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Effects of manure and chemical fertilizers on maize performance in the steep hillside with and without terraces in North Halmahera, Indonesia

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Abstract

Improper soil management inland with steep slopes is one of the causes of decreased agricultural productivity in hilly areas. The use of terraces on steep slopes is considered effective in preventing erosion. However, this does not increase agricultural productivity significantly. Therefore, this study aimed to analyze the performance of maize on land with and without terraces as affected by the addition of goat manure and NPK. A field experiment was arranged in a randomized complete block design, consisting of 12 experimental plots that were made on a hill with a slope of 79 % with three replications. Plant tissue samples were analyzed for assessing N, P, and K content. However, soil samples were measured for N, P, K, SOC, pH H_2O, EC, CEC, and soil texture. Data were analyzed using analysis of variance and continued with a Post-Hoc test (DMRT at α= 5 %). The application of manure and NPK fertilizers significantly improved EC, SOC, N, and P in soil, also N and P content in plant tissues. Goat manure played a role in improving soil properties, while NPK fertilizers played a role in supplying nutrient availability directly to plants. The best performance of maize was on land without terraces and cover crops (sweet potato). Competition for nutrients between maize and sweet potato occurred on land with terraces so that the performance of maize tended to be lower. Soil management on land with terraces needs to consider nutrient management and selection of cover crops so that both can increase maize productivity.

INTRODUCTION

Soil management and improvement of agricultural productivity have become a global concern in maintaining food security and environmental quality. Improper land management practices are believed to be one of the causes of land degradation. In recent decades, land degradation has increased in many countries, most of which are caused by the agricultural sector. In Halmahera, land degradation is also found in several agricultural areas with inappropriate land use accompanied by the absence of conservation measures (Rofita et al., 2021). Agricultural intensification has caused soil compaction, decreased organic carbon in the soil, increased evapotranspiration rates, and led to excessive erosion (Lal, 2004). The impact of agricultural intensification is not significant. However, in the long term, it will cause environmental damage and a decrease in agricultural production. The socio-economic aspects of the community are also affected by the destruction of agricultural land, thereby leading to poverty. According to Fronning et al. (2008), soil conservation practices can be carried out by applying manure, cover crops, and terraces to reduce the impact of land degradation and improve soil quality.

Manure can be used as a soil conditioner to improve the soil's physical, chemical, and biological properties. According to Sistani et al. (2008), manure can be

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used as a source of nitrogen and phosphorus in the soil to improve the growth of crops. Improved soil aggregation due to the application of manure can also increase root growth and plant productivity. In manure, there are very abundant microorganisms so that, if applied in the soil, it can play a role in increasing the activity of microorganisms in the rhizosphere zone, which should have an effect on the supply of nutrients and plant growth. Some previous researchers tended to report the superiority of manure compared to chemical fertilizers because it could increase crop productivity (McAndrews et al., 2006). Manure will supply slow-release nutrients for plants so that their use can be sustainable and more environmentally friendly.

Land management practices in areas prone to erosion are often carried out using terracing. Terracing is a conservation technique that has been developed for a long time, considered capable of reducing erosion (Arnáez et al., 2015). The application of terracing alone is not sufficient to produce agricultural products. Thus, a combination of manure and chemical fertilizers is needed to increase crop yields. Some researchers recommend manure over chemical fertilizers, yet their properties are site-specific, depending on the interaction between soil edaphic conditions and plants. The very dynamic nature of the soil as affected by the addition of manure and chemical fertilizers needs to be studied further to find a suitable formulation to be used in terraced land.

MATERIALS AND METHODS

Study area and experimental design

The experimental research was conducted in Limau Village, North Galela District, North Halmahera Regency, North Maluku Province, Indonesia (127° 50' 30.6", 01° 55' 15.1"). The research site is located on a hillside, with a slope of 79 % (steep) and an altitude of 18 m above sea level. Steep slopes have a high risk for erosion, triggering land damage. Accordingly, this research was designed to overcome such problems. In general, the soil texture at the study site is classified as clay soil with a sticky consistency, while the soil pH is neutral, and some of the initial soil chemical properties are low. The result of soil analysis before treatment are presented in Table 1.

Table 1. Soil analysis before treatment

Parameter	Value	Category
Sand (%)	7	
Silt (%)	35	Clay texture
Clay (%)	58	
pH H_2O	6.81	Neutral
SOC (%)	1.37	Low
N-total (%)	0.14	Low
P-available (ppm)	1	Low
P-total (%)	0.004	Low
K-total (%)	0.007	Low
CEC (cmol(+).kg^{-1})	16.8	Low

The materials used for the experiment were maize plants (cultivar Bisi 2), organic fertilizer from goat manure, and chemical fertilizers with active ingredients of nitrogen (N), phosphorus (P), and potassium (K). The experiment was arranged in a randomized complete block design (RCBD) consisting of three factors, namely (1) land with and without terraces, (2) the use of goat manure at a dose of 0 ton.ha^{-1}, 10 ton.ha^{-1}, 20 ton.ha^{-1}, and 30 ton.ha^{-1} and (3) the use of NPK fertilizers at a dose of 0 kg.ha^{-1}, 150 kg.ha^{-1}, and 300 kg.ha^{-1}, where each treatment combination was made into three replications. The appearance of the land with and without terraces can be seen in Figure 1. The application of goat manure and chemical fertilizers was carried out evenly. The treatment combinations in more detail are presented in Table 2.

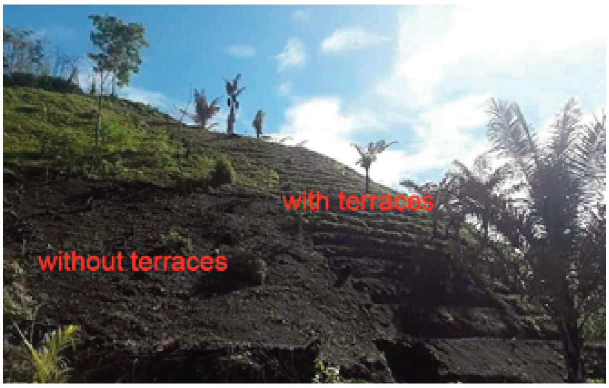

Figure 1. Land with terraces and without terraces

Table 2. The doses of fertilizers

Code	The doses of fertilizers
T0P0	0 ton.ha^{-1} goat manure + 0 kg.ha^{-1} NPK fertilizer
T0P1	0 ton.ha^{-1} goat manure + 150 kg.ha^{-1} NPK fertilizer
T0P2	0 ton.ha^{-1} goat manure + 300 kg.ha^{-1} NPK fertilizer
T1P0	10 ton.ha^{-1} goat manure + 0 kg.ha^{-1} NPK fertilizer
T1P1	10 ton.ha^{-1} goat manure + 150 kg.ha^{-1} NPK fertilizer
T1P2	10 ton.ha^{-1} goat manure + 300 kg.ha^{-1} NPK fertilizer
T2P0	20 ton.ha^{-1} goat manure + 0 kg.ha^{-1} NPK fertilizer
T2P1	20 ton.ha^{-1} goat manure + 150 kg.ha^{-1} NPK fertilizer
T2P2	20 ton.ha^{-1} goat manure + 300 kg.ha^{-1} NPK fertilizer
T3P0	30 ton.ha^{-1} goat manure + 0 kg.ha^{-1} NPK fertilizer
T3P1	30 ton.ha^{-1} goat manure + 150 kg.ha^{-1} NPK fertilizer
T3P2	30 ton.ha^{-1} goat manure + 300 kg.ha^{-1} NPK fertilizer

Growth measurement and sampling

Plant growth was observed by measuring plant height and counting the number of leaves. Growth measurement was performed at 2, 4, 6, and 8 weeks after planting. The same time, weeds and pests were controlled once a week. At harvest, the maize cobs were weighed, and plant samples were taken, in which the stems and leaves were composited to analyze the nutrient uptake (N, P, and K contained in plant tissues). Soil samples were also taken from each rhizosphere zone to determine the chemical properties of the soil after treatment. The soil chemical properties observed include pH, electrical conductivity, organic C, total N, total P, total K, and cation exchange capacity.

Statistical analysis

The results of soil and plant analysis are presented in tables and bar charts. Meanwhile, the statistical analysis was carried out using the Statistical Analysis System (SAS) software version 9.1. The effects of the treatments on the variables were tested using a one-way analysis of variance (ANOVA) and Duncan's multiple range test (significant $P < 0.05$) to compare the mean of each treatment. The correlation between variables was analyzed at $\alpha = 5$ % using Minitab 16.

RESULTS AND DISCUSSION

The application of a combination of NPK fertilizer and goat cage did not significantly affect the pH value of the soil (Figure 2A). The application of organic fertilizers can increase soil pH due to their complete decomposition process, making them able to release nutrients (K, Ca, and Mg) into the soil and increase humus colloids (Brar et al., 2015; Neina, 2019). According to Hariadi et al., (2016), goat dung material has a pH of around 7.73–8.38, which is higher compared to cow dung material, which has a pH

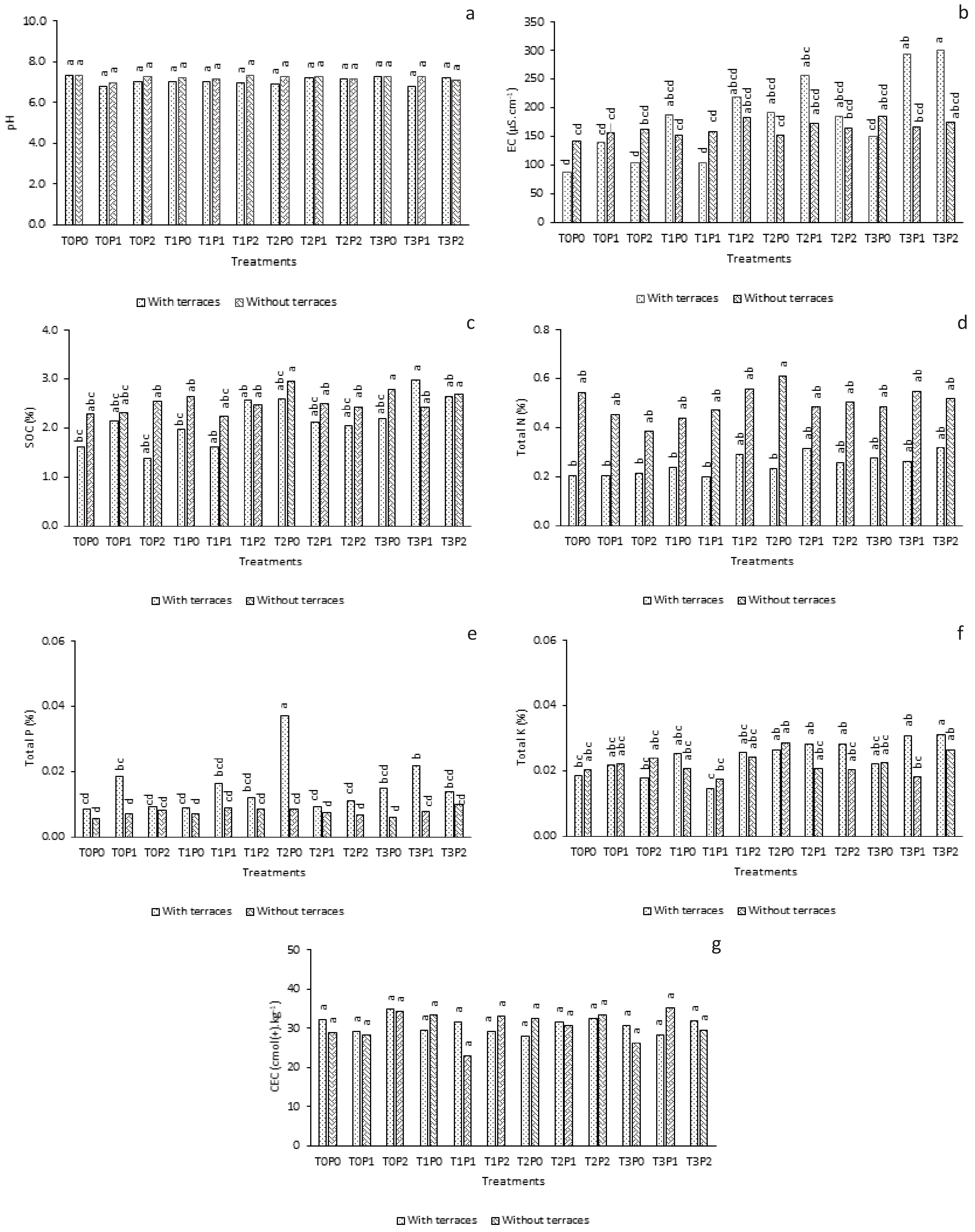

Figure 2. Soil chemical properties in the land with and without terraces, T0= 0 ton.ha^{-1} goat manure, T1= 10 ton.ha^{-1} goat manure, T2= 20 ton.ha^{-1} goat manure, T3= 30 ton.ha^{-1} goat manure, P0= 0 kg.ha^{-1} NPK fertilizer, P1= 150 kg.ha^{-1} NPK fertilizer, P2= 300 kg.ha^{-1} NPK fertilizer

Table 3. Effects of terraces on the soil chemical properties after fertilizer applications

Variables	Unit	With terraces	Without terraces
Soil pH	-	7.21 a	7.05 a
EC	µS.cm^{-1}	184.75 a	164.19 a
Soil organic C	%	2.15 b	2.52 a
Total N	%	0.25 b	0.50 a
Total P	%	0.015 a	0.007 b
Total K	%	0.024 a	0.022 a
CEC	Cmol (+).kg^{-1}	30.70 a	30.65 a

Remarks: Means followed by the same letters in the same row are not significantly different according to DMRT α= 5 %.

ranging from 7.59–8.10 so that the ability of goat dung to increase soil pH is better than that of cow dung. After the application of NPK fertilization and goat pens, the condition of the soil characteristics was better on the part of the land with the terrace because there was a flat part of the terrace bench (Table 3). Meanwhile, in the land without terraces, N, P, and K nutrients were possibly dissolved along with soil erosion and surface water runoff.

The combination of 30 ton.ha^{-1} goat manure and 300 kg.ha^{-1} NPK fertilizer could significantly increase the electrical conductivity (EC) in the soil (Figure 2B). In general, land with terraces has a higher value of electrical conductivity compared to that without terraces. The effect of terracing on the electrical conductivity is possibly due to the difference in the degree of water saturation. Land with terraces has a higher degree of water saturation on the sloping terrace bench, while land without terraces has a relatively lower degree of water saturation (Bai et al., 2019). The degree of water saturation plays an important role in the dissolution of ions in the soil, and the dissolved ions affect the electrical conductivity of the soil (Ismayilov et al., 2021). The application of manure and NPK fertilizers causes the electrical conductivity to vary more in each treatment. However, the pattern showed that the higher the dose given, the higher the electrical conductivity. Although there was an increase in the electrical conductivity of the soil after treatment, the value in each treatment was still relatively low (< 1000 S.cm^{-1}). Maize plants have a tolerance to the soil electrical conductivity in the range of 1700 S.cm^{-1} so that treatment in both types of land could still improve the growth of maize. Hanifa et al. (2019) added that increasing the dose of fertilizer in the soil could positively increase dissolved ions and electrical conductivity in the soil.

Soil organic C is an important indicator of soil fertility and quality. The highest soil organic C in the land with terraces was found in the treatment of 30 ton.ha^{-1} goat manure and 150 kg.ha^{-1} NPK fertilizer, which was 2.97 %. Meanwhile, in the land without terraces, the highest values was found in the treatment of 20 ton.ha^{-1} goat manure and 300 kg.ha^{-1} NPK fertilizer, 30 ton.ha^{-1} goat manure and 0 kg.ha^{-1} NPK fertilizer, and 30 ton.ha^{-1} goat manure and 300 kg.ha^{-1} NPK fertilizer, which were 2.95 %, 2.78 %, and 2.69 % (medium), respectively (Figure 2C). The application of goat manure has a significant effect on increasing soil organic C because it contains many fractions of organic compounds easily decomposed and soluble in water (Köninger et al., 2021). In addition, goat manure also increases organic C in a land without terracing (Table 3). The soil organic C content also varied greatly in each treatment, which tended to be higher in the land without terraces. This result is supported by Li and Lindstrom (2001), reporting that the soil organic C content in the land without terraces is higher compared to that in the land with terraces. The high soil organic C content in the land without terraces is probably because of the movement of organic humus material from the plants above it, dissolved by water (Mai et al., 2013). Although it is believed that organic matter can improve soil physico-chemical properties by increasing cation exchange capacity and improving soil structure, organic matter may be transported by surface water flows. The steep slopes cause surface water to flow at a higher speed and allow the transport of soil and organic matter. Deng et al. (2021) added that the soil quality tended to decrease after land modification into terraces because there was a reversal of soil material into terrace benches. The process of reversing soil material can erode the topsoil or surface soil layers, which tend to be fertile, thereby exposing the sub-surface soil material (Liang et al., 2018). The land modification into terraces will reduce soil nutrient content and soil organic C in the early years (Zhou et al., 2015).

The total N content can come from goat manure and NPK chemical fertilizers. Nitrogen is very mobile, and its content in the soil is dynamic. N can be lost, either being dissolved by water or being evaporated into the atmosphere (Purwanto and Alam, 2020). The total N content of the soil was higher in the land without terraces than in the land with terraces (Table 3). Giving various combinations of treatments can also significantly affect the increase in total N in the soil so that the average is in the medium to high class (Figure 2D). The content of N in the soil plays an important role in the process of plant growth, leading to competition for its presence in the soil between several plants (Utami et al., 2020). The lower content of total N in the land with terraces is due to the competition for nutrient uptake between maize and ground cover crops (sweet potato) (Figure 5). Cover crops on land with terraces can function as a control for soil erosion and surface water runoff. However, a cover crop is also a weakness due to the competition for nutrients, making the selection of cover crops necessary for conservation efforts (Haruna and Nkongolo, 2020). Legume cover crops are more suitable for reducing soil erosion, fertilizing the soil, and increasing soil organic matter content (Noviyanto et al., 2017). Figure 5 presents the land with terraces and without terraces, in which land with terraces has maize plants accompanied by sweet potato plants as ground cover crops.

The combination of 30 $ton.ha^{-1}$ goat manure + 300 $kg.ha^{-1}$ NPK showed a significant effect on increasing the total P in the land with and without terraces, categorized in the low to moderate criteria (Figure 2E). Although there was an increase in both areas, the land with terraces showed a more significant difference than the land without ones (Table 3). The flat part of the terrace allows the availability of P in the soil to be facilitated from goat manure and NPK fertilizers. The application of goat manure can increase the availability of P in the soil directly by the mineralization process or indirectly by the release of fixed P (Banamtuan et al., 2020). The mineralization process of organic matter will be able to release inorganic P (PO_4^{3-}) and organic P (phytin and nucleic acid), where both types of P will be utilized by plants (Alori et al., 2017). However, the sweet potato plants in the land with terraces as cover crops did not affect the total P content in the soil.

The total K content in the soil after being treated with goat manure and NPK fertilizer tended to vary (Figure 2F), but there was no significant difference between land with terraces and without terraces (Table 3). The increase in total K in the soil occurred in the 30 $ton.ha^{-1}$ goat manure + 300 $kg.ha^{-1}$ NPK fertilizer with the highest doses of goat manure and NPK fertilizers. Although different doses of fertilization were given, the total K content in the soil was still low to moderate. The application of goat manure and NPK fertilizers can increase the availability of K in the soil. According to Hendra et al. (2018), the K content of goat manure is higher than that of cow manure by 0.17 % so that it can serve as a source of nutrition for maize plants. The high K content in goat manure significantly increased total K in the soil although it was still in the low to moderate grade range.

There was no significant difference in the cation exchange capacity (CEC) of the soil after treatment in the land with and without terraces (Table 3). Although it did not provide a significant difference, the combination of treatments could increase the CEC to be in the medium and high criteria (Figure 2G). The addition of manure in the soil will increase the negative charge through colloidal humus, thereby increasing the soil CEC. Humus in the soil is resulted from the decomposition process of organic material from goat manure, which has more dynamic properties and is easily destroyed (Alam et al., 2014). The value of CEC is determined by the content of clay and organic matter so that the application of terraces did not have a significant effect. However, the land with terraces had a higher CEC than the land without ones, with a difference of 0.05 $cmol(+).kg^{-1}$ (Table 3). The land without terraces tends to experience more intensive soil erosion, eroding the surface soil material. Erosion of soil material causes the underground horizon to be exposed, thereby affecting the clay content in the soil, which serves as a source of soil CEC (Noviyanto et al., 2020). CEC can describe the soil's ability to absorb cations and exchange them to be available to plants (Strawn, 2021).

Nutrient uptake and plant growth

The differences of land condition affect the N and P uptake, but not the same in the K uptake. N uptake was highest in land without terraces, while P uptake was highest in land with terraces (Table 4). Plants can absorb nutrients by diffusion, mass flow, and direct contact through plant roots (Hillel, 2007; Badruzzaman et al., 2012). The combination treatment of NPK fertilizer and goat manure can only increase the total N and P content of the soil, and is not always in sync with the uptake of N and P in plant tissues which tend to have lower criteria (Figures 3A and 3B). The highest N uptake was found in the treatment of 30 $ton.ha^{-1}$ goat manure and 300 $kg.ha^{-1}$ + NPK fertilizer at land without terraces, while the highest P uptake of plants were obtained in the same doses in the land with terraces. Organic fertilizer from goat manure allows slow-release of N and P, while NPK fertilizer releases N and P directly to be used by plants (Han et al., 2016). The combination of treatments on land with and without terraces had no significant effect on K uptake in plants (Figure 3C), because the availability of K in the soil was still relatively low even though a combination of goat manure and NPK was given or even though there was an insignificant increase in the total K content of the soil.

Table 4. Effects of terracing on the nutrient uptake in plants

Variables	Unit	With terraces	Without terraces
N uptake	%	1.40 b	1.56 a
P uptake	%	0.40 a	0.32 b
K uptake	%	1.44 a	1.49 a

Remarks: Means followed by the same letters in the same row are not significantly different according to DMRT α= 5 %.

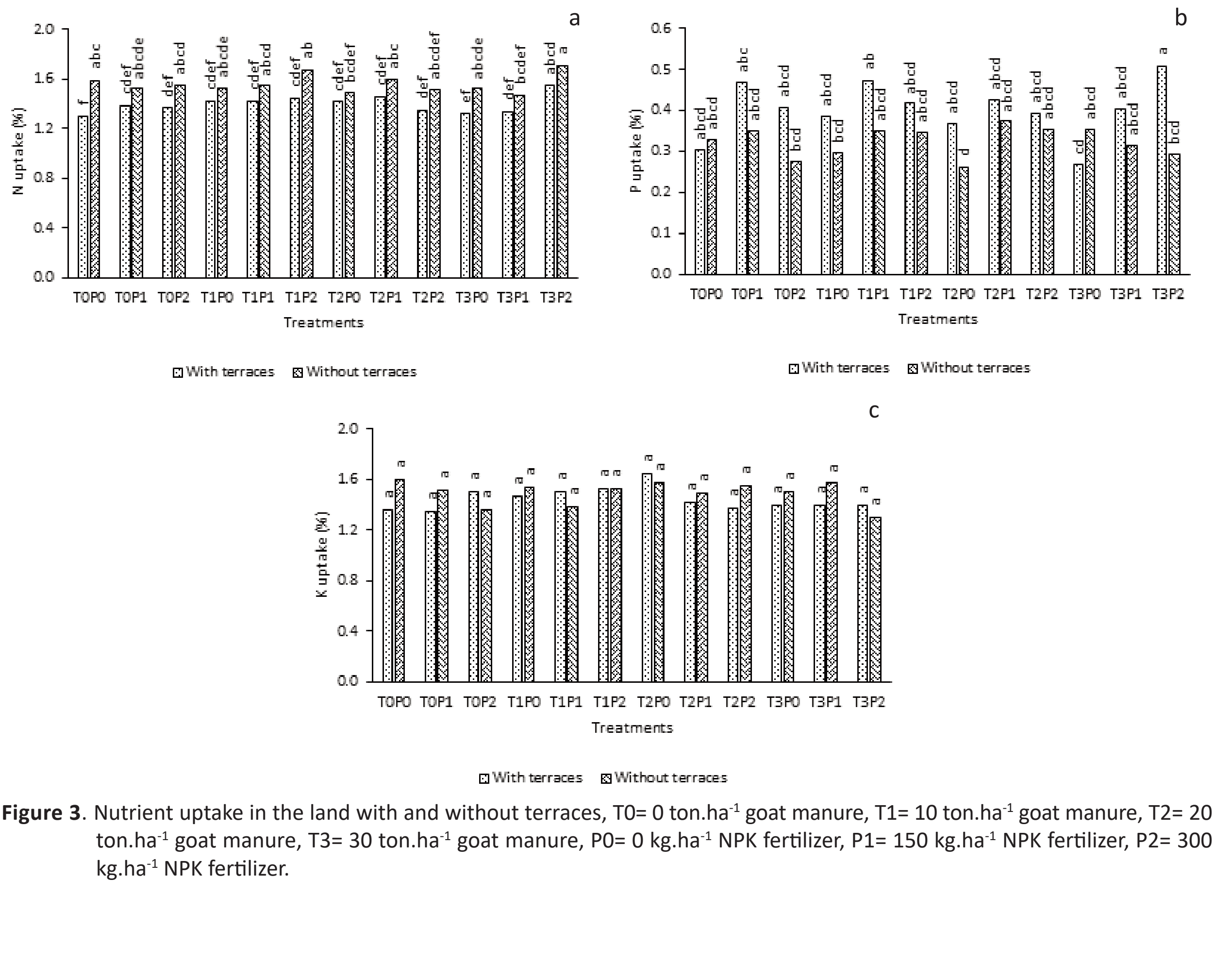

Figure 3. Nutrient uptake in the land with and without terraces, T0= 0 $ton.ha^{-1}$ goat manure, T1= 10 $ton.ha^{-1}$ goat manure, T2= 20 $ton.ha^{-1}$ goat manure, T3= 30 $ton.ha^{-1}$ goat manure, P0= 0 $kg.ha^{-1}$ NPK fertilizer, P1= 150 $kg.ha^{-1}$ NPK fertilizer, P2= 300 $kg.ha^{-1}$ NPK fertilizer.

The goat manure and NPK fertilizer showed no significant effect in the end of observation which is 8 weeks after planting in both terraces and without terraces (Table 5). Plant height and the number of leaves were positively correlated with the increase in the maize cob weight (Table 6). The average plant height was about 250 cm, with an average number of 14 leaves. Although some agronomic factors are not correlated with nutrient uptake and soil chemical properties, some researchers agree that there are complex biochemical processes in plant tissues, which can be influenced by soil chemical properties (Castillo et al., 2021; Yadav et al., 2021).

The N uptake was correlated with soil organic C and total soil N (Table 6). The use of chemical fertilizers combined with organic fertilizers has been widely reported. Organic fertilizers can improve soil physicochemical properties, increase soil nutrient availability and promote plant growth (Mi et al., 2018; Choudhary et al., 2018; Shi et al., 2019). In this

Table 5. Plant height and the number of leaves in the land with and without terraces

Code	With terraces				Without terraces			
	2 WAP	4 WAP	6 WAP	8 WAP	2 WAP	4 WAP	6 WAP	8 WAP
Plant height								
T0P0	24 ± 3.6 abc	38 ± 1.5 ab	114 ± 10.5 ab	260 ± 20.0 a	27 ± 6.4 ab	50 ± 10.5 ab	101 ± 31.0 ab	250 ± 78.1 a
T0P1	18 ± 5.8 bc	42 ± 11.9 ab	122 ± 32.8 ab	259 ± 60.0 a	21 ± 9.1 abc	47 ± 18.9 ab	103 ± 50.4 ab	232 ± 56.2 a
T0P2	21 ± 5.6 abc	35 ± 6.8 b	119 ± 41.0 ab	243 ± 80.0 a	27 ± 6.7 abc	51 ± 7.8 ab	95 ± 13.8 ab	240 ± 26.5 a
T1P0	27 ± 7.0 ab	48 ± 2.5 ab	151 ± 8.7 a	280 ± 17.3 a	23 ± 5.8 abc	60 ± 10.0 a	117 ± 37.9 ab	237 ± 47.3 a
T1P1	17 ± 2.9 c	38 ± 7.2 ab	118 ± 36.6 ab	257 ± 51.3 a	20 ± 5.3 abc	53 ± 13.6 ab	121 ± 38.0 ab	237 ± 49.3 a
T1P2	20 ± 5.3 abc	37 ± 8.1 ab	124 ± 21.4 ab	267 ± 35.1 a	20 ± 9.5 abc	54 ± 21.8 ab	146 ± 18.0 ab	283 ± 11.5 a
T2P0	24 ± 2.3 abc	37 ± 2.9 ab	90 ± 25.1 b	227 ± 25.2 a	25 ± 2.9 abc	50 ± 18.0 ab	145 ± 16.7 ab	275 ± 26.0 a
T2P1	21 ± 6.1 abc	43 ± 8.1 ab	128 ± 28.0 ab	258 ± 17.6 a	25 ± 7.5 abc	56 ± 13.3 ab	100 ± 36.7 ab	227 ± 28.9 a
T2P2	19 ± 4.2 bc	51 ± 6.2 ab	148 ± 15.5 a	285 ± 35.0 a	25 ± 7.0 abc	49 ± 18.8 ab	131 ± 27.3 ab	283 ± 5.8 a
T3P0	25 ± 5.0 abc	46 ± 9.5 ab	132 ± 22.6 ab	210 ± 79.4 a	25 ± 7.2 abc	49 ± 13.3 ab	99 ± 12.3 ab	220 ± 34.6 a
T3P1	19 ± 5.1 bc	39 ± 14.6 ab	118 ± 26.1 ab	273 ± 23.1 a	26 ± 9.5 abc	59 ± 7.9 ab	126 ± 23.5 ab	263 ± 37.9 a
T3P2	19 ± 4.7 bc	36 ± 7.6 ab	111 ± 30.3 ab	263 ± 47.3 a	30 ± 5.5 a	48 ± 15.7 ab	99 ± 42.4 ab	267 ± 11.5 a
The number of leaves								
T0P0	7 ± 0.0 abcd	10 ± 0.6 ab	15 ± 0.6 abc	14 ± 2.1 ab	8 ± 1.0 a	9 ± 1.4 ab	14 ± 2.6 abc	13 ± 2.5 ab
T0P1	5 ± 1.2 e	10 ± 2.6 ab	14 ± 2.1 abc	14 ± 1.5 ab	7 ± 1.0 abcd	11 ± 0.7 ab	14 ± 1.5 abc	15 ± 0.6 ab
T0P2	5 ± 0.6 e	9 ± 3.5 ab	13 ± 1.5 abc	15 ± 2.5 ab	7 ± 0.6 abc	9 ± 2.1 ab	12 ± 1.2 bc	14 ± 1.5 ab
T1P0	6 ± 1.0 cde	11 ± 1.2 a	16 ± 2.1 ab	14 ± 1.2 ab	8 ± 0.6 ab	9 ± 0.7 ab	11 ± 1.5 c	14 ± 1.2 ab
T1P1	5 ± 0.6 e	9 ± 2.3 ab	14 ± 2.1 abc	14 ± 1.7 ab	7 ± 1.0 abcd	9 ± 2.8 ab	13 ± 3.6 abc	14 ± 3.0 ab
T1P2	7 ± 0.6 abcde	9 ± 1.7 ab	16 ± 1.2 abc	15 ± 0.6 ab	7 ± 0.6 abcde	11 ± 1.4 ab	14 ± 0.6 abc	15 ± 0.6 ab
T2P0	7 ± 1.2 abc	8 ± 2.1 b	14 ± 3.6 abc	13 ± 2.3 ab	8 ± 0.6 ab	11 ± 0.0 ab	14 ± 1.0 abc	16 ± 2.1 a
T2P1	5 ± 0.6 e	9 ± 2.6 ab	15 ± 1.2 abc	14 ± 2.1 ab	7 ± 1.5 abcde	10 ± 1.4 ab	12 ± 2.5 abc	13 ± 0.6 ab
T2P2	6 ± 1.0 cde	11 ± 0.6 ab	16 ± 1.2 a	16 ± 0.6 a	7 ± 0.0 abcd	11 ± 0.0 ab	14 ± 0.6 abc	14 ± 1.0 ab
T3P0	7 ± 0.6 abcde	10 ± 2.1 ab	14 ± 2.1 abc	12 ± 3.5 b	8 ± 1.5 ab	9 ± 1.4 ab	12 ± 1.2 bc	12 ± 2.1 b
T3P1	6 ± 0.6 de	9 ± 1.5 ab	14 ± 3.5 abc	15 ± 1.7 ab	8 ± 0.6 ab	11 ± 2.1 ab	14 ± 1.2 abc	15 ± 1.0 ab
T3P2	6 ± 0.6 bcde	9 ± 2.5 ab	14 ± 2.9 abc	14 ± 1.5 ab	8 ± 0.0 a	8 ± 4.2 ab	13 ± 2.0 abc	14 ± 0.6 ab

Remarks: Means followed by the same letters in the same column are not significantly different according to DMRT α= 5 %, T0= 0 ton.ha^{-1} goat manure, T1= 10 ton.ha^{-1} goat manure, T2= 20 ton.ha^{-1} goat manure, T3= 30 ton.ha^{-1} goat manure, P0= 0 kg.ha^{-1} NPK fertilizer, P1= 150 kg.ha^{-1} NPK fertilizer, P2= 300 kg.ha^{-1} NPK fertilizer.

Table 6. Correlation between variables

Variable	pH	EC	SOC	N total	P total	K total	CEC	N uptake	P uptake	K uptake	Plant height	Leaf
EC	0.179											
SOC	0.157	0.570*										
N total	0.346*	0.240*	0.538*									
P total	-0.276*	0.243*	-0.029	-0.151								
K total	0.118	0.636*	0.412*	0.220	0.275*							
CEC	-0.158	-0.022	0.044	-0.158	-0.114	0.111						
N uptake	0.060	-0.026	0.355*	0.467*	-0.313*	-0.101	-0.206					
P uptake	0.007	0.253*	-0.016	-0.128	0.167	0.170	-0.269*	-0.145				
K uptake	-0.031	-0.076	0.002	0.052	0.052	-0.167	-0.221	0.147	0.166			
Plant height	0.109	0.195	0.082	-0.084	-0.085	0.203	0.153	-0.059	-0.021	-0.155		
Leaf	0.027	0.168	0.022	-0.082	0.009	0.130	0.115	-0.196	0.083	0.092	0.634*	
Maize cob	-0.056	0.143	0.150	0.078	-0.154	-0.063	0.066	0.102	0.021	0.029	0.199	0.255*

Remarks: (*) significant at α= 5 %, EC= Electrical Conductivity, SOC= Soil Organic Carbon, CEC= Cation Exchange Capacity.

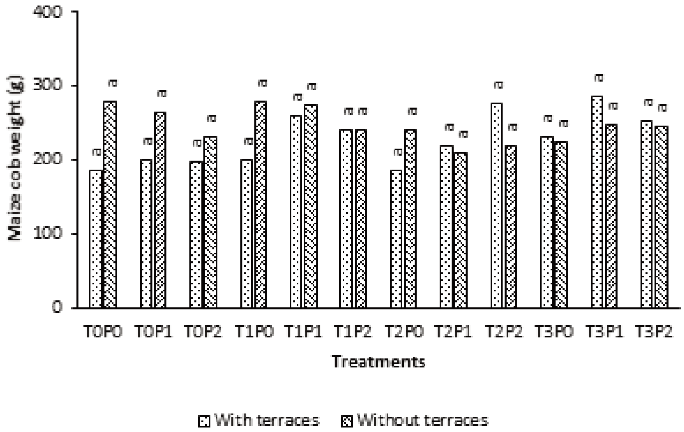

Figure 4. Maize cob weight in the land with and without terraces, T0= 0 ton.ha^{-1} goat manure, T1= 10 ton.ha^{-1} goat manure, T2= 20 ton.ha^{-1} goat manure, T3= 30 ton.ha^{-1} goat manure, P0= 0 kg.ha^{-1} NPK fertilizer, P1= 150 kg.ha^{-1} NPK fertilizer, P2= 300 kg.ha^{-1} NPK fertilizer.

study, the application of organic fertilizer significantly increased soil organic C to 2.97 % (Figure 2C), thereby improving the availability of total N in the soil and N uptake in plant tissues. The use of goat manure as a source of soil organic matter has gone through complex biochemical reactions when applied to the soil and during the planting period (Hua et al., 2020). Organic matter contains organic functional groups such as carboxylic and phenolic groups, where dissociation of these organic acid functional groups can increase soil CEC and retention to acidity (Schellekens et al., 2017). P uptake in maize was also correlated with soil CEC (Table 6), making it possible that organic fertilizers could positively supply P availability in the soil (Figure 2E) and promote P uptake in plant tissues (Figure 3B). Cai et al. (2019) reported that the application of manure into the soil positively increased pH, carbon sequestration, total N, and available N and P.

The effect of fertilization with a dose of 30 ton.ha^{-1} goat manure + 150 kg.ha^{-1} NPK fertilizer on land with terraces gave the highest corncob weight yield (Figure 4). Desta et al. (2021) added that land with terraces had better potential than land without terraces. However, the ground cover plants allowed competition for soil nutrient absorption to occur. The period of terracing is also possible to influence soil characteristics and fertility (Liu and Zhou, 2017). Terracing was carried out just before the research started so that in the short term, it has not been able to produce high maize productivity. Continuous application of organic matter can improve soil properties, thereby increasing maize productivity in the long term (Chen et al., 2020). Specific soil edaphic conditions can affect the growth of maize plants.

Utilization of land with sloping to steep topography for the agricultural sector can only be done with terracing techniques. Land without terraces is better used for protection forest or as a reservoir area. Terracing is the oldest technique for conserving soil and water in hilly or mountainous areas that have experienced increasing population pressure (Deng et al., 2021). Terraces are constructed along contour lines to increase the arable surface area and conserve soil and water on hillsides. Slope management using terraces is one of the most effective land engineering actions to be carried out, which in the process requires good design, proper development, and proper maintenance (Cao et al., 2013).

Constructing terraces on sloping land can reduce the steepness of the slopes by dividing the slope into smaller, sloping sections. Modified slopes can change hydrological pathways, reduce surface runoff, and increase land catchment areas (Uchida et al., 2013). The use of terraces can increase the moisture content of the soil by improving the soil's infiltration ability and capacity to hold groundwater (Wei et al., 2016). The terraced part of the land can store more water, thereby providing sufficient water for plant cultivation. Crops will be able to grow well on land with terraces. Besides, this technique is more environmentally friendly since it reduces soil erosion, maintains slope stability, and reduces the risk of flooding.

CONCLUSIONS

The combination of goat manure with NPK fertilizer can significantly increase EC, soil organic C, total N, and total P in both land types (with and without terracing). The increase in the dose of combined fertilizer is in line with the increase in agronomic indicators such as nutrient uptake, increased plant growth, and maize cob production. Provision of goat manure and NPK fertilizer can be useful to improve the performance of maize plants, even on land without terraces. The utilization of livestock manure is an alternative to providing local organic matter that can be combined with inorganic fertilizers that are useful in agricultural cultivation in various topographic conditions with or without terracing modifications.

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REFERENCES

Alam, K., Islam, M., Salahin, N., and Hasanuzzaman, M. (2014). Effect of tillage practices on soil properties and crop productivity in wheat-mungbean-rice cropping. *Scientific World Journal*, 2014, pp. 1–15.

Alori, E. T., Glick, B. R., and Babalola, O. O. (2017). Microbial phosphorus solubilization and its potential for use in sustainable agriculture. *Frontiers in Microbiology*, 8, pp. 1–8.

Arnáez, J., Lana-Renault, N., Lasanta, T., Ruiz-Flaño, P., and Castroviejo, J. (2015). Effects of farming terraces on hydrological and geomorphological processes: A review. *Catena*, 128, pp. 122–134.

Badruzzaman, M., Pinzon, J., Oppenheimer, J., and Jacangelo, J. G. (2012). Sources of nutrients impacting surface waters in Florida: A review. *Journal of Environmental Management*, 109, pp. 80–92.

Bai, J., Yang, S., Zhang, Y., Liu, X., and Guan, Y. (2019). Assessing the impact of terraces and vegetation on runoffand sediment routing using the time-area method in the Chinese Loess Plateau. *Water*, 11(4), pp. 1–20.

Banamtuan, E., Suwardi, S., Iskandar, I., Sumawinata, B., and Banamtuan, E. (2020). Application of solid and liquid organic matter to increase P availability in Inceptisol. I*OP Conference Series: Earth and Environmental Science*, 497(1), pp. 1–7.

Brar, B. S., Singh, J., Singh, G., and Kaur, G. (2015). Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize-wheat rotation. *Agronomy*, 5(2), pp. 220–238.

Cai, A., Xu, M., Wang, B., Zhang, W., Liang, G., Hou, E., and Luo, Y. (2019). Manure acts as a better fertilizer for increasing crop yields than synthetic fertilizer does by improving soil fertility. *Soil and Tillage Research*, 189, pp. 168–175.

Cao, Y., Wu, Y., Zhang, Y., and Tian, J. (2013). Landscape pattern and sustainability of a 1300-year-old agricultural landscape in subtropical mountain areas, Southwestern China. *International Journal of Sustainable Development and World Ecology*, 20(4), pp. 349–357.

Castillo, P., Serra, I., Townley, B., Aburto, F., López, S., Tapia, J., and Contreras, M. (2021). Biogeochemistry of plant essential mineral nutrients across rock, soil, water and fruits in vineyards of Central Chile. *Catena*, 196, pp. 104905.

Chen, D., Wei, W., Daryanto, S., and Tarolli, P. (2020). Does terracing enhance soil organic carbon sequestration? A national-scale data analysis in China. *Science of the Total Environment*, 721, pp. 137751.

Choudhary, M., Panday, S. C., Meena, V. S., Singh, S., Yadav, R. P., Mahanta, D., Mondal, T., Mishra, P. K., Bisht, J. K., and Pattanayak, A. (2018). Long-term effects of organic manure and inorganic fertilization on sustainability and chemical soil quality indicators of soybean-wheat cropping system in the Indian mid-Himalayas. *Agriculture, Ecosystems and Environment*, 257, pp. 38–46.

Deng, C., Zhang, G., Liu, Y., Nie, X., Li, Z., Liu, J., and Zhu, D. (2021). Advantages and disadvantages of terracing: A comprehensive review. *International Soil and Water Conservation Research*, 9(3), pp. 344–359.

Desta, G., Tamene, L., Abera, W., Amede, T., and Whitbread, A. (2021). Effects of land management practices and land cover types on soil loss and crop productivity in Ethiopia: A review.

International Soil and Water Conservation Research, 9(4), pp. 544–554.

Fronning, B. E., Thelen, K. D., and Min, D. H. (2008). Use of manure, compost, and cover crops to supplant crop residue carbon in corn stover removed cropping systems. *Agronomy Journal,* 100(6), pp. 1703–1710.

Han, S. H., An, J. Y., Hwang, J., Kim, S. Bin, and Park, B. B. (2016). The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (*Liriodendron tulipifera* Lin.) in a nursery system. *Forest Science and Technology*, 12(3), pp. 137–143.

Hanifa, H., Utami, S. N. H., Wulandari, C., and Yusuf, W. A. (2019). Soil chemical properties and corn productivity as affected by application of different types of fertilizer and planting method in acid sulfate soil. *IOP Conference Series: Earth and Environmental Science*, 393(1). pp. 1–8.

Hariadi, Y. C., Nurhayati, A. Y., and Hariyani, P. (2016). Biophysical monitoring on the effect on different composition of goat and cow manure on the growth response of maize to support sustainability. *Agriculture and Agricultural Science Procedia*, 9, pp. 118–127.

Haruna, S. I., and Nkongolo, N. V. (2020). Influence of cover crop, tillage, and crop rotation management on soil nutrients. *Agriculture*, 10(6), pp. 1–14.

Hendra, A. C., Sebayang, H. T., and Suminarti, N. E. (2018). Pengaruh kombinasi pupuk kandang kambing dan kalium pada pertumbuhan dan hasil tanaman jagung manis (*Zea mays* sacharata Sturt). *Jurnal Produksi Tanaman*, 6(10), pp. 2470–2475.

Hillel, D. (2007). *Soil in the environment: crucible of terrestrial life.* 1st ed. San Diego, California: Academic Press (Elsevier), pp. 1–320.

Hua, W., Luo, P., An, N., Cai, F., Zhang, S., Chen, K., Yang, J., and Han, X. (2020). Manure application increased crop yields by promoting nitrogen use efficiency in the soils of 40-year soybean-maize rotation. *Scientific Reports*, 10(1), pp. 1–10.

Ismayilov, A. I., Mamedov, A. I., Fujimaki, H., Tsunekawa, A., and Levy, G. J. (2021). Soil salinity type effects on the relationship between the electrical conductivity and salt content for 1:5 soil-to-water extract. *Sustainability*, 13(6), pp. 1–11.

Köninger, J., Lugato, E., Panagos, P., Kochupillai, M., Orgiazzi, A., Briones, M.J.I. (2021). Manure management and soil biodiversity: Towards more sustainable food systems in the EU. *Agricultural Systems*, 194, pp. 103251.

Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science*, 304(5677), pp. 1623–1627.

Li, Y. and Lindstrom, M. J. (2001). Evaluating soil quality-soil redistribution relationship on terraces and steep hillslope. *Soil Science Society of America Journal*, 65(5), pp. 1500–1508.

Liang, Y., Lal, R., Guo, S., Liu, R., and Hu, Y. (2018). Impacts of simulated erosion and soil amendments on greenhouse gas fluxes and maize yield in Miamian soil of central Ohio. *Scientific Reports*, 8(1), pp. 1–11.

Liu, C. A. and Zhou, L. M. (2017). Soil organic carbon sequestration and fertility response to newly-built terraces with organic manure and mineral fertilizer in a semi-arid environment. *Soil and Tillage Research*, 172, pp. 39–47.

Mai, V. T., van Keulen, H., Hessel, R., Ritsema, C., Roetter, R., and Phien, T. (2013). Influence of paddy rice terraces on soil erosion of a small watershed in a hilly area of Northern Vietnam. *Paddy and Water Environment*, 11(1–4), pp. 285–298.

McAndrews, G. M., Liebman, M., Cambardella, C. A., and Richard, T. L. (2006). Residual effects of composted and fresh solid swine (*Sus scrofa* L.) manure on soybean [*Glycine max* (L.) Merr.] growth and yield. *Agronomy Journal*, 98(4), pp. 873–882.

Mi, W., Sun, Y., Xia, S., Zhao, H., Mi, W., Brookes, P. C., Liu, Y., and Wu, L. (2018). Effect of inorganic fertilizers with organic amendments on soil chemical properties and rice yield in a low-productivity paddy soil. *Geoderma*, 320, pp. 23–29.

Neina, D. (2019). The role of soil pH in plant nutrition and soil remediation. *Applied and Environmental Soil Science*, 2019(3), pp. 1–10.

Noviyanto, A., Purwanto, P., Minardi, S., and Supriyadi, S. (2017). The assessment of soil quality of various age of land reclamation after coal mining: a chronosequence study. *Journal of Degraded and Mining Lands Management*, 05(01), pp. 1009–1018.

Noviyanto, A., Sartohadi, J., and Purwanto, B. H. (2020). The distribution of soil morphological characteristics for landslide-impacted Sumbing Volcano, Central Java-Indonesia. *Geoenvironmental Disasters*, 7(25), pp. 1–19.

Purwanto, B. H. and Alam, S. (2020). Impact of intensive agricultural management on carbon and nitrogen dynamics in the humid tropics. *Soil Science and Plant Nutrition*, 66(1), pp. 50–59.

Rofita, Utami, S.N.H., Maas, A., and Nurudin, M. (2021). Spatial distribution of soil morphology and physicochemical properties to assess land degradation under different NDVI and TRI in North Halmahera, Indonesia. *Journal of Degraded and Mining Lands Management*, 9(1), pp. 3137–3157.

Schellekens, J., Buurman, P., Kalbitz, K., Zomeren, A. Van, Vidal-Torrado, P., Cerli, C., and Comans, R. N. J. (2017). Molecular features of humic acids and fulvic acids from contrasting environments. *Environmental Science and Technology*, 51(3), pp. 1330–1339.

Shi, R. Y., Liu, Z. D., Li, Y., Jiang, T., Xu, M., Li, J. Y., and Xu, R. K. (2019). Mechanisms for increasing soil resistance to acidification by long-term manure application. *Soil and Tillage Research*, 185, pp. 77–84.

Sistani, K. R., Sikora, F. J., and Rasnake, M. (2008). Poultry litter and tillage influences on corn production and soil nutrients in a Kentucky silt loam soil. *Soil and Tillage Research*, 98(2), pp. 130–139.

Strawn, D. G. (2021). Sorption mechanisms of chemicals in soils. *Soil Systems*, 5(1), pp. 1–22.

Uchida, E., Sato, K., Cunin, O., and Toyouchi, K. (2013). A reconsideration of the construction period of the cruciform terraces and the elevated causeways in the Angkor Monuments, based on the magnetic susceptibility of the sandstone blocks. *Archaeometry*, 55(6), pp. 1034–1047.

Utami, S. N. H., Abduh, A. M., Hanudin, E., and Purwanto, B. H. (2020). Study on the NPK uptake and growth of rice under two different cropping systems with different doses of organic fertilizer in the Imogiri Subdistrict, Yogyakarta Province, Indonesia. *Sarhad Journal of Agriculture*, 36(4), pp. 1190–1202.

Wei, W., Chen, D., Wang, L., Daryanto, S., Chen, L., Yu, Y., Lu, Y., Sun, G., and Feng, T. (2016). Global synthesis of the classifications, distributions, benefits and issues of terracing. *Earth-Science Reviews,* 159(18), pp. 388–403.

Yadav, A. N., Kour, D., Kaur, T., Devi, R., Yadav, A., Dikilitas, M., Abdel-Azeem, A. M., Ahluwalia, A. S., and Saxena, A. K. (2021). Biodiversity, and biotechnological contribution of beneficial soil microbiomes for nutrient cycling, plant growth improvement and nutrient uptake. *Biocatalysis and Agricultural Biotechnology*, 33, pp. 102009.

Zhou, K., Sui, Y., Liu, X., Zhang, X., Jin, J., Wang, G., and Herbert, S. J. (2015). Crop rotation with nine-year continuous cattle manure addition restores farmland productivity of artificially eroded Mollisols in Northeast China. *Field Crops Research*, 171, pp. 138–145.