcanism is a critical local factor in influencing soil development. Here, we found that multiple processes related to volcanism, especially the presence of parent material from volcanic activity, greatly influenced the characteristics of the soils formed. The soils formed are mainly andisols, typical of active volcanic soils. These soils will experience further development under the influence of other soil-forming factors, especially climate and the combination of local factors, namely volcanism and human activities. These findings summarize the results of studies conducted over six decades on the western side of the Ring of Fire. Although relatively few studies have been conducted, they have provided a picture and a well-established theoretical foundation for soil development under the influence of volcanic activity as a local factor.

In this study, there are still limitations, namely, the database used is only focused on Scopus to obtain high-quality publication manuscripts. As a consequence, the results obtained are also relatively few. Given the lack of publications in highly reputable databases such as Scopus, future studies are recommended to expand the search to other databases. Moreover, future studies are also recommended to explore the results of studies in different regions in the Ring of Fire and other regions worldwide.

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