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Soil Biological Properties across Slope Classes under Cassava (*Manihot esculenta* Crantz) Cultivation in Nagari Koto Tangah Batu Hampa, Akabiluru District, Lima Puluh Kota Regency

Salim Azhari[1], Oktanis Emalinda[2], Gusnidar[3]

Department of Soil Science, Faculty of Agriculture, Universitas Andalas, Padang, Indonesia

Article Information

Received: 19 July 2026

Revised: 31 August 2026

Accepted: 12 September 2026

Available online: 30 September 2026

Keywords

Cassava, Inceptisol, Slope class, Soil biological properties, Soil microorganisms

Corresponding Author

Name: Salim Azhari

E-mail: Salimazhari2023@gmail.com

ABSTRACT

Cassava is widely cultivated on sloping land in Nagari Koto Tangah Batu Hampa, Akabiluru District, Lima Puluh Kota Regency, where slope gradient may influence soil biological activity and, in turn, soil fertility. This study aimed to assess soil biological properties across several slope classes planted with cassava (Manihot esculenta Crantz). A survey method was used. Soil samples were collected from Inceptisols under monoculture cassava of the same plant age by purposive random sampling on four slope classes (0–8%, 8–15%, 15–25%, and 25–45%). Composite samples were taken at a depth of 0–20 cm with three replicates per slope class, giving 12 samples. Analyses were carried out at the Soil Science Laboratory, Faculty of Agriculture, Universitas Andalas, Padang, and covered soil microbial respiration, total bacterial and fungal populations, and the visual diversity of

DOI:

https://doi.org/10.35730/ergq4n30

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bacterial and fungal colonies. Total populations of bacteria and fungi and microbial respiration decreased as slope class increased. Bacterial populations ranged from 4.03×10^7 to 7.83×10^7 CFU/g soil and fungal populations from 5.23×10^6 to 7.73×10^6 CFU/g soil, with the highest values on the 0–8% slope and the lowest on the 25–45% slope. Microbial respiration ranged from 12.18 to 14.24 mg CO_2/m^2/day and was classified as low activity on all slope classes. Farmers cultivating cassava on sloping land are encouraged to apply organic fertilizers such as manure or compost to maintain soil organic matter and microbial activity.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a tropical and subtropical crop of the family Euphorbiaceae and an important source of dietary carbohydrate and of raw material for the food, chemical, and animal-feed industries (Lidiasari, 2006). Its tubers are used as a carbohydrate source and its leaves as a vegetable, and products derived from it include tapioca flour, bioethanol, liquid sugar, sorbitol, and monosodium glutamate (Yuliawati, 2009). In Indonesia, cassava is a staple food after rice and maize, which keeps demand high and encourages widespread cultivation.

Nagari Koto Tangah Batu Hampa, in Akabiluru District, Lima Puluh Kota Regency, West Sumatra, is a cassava-growing area with a hilly to undulating landscape, and its slope map shows classes ranging from flat to steep (>40%). Slope gradient is among the topographic properties that most strongly influence surface runoff and erosion (Kohnke & Bertrand, 1959). The steeper the slope, the greater the runoff and the more intense the weathering, leaching, and transport of soil material (Arsyad, 2010). Erosion removes the organic-matter-rich topsoil together with nutrients and soil

DOI:
https://doi.org/10.35730/ergq4n30

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microorganisms, which lowers land quality (Hardjowigeno, 2010). The risk is very high when land steeper than 30% is cultivated for annual crops (Baver, 1959), yet cassava is planted on slopes of this kind in the area.

Cassava in the nagari is grown mostly as a monoculture on Inceptisols. A single crop on the same land returns little plant residue to the soil, which reduces the supply of nutrients and energy for soil microorganisms, and microbial biodiversity tends to be higher in soils under varied vegetation (Coleman & Whitman, 2005). Slope and cropping system may therefore act together on soil biological properties.

Good soil biological condition is indicated by abundant soil organisms, high biological activity, and ample soil organic matter, and microbial activity is closely related to population size and to organic matter as an energy source (Hanafiah et al., 2009). Ardi (2009) reported that total microbial populations decline as slope gradient increases and as soil depth increases in natural forest. Because soil microorganisms are primary decomposers, differences in soil biological properties can be approached by measuring soil respiration and the total populations of bacteria and fungi. Therefore, this study aimed to assess soil biological properties, namely total bacterial and fungal populations, visual colony diversity, and microbial respiration, across several slope classes planted with cassava in Nagari Koto Tangah Batu Hampa, Akabiluru District, Lima Puluh Kota Regency. The findings are expected to inform land management recommendations for cassava farmers working on sloping land.

METHODS AND IMPLEMENTATION

This study used a survey method and was carried out from January to June 2023 in two stages: soil sampling in the field and sample analysis in the laboratory. Field sampling took place in Nagari Koto Tangah Batu Hampa, Akabiluru District, Lima Puluh Kota Regency, West Sumatra, Indonesia, and laboratory analyses were performed at the Biology and Chemistry Laboratory, Department of Soil Science, Faculty of Agriculture, Universitas Andalas, Padang. Preparation included a literature study and the collection of secondary data (administrative, slope, soil, land-use, and sampling-point maps, and rainfall data). Interpretation of the slope map yielded land units under

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cassava in four slope classes following the national land rehabilitation guidelines (Direktorat Jenderal Reboisasi dan Rehabilitasi Lahan, 1986): 0–8% (flat), >8–15% (gently sloping), >15–25% (moderately steep), and >25–45% (steep). A preliminary survey was then conducted to locate the study area, verify the mapped sampling points in the field, identify access routes, and obtain permission from the nagari government.

At each slope class, soil samples were collected by purposive random sampling from cassava fields of the same plant age that were managed as monoculture on Inceptisol. Within each slope class, composite samples were taken at random with three replicates at a depth of 0–20 cm, giving 12 samples in total (Table 1). Disturbed soil samples were taken with a Belgian auger, combined into a composite sample for each plot, placed in a plastic bag, and kept in a cool box until analysis. Materials used in the analyses included Nutrient Agar, nitrogen-free medium, potassium hydroxide (KOH), distilled water, and hydrochloric acid (HCl).

Table 1. Sampling Points, Slope Classes, and Geographic Positions

No	Land use and slope class	Geographic position	Replicates
1	Cassava, 0–8% (flat)	00°16′25.1″ S; 100°35′13.2″ E	3
2	Cassava, 8–15% (gently sloping)	00°15′29.7″ S; 100°35′03.1″ E	3
3	Cassava, 15–25% (moderately steep)	00°16′32.7″ S; 100°35′10.8″ E	3
4	Cassava, 25–45% (steep)	00°15′24.4″ S; 100°34′48.7″ E	3
	Total		**12**

Soil microbial respiration was measured in the field from the amount of CO_2 released by soil microorganisms. Two film bottles, one containing 10 mL of KOH and the other 10 mL of distilled water, were each placed on a support above the soil surface and covered with an inverted jar. After 4 hours of incubation, the bottles were taken to the laboratory and titrated with HCl (Schinner et al., 1996). Respiration was calculated as:

$$Respiration\ (mg\ CO_2/m^2/day) = (S - C) \times 2 \times 25 \times 6$$

where S is the volume of HCl used for the sample (mL), C is the volume of HCl used for the blank (mL), 2 is the mg of CO_2 equivalent to 1 mL of 1 N HCl, 25 is the factor converting the 20 × 20 cm

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https://doi.org/10.35730/ergq4n30

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box area to 1 m², and 6 converts the 4-hour incubation to 24 hours. Total populations of soil bacteria and fungi were determined by the dilution plate count method (Balai Penelitian Tanah, 2007):

$$Total\ population\ (CFU/g\ soil) = number\ of\ colonies \times (1/fp)$$

where fp is the dilution factor of the plate on which the colonies were counted. The visual diversity of bacterial and fungal colonies was observed from colony shape, size, and color. Data were entered into and calculated in Microsoft Excel and are presented descriptively.

RESULTS AND DISCUSSION

General conditions of the study site

Nagari Koto Tangah Batu Hampa covers 2,221.64 ha and is the largest nagari in Akabiluru District, which lies at 540–1,100 m above sea level. The nagari is bordered by Nagari Durian Gadang to the north, Nagari Padang Tarok to the west, Nagari Barulak to the south, and Nagari Situjuah Banda Dalam to the east (Badan Pusat Statistik Kabupaten 50 Kota, 2020). The soil map used in this study shows that the nagari is dominated by Inceptisols. Topography ranges from flat and undulating to hilly, with hills predominating, and land is used for paddy fields, plantations, shrubland, dryland fields, and pine forest.

Interviews with local farmers indicated that cassava has long been grown at the sampling sites and that the nagari is the largest cassava producer in the district, with production reaching 45.36 tons per year. Farmers regard cassava as easy to plant and maintain and grow it intensively as a monoculture. The soil is tilled manually with a hoe each planting season, weeds are controlled with the herbicide Roundup, and farmers apply only manure at 5–10 t/ha, once or twice per season (at planting and again when the plants are 3–4 months old). Chemical fertilizers are not used because of their cost. Cultivation techniques were otherwise similar on all slopes. Planting distance was 100 cm × 100 cm on the 0–8%, 8–15%, and 15–25% slopes and 100 cm × 150 cm on the 25–45% slope. Yields were about 10–12 kg per clump on the 0–8% and 8–15% slopes, 7–9 kg on the 15–25% slope, and 5–8 kg on the 25–45% slope. Farmers attributed the lower yield on the steepest land to

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erosion of the topsoil, which leaves tubers exposed at the surface so that they cannot develop well. Steep slopes also reduce the physical, chemical, and biological quality of the soil (Arsyad, 2010).

Total populations of soil bacteria and fungi

Total microbial population is the count of soil microorganisms that develop on the incubation medium. The total populations of bacteria and fungi on each slope class are shown in Table 2.

Table 2. Total Populations of Soil Bacteria and Fungi on Different Slope Classes under Cassava

Slope class	Bacteria (× 10^7 CFU/g soil)	Fungi (× 10^6 CFU/g soil)
0–8% (flat)	7.83	7.73
8–15% (gently sloping)	6.60	6.87
15–25% (moderately steep)	5.60	6.30
25–45% (steep)	4.03	5.23

Total bacterial populations ranged from 4.03 × 10^7 to 7.83 × 10^7 CFU/g soil and fungal populations from 5.23 × 10^6 to 7.73 × 10^6 CFU/g soil. Both groups were highest on the 0–8% slope (7.83 × 10^7 and 7.73 × 10^6 CFU/g soil) and lowest on the 25–45% slope (4.03 × 10^7 and 5.23 × 10^6 CFU/g soil), and values decreased with each increase in slope class. Relative to the 0–8% slope, bacterial and fungal populations on the 25–45% slope were about 48.5% and 32.3% lower, respectively.

The highest populations on the 0–8% slope are likely related to the flat terrain, where the topsoil is less likely to be carried away by runoff. The topsoil contains more organic matter than the layers below, and microorganisms use organic matter as a source of carbon and energy for growth; runoff, in contrast, transports organic-matter-rich material to lower ground (Murti, 2019). Alfadison (2022), who studied the same cassava land, reported soil organic matter of 1.80–5.42% (very low to moderate), highest on the 0–8% slope and lowest on the 25–45% slope, the same order as the microbial populations in Table 2. Alfadison (2022) also reported that lower bulk density corresponded to higher total pore space and higher organic matter at this site, conditions that favor microbial activity.

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The decline of microbial populations with increasing slope agrees with Ardi (2009), who found that total microbial populations decreased as slope gradient increased. On the steepest slope, erosion strips away the topsoil and with it organic matter, the energy source of soil microorganisms, so growth is limited. Sloping land is prone to erosion damage such as loss of organic matter, nutrients, and soil water, and heavily eroded soils tend to be compacted because the loose topsoil has been removed (Hardjowigeno, 2010). These conditions probably explain why the lowest populations (4.03×10^7 CFU/g soil for bacteria and 5.23×10^6 CFU/g soil for fungi) occurred on the 25–45% slope.

Visual diversity of soil bacteria and fungi

The visual diversity of soil microorganisms was assessed from colony size, shape, and color; a greater variety of colony types may indicate higher activity of soil microorganisms. All bacterial and fungal colonies were white, but they differed in shape and size (Table 3).

Table 3. Visual Diversity of Soil Bacterial and Fungal Colonies on Different Slope Classes

Slope class	Bacteria	Fungi
0–8%	Filamentous White specks White, round	White, round White specks Hyphal
8–15%	White, amorphous Irregular, spreading	White specks White, amorphous White, round Irregular, spreading
15–25%	Filamentous White specks Irregular, spreading	White, round White, amorphous Irregular, spreading
25–45%	Filamentous White, round Irregular, spreading	White, round White, amorphous

Taking bacteria and fungi together, six colony forms were recorded on the 0–8%, 8–15%, and 15–25% slopes and five on the 25–45% slope, so differences in visual diversity among slope classes were small. Hyphal fungal colonies were recorded only on the 0–8% slope, and the steepest slope yielded the fewest colony forms, which is consistent with its lowest organic matter content: low

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organic matter reduces the energy source available to microorganisms for growth and activity (Hanafiah et al., 2009). Because these observations rest on colony morphology alone, they do not identify taxa and should be read as an indication only.

Microbial diversity is influenced by soil pH, organic matter, nutrient availability, aeration, and drainage. Hadenia (2022) reported soil pH of 5.13–5.34 (slightly acid to acid) at the same site, with the highest value on the 0–8% slope, and a more acidic soil lowers microbial activity (Syahputra, 2007). Bulk density, total pore space, and organic matter also shape microbial activity and diversity (Alfadison, 2022). Land use is a further factor, because microbial biodiversity is higher in soils under different vegetation (Coleman & Whitman, 2005); since cassava was grown intensively as a monoculture on all slopes, vegetation is unlikely to explain the differences among slope classes in this study.

Soil microbial respiration

Soil respiration reflects the activity of soil microorganisms, which consume O_2 and release CO_2. Respiration ranged from 12.18 to 14.24 mg $CO_2/m^2/day$ (Table 4) and was classified as low activity on all slope classes.

Table 4. Soil Microbial Respiration on Different Slope Classes under Cassava

Slope class	Microbial respiration (mg $CO_2/m^2/day$)	Criterion*
0–8% (flat)	14.24	Low activity
8–15% (gently sloping)	13.38	Low activity
15–25% (moderately steep)	12.70	Low activity
25–45% (steep)	12.18	Low activity

**Criteria after Evanylo and Robert (2009).*

Respiration was highest on the 0–8% slope (14.24 mg $CO_2/m^2/day$) and lowest on the 25–45% slope (12.18 mg $CO_2/m^2/day$), a difference of about 14.5%, and it declined with each increase in slope class. This follows the pattern of total microbial populations: respiration is directly proportional to the total microbial population, so a larger population produces more CO_2 (Sembiring, 2019). On the 25–45% slope, most of the organic matter at the soil surface is carried away by runoff, which

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reduces the energy source for microorganisms; the resulting smaller populations show lower activity and therefore lower respiration. Respiration is also influenced by organic matter content, because organic matter is the energy source of soil microorganisms and respiration rises as decomposition increases (Sembiring, 2019).

Soil pH, organic matter, and total microbial population together determine microbial activity: acid soil (Syahputra, 2007), little organic matter, and small populations (Hanafiah et al., 2009) all depress it. The low respiration recorded on every slope class may therefore reflect the generally low organic matter (as low as 1.80%) and acidic conditions (pH 5.13–5.34) reported for this site, in addition to the effect of slope.

Overall interpretation and limitations

Taken together, the three indicators decreased as slope class increased and were consistently highest on the flat land and lowest on the steepest land, with the loss of organic matter through erosion the most plausible common cause. Because plant age, cropping system, and farmer management were similar among sites, slope appears to be the main factor that differed, although this was not tested statistically. The findings should be read in light of several limitations: only three composite replicates per slope class and a single sampling occasion, descriptive presentation without statistical tests, morphological rather than taxonomic identification of colonies, and reliance on organic matter, pH, and bulk density data reported by earlier studies at the same site. Under these conditions, maintaining soil organic matter through manure or compost is a practical way for farmers to sustain microbial activity on sloping cassava land.

CONCLUSION

Total populations of bacteria and fungi and soil microbial respiration decreased as slope class increased under cassava cultivation in Nagari Koto Tangah Batu Hampa. Bacterial populations ranged from 4.03×10^7 to 7.83×10^7 CFU/g soil and fungal populations from 5.23×10^6 to 7.73×10^6 CFU/g soil, with the highest values on the 0–8% slope and the lowest on the 25–45% slope. Microbial respiration ranged from 12.18 to 14.24 mg $CO_2/m^2/day$ and was classified as low activity

DOI:
https://doi.org/10.35730/ergq4n30

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on all slope classes. Farmers who grow cassava on sloping land are advised to add organic fertilizers such as manure or compost to maintain soil organic matter and, with it, the activity of soil microorganisms. Future studies should use more replicates and statistical analysis, measure organic matter and pH on the same samples, and identify the bacterial and fungal groups involved.

ACKNOWLEDGEMENTS

The authors express sincere gratitude to the Department of Soil Science, Faculty of Agriculture, Universitas Andalas, the Soil Science Laboratory, the government of Nagari Koto Tangah Batu Hampa, and the local farmers who supported this study and allowed sampling on their land.

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