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Integrated polyacrylamide and compost from salak fronds application for erosion control and soil quality improvement in Sidimpuan salak plantations on sloping land

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Abstract

Introduction: Sidimpuan salak (*Salacca sumatrana* Becc.) plants as conservation plants can withstand erosion on slopes. Over time, it turns out that the physical environment of the soil on salak land still needs improvement to increase production.

Materials and methods: An experimental method is used in the study. Stage I is the composting of salak. The treatments were as follows: P0 = chopped salak leaf stalks (control), P1 = chopped salak leaf stalks + manure, P2 = chopped salak leaf stalks + manure + polyacrylamide (PAM). Each treatment was repeated four times. In stage II the provision of integrated compost with PAM on the soil was completed using a factorial randomised block design with two treatment factors and three replications so that there are 12 treatment combinations and 36 experimental units.

Results and discussion: The results of observations of the physical properties of compost are changes in temperature and colour of the compost. Composting in the fourth week can be observed that the physical properties of the compost experienced a decrease in temperature to 26.5°C. The decomposition process is concluded, resulting in a biologically stable and mature compost material.

Conclusions: The results of the calculation of the erosion rate from the physical properties of the soil using the USLE method are the lowest at 6.77 $Mg \cdot ha^{-1} \cdot yr^{-1}$ (PAM 30 g + compost + manure). The use of integrated PAM compost has an effect on soil erosion and can reduce soil erosion lower than the tolerance erosion (7.125 $Mg \cdot ha^{-1} \cdot yr^{-1}$).

Keywords: leaf compost, marginal land, polyacrylamide (PAM), Sidimpuan salak, slope erosion

INTRODUCTION

Erosion is a global environmental issue that impacts soil productivity, river sedimentation, and causes floods and landslides. Eroded and degraded land is a problem in tropical countries, especially in Indonesia. Soil that has experienced erosion is characterised by a reduction in topsoil layer, low pH, and low organic matter, which results in low land productivity (Nasution, 2019).

South Tapanuli is a region with a relatively high rainfall of 2,583 mm in 2023 (BPS, 2024). According to Nasution (2019), the sharp change from highland to lowland terrain makes South

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Tapanuli prone to erosion, with slopes ranging from 7 to 75%, making it vulnerable to erosion.

The flagship crop in South Tapanuli is Sidimpuan salak (*Salacca sumatrana* Becc.). Its fruit is highly favoured by the community. However, the demand from both within the region and outside has not been met due to a decline in production, and in some cases, there is no production at all (Adelina, 2022). Generally, farmers cultivate salak plants traditionally without fertilisation inputs.

The use of land for salak cultivation on slopes without fertilisation, either organic or inorganic, and the continuous removal of soil nutrients through harvesting can lead to soil degradation. Salak plants, as conservation crops, must be maintained, but this should be accompanied by other conservation measures such as the addition of soil stabilising agents (polyacrylamide – PAM) and other ameliorants to increase soil productivity and prevent erosion.

Polyacrylamide is a type of non-hydroponic soil stabilising polymer that binds OH groups on clay particles through hydrogen bonds (Lovita *et al.*, 2022). This polymer has the potential to reduce soil erosion through soil conditioning integrated with ameliorants, as applied in tropical highland areas (Kebede *et al.*, 2022). Ameliorants in the Sidimpuan area can include compost made from organic waste from salak cultivation, such as salak fronds (Amnah and Friska, 2019).

The use of PAM as a soil stabilising agent to reduce erosion rates has been applied in several regions in Indonesia; however, there is no information on its use either independently or integrated with other amendments on sloped land in Indonesia. Therefore, the aim of this study is to test the erosion rate and the yield of salak plants after the application of PAM and salak fronds compost through the calculation of erosion rates, soil texture, organic matter, and salak production.

MATERIALS AND METHODS

RESEARCH LOCATION

The field study was conducted on the Sidimpuan salak plantation land in Sitaratoit Village Around 1°22'00" N–1°23'00" N and 99°15'00" E–99°16'00" E, Angkola Barat District, South Tapanuli Regency with a slope of 35%. The compost production will take place at the Martabe Prima Lestari Compost House in Lubuk Raya Village, Padangsidimpuan Hutaimbaru District. Meanwhile, the chemical analysis of the compost will be carried out at the P3IN Laboratory, Andalas University, Padang.

RESEARCH METHODS

The composting of Sidimpuan salak fronds used a one-factor randomised complete block design with three treatment levels, replicated four times (P0 = chopped salak fronds – control, P1 = chopped salak fronds + cow manure, P2 = chopped salak fronds + cow manure + polyacrylamide).

Salak fronds were collected from Sitaratoit Village, Angkola Barat District, South Tapanuli Regency. The salak fronds were chopped using a chopper machine. Chopped salak fronds (10 kg) were taken and cow manure (5 kg) was added according to the treatment. To accelerate the decomposition process, 25 cm^3 of molasses in 5 dm^3 of water and 20 cm^3 of effective microorganisms 4 (EM4) were added to each treatment. The materials were mixed thoroughly and spread to a height of 15–20 cm, then covered with a tarpaulin. For the PAM treatment, it was added after the compost temperature dropped to approximately 20–25°C and mixed evenly into the material. Data were analysed using ANOVA followed by Duncan's multiple range test (DMRT) at a 5% level if the F test showed significant effects.

The study used a factorial randomised complete block design with two treatment factors (factor 1 – polyacrylamide dosage: M0 = control, M1 = 30 $g \cdot plant^{-1}$, M2 = 60 $g \cdot plant^{-1}$, M3 = 90 $g \cdot plant^{-1}$; factor 2 – Sidimpuan salak fronds compost, K0 = chopped salak fronds compost (control), K1 = chopped salak fronds compost + cow manure, K2 = chopped salak fronds compost + cow manure + polyacrylamide).

The plants used were 15-year-old productive Sidimpuan salak plants that were fruiting, with fruit diameter of 2.5 cm. The salak fronds compost was applied by scattering the compost around the base of the plant at a distance of 50 cm from the stem, at a rate of 800 g per plant. Polyacrylamide was applied by mixing it with the soil surrounding the plant stem at a distance of 50 cm from the stem, with the dosage according to the treatment.

The soil erosion rate was measured using the USLE model, which is formulated as a multiplication equation that includes six controlling factors (Wischmeier and Smith, 1978; Renard *et al.*, 1997) as follows:

$$A = R \cdot L \cdot S \cdot K \cdot C \cdot P \tag{1}$$

where: A = the average annual soil erosion potential ($Mg \cdot ha^{-1} \cdot yr^{-1}$), R = the rainfall erosivity factor ($mm \cdot month^{-1}$), L = the slope length factor (m), S = the slope steepness factor (%), K = the soil erodibility factor ($Mg \cdot ha^{-1} \cdot yr^{-1}$), C = the average annual land cover and management factor (dimensionless), and P = the conservation practice factor (dimensionless).

Soil samples were taken compositely from slopes >35% in the salak land at 250 g per treatment unit.

The average monthly erosivity index (Rm) is calculated acc. to Equation (2)

$$Rm = 6.119 Pm^{1.21} \cdot HH^{-0.47} \cdot P\max^{0.53} \tag{2}$$

where: Pm = the monthly precipitation (cm), HH = the average number of rainy days per month, and Pmax = the maximum 24-hour rainfall during the respective month.

The erodibility (K) is calculated acc. to Equation (3):

$$100K = 1.292\left[2.1M^{1.14} \cdot 10^{-4}(12 - a) + 3.25(b - 2) + 2.5(c - 3)\right] \tag{3}$$

where: M = the silt fraction (· 100 (percentage of clay fraction)), a = the organic matter content, b = the soil structure class, and c = the permeability class.

$$LS = \sqrt{x}\left(0.0138 + 0.00965S + 0.00138S^2\right) \tag{4}$$

where: L = the slope length (m), S = the slope steepness (%) (Inhazama, Mustofa and Syafi'i, 2024).

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RESULTS AND DISCUSSION

CHEMICAL PROPERTY CHANGES OF COMPOST

Chemical property changes of compost during decomposition were observed in this study. Decomposition was carried out by microorganisms such as bacteria, fungi, and invertebrates like earthworms, ants, and worms. The decomposition process of salak palm fronds compost took only four weeks to convert raw materials into plant-available nutrients. The transformation of compost materials during decomposition, including changes in nitrogen, phosphorus, potassium, moisture content, organic carbon, and C:N ratio.

The results showed changes in nutrient content and compost characteristics after the decomposition process. The nitrogen content increased significantly in the P2 treatment (chopped salak fronds + cow manure + polyacrylamide), reaching 4.1%, which was higher than in P0 (chopped salak fronds as control) and P1 (chopped salak fronds + cow manure). The increase in nitrogen content indicates that the addition of cow manure and polyacrylamide enhanced microbial activity during decomposition.

Similarly, phosphorus and potassium contents also showed higher values in the P2 treatment compared to the other treatments. The increase in these nutrients suggests that the combined application of cow manure and polyacrylamide improved the mineralisation process during composting.

Organic carbon content tended to decrease after decomposition, indicating that carbon compounds were utilised by microorganisms as an energy source. Consequently, the C:N ratio also decreased, reflecting the maturity of the compost. In addition, the moisture content of the compost remained within an appropriate range to support microbial activity during the decomposition process.

The use of polyacrylamide and salak fronds compost, amended with animal manure, was found to facilitate the decomposition of organic materials into inorganic forms that can be absorbed by plants after several weeks of application to salak land (Rita *et al.*, 2024). This is consistent with the findings of Athena (2019), who demonstrated that PAM can improve soil physical properties, including aggregate stability, thereby promoting nutrient uptake by plants.

The phosphorus (P) content availability during compost fertiliser decomposition (Tab. 1) indicates that treatment P2

Table 1. Changes in the decomposition characteristics of the composted material

Treatment	Composting week	Average value / fixed condition value	High price	Low price	Closing price
Nitrogen (%)					
P0	1	0.42	2.415	2.32	2.510
	2		1.825	2.18	1.470
	3		2.455	2.32	2.590
	4		1.497	0.42	2.574
P1	1		3.280	2.35	4.210
	2		1.025	1.73	0.320
	3		0.790	1.40	0.180
	4		2.560	3.05	2.070
P2	1		3.205	2.94	3.470
	2		3.603	3.11	4.096
	3		2.910	2.57	3.250
	4		2.905	2.83	2.980
Phosphorus (%)					
P0	1	0.023	1.4765	0.023	2.930
	2		0.9035	0.027	1.780
	3		1.1290	0.028	2.230
	4		0.8925	0.038	1.747
P1	1		2.0700	0.060	4.080
	2		1.0525	0.025	2.080
	3		0.9565	0.033	1.880
	4		1.0290	0.054	2.004
P2	1		1.3765	0.053	2.700
	2		1.4630	0.038	2.888
	3		2.2580	0.056	4.460
	4		1.8245	0.039	3.610

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cont. Tab. 1

Treatment	Composting week	Average value / fixed condition value	High price	Low price	Closing price
Potassium (%)					
P0	1	0.371	1.7860	1.362	2.210
	2		1.6265	1.683	1.570
	3		2.1555	1.721	2.590
	4		2.0510	2.085	2.017
P1	1		1.3055	0.371	2.240
	2		1.7350	1.590	1.880
	3		1.6450	1.870	1.420
	4		1.6075	1.595	1.620
P2	1		1.6830	1.596	1.770
	2		2.369	1.370	3.368
	3		2.6900	1.720	3.660
	4		0.9465	1.783	0.110
C-organic (%)					
P0	1	8.79	33.65	20.03	26.840
	2		29.48	8.79	19.135
	3		35.94	21.67	28.805
	4		29.87	15.71	22.790
P1	1		37.58	21.55	29.565
	2		30.97	14.48	22.725
	3		30.78	11.35	21.065
	4		39.91	15.78	27.845
P2	1		31.73	17.66	24.695
	2		29.07	22.72	25.895
	3		37.85	19.24	28.545
	4		33.31	13.99	23.650
C:N (%)					
P0	1	6.1	14.503	7.960	11.2315
	2		13.711	5.940	9.8255
	3		15.491	8.360	11.9255
	4		71.119	6.100	38.6095
P1	1		15.991	5.120	10.5555
	2		17.901	45.530	31.7155
	3		21.985	62.360	42.1725
	4		13.085	7.626	10.3555
P2	1		10.792	5.080	7.9360
	2		9.347	5.546	7.4465
	3		14.720	5.900	10.3100
	4		11.770	4.680	8.2250
Moisture content (%)					
P0	1	0.12	0.38	0.42	0.400
	2		0.16	1.00	0.580
	3		0.17	0.57	0.370
	4		0.22	0.90	0.560
P1	1		0.33	1.00	0.665
	2		0.14	0.30	0.220

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cont. Tab. 1

Treatment	Composting week	Average value / fixed condition value	High price	Low price	Closing price
P1	3	0.12	0.13	0.80	0.465
	4		0.10	0.30	0.200
P2	1		0.13	0.53	0.330
	2		0.13	1.00	0.565
	3		0.13	0.66	0.395
	4		0.13	0.12	0.125

Explanations: P0 = chopped salak fronds (control), P1 = chopped salak fronds + cow manure, P2 = chopped salak fronds + cow manure + polyacrylamide.
Source: own study.

exhibited the highest content (4.46%), surpassing P1 and P0. The enhanced P availability in treatment P2 was attributed to the decomposition of organic matter in the soil. This finding is consistent with Erkossa, Williams and Laekemariam (2018), who reported that organic material application can increase soil P content, yielding significant results after testing, compared to pre-treatment conditions.

The application of compost resulted in increased potassium (K) availability in the soil (Tab. 1), with treatment P2 (salak palm fronds + animal manure + PAM) exhibiting the highest K content (3.66%) after two months of application on salak land. This finding is consistent with Song *et al.* (2024), who reported significant increases in bioavailable P and K in the soil after regular compost application. Furthermore, Wang, C. *et al.* (2024) demonstrated that the use of PAM with organic materials can enhance soil properties and mitigate nutrient leaching, including N, P, Cu, and Zn.

The reduction in soil carbon content, as depicted in Table 1, to less than 30%, was followed by the release of N, P, and K, leading to enhanced nutrient availability in the soil. Despite the release of heat during decomposition, the soil organic matter content increased. This result supports the findings of Qiang *et al.* (2024), who demonstrated that the application of organic amendments with polyacrylamide can enhance soil organic matter content.

The C:N ratio of salak palm fronds compost after decomposition, as depicted in Table 1, was found to be low (≤10%) in treatment P2. This finding is consistent with Ahmad *et al.* (2020), who reported that the application of organic amendments optimised the soil C:N ratio, providing a carbon source for microbial growth, and enhancing microbial activity and metabolism, which in turn increased nitrogen immobilisation and reduced nutrient loss.

The results presented in Table 1 indicate that the moisture content of the compost material increased after decomposition. Treatment P1 (salak fronds + cow manure) exhibited a higher moisture content (0.6%) compared to the other treatments. The combination of palm fronds and cow manure resulted in improved water retention. However, no significant differences in moisture content were observed among all treatments, suggesting that all treatments had comparable moisture levels. This finding is in agreement with Paradelo, Basanta and Barral (2019), who found that the addition of humectant materials and the type of compost used did not significantly affect the water-holding capacity of compost-based substrates.

SOIL BULK DENSITY

Mature compost was applied to the salak land along with polyacrylamide according to the specified treatments. The changes in soil bulk density before and after the application of polyacrylamide integrated with salak fronds compost can be seen in Figure 1.

In Figure 1, the effect of compost application on soil bulk density is shown, with the treatment (M3K0) PAM 90 g + fronds resulting in the lowest soil bulk density of 0.57 g·cm^{-3}, compared to the soil bulk density of 1.0 g·cm^{-3} before the treatment. The observations indicate that PAM, combined with organic material, can affect soil physical properties, particularly soil porosity, and influence soil aggregates, which in turn affects soil bulk density. The higher the organic matter content in the soil, the lower the soil bulk density will be. Molecules of PAM are absorbed by soil particles (mostly on their outer surface) (Mamedov *et al.*, 2011, which enhances soil aggregates and structural stability more than organic or inorganic amendments (Orts *et al.*, 2007; Karami *et al.*, 2012). La Andi *et al.* (2023) stated that increasing organic material in the soil leads to enhanced microbial activity, improved soil porosity, and reduced soil bulk density. Amnah and Friska (2019) added that PAM can improve aggregate stability and soil properties.

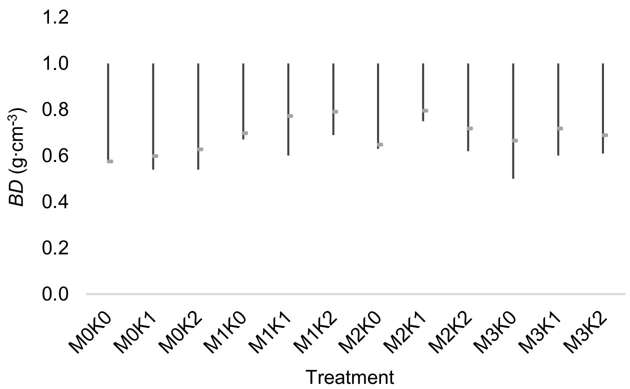

Fig. 1. The effect of the application of polyacrylamide (PAAM) and fronds compost on soil bulk density (*BD*, g·cm^{-3}); M0K0 = fronds, M0K1 = fronds + cow manure, M0K2 = fronds + fronds + cow manure + PAM, M1K0 = PAM 30 g + fronds, M1K1 = PAM 30 g + fronds + cow manure, M1K2 = PAM 30 g + fronds + cow manure + PAM 30 g, M2K0 = PAM 60 g + fronds, M2K1 = PAM 60 g + fronds + cow manure, M2K2 = PAM 60 g + fronds + cow manure + PAM 30 g, M3K0 = PAM 90 g + fronds, M3K1 = PAM 90 g + fronds + cow manure, M3K2 = PAM 90 g + fronds + cow manure + PAM; source: own study

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GROUNDWATER CONTENT

The treatment of salak fronds compost with PAM and the combination of treatments significantly affected soil moisture content (Tab. 2). This study used well-decomposed salak fronds compost, which increases soil organic matter and enhances the soil's water retention capacity. The highest water content was 70.33%, which occurred in the treatment of M3K2 (PAM 90 + fronds + cow manure + PAM). According to Kebede *et al.* (2022), the application of PAM with organic ameliorants can increase soil moisture content compared to other treatments. Planting media that use compost material can improve soil moisture content because compost-based media enhance the water retention ability of the soil (Nasution and Fitria, 2023).

Table 2. The effect of polyacrylamide (PAM) and salak fronds compost on soil moisture content

Treatment	Soil moisture content (%) at			
	K0 (fronds)	K1 (fronds + cow manure)	K2 (fronds + cow manure + PAM)	average
M0 (control)	53.00[a]	53.33[b]	56.00[d]	54.11
M1 (PAM 30 g)	56.33[b]	60.00[c]	65.00[a]	60.44
M2 (PAM 60 g)	63.00[d]	56.00[a]	66.66[c]	61.89
M3 (PAM 90 g)	64.00[c]	68.67[d]	70.33[b]	67.67
Average	**59.00[a]**	**59.50[a]**	**64.50[a]**	–

Explanations: numbers followed by the same lowercase letters in the same column are not significantly different based on the Duncan's new multiple range test (DNMRT) at 5% level.
Source: own study.

SOIL TEXTURE

Soil texture is one of the physical properties of soil that can change both quickly and slowly. Amendments in the form of organic or chemical materials always influence the development of soil structure. The effect of PAM integrated with salak fronds compost on soil texture changes can be seen in Table 3.

SOIL ORGANIC CARBON

The use of PAM integrated with salak fronds compost applied to salak land for 4 weeks has an effect on soil organic carbon content. This can be seen in Figure 2.

The presence of organic carbon (organic C) in soil significantly affects changes in its physical and chemical properties as well as nutrient availability for plants. The application of PAM integrated with salak fronds compost can increase soil organic carbon content (Fig. 2). In this study, treatment over a period of four weeks on salak plantation land was found to alter the soil's organic carbon content. The highest organic C content was observed in the M3K0 treatment (PAM 90 g + fronds), with organic C value of 8.15%.

In this study, treatment with the application of 30 g of PAM and cow manure + PAM resulted in the highest change in organic C

Table 3. Results of the texture data analysis in salak land under the influence of polyacrylamide (PAM) and salak fronds compost treatments

No	Treatment	Texture		
		sand (%)	silt (%)	clay (%)
1	M0	47.56	53,00	35.56
2	M1	43.56	53.22	38.89
3	M2	47.44	41.44	38.94
4	M3	27.67	65.67	48.83
5	K0	39.17	59.96	41.13
6	K1	42.08	51.13	41.17
7	K2	43.42	48.92	39.38
8	M0K0	43.33[a]	70.67	30.67
9	M0K1	49.67[b]	44.17	38.00
10	M0K2	49.67[c]	44.17	38.00
11	M1K0	36.00[a]	59.33	47.00
12	M1K1	39.67[b]	65,00	38.83
13	M1K2	55.00[c]	35.33	30.83
14	M2K0	49.67[a]	44.17	38.00
15	M2K1	51.33[b]	29.67	39.00
16	M2K2	41.33[c]	50.50	39.83
17	M3K0	27.67[a]	65.67	48.83
18	M3K1	27.67[b]	65.67	48.83
19	M3K2	27.67[c]	65.67	48.83

Explanations: treatments as in Fig. 1, numbers followed by the same lowercase letters in the same column are not significantly different based on the Duncan's multiple range test (DMRT) at 5% level.
Source: own study.

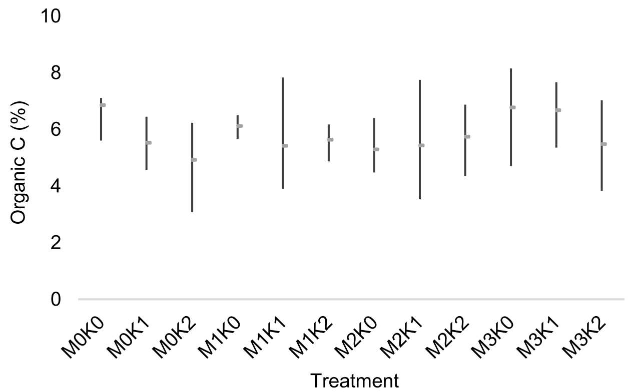

Fig. 2. The effect of applying polyacrylamide (PAM) integrated with salak fronds compost on soil organic carbon (C-org); treatments as in Fig. 1; source: own study

value. The combination of PAM and cow manure was able to increase soil organic carbon content on the observed salak plantation land. According to Nurmansyah (2023), the application of compost mixed with cow manure can enhance soil organic carbon content in peanut plantation land. This finding is supported by Banamtuan *et al.* (2023) and Ikbal, Iskandar and Budi (2016), who stated that soil organic carbon content can increase following the addition of compost and humic substances.

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NITROGEN

Nitrogen is an essential nutrient required by plants, and its role cannot be replaced by other elements. In this study, the availability of nitrogen in the soil increased after the application of polyacrylamide integrated with compost on salak plantation land. The effects of the treatment on salak plantation land are shown in Figure 3.

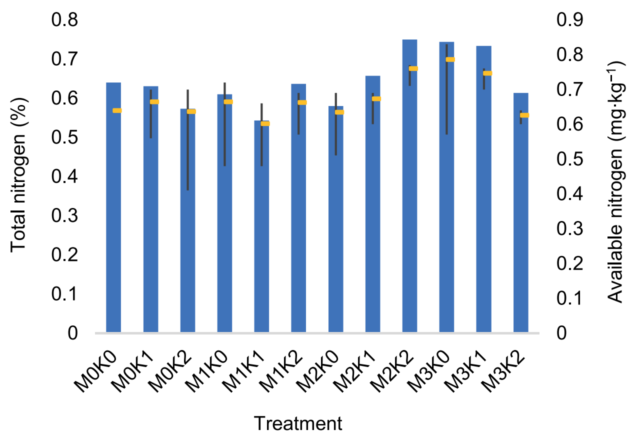

Fig. 3. The effect of polyacrylamide (PAM) integrated with salak fronds compost on soil nitrogen content; treatments as in Fig. 1; source: own study

The effect of PAM treatment integrated with salak fronds compost can influence the availability of nitrogen in the soil. The highest nitrogen content was 0.77, observed in the M2K2 treatment (PAM 60 g + fronds + cow manure + PAM). Nitrogen availability is affected by the application of PAM and fronds compost, as the decomposition of compost gradually releases nitrogen into the soil, making it available for plants. According to Saputri (2023), the addition of cow manure compost can increase nitrogen availability in the soil. Posmanik, Nejidat and Gross (2023) further stated that the application of compost combined with other amendments can enhance microbial activity, which facilitates nitrogen release in the soil.

SOIL EROSION

Erosion measurements were conducted four weeks after the application of PAM integrated with salak fronds compost in the research area. Erosion was calculated using the USLE model. The amount of erosion occurring on the salak plantation land after treatment is shown in Table 4.

The lowest erosion value in our study was 6.77 $Mg \cdot ha^{-1} \cdot yr^{-1}$, observed in the M1K1 treatment (PAM 30 g + fronds + manure) – Table 4. The highest erosion value is 7.72 $Mg \cdot ha^{-1} \cdot yr^{-1}$, observed in the M0K0 treatment (control + fronds). The application of PAM integrated with salak fronds compost has a significant effect on erosion values.

The application of PAM can increase aggregate stability and retain water absorbed compared to without PAM (Mamedov *et al.*, 2021; Ramadhani, 2023). Polyacrylamide and organic materials improve soil infiltration and porosity (Kebede *et al.*, 2022). Lamato, Nurmi and Azis (2023) stated that organic soil materials can influence soil erodibility because organic matter functions as a binder in the formation of soil aggregates, thus preventing soil erosion. Additionally, Istiqomah, Aryanto and Purwiyono (2021) and Gan *et al.* (2024) stated that soil aggregate formation is crucial in preventing erosion on slopes. The change in erosion values before and after treatment can be seen in Figure 4.

Table 4. The effect of PAM and salak fronds compost on soil erosion

Treatment	Soil erosion ($Mg \cdot ha^{-1} \cdot yr^{-1}$)			
	K0 (fronds)	K1 (fronds + cow manure)	K2 (fronds + cow manure + PAM)	average
M0 (control)	7.2^{a}	7.01^{b}	6.84^{c}	7.19
M1 (PAM 30 g)	6.98^{b}	6.77^{c}	7.07^{d}	6.94
M2 (PAM 60 g)	6.96^{c}	7.16^{d}	6.99^{a}	7.03
M3 (PAM 90 g)	6.89^{d}	6.93^{a}	6.82^{b}	6.88
Average	**7.14**	**6.97**	**6.93**	–

Explanations: treatments as in Fig. 1, numbers followed by the same lowercase letters in the same column are not significantly different based on the Duncan's multiple range test (DMRT) at 5% level.
Source: own study.

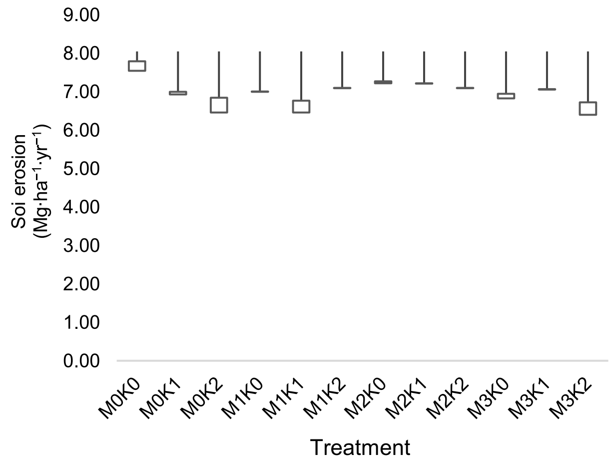

Fig. 4. The effect of polyacrylamide (PAM) and salak fronds compost on soil erosion before and after treatment ($Mg \cdot ha^{-1} \cdot yr^{-1}$); treatments as in Fig. 1; source: own study

The erosion tolerance value T = 1.25 $mm \cdot yr^{-1} \approx 7.125$ $Mg \cdot ha^{-1} \cdot yr^{-1}$, erosion < T value. The calculation of erosion rate from the soil's physical properties using the USLE method shows that the lowest rate is 6.77 $Mg \cdot ha^{-1} \cdot yr^{-1}$. The expected result from this study is an erosion rate < T value (erosion tolerance), which is 7.125 $Mg \cdot ha^{-1} \cdot yr^{-1}$. The results obtained from the study on the use of PAM and compost met the expected outcomes. The addition of organic materials shows a trend of decreasing K value (erodibility), which is consistent with the increase in soil organic matter and ecological environmental improvement (Imtinan *et al.*, 2024). To minimise soil erosion and its negative impacts, the integration of conservation measures, such as soil ameliorants, vegetative cover, and structural techniques, can improve soil properties, topography, and structure, thereby reducing surface runoff and sediment yield, and consequently minimising sedimentation (Broetto *et al.*,

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2017; Ebling, 2022). Soil erosion can be reduced by applying PAM + manure, and therefore, this is recommended for eroded land (Tilahun *et al*., 2024; Saragih, 2023).

According to Mulualem *et al*. (2022), PAM + amendments significantly reduce phosphorus loss due to water erosion (61%), and nitrogen loss due to erosion, leaching, and emissions by 55%, 10%, and 3%, respectively; and increase nitrogen use efficiency by 31% compared to the control. Zhang *et al*. (2021) stated that PAM was found to be the best amendment in terms of increasing the number of small pores in the soil, thereby improving water retention compared to other treatments. According to Wang, H. *et al*. (2024), PAM powder can improve soil porosity, thereby increasing the soil's water-holding capacity and reducing water loss and soil erodibility.

SALACCA PRODUCTION

The effect of applying PAM integrated with salak fronds compost after two months on the salak stem can influence the fruit weight per plant (g). Table 5 shows the effect of the treatment application on the salak fruit weight.

Table 5. The effect of polyacrylamide (PAM) and salacca fronds compost on the weight of salacca fruit

Treatment	Weight (kg) at			
	K0 (fronds)	K1 (fronds + cow manure)	K2 (frond + cow manure + PAM)	average
M0 (control)	1.47^{a}	1.43^{b}	1.50^{c}	1.47
M1 (PAM 30 g)	1.47^{b}	1.47^{a}	1.67^{d}	1.53
M2 (PAM 60 g)	1.63^{c}	1.57^{d}	1.67^{a}	1.62
M3 (PAM 90 g)	1.70^{d}	1.70^{c}	2.10^{d}	1.83
Average	**1.57^{ab}**	**1.54^{a}**	**6.43^{b}**	–

Explanations: treatments as in Fig. 1, numbers followed by the same lowercase letters in the same column are not significantly different based on the Duncan's multiple range test (DMRT) at 5% level.
Source: own study.

The highest production was 2.1 kg (M3K2 treatment – 90 g PAM + fronds + cow manure + PAM), and the lowest production was 1.43 kg (M0K1 treatment – control + fronds + cow manure) – Table 5. The nutrients from the compost, which had decomposed for two months, can be absorbed by the plant's roots, thus influencing the production of salacca plants. It is suspected that the application of compost can improve the growing medium conditions, including the physical, chemical, and biological properties of the soil, which activate microbial life, increase the soil's nutrient absorption capacity, enhance soil fertility, and promote vegetative plant development. Stokes *et al.* (2023) and Nasution *et al.* (2024) state that the complex relationship between parameters can affect plant productivity through their influence on the bioavailability of plant nutrients. In tropical regions, where the carbon mineralisation rate of the soil is relatively high, it is important to continuously monitor the concentration of soil organic matter to avoid adverse impacts on plant productivity.

CONCLUSIONS

The decomposition process resulted in significant changes in compost composition, including increased concentrations of nitrogen (N), phosphorus (P), potassium (K), organic carbon (C-org), and moisture content, accompanied by a decrease in the carbon-to-nitrogen (C:N) ratio. The integration of polyacrylamide (PAM) with salak leaf-stalk compost significantly improved soil physical and chemical properties on sloping salak plantations. The composting process reached maturity within four weeks, as indicated by stabilized temperature (26.5°C) and uniform dark coloration, confirming complete decomposition and suitability for field application. Field application of PAM combined with compost enhanced soil water retention, bulk density, sand fraction distribution, and soil organic carbon content, demonstrating improved soil structural stability and fertility. These improvements contributed directly to reducing soil erosion rates. The lowest predicted erosion rate, calculated using the Universal Soil Loss Equation (USLE), was 6.77 $Mg \cdot ha^{-1} \cdot yr^{-1}$ under the treatment of 30 g PAM combined with compost and manure. This value is lower than the established soil erosion tolerance threshold (7.125 $Mg \cdot ha^{-1} \cdot yr^{-1}$), indicating that the integrated amendment effectively controls soil loss on slopes. Overall, the combined application of PAM and salak leaf-stalk compost represents an effective soil conservation strategy for marginal sloping lands. The treatment not only reduces erosion below tolerance limits but also enhances soil quality, thereby supporting sustainable production of Sidimpuan salak. This integrated vegetative–chemical approach offers a practical and environmentally sound solution for erosion management in tropical slope agroecosystems.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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