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Impact of Mount Marapi Eruption on Purple Sweet Potato (Ipomoea batatas L.) Cultivation in Nagari Tabek Panjang, West Sumatra, Indonesia

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Abstract

This study aims to examine the effectiveness of Tithonia (Tithonia diversifolia) compost as an alternative fertilizer in the disaster-prone area of Nagari Bukik Batabuah, Canduang District, Agam Regency, West Sumatra. The method involved the production of Tithonia compost using locally available materials, with the addition of EM4 and molasses as bioactivators to accelerate the decomposition process. Results indicated that Tithonia compost contains high nutrient content, particularly nitrogen (2.7–3.59%), phosphorus (0.14–0.47%), and potassium (0.25–4.10%), which has the potential to reduce dependency on chemical fertilizers. The application of Tithonia compost improved soil structure, increased organic matter content, and enhanced soil porosity, thereby contributing to increased land resilience against erosion and landslides—the primary disaster threats in Bukik Batabuah. Economic analysis showed savings of approximately 50–75% compared to conventional chemical fertilizer costs. Implementation of this technology among farmers requires a participatory approach through the establishment of compost producer groups at the jorong (hamlet) level and support from various stakeholders. In conclusion, Tithonia compost represents an effective, economical, and sustainable organic fertilizer alternative that can support agricultural resilience in disaster-prone areas.

Keywords: compost fertilizer; Tithonia diversifolia; sustainable agriculture; disaster-prone area; disaster mitigation

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Introduction

Volcanic eruptions are among the most destructive natural disasters affecting agricultural production globally. Mount Marapi (Gunung Marapi), located in West Sumatra Province, Indonesia, is one of the most active stratovolcanoes in Sumatra, with a recorded eruptive history spanning over two centuries [1]. On 3 December 2023, Mount Marapi experienced a significant explosive eruption, ejecting volcanic ash columns reaching 3,000 meters above the crater, triggering ashfall over surrounding areas and prompting a hazard status elevation to Level III (Alert) on 9 January 2024 [2].

Nagari Tabek Panjang, situated in Canduang District, Agam Regency, lies within the agricultural zones most severely impacted by this eruption. This area is a recognized production center for purple sweet potato (Ipomoea batatas L.), a high-value horticultural commodity with important roles in local food security and household income [3]. The accumulation of volcanic ash and cold lava flows directly disrupted crop growth cycles, altered soil properties, and caused substantial economic losses to farming communities [4].

Purple sweet potato is a nutritionally significant crop, rich in anthocyanins, dietary fiber, vitamins, and minerals [5]. It is also commercially valuable, with growing market demand at local and national levels. The crop's sensitivity to environmental disturbances makes it particularly vulnerable to volcanic hazards, especially soil chemistry changes induced by ashfall [6]. Understanding the extent of eruption impacts on this crop is therefore critical for designing targeted recovery interventions.

Volcanic ash deposition alters soil physical and chemical characteristics in complex ways. In the short term, it reduces photosynthetic efficiency by coating leaf surfaces, impedes drainage and aeration, and modifies soil pH and nutrient availability [7, 8]. However, in the long term, weathered volcanic materials may improve soil fertility by contributing minerals such as potassium, calcium, and phosphorus [9, 10]. The balance between these short-term negative and long-term positive effects is poorly understood in the context of tropical root crops such as sweet potato.

Socio-economic consequences of eruptions on farming communities include income reduction, increased production costs, psychological stress, and disrupted livelihood systems [11, 12]. Farmers' adaptive capacities are often constrained by limited access to financial resources, extension services, and improved agricultural inputs [13]. Post-eruption recovery thus requires comprehensive strategies integrating technical, financial, and institutional support [14].

Previous studies on eruption impacts on agriculture have largely focused on staple crops such as rice and corn in Java [15, 16], with limited attention to Sumatran contexts or specialty horticultural crops. Research specifically addressing the impacts of Mount Marapi on purple sweet potato farming and farmer adaptation strategies remains scarce. This study addresses this gap by providing empirical evidence from field observations, farmer interviews, and soil laboratory analysis conducted in Nagari Tabek Panjang.

This study aims to: (1) identify the physical impacts of Mount Marapi eruption on farmland and purple sweet potato crops; (2) analyze the socio-economic impacts on farming households; and (3) provide evidence-based recommendations for post-eruption land management and crop rehabilitation. The findings are expected to contribute to the development of sustainable disaster response policies for agricultural communities in volcanically active regions of Indonesia.

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2. Literature Review

2.1 Volcanic Eruptions and Agricultural Impacts

Volcanic eruptions pose multi-dimensional risks to agricultural systems. Ashfall reduces incoming solar radiation, physically damages crops through abrasion and weight loading, and introduces toxic compounds into the soil environment [17]. The extent of damage depends on ash thickness, particle size, chemical composition, and crop growth stage at the time of eruption [7].

Research following the 2010 eruption of Mount Merapi in Central Java documented yield losses of 30–70% for various crops in the immediate post-eruption period, with soil pH reductions of up to two units [15]. Similar findings were reported after eruptions of Sinabung volcano in North Sumatra, where rice and vegetable production declined sharply due to ashfall and lahar events [16]. Cold lava flows (lahar) cause particularly severe and long-lasting damage, burying topsoil and agricultural infrastructure under meters of coarse volcanic material [8].

The chemical composition of volcanic ash from andesitic volcanoes such as Mount Marapi typically includes silica, aluminum, iron, calcium, potassium, and sulfur compounds [9]. While sulfur and fluorine components are immediately phytotoxic, the mineral-rich composition provides potential long-term soil fertility benefits as ash weathers and integrates into the soil matrix [10]. Studies from Indonesia, the Philippines, and Japan have demonstrated measurable improvements in soil fertility indicators five to ten years after major eruptions [18].

2.2 Purple Sweet Potato Cultivation

Purple sweet potato (Ipomoea batatas L.) is a versatile crop adapted to tropical and subtropical climates. It performs optimally in well-drained, loamy soils with pH ranging from 5.5 to 7.0, temperatures between 20–30°C, and moderate rainfall evenly distributed throughout the growing season [5, 19]. The crop is relatively tolerant of low-fertility soils, but its anthocyanin content and root yield are significantly influenced by soil nutrient status, particularly potassium and phosphorus availability [6].

In West Sumatra, purple sweet potato cultivation has expanded due to increasing market demand driven by health-conscious consumers and food processing industries [20]. Nagari Tabek Panjang has emerged as one of the primary production centers in Agam Regency, with farmers having developed locally adapted cultivation practices over multiple generations [3]. Crop yields typically range from 15–25 tons per hectare under favorable conditions, making it one of the most productive horticultural crops in the area [19].

The crop's vulnerability to abiotic stress, particularly soil waterlogging, extreme temperatures, and sudden changes in soil chemistry, makes it susceptible to productivity losses during volcanic events [5, 6]. Post-eruption soil acidification, reduced macronutrient availability, and disrupted microbial communities can all impair root development, anthocyanin synthesis, and overall crop performance [21].

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2.3 Farmer Adaptation and Post-Eruption Recovery

Farmers in volcanic hazard zones typically employ a range of adaptation strategies, including crop diversification, adjusting planting calendars, mechanical removal of ash deposits, application of lime to correct soil pH, and adoption of improved varieties more tolerant to stress conditions [13, 22]. The effectiveness of these strategies depends on the severity of eruption impact, the availability of capital and labor, and access to agricultural extension services [14].

Government and institutional support mechanisms are critical for accelerating agricultural recovery following disasters. Provision of subsidized inputs, emergency assistance programs, technical training, and market access support have been shown to reduce recovery time and improve livelihood resilience in affected communities [11, 23]. In Indonesia, the National Disaster Management Agency (BNPB) and regional agricultural departments play key coordinating roles in post-disaster agricultural rehabilitation [12].

3. Methodology

3.1 Study Site and Period

This study was conducted in Nagari Tabek Panjang, Canduang District, Agam Regency, West Sumatra Province, Indonesia (0°22'S, 100°28'E; elevation approximately 850 m asl). The research was carried out from 12 August to 1 September 2024, approximately eight months after the initial eruption of Mount Marapi on 3 December 2023, allowing for assessment of both immediate and medium-term impacts.

3.2 Data Collection

A mixed-methods approach was employed, combining qualitative and quantitative data collection techniques. Primary data were gathered through: (1) structured direct field observation of crop and land conditions; (2) semi-structured interviews with 25 purposively selected farmers cultivating purple sweet potato in the affected area; and (3) collection of 10 composite soil samples from affected plots for laboratory analysis.

Field observations focused on: volcanic ash deposit thickness and distribution; physical damage to plants (leaf discoloration, stem damage, root exposure); and extent of cold lava damage to land structures. Photographic documentation was systematically conducted throughout the study period to support observational records.

Soil samples were collected from the 0–20 cm topsoil horizon using a standard soil auger. Samples were analyzed at the Soil Science Laboratory of Universitas Prima Nusantara Bukittinggi for: soil pH (H_2O and KCl); available macronutrients (N, P, K); soil texture (hydrometer method); and organic matter content (Walkley-Black method).

3.3 Data Analysis

Quantitative data on crop yields were analyzed using descriptive statistics to characterize pre- and post-eruption production levels. Soil chemical data were interpreted against Indonesian standard fertility criteria [24]. Qualitative interview data were analyzed using thematic analysis to identify recurrent patterns in farmer experiences, economic impacts, and adaptation strategies. Results were triangulated across data sources to enhance validity [25].

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4. Results and Discussion

4.1 Physical Impacts on Farmland

Field observations revealed that volcanic ash from the December 2023 eruption of Mount Marapi had deposited across virtually all agricultural plots in Nagari Tabek Panjang. Ash layer thickness ranged from 1 cm in areas farther from the volcano to more than 5 cm in plots located closest to the affected slopes. The ash was predominantly fine-grained with a grayish-white coloration, consistent with the andesitic composition of Mount Marapi ejecta [1, 9].

Laboratory analysis of soil samples collected from affected plots revealed significant deterioration in soil chemical properties (Table 1). Mean soil pH declined from a baseline of 6.5 (slightly acidic, suitable for most crops) to 5.2 (strongly acidic), a shift that falls below the optimal range for purple sweet potato cultivation [5]. Available nitrogen decreased by an estimated 28%, available phosphorus by 22%, and exchangeable potassium by 31% relative to pre-eruption reference values obtained from the District Agricultural Office.

Cold lava flows affected approximately 15% of the agricultural area, depositing coarse-grained volcanic debris that rendered land unusable for immediate agricultural activities. Soil texture analysis of lava-impacted areas showed high proportions of gravel and sand fractions (>60%), with severely reduced organic matter content (<1%), indicating the near-total disruption of productive topsoil in these zones [8].

Table 1. Soil chemical properties before and after Mount Marapi eruption in Nagari Tabek Panjang

Parameter	Pre-eruption	Post-eruption	Optimal Range*
pH (H_2O)	6.5	5.2	5.5–7.0
N-total (%)	0.25	0.18	0.21–0.50
P-available (ppm)	28.4	22.1	>25
K-exch. (me/100g)	0.42	0.29	>0.30
Organic matter (%)	3.2	2.1	>2.0

* Based on soil fertility criteria for Ipomoea batatas L. [5, 19, 24]

4.2 Impacts on Crop Growth and Yield

Observations of purple sweet potato plants at various growth stages revealed multiple categories of eruption-related damage. Ash coating on leaf surfaces resulted in visible reductions in leaf color intensity and turgor, consistent with impaired photosynthetic capacity documented in similar studies [7, 26]. Severe ash loading caused physical lodging of vine stems and mechanical damage to leaf margins and petioles.

Yield data collected through farmer interviews and field verification indicated that mean productivity declined by 40–60% compared to the previous cropping season (Figure 1). Farmers in areas with ash deposits exceeding 3 cm reported the most severe losses, with some plots experiencing near-total crop failure. The combination of reduced photosynthesis, nutrient deficiency, and soil acidification created multiple simultaneous stressors that overwhelmed the plant's compensatory mechanisms [6, 21].

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Cold lava-affected plots showed the most extreme and lasting damage, with topsoil replaced by infertile volcanic debris. These areas were assessed as requiring a minimum of 12–18 months of intensive rehabilitation before resuming production, consistent with recovery timelines documented after other Indonesian volcanic events [8, 15].

4.3 Socio-Economic Impacts on Farming Households

Interviews with 25 farmers revealed substantial and multifaceted socio-economic consequences of the eruption. Mean household agricultural income declined by an estimated 52% during the affected season, with total farm-level losses ranging from IDR 8 million to IDR 45 million per household, depending on land size and location relative to the volcanic hazard zone.

Production costs simultaneously increased by approximately 35% due to additional labor requirements for ash removal, additional inputs for soil amendment (lime, fertilizers), and costs associated with replanting after crop failure. This cost-income squeeze severely constrained farmers' financial resilience, with 68% of respondents reporting inability to repay existing agricultural credit obligations during the affected season [11].

Beyond direct financial impacts, the eruption generated significant psychological distress. Farmers described anxiety related to ongoing volcanic activity, uncertainty about future crop seasons, and concern about the long-term viability of purple sweet potato farming in the area. These psychosocial impacts align with findings from studies of other eruption-affected farming communities in Indonesia and the Philippines [12, 23].

Social disruption was also documented, including temporary displacement of farming families living on steep slopes within the hazard zone, which disrupted farm management activities and reduced the labor available for post-eruption recovery operations. Some households reported considering permanently abandoning their agricultural plots, representing a potential long-term threat to the agricultural identity and food system of the community [13].

4.4 Farmer Adaptation Strategies

Despite significant challenges, farmers in Nagari Tabek Panjang demonstrated considerable resilience and agency in responding to the eruption. The most widely adopted adaptation strategy was mechanical removal of volcanic ash from crop surfaces and field drainage channels through intensive manual irrigation (reported by 88% of respondents). Land reworking through deep tillage was practiced by 72% of farmers to mix ash with the underlying soil horizon and improve aeration and root penetration [22].

Adjustment of planting schedules was employed by 64% of farmers, who delayed replanting until volcanic activity had stabilized and initial ash removal was completed. Application of agricultural lime ($Ca(OH)_2$) to correct soil acidification was practiced by 44% of respondents, though limited financial resources constrained wider adoption. A minority of farmers (24%) began experimenting with alternative crops more tolerant of acidic and ash-affected soils, such as cassava and taro, as a transitional livelihood strategy [13, 27].

Farmers identified several critical barriers to effective adaptation, including: limited access to subsidized agricultural inputs; insufficient technical guidance from agricultural extension officers on post-eruption soil management; restricted access to credit during the disaster period; and inadequate market connectivity for whatever limited production could be achieved. These barriers highlight the insufficiency of individual adaptive capacity alone and underscore the necessity of systemic institutional support [14, 28].

The potential long-term fertility benefits of volcanic ash were recognized by a small number of more experienced farmers, who noted historical observations of improved soil productivity in previously eruption-affected areas. This knowledge aligns with documented cases from other Indonesian volcanic systems where, following a recovery period

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of three to five years, affected soils showed enhanced mineral nutrient profiles and improved crop productivity [10, 18].

1. Conclusion

This study demonstrates that the December 2023 eruption of Mount Marapi caused severe and multidimensional impacts on purple sweet potato cultivation in Nagari Tabek Panjang. Volcanic ash deposition altered soil chemical properties significantly, reducing pH from 6.5 to 5.2 and diminishing available macronutrients, while physical damage from ash loading and cold lava flows directly impaired plant physiology and land structure. These conditions resulted in crop yield reductions of 40–60%, with cascading socio-economic consequences including income losses averaging 52% and substantially increased production costs for affected farming households.

Farmers demonstrated adaptive resilience through ash removal, land reworking, adjusted planting schedules, and partial crop substitution. However, the scale of damage and the financial constraints of small-scale farmers mean that household-level adaptive capacity alone is insufficient for timely and complete recovery. Institutional support through subsidized input provision, technical extension services, emergency credit access, and infrastructure rehabilitation is urgently needed.

Looking forward, the mineral-rich composition of Mount Marapi volcanic ash presents a potential long-term opportunity for soil fertility enhancement, provided that appropriate land management and rehabilitation practices are implemented. Sustained research monitoring of soil fertility dynamics and crop performance over a three-to-five-year recovery period is recommended to capture these longer-term processes and to inform adaptive management recommendations for the region.

The findings of this study contribute empirical evidence to the growing body of literature on agricultural vulnerability and resilience in volcanic hazard zones, and provide a practical foundation for developing integrated post-eruption recovery strategies in West Sumatra and comparable volcanic agricultural landscapes across Indonesia and Southeast Asia.

5. Declarations

5.1. Author Contributions

Conceptualization: F.A., S.A., and T.A.; Methodology: S.A.; Software: F.A.; Validation: F.A., S.A., and T.A.; Formal Analysis: F.A., S.A., and T.A.; Investigation: F.A.; Resources: S.A.; Data Curation: S.A.; Writing Original Draft Preparation: F.A., S.A., and T.A.; Writing Review and Editing: S.A., F.A., and T.A.; Visualization: F.A.; All authors have read and agreed to the published version of the manuscript.

FA is abbreviation of "Firs Author", SA is abbreviation of "Second Author", and TA is abbreviation of "Third Author".

5.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

5.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

5.4. Institutional Review Board Statement

Not applicable.

5.5. Informed Consent Statement

Not applicable.

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5.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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