Soil quality significance of goat pens positioned on the hilltop of sloping cocoa farms in PolmanSulawesi

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Soil quality significance of goat pens positioned on the hilltop of sloping cocoa farms in Polman-Sulawesi

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Abstract. Many smallholder cocoa farmers in Polman, West Sulawesi-Indonesia breed goats traditionally on hilltop of the sloped cocoa farms. The goat's manure is deposited under the pens, not distributed on the farm. We investigated the significance of this traditional goat breeding on the hilltop of sloping cocoa farms on soil quality based on the distance from the pens along the slope direction. We selected three sloped-cocoa farms where this traditional model had been practiced for years. The farms studied had 30 to 70% slopes, clay loam to clay soil textures. Along a transect lane, 0-5, 5-10, and 10-15 meters from the pen on each farm, we measured soil bulk density, hydraulic conductivity (HC), soil organic carbon (SOC), pH, soil nitrogen, phosphorus, potassium, cation exchangeable capacity (CEC) and earthworm population. This traditional practice improved soil quality compared to the adjacent farms which were not affected by the practice (control). Soil HC, SOC, N, P, K and CEC, and earthworm population were markedly higher under this system compared to the control, especially at 0 to 5 m distance from the manure deposit. The beneficial effects of this system were limited only within 10 m from the pens, beyond which soil quality was practically similar to the control site. This traditional system may be considered as an appropriate practice for soil quality maintenance in sloping cocoa farm, but an improvement is needed for greater benefits and reduced risks through terrace construction and manure deposition every 5-10 m range along the slope.

1. Introduction

Slope is a key measure for land capability and suitability assessment; steeper slope leads to greater limitations for agricultural use and more rapid processes of land degradation [1, 2, 3] and nutrient losses [4]. Farming on steep land is ecologically fragile with serious consequences on land and environmental degradation. Nevertheless, farming on steep slopes of mountainous areas is widespread and increasingly practiced in the tropics [5, 6, 7, 8]. As population density increases, more steep land in the tropics will become inhabited and cultivated in the future.

Use of sloping land for agriculture and living is a very long history, not merely associated with scarcity, increasing demand for land, and high price of more suitable land. Regulation, such as regional spatial planning, has often been unsuccessful in preventing people from utilizing sloping land, including in Indonesia. In fact, in particular areas of sloping land, farmers are found to be adaptive to their unique environment and culture in rural areas, preserving biodiversity, supporting resilient ecosystems, some

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of those coordinated by Globally Important Agricultural Heritage Systems (GIAHS) in Nishi Awa – Japan and other places all around the world as indicated by Food and Agriculture Organization of the United Nations (http://www.fao.org/giahs/en/) and reported by [9].

According to Digital Elevation Model (30 m resolution) data, about 60 % percent of the area of Polewali Mandar (Polman) District, West Sulawesi, Indonesia is mountainous (33 % of the district is steeper than >45 %, and 27 % of the region is 25-45 % slope). Considerable portion of this mountainous area is used for settlement and for agriculture, including for cocoa production. Cocoa is fundamental to the economy of the district, producing over 33,000 tons cocoa beans annually from 49,000 ha cocoa farm [10]. Tubbi Taramanu (Tutar) and Luyo are among the major sub-districts producing cocoa in the district, whose areas are predominantly sloping lands. In 2020, these two sub-districts produced 4,600 ton and 4,200 cocoa beans and 9,100 and 15,600 goats, respectively [10].

Majority of the farmers in these sub-districts dedicated their lives to produce cocoa and breed goats within their cocoa farms with simple and traditional management. On sloped cocoa farms with no terrace but generally well covered by tree canopies and litter, they generally position their houses on the hilltop and place the goat pens next to the houses for easy management. The goats are fed from the greens of shade trees (mainly *Gliricidia sepium*) pruned from the cocoa farm. The goat's wastes (manure and urine) are just deposited on the ground below the pen, not spread or applied to the whole farm. During the rainy season, runoff water carries the waste suspension to the lower part of the slope. We observed, cocoa trees near or below the waste deposit look healthier than the trees far from the deposit. The traditional practice of placing the pen on the hilltop might be intended to supply nutrients for the plants below the pen. Similarly, in Tana Toraja District, South Sulawesi, until 1960s farmers used to position water buffalo pens on the upper hillside of sloping farms to improve fertility of the soil in the lower part of the slope. Unfortunately, other than qualitative observation on tree conditions, no quantitative data available to explain the science of such practice. Studies on sloping land have mainly focused on the erosion [5, 8, 11, 12] and nutrient transport [11, 12] consequences. We hypothesized that if erosion process was well controlled by good vegetative control, transport of manure suspension from goat pen on hilltop of sloping cocoa farm should improve quality of the soil at the lower site of the slope. However, how far along the lower position of the slope can this mechanism improve soil quality? We therefore evaluated the significance of gravitational spread of goat waste suspension on sloping cocoa farm in Sulawesi on soil quality enhancement. The findings could provide practical recommendation for better practice of integrated cocoa – goat production on a sloping farm under the management system adaptive to the local farmers in Polman, Sulawesi.

2. Methods

2.1. The site characteristics and goat management

We conducted the research in three locations in the District of Polman-West Sulawesi, Indonesia, namely Pussui (sub-district Luyo) and Tutar-1 and Tutar-2 (sub-district Tubbi Taramanu), where farmers practiced integrated cocoa-goat production on sloping land. The slopes of the respective farms were 20-30, 60-70 and 30-40% (table 1, figure 1). Textures of the soil were clay loam and clay. Raised-floor wooden goat pens were positioned on the hilltop of the farms (figure 2), thereby suspension of goat's solid and liquid wastes can be transported from goat pens down to the lower side of the slope during the rainy seasons. The area has an average annual rainfall of 1833 mm. Each pen accommodated in average 15 to 20 Etowah crossbred goats. Typical look of the goat pens is shown in figure 2. The farms did not have conservation structure, but were well covered by the canopies of cocoa (mostly 3 m x 3 m planting distance) and shade trees (*Gliricidia sepium*, bananas and wood species) in between the cocoa trees and by dry cocoa leaves as surface mulch and grasses. The goats were fed with the greens from the farms, especially leaves of *Gliricidia sepium* and cocoa, while the plants benefited the nutrients from the goat's solid and liquid wastes carried by runoff. The farmers in the studied farms had implemented this integrated cocoa-goat system for over 15 years.

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Table 1. Slope, soil texture and Etowah goat breeding characteristics of the three sites (Pussui, Tutar-1 and Tutar-2) studied. Geographical position and slope characteristics of the sites are shown in figure 1.

Soil property	Pusui	Tutar-1	Tutar-2
Slope variation (%)	20-40	60-70	30-40
Texture (USDA[†]):	Clay loam	Clay	Clay
Clay (<2μm)	285	410	405
Silt (2-50 μm)	297	356	321
Sand (50-2000 μm)	380	230	260
Average number of goats bred	16	20	15
Length of breeding goats (yr)	13	18	15
Pen position on the farm	Hilltop	Hilltop	Hilltop
Farm land cover	Cocoa and shade trees, grasses[‡]	Cocoa and shade trees, grasses	Cocoa and shade trees, grasses

[†]Five samples were collected on each farm. The composite samples were determined according to Gee and Bauder (1986).
[‡]Shade trees included *Gliricidia sepium*, bananas and woody horticultural crops.

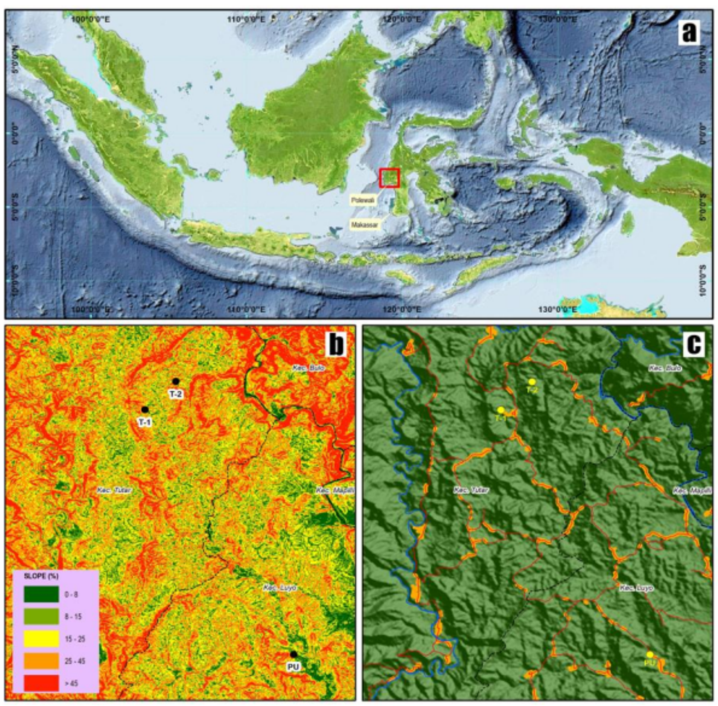

Figure 1. Location of the research sites showing its position in the map of Indonesia indicated by red square (a), slope of the study area (b), and access road (red line) and villages (orange-area) in the sub-districts of *Tutar* and *Luyo* demonstrating the mountainous nature of the area (c). The road and villages are generally situated on the

top-hill or mid-hill (compare b and c). The black circles (b) or yellow circles (c) are position of the sites: PU (Pussui), T-1 (Tutar-1) and T-2 (Tutar-2). Sloping land agriculture and settlement are common in the area due to limited suitable areas.

Figure 2. Typical look of the raised-floor wooden goat pens positioned on the hilltop of sloped farms in Polman District. The wooden pens are generally 6-m wide. Cocoa trees below the pen look healthy and the surface soil is generally well covered by tree canopies, grasses and litter.

2.2. Soil sampling and measurements

We separated the farm areas studied into two sections according to the slope direction, *i.e.* the section within the manure and urine suspension surface flow path during rain ("manure suspension pathway"), and the section adjacent to it, not within the manure suspension pathway, as the control site. On the manure suspension pathway, we divided the observation transect path into three observation segments along the slope, *i.e.* 0-5, 5-10, and 10-15 m from the middle point of the goat pen, 8-m wide (the goat pens are generally 6-m wide). Similarly, on the control site we also made observation transect path extended from the hilltop to 15 meters down the slope. Between the cocoa and shade trees within the transect path, we randomly collected both undisturbed (with ring samplers) and disturbed soil samples at 0 to 10 cm depth, five replicates in each observation segment for every measurement.

Using undisturbed samples in laboratory, we measured soil hydraulic conductivity according to Darcy's law [13], determined soil bulk density using standard 70-mm inner diameter, 50-mm long ring samplers [14], and calculated soil porosity according to the bulk density value, assuming particle density of 2.65 Mg m^{-3} [15]. Earthworms was counted using a hand sorting method [16, 17, 18] from 30 cm x 30 cm square and 20 cm depth area. Soil chemical properties were determined from composite of five replicate soil samples in each observation segment. We determined soil organic carbon according to the procedure outlined by [19], total nitrogen with Kjeldahl method [20], phosphorus [21], exchangeable potassium [22] and cation exchangeable capacity according to [23]. Soil pH was measured electrometrically (electrode paired) in water, 1/2.5 ratio [24].

Solid waste (feces) and urine production of individual goat was measured daily in every pen. The feces and goat body weight data obtained was regressed to obtain regression function, coefficient of determination and data plot.

Descriptive statistics was used for assessing differences between means of five replicates of the measured parameters. Incidence of soil erosion was qualitatively assessed, focusing on erosion types observed and its estimated percentage of the farm area.

3. Results

3.1. Soil physical properties

There was a clear trend of marginally lower bulk density (approximately 1.1 compared with 1.2 Mg/m^3), hence marginally greater total soil porosity of the soil near the pen (0 to 5 m) compared to the soil at 5 to 10 and 10 to 15 m distance from the pen and compared to the control (table 2). Because of these small differences, effects of the practice on bulk density and porosity were relatively trivial.

However, a clearer effect was found in hydraulic conductivity (reflecting difference in conducting pores or macro porosity rather than total pores). The farm area segment immediately adjacent to the pen or manure deposit (0-5 m distance) had markedly greater hydraulic conductivity compared with the area further from the pen (5-15 m) and control (table 2).

Table 2. Soil bulk density, total porosity and hydraulic conductivity along the slope, 0 to 15-meter-long from the goat pen at three sites (Pussui, Tutar-1 and Tutar-2). Values in the brackets are standard errors of the means of five replicates.

Distance from goat pen (m)	Pussui	Tutar-1	Tutar-2
	Bulk density (Mg/m^3)		
0-5	1.13 (0.02)	1.08 (0.06)	1.16 (0.07)
5-10	1.21 (0.03)	1.15 (0.08)	1.24 (0.07)
10-15	1.18 (0.03)	1.24 (0.07)	1.18 (0.10)
Control	1.22 (0.05)	1.20 (0.08)	1.18 (0.05)
	Total porosity (m^3/m^3)		
0-5	0.57 (0.01)	0.59 (0.04)	0.56 (0.04)
5-10	0.54 (0.03)	0.57 (0.05)	0.53 (0.04)
10-15	0.55 (0.04)	0.53 (0.04)	0.55 (0.06)
Control	0.54 (0.04)	0.55 (0.04)	0.55 (0.03)
	Hydraulic conductivity (cm/h)		
0-5	57.2 (22.4)	61.2 (23.2)	40.6 (20.1)
5-10	30.1 (10.7)	45.9 (21.8)	33.4 (18.4)
10-15	35.3 (12.1)	47.1 (10.3)	20.9 (9.2)
Control	28.4 (7.89)	23.8 (15.1)	17.2 (10.1)

3.2. Earthworm population

Earthworm population was about three to five times greater on 0-5 m from the pen compared to the control area of all farms studied (table 3). Earthworm count sharply decreased with distance from the pen, i.e. from about 110-140 at 0-5 m distance from the pen down to around 10-80 at 10-15 m distance. A more drastic decline as the distance advanced from 0-5 to 5-15 m was observed at Pussui (from 122 to 40), and at Tutar-2 (from 111 to 36). This was coincided with gentler slope of these two farms compared with the farm at Tutar-1. At 5 to 15 m distance from the pen, earthworm population in Pussui and Tutar-2 were similar to that in the control site.

Table 3. Earthworm population distribution along the slope, 0 to 15-m-long from the goat pen at three sites (Pussui, Tutar-1 and Tutar-2). Values in the brackets are standard errors of the means of five replicates.

Distance from goat pen (m)	Pussui	Tutar-1	Tutar-2
0-5	122 (30)	142 (24)	111 (28)
5-10	40 (6.7)	84 (20)	36 (13)
10-15	38 (7.5)	80 (33)	13 (6.5)
Control	47 (8.9)	33 (13)	24 (9.6)

3.3. Soil chemical properties

Effects of this traditional system practice on soil fertility was only apparent on the area closest (0-5 m) to the pen. Organic carbon, contents of total nitrogen, available phosphorus and exchangeable potassium, as well as cation exchangeable capacity were higher in 0 to 5 m area from the pen compared to the control site (table 4). However, the figures between the control area and 5 to 15 m from the pen were similar. Effect of the system practiced on soil pH was not obvious, although soil pH at 0-5 m distance was one-tenth of the scale higher compared with the distance beyond 5 m (table 4).

Table 4. Soil chemical properties along the slope, 0 to 15-m-long from the goat pen at three sites (Pussui, Tutar-1 and Tutar-2). Values given are composite of five random samples in each observation segment at 0-5, 5-10 and 10-14 m distance from goat pen.

Distance from goat pen (m)	Pussui	Tutar-1	Tutar-2
		-----------------C organic (g/100g)-----------------	
0-5	2.37	1.91	1.90
5-10	1.10	0.71	0.79
10-15	1.07	0.80	0.62
Control	1.16	0.80	0.67
		-----------------N total (g/100g)----------------	
0-5	0.22	0.18	0.17
5-10	0.10	0.06	0.06
10-15	0.08	0.06	0.05
Control	0.11	0.11	0.08
		-------------P-avail. (mg/kg)------------	
0-5	10.43	9.73	9.88
5-10	5.38	8.37	9.64
10-15	4.09	3.17	5.40
Control	4.87	5.38	7.71
		-----------K-exch. (cmol/kg)----------	
0-5	0.13	0.19	0.21
5-10	0.11	0.20	0.11
10-15	0.08	0.12	0.05
Control	0.11	0.11	0.12
		------------CEC (cmol/kg)---------------	
0-5	27.95	26.05	27.72
5-10	27.25	24.50	23.63
10-15	17.38	23.63	22.42
Control	21.13	18.74	21.46
		-----------------pH in water, 1:2.5--------------	
0-5	6.3	6.1	6.3
5-10	6.1	5.8	6.1
10-15	6.1	6.0	6.1
Control	5.8	6.0	5.9

3.4. Goat's feces produced

The Etowah goats bred by the farmers in the study area produced valuable waste for soil fertility amelioration or maintenance. A-25 kg Etowah goat produced in average 600 g fresh manure per day (figure 3) or 219 kg fresh manure per year, and 0.272 L urine per day (data of urine not presented). This amount is equivalent to approximately 100 kg dry manure per goat per year. As each farmer bred 15 to 20 goats per pen (table 1), a pen of goats in the study area yielded in average 1.5-2.0 Mg/yr dry goat manure. Our analysis revealed that this goat manure contained 162.2 g/kg organic carbon, 7.8 g/kg nitrogen, 5.6 g/kg phosphor and 11.7 g/kg potassium. Hence, from a single goat pen, farmers in the study area produced 243-324 kg C (418-558 kg organic matter), 12-16 kg N, 8-11 kg P and 18-23 kg K per pen every year.

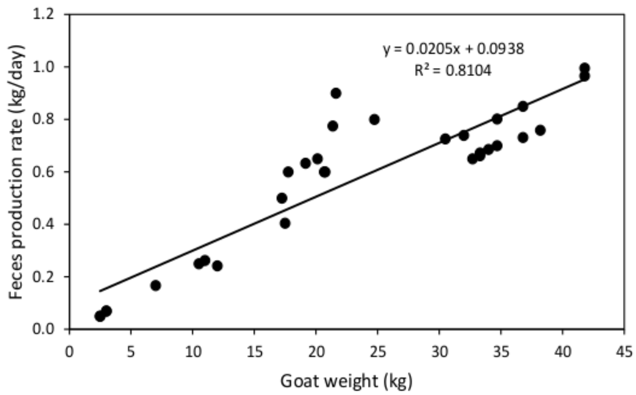

Figure 3. Goat feces (solid waste) production rate in the farms studied as related to goat weight.

3.5. Soil erosion

We observed spots of sheet erosion on the uncovered farm surface soil, especially at Tutar-1 whose slope was greater than 60 % (figure 4). However, this eroded part was below 5 % of the farm area. Having 1,833 mm mean annual rainfall, steep sloped farms have landslide potential. Yet, the local farmers claimed landslide rarely occurs in the area, particularly in the cocoa farms, which are generally cocoa-based agroforestry [25] We did not measure erosion in a form of transportation of fine soil particles.

Figure 4. Sheet erosion (right) on >60% sloping cocoa farm of Tutar-1 on uncovered surface soil spot. (Photo of Mr. Mahayuddin).

4. Discussion

Our data revealed that the traditional practice of positioning goat pen on the hilltop of sloping cocoa farms in Polman led to noticeably greater soil organic carbon (table 4), earthworm population (table 3) and hydraulic conductivity (table 2), particularly in the area adjacent to the manure deposit (0-5 m from the pen). The effects could extend to 10 m from the pen in steep sloping farm, as at Tutar-1. Effects on other soil properties were less obvious.

An average annual rainfall of 1,833 mm in the area [10] should provide sufficient energy to transport the manure suspension (solid and urine) during the rainy seasons down to the lower position of the farm. The suspension transport increased soil organic carbon (SOC) content, especially in the nearest area to the manure deposit, within 0-5 m distance (table 4). Increased SOC should have significant consequences on soil quality in general. Sufficient soil organic matter (SOM) under appropriate land management is essential for earthworm growth and reproduction, and its effects on SOM and soil functions [26, 27, 28] as revealed in table 3. The earthworms subsequently create macropore channels to improve soil hydraulic conductivity [26, 29, 30, 31] including in steep-sloping land [32] as presented in table 2.

The integrated cocoa-goat system practiced by the farmers in the study area has soil fertility merits (table 4), valuable for soil quality amelioration and for adaptation to climate change. As pointed out in Section 3.4, a single pen with 15-20 Etowah goats in a farm approximately produced 300 kg SOC (500 kg organic matter), 15 kg nitrogen, 10 kg phosphor and 20 kg potassium per year. This amount is worth for improving SOC from low/very low ($\leq$ 1 g/100 g) to moderate levels ($\geq$ 2 g/100 g equivalent to $\geq$ 40 Mg C/ha per 0.2 m soil depth) (table 4) within about 15 years of practice. Such SOC sequestration contributed by farmers is in line with global efforts for climate change mitigation toward the 4‰ initiative [33, 25]. Our analysis revealed, the nutrients gained from the goat manure can meet about 20 % of N, 100 % P and 80 % K demands to produce 1 Mg dry cocoa beans per hectare per year. This nutrient gain is significant to reduce dependence on fertilizers [34]. Since these beneficial effects were only obvious within a short distance from the pen, the challenge is how to distribute or extend this valuable resource to larger area in the farm, not only limited to 0-5 m distance.

Manure suspension transport as assisted by slope is instrumental to the process of soil quality enhancement in this system [32], especially to what extent would the downward transport of soil fertility improve soil quality. Having steeper slope, the farm in Tutar-1 had higher earthworm population and hydraulic conductivity even at 5 to 15 m distance from the pen compared with Pussui and Tutar-2 sites which had gentler slope (tables 3 and 4). However, steeper slope leads to higher erosion risk [5, 35] and potential fine particle and nutrient transport [12, 35, 4, 36], particularly crucial when the surface soil is directly exposed to raindrop impact (figure 3). Therefore, it is absolutely critical in this traditional system to keep the surface soil protected.

In addition to maintaining good surface soil cover by the tree canopies and litter, terrace construction is necessary to reduce erosion risk and climate change adaptation on sloping agricultural land [37, 38, 39]. The terrace must be appropriately designed, properly constructed and maintained to minimize potential for provoked degradation of sloping land [37]. Our data reveal that the waste suspension distribution was negligible beyond 10 m distance from the pen (most significant within 0-5 m distance), we suggest manure deposit should be deposited and terrace should be constructed every 5 to 10-m range along the slope, rather than currently practiced only from single source on the hilltop (under the pen) without terrace. This 5 to 10-m distance manure deposit and terrace arrangement should stimulate growth and reproduction of earthworms and increase hydraulic conductivity to reduce potential runoff in the farm area, improve its soil fertility and soil carbon storage advantages, beyond 10 m from the pen.

Inclusion of well-designed terraces into sloping agriculture system practiced in Polman should enhance its beneficial effects on soil quality for efficient soil nutrients management [4, 36,] and erosion control [37]. Combination of terracing, soil conservation practices, soil cover, hedgerows and vegetation ridges under agroforestry systems should be encouraged. An agroforestry scheme called Sloping Agricultural Land Technology (SALT) has been proven to be appropriate for use by typical hilly-land farmers in the Philippines and other places to help control soil erosion and increase crop yields [39, 40]. SALT utilizes nitrogen-fixing trees as soil binder, fertilizer generator, and livestock feed source. The system also includes annual and perennial diversified food crops grown in the spaces between the hedgerows. The livestock produces organic matter and nutrients for the systems, reducing dependence on fertilizers [41]. Furthermore, Gusli et al. [25] concluded that cocoa-based agroforestry in the study area led to improved soil quality and more adaptive to climate change as opposed to cocoa monoculture. Agroforestry systems has long been practiced to control erosion on arable tropical steep lands [5].

5. Conclusions

The practice of placing goat's pen on the hilltop of sloping cocoa farms in Polman, Sulawesi has soil quality enhancement merit along the slope direction. However, its valuable effects were mainly limited to 0-5 m distance or maximum to 10 m distance in steeper slope. Soil organic carbon, hydraulic conductivity, nitrogen, phosphorus, potassium, cation exchangeable capacity and earthworm population were markedly higher within this short distance from the manure deposit under the pens. Nevertheless, sheet erosion was also observed. Hence, an improvement is needed to enhance its positive effects, while reducing the risks. Terraces should be constructed and manure needs to be deposited every 5-10 m range along the slope, and the surface soil must be well protected from raindrop impact by tree canopies and litter under cocoa-based agroforestry system.

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References

[1] Zolekar R B and Bhagat VS 2015 Multi-criteria land suitability analysis for agriculture in hilly zone: remote sensing and GIS approach. *Comput. Electron. Agric.* **118** 300–321 https://doi.org/10.1016/j.compag.2015.09.016

[2] Everest T, Sungur A and Özcan H 2020 Determination of agricultural land suitability with a multiple-criteria decision-making method in Northwestern Turkey *Int. J. Environ. Sci. Technol.* https://doi.org/10.1007/s13762-020-02869-9

[3] Taghizadeh-Mehrjardi R, Nabiollahi K, Rasoli L, Kerry R and Scholten T 2020 Land suitability assessment and agricultural production sustainability using machine learning models *Agronomy* **10** 1–20 https://doi.org/10.3390/agronomy10040573

[4] Li Y, Wang, C and Tang H 2006 Research advances in nutrient runoff on sloping land in watersheds *Aquat. Ecosyst. Heal. Manag.* **9** 27–32 https://doi.org/10.1080/14634980600559379

[5] Lal R 1990 Agroforestry systems to control erosion on arable tropical steeplands, in: Research Needs and Applications to Reduce Erosion and Sedimentation in Tropical Steeplands *Proc., Symposium, Suva* No.192 (Fiji: IAHS-AISH Publ.) pp 338–346

[6] Craswell E T, Sajjapongse A, Howlett D J B and Dowling A J 1997 Agroforestry in the management of sloping lands in Asia and the Pacific *Agroforestry Systems* **38** 121–137 https://doi.org/10.1007/978-94-015-9008-2_5

[7] Wezel A, Steinmüller N and Friederichsen J R 2002 Slope position effects on soil fertility and crop productivity and implications for soil conservation in upland northwest Vietnam *Agriculture Ecosystem & Environment* **91** (1-3) 113–126

[8] Romero-Perezgrovas R and Cheesman S 2014 Conservation Agriculture as an alternative for soil erosion control and crop production in steep-slopes regions cultivated by Small-scale farmers in Motozintla, Mexico *World J. Agric. Res.* **2** 18–24 https://doi.org/10.12691/wjar-2-6a-4

[9] Singh R S G S 2017 Traditional agriculture: a climate-smart approach for sustainable food production. Energy *Ecol. Environ.* **2** 296–316 https://doi.org/10.1007/s40974-017-0074-7

[10] BPS *Kabupaten Polman* 2020 (Sulawesi Barat: Badan Pusat Statistik) https://polewalimandarkab.bps.go.id/

[11] Lü Y, Fu B, Chen L and Liu G 2015 Nutrient transport associated with water erosion: progress

and prospect *Progress in Physical Geography: Earth and Environment* **31** (6) 607–620 https://doi.org/10.1177/0309133307087085
[12] Mao Y, Hu W, Chau H W, Lei B, Di H, Chen A, Hou M and Whitley S 2020 Combined cultivation pattern reduces soil erosion and and nutrient loss from sloping farmland on red soil in Southwestern China *Agronomy* **10**(8) 1071 https://doi.org/10.3390/agronomy10081071
[13] Klute A and Dirksen C 1986 *Hydraulic Conductivity And Diffusivity: Laboratory methods in: Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods* (Madison: Soil Science Society of America, American Society of Agronomy) pp 687–734
[14] Blake G R and Hartge K H 1986 *Bulk Density in: Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods* (Madison: Soil Science Society of America, American Society of Agronomy) pp 363–375
[15] Hillel D 2013 *Introduction to Soil Physics* (United States of America: Academic Press) pp 392 https://doi.org/10.1016/C2009-0-03052-9
[16] Raw F 1960 Earthworm population studies : A comparison of sampling methods *Nature* **187** 257 https://doi.org/10.1038/187257a0
[17] Nordström S and Rundgren S 1972 Methods of sampling lumbricids *Oikos* **23**(3) 344-352 https://doi.org/10.2307/3543173
[18] Singh J, Singh S and Vig A P 2016 Extraction of earthworm from soil by different sampling methods: a review *Environ. Dev. Sustain.* **18** 1521–1539 https://doi.org/10.1007/s10668-015-9703-5
[19] Nelson D W and Sommers L E 1982 Total carbon, organic carbon, and organic matter *Methods of Soil Analysist* ed A L, D E Baker, D R Keeney (Madison: American Society of Agronomy Publ.) pp 539–579
[20] Bremner J M and Mulvaney C S 1982 Nitrogen total *Methods of Soil Analysis: Part 2, Chemical and Microbiological Properties* ed A L, R H Miller, D R Keeney (Madison: American Society of Agronomy, Soil Science Society of America) 595-624
[21] Olsen S R and Sommers L E 1982 Phosphorus in *Methods of Soil Analysis Part 2 Chemical and Microbiological Properties* ed A L (Madison: American Society of Agronomy, Soil Science Society of America) pp 403–430
[22] Knudsen D, Peterson G A and Pratt P 1982 Lithium, sodium, and potassium in *Methods of Soil Analysis Part 2 Chemical and Microbiological Properties* ed A L (Madison: American society of agronomy) pp 225–246
[23] Rhoades J D 1982 Cation exchange capacity in *Methods of Soil Analysis Part 2 Chemical and Microbiological Properties* ed A L, R H Miller, D R Keeney (Madison: American society of Agronomy Inc., Soil Science Society of America Inc.) pp 149–157
[24] McLean E O 1982 Soil pH and lime requirement in *Methods of Soil Analysis Part 2 Chemical and Microbiological Properties* ed A L (Madison: American society of Agronomy Inc., Soil Science Society of America Inc.) pp 199–224
[25] Gusli S, Sumeni S, Sabodin R, Muqfi I H, Nur M, Hairiah K, Useng D and Noordwijk M Van 2020 Soil organic matter, mitigation of and adaptation to climate change in cocoa–based agroforestry systems *Land* **9** 323 https://doi.org/10.3390/land9090323
[26] Zachmann J E, Linden D R and Clapp C E 1987 Macroporous infiltration and redistribution as affected by earthworms, tillage, and residue *Soil Sci. Soc. Am. J.* **51** 1580–1586 https://doi.org/10.2136/sssaj1987.03615995005100060032x
[27] Fonte S J, Barrios E and Six J 2010 Earthworms, soil fertility and aggregate-associated soil organic matter dynamics in the Quesungual agroforestry system *Geoderma* **155** 320–328 https://doi.org/10.1016/j.geoderma.2009.12.016
[28] Bertrand M, Barot S, Blouin M, Whalen J, De Oliveira T and Roger-Estrade J 2015 Earthworm services for cropping systems A review *Agron. Sustain. Dev.* https://doi.org/10.1007/s13593-014-0269-7
[29] Trojan M D and Linden D R 1998 Macroporosity and hydraulic properties of earthworm-affected

soils as influenced by tillage and residue management *Soil Sci. Soc. Am. J.* https://doi.org/10.2136/sssaj1998.03615995006200060029x

[30] Capowiez Y, Cadoux S, Bouchant P, Ruy S, Roger-Estrade J, Richard G and Boizard H 2009 The effect of tillage type and cropping system on earthworm communities, macroporosity and water infiltration *Soil Tillage Res.* **105** 209–216 https://doi.org/10.1016/j.still.2009.09.002

[31] Van Schaik L, Palm J, Klaus J, Zehe E and Schröder B 2014 Linking spatial earthworm distribution to macropore numbers and hydrological effectiveness *Ecohydrology* **7** 401–408 https://doi.org/10.1002/eco.1358

[32] Jouquet P, Janeau J L, Pisano A, Sy H T, Orange D, Minh L T N and Valentin C 2012 Influence of earthworms and termites on runoff and erosion in a tropical steep slope fallow in Vietnam: A rainfall simulation experiment *Appl. Soil Ecol.* **61** 161–168 https://doi.org/10.1016/j.apsoil.2012.04.004

[33] Minasny B, Malone B P, Mcbratney A B, Angers D A, Arrouays D, Chambers A, Chaplot V, Chen Z, Cheng K, Das B S, Field D J, Gimona A, Hedley C B, Young, S, Mandal B, Marchant B P, Martin M, Mcconkey B G, Leatitia V, Rourke S O, Richer-de-forges A C, Odeh I, Padarian J, Paustian K, Pan G, Poggio L, Savin I, Stolbovoy V, Stockmann U, Sulaeman Y, Tsui C, Vågen T, Wesemael B Van, Winowiecki L, Arrouays D, Martin M, Richer-de-forges A C and Mulder V L 2017 Geoderma soil carbon 4 per mille *Geoderma* **292** 59–86 https://doi.org/10.1016/j.geoderma.2017.01.002

[34] Gusli S, Zakaria B, Sakri, Muliadi, Toleng L 2005 The significance of introducing goats into Sulawesi cocoa farming system to reduce dependence on inorganic fertilizers and to increase smallholders profitability *Proc. 4th Malaysian International Cocoa Conference* (Malaysia: Malaysian Cocoa Board) p 280-287 https://agris.fao.org/agris-search/

[35] Ross S M and Dykes A 1996 Soil conditions, erosion and nutrient loss on steep slopes under mixed dipterocarp forest in Brunei Darussalam, in *Tropical Rainforest Research* vol. 74 ed Edwards D S, Booth W E, Choy S C (Springer, Dordrecht) pp 259–270 https://doi.org/10.1007/978-94-009-1685-2_24

[36] Sharpley A N, Daniels M B, Brye K R, VanDevender K, Burke J, Berry L G and Webb P 2020 Fate and transport of phosphorus-containing land-applied swine slurry in a karst watershed *Agrosystems Geosci. Environ.* **3** 1–14 https://doi.org/10.1002/agg2.20096

[37] Dorren L and Rey F 2004 A review of the effect of terracing on erosion *Soil Conserv. Prot. Eur.* 97–108

[38] Bocco G and Napoletano B M 2017 The prospects of terrace agriculture as an adaptation to climate change in Latin America *Geogr. Compass* **11** 1–13 https://doi.org/10.1111/gec3.12330

[39] Tacio H D 1993 Sloping agricultural land technology (SALT): a sustainable agroforestry scheme for the uplands *Agrofor. Syst.* **22** 145–152 https://doi.org/10.1007/BF00705143

[40] Kosmowski F 2018 Soil water management practices (terraces) helped to mitigate the 2015 drought in Ethiopia *Agric. Water Manag.* **204** 11–16 https://doi.org/10.1016/j.agwat.2018.02.025

[41] Lamichhane K 2013 Effectiveness of sloping agricultural land technology on soil fertility status of mid-hills in Nepal *J. For. Res.* **24** 767–775 https://doi.org/10.1007/s11676-013-0415-0

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