Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2022.v27i1.27-35

The Effectiveness and Valuation of Using Silt Pit to Reduce Erosion and Nutrient Loss of Andosol

Andi Masnang[1*], Asmanur Jannah[1], Reny Andriyanty[2] and Umi Haryati[3]

[1]*Department of Agrotechnology Faculty of Agriculture, Nusa Bangsa University*
Jl. KH. Sholeh Iskandar Km 4, Tanah Sereal-Bogor, Indonesia.
[2]*Department of Management Faculty of Economics IBI Kosgoro 1957 Jakarta, Indonesia*
[3]*Indonesian Center for Agricultural Land Resources Research and Development (ICALRRD), Bogor, Indonesia*
**e-mail: andimasnang65@gmail.com*

Received 04 August, 2021; Revised 23 November, 2021; Accepted 31 January 2022

ABSTRACT

The silt pit is a method of soil management that functions to accommodate and absorb surface runoff. The research aimed to determine the silt pit effectiveness for erosion reduction and nutrient loss. The research is located at 576 above sea level (asl) in Sukamantri village, Taman Sari district, Bogor Regency. The experiment used a randomized block design with three replications and a slope group. The treatments were R0 (without silt pit); R1 (silt pit); R2 (silt pit + mulch); R3 (silt pit + mulch + biopore tube), R4 (silt pit + mulch + biopore tube + vertical crop tube). The highest runoff-decreasing occurred on R4 treatment, which pressed down 29.38% runoff. The highest value of erosion-decreasing occurred on R2 as 68.74% and followed by effectiveness in reducing the loss of 71% Organic C, 76% available P, and 67% total N. The dry seeds peanut yield was around 0.54 - 0.86 Mg ha^{-1}, dried pods was 0.96 - 1.33 Mg ha^{-1}, and dried biomass was 5.16 - 6.23 Mg ha^{-1} and not significantly different between all treatments. This study recommends that farmers apply silt pit innovation technology with a combination of mulch, biopore, and mature green media because the incremental B/C ratio was 1.175. It is a good economic indicator for farmers.

Keywords: Andosol, erosion, runoff, silt pit

INTRODUCTION

Andosol soil area in Indonesia reaches 5.4 million hectares, with potential soil for agriculture reaching 2.050 million hectares (38%). The organic C content of Andosol in Indonesia is ranged from 1.24% to 22.46%. Based on the topography, the potential Andosol for the crop on sloping soil was less than 15% with 1.166.452 hectares (BBSDLP, 2014). It supports optimized plant growth if it is managed by the principles of soil and water conservation for soil erosion prevention (Kuzucu and Dökmen 2015; Dumanski 2015; Wang et al., 2015; Bhan and Behera 2014; Golosov and Belyaev 2013; Liu *et al.* 2013). The characteristic of Andosol accumulated the organic matter on the soil surface (Mankasingh and Gísladóttir 2019). The soil organic matter could be changed by erosion (Liu *et al.* 2019; Lord and Sakrabani 2019; Rizinjirabake, Tenenbaum *et al.* 2019;Lord and Sakrabani 2019; Endale *et al.* 2017; and Borrelli *et al.* 2016). It causes carbon redistribution on soil superficies. Some parts of the soil surface lose organic carbon. Meanwhile, other parts receive carbon. Silt pit can be used to control the organic C loss by execution on sloping land (Reinwarth *et al.* 2019). A silt pit is an orifice or cross-sectional area (Moradi *et al.* 2015). It functions to flow superficies containing and percolating. The soil arrangement by silt pit technology presses around 54% runoff surface compared without silt pit (Masnang *et al.* 2014). Andosol cultivated for vegetable crops without soil and water conservation measures 2.3-8.4 times the tolerable limit (Sukarman and Dariah 2014).

One of the technical forms of soil conservation is silt pit, biopore and vertical cultivation integration. Farmers think conservation with silt pit application can reduce soil fertility and plant yields (Shrestha and Ligonja 2015). Consequently, the silt pit technology has to be innovated and creative to persuade the farmer. This research planted peanut as the main plant and combined it with cayenne pepper as a vertical plant. The idea was redesigned from the research of Donjadee and Tingsanchali (2016).

This study aimed to measure the effectiveness of silt pits in reducing soil nutrients and economic losses due to erosion in Andosols.

MATERIALS AND METHODS

The research was located in the Sukamantri village sub-district of Tamansari Bogor region at an altitude of 576 meters above sea level, with 06°39'19" south latitude and 106°45'48" east longitude with a 15% slope. The cultivated peanut was used as a soil productivity indicator.

Experimental Design

The experiment used a randomized group design, with five randomized arranged experiments for each group. The experiment consisted of: a control plot without silt pit (R0), silt pit (R1), silt pit combined with secondary vegetation mulch (R2), silt pit with secondary vegetation mulch combined with biopore tube (R3), silt pit with secondary vegetation mulch and biopore tube and vertical plant tube (R4). The experiment was replicated three times on various slope groups. Totaly there were 15 experimental units. Each research response variable was analyzed by ANOVA test for significant variance and correlation coefficient test. The further test used Duncan's Multiple Difference Test at a 95% significance level.

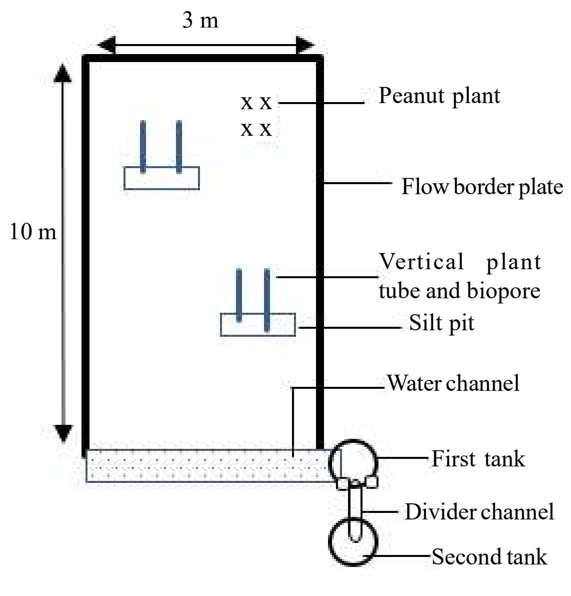

Figure 1. Observation plot sketch.

Research Implementation

The experiment started with the creation of an experimental plot. The size of the plot was 10 meters long and three meters wide. Each plot was lined with a plastic matter height of 20 cm above ground level and 15 cm below the soil surface to prevent water seepage. A gutter was installed at the plot's lower end to drain water to the holding tank. For anticipating the significant surface runoff, two storage tanks with each capacity of 60 liters have been implemented. The first tank made three outlet holes in which one outlet connected with the second holding tank. Each experimental plot (except control) was made of a silt pit measuring 100 cm length, 50 cm width, and 40 cm depth. In the R3 and R4 were installed two paralon pipes. The pipe worked as a biopore and vertical intercrops planted (cayenne pepper). All plots were planted with peanuts with a plant spacing of 25 cm × 25 cm (Figure 1).

Research Observation

The Rainfall and Erosion Measurement

The rainfall measuring device used the Ombrometer type. The Measurement count is at 7.00 a.m. every morning. It was measured with tools (in liters) and a ruler. The results showed in water height (mm) and rainfall percentage. The erosion sample taken in each plot on rainy days caused the runoff. Every sample sediment dried in the oven at 105°C temperature until its weight became constant and then scaled on 24 hours. The same analysis method was also applied to determine the soil organic C, total N, and P_2O_5.

The Economic Assessment of Soil Nutrient Loss Caused by Erosion.

The assessment was approached by the nutrient (C, N, P, and K) loss through sediment matter to convert into organic fertilizer, Urea, and TSP/SP-36 value. The nutrient loss value was estimated by the percentage of nutrient content in the fertilizer. The N value on urea fertilizer was estimated at 46,6%, and the P on TSP Fertilizer was 48%. The C-value on petrorganik was 12,30%. The prevailing retail price of each fertilizer type was the current price in the research location. The organic fertilizer was worth Rp.550 per kg; Urea was worth Rp.3,900 per kg, and TSP was worth Rp.3,650 per kg. The N percentage value determines the erosion economic value caused by N loss in sediments multiplied by N percentage in Urea converted in the monetary unit that refers to the current price.

RESULTS AND DISCUSSION

Erosion and Surface Runoff

The silt pit was the form of water and soil conservation technology (Reinwarth *et al.* 2019). The mechanical conservation method was the embankments constructed across the slope to intercept surface runoff and protect soil erosion. Its implementation was integrated with mulch, biopore, vertical planting; neither can reduce erosion and runoff. The erosion and runoff in R1 to R4 were significantly lower than R0. The erosion reduction was reached 59% on the R1 experiment and 68% on the R2 experiment compared to the control. The control experiment erosion occurred as 26.95 Mg ha^{-1}, which was lower than tolerable soil loss, 13.46 Mg ha^{-1}. For the R1 till R4 experiments, the tolerable soil loss was 11 Mg ha^{-1}. It concluded that R1 till R4 was under the erosion threshold value.

The integration of silt pits with mulch, biopore, vertical plants could control erosion below the erosion threshold. The silt pit reduced the soil damage and was safe for the environment (environmentally friendly). There was no significant difference on R1 until R4 on controlling the erosion and runoff, and it indicated that all treatments have the same effectiveness. The silt pit experiments (R1 till R4) showed a low runoff and significantly differed from the control (R0). The runoff in the control experiment was 113.05 mm (9.0% from 1,249.61 mm rainfall). The R4 experiment reduced the 29.38% runoff level. The effectiveness of runoff decreasing was 68.74% on the R2 experiment (Table 1).

The level of effectiveness of the silt pit in the surface runoff reduction was determined from the number of silt pits, the distance of silt pits, and the size of the silt pit (Abdulaali *et al.* 2020); Bohluli *et al.* 2014). Based on the results of Wahyuni *et al.* (2015) research, the applications of 9 silt pits per plot without mulch on a cocoa field with a 4% slope can reduce runoff by 32%, while 16 silt pits combined with cocoa leaf mulch and straw can reduce runoff by up to 82% compared to a control. Besides that, using a silt pit can increase the stability of the aggregate by up to 44.7% (Ping *et al.* 2012). The effectiveness of silt pit application was relatively high in suppressing erosion, which reached 88.55% (Deviantie *et al.* 2020). It depends on soil structure and land cover conditions, and the shorter the distance between silt pits on the same slope, the more effective it was in suppressing erosion and runoff and increasing the water content of the soil. The research by Pratiwi and Salim (2013) on a gently sloping land showed that applying a silt pit with a distance of 5 meters could suppress erosion by 13.56% greater than the provision of a distance of 10 meters that could reduce erosion by 5.08%. According to Masnang *et al.* (2016), using a silt pit at a distance of 2 meters could reduce the amount of runoff by 54% and 34% at a silt pit distance of 4 meters. As the result of the hole's presence, it could accommodate the water, decrease the velocity, and increase the infiltration rate. An infiltration surface presence also causes the increase of infiltration rate because the channel walls are absorbent.

Table 1. The silt pit effect on the effectiveness of runoff and erosion reducing.

Treatment	Runoff (mm)	Rainfall (%)	Effectiveness of runoff reducing (%)	Erosion (Mg ha^{-1})	Effectiveness of erosion reducing (%)
R0	113.05 a*	9.05**	-	26.95 a	-
R1	83.83 b	6.71	25.84***	10.96 a	59.32
R2	88.17 b	7.06	22.01	8.43 a	68.74
R3	81.00 b	6.48	28.35	10.91 a	59.51
R4	79.83 b	6.39	29.38	10.09 a	62.58

Note:
R0= treatment without silt pit;
R1=treatment with silt pit;
R2=treatment with silt pit+ mulch;
R3=treatment with silt pit+ mulch+ biopore tube;
R4= treatment with silt pit+ mulch+ biopore tube+vertical plant tube.
* The numbers followed by different letters on the same line were significantly different at the 5% level of DMRT.
**Total rainfall = 1249.61mm
***The effectiveness of runoff and erosion reducing treatment counted by silt pit treatment and control comparison.

The Nutrient Loss

Soil nutrients could be carried away in runoff and erosion. Elements which was soluble in water were usually carried away with surface runoff. Nutrients that are absorbed in colloids were carried away by erosion. Therefore, loss of nutrients can occur through surface runoff and erosion (Zhang et al., 2016). The results showed that silt pits could reduce a nutrient loss (Table 2). It was presumably due to the function of the silt pit, which could reduce the amount of surface runoff and erosion. The silt pit keeps the nutrient-rich topsoil carried away by erosion and surface runoff as the topsoil trap in the silt pit. Loss of organic C and soil nutrients decreased significantly in the single silt pit treatment and the integrated silt pit treatment. The silt pit + mulch (R2) could reduce C as 71% organic C, 76% available P, and 67% total N, respectively. The effectiveness of organic C and reducing nutrient loss indicated that some of them are carried away by runoff to the silt pit. The silt pit cut short the slope and reduced sediment runoff (Reinwarth *et al.* 2019). The highest runoff and erosion occurred on the plot without silt pit treatment (Table 1) because the speed and the transportation capacity were higher in sloping areas. It carried large quantities of large and small soil particles and impacted the loss of Organic C, Total N, and P-avail. The nitrogen lost through surface runoff was less than Organic C and P-avail. The amount of nitrogen in the soil varies but is generally low. The presence of the element N in the soil was minimal, so it was necessary to prevent N loss through erosion because it contains the highest N (Table 2).

The Silt Pit Impact on Nutrient Loss Economic Valuation

Soil production and soil infertility were influenced by erosion. The erosion process increased the C, N, and P leaching. In the long run, it imperiled agriculture (Rop *et al.* 2019; GAO *et al.* 2019; Jacobs *et al.* 2017), particularly in economic valuation (Table 3). The erosion economic valuation is approached by soil nutrient loss transported along with the erosion matters (Ebabu *et al.* 2019; Gonzalez 2018). The loss value converted into organic fertilizer, Urea, and TSP.

Based on Table 3, the highest dissolved sediment occurred on R0 treatment (without silt pit), and the total loss-cost was 7.6 million rupiahs. The total loss-cost details were Organic C loss with 6.4 million rupiahs, the P_2O_5 with a value of 1.1 million rupiahs, and the Total N loss-cost as 123,088 rupiahs. The cost of control treatments (without silt pit) showed 300% higher than silt-pit treatment (R1, R2, R3, and R4) with an average cost of 2.4 million rupiahs.

Crop Yields

The dryland farming on sloping areas must apply incentive cultivation (GAO *et al.* 2019; Saida *et al.* 2016). The cultivation must prevent the soil's physical function degradation and nutrient loss. Based on these experiments, the dry seeds of peanut yields were around 0.54 - 0.86 Mg ha^{-1}, dried pods were 0.96 - 1.33 Mg ha^{-1}, and dry biomass was 5.16 - 6.23 Mg ha^{-1} and not significantly different between all treatments. The temporary allegations determined that the silt pit was implemented only in one planting season, and it did not impact crop yields

Table 2. The silt pit effect on the effectiveness of reducing the Organic C, P-avail, and Total N loss.

Treatment	Loss C-org (kg ha^{-1})	Effectiveness Reduce (%)	Loss P_2O_5 (kg ha^{-1})	Effectiveness Reduce (%)	Loss Total N (kg ha^{-1})	Effectiveness Reduce (%)
R0	1420.96 a*	-	141.98 a	-	14.71 a	-
R1	415.70 b	70.74**	39.48 b	72.20	4.75 b	67.67
R2	412.13 b	71.00	33.78 b	76.21	4.78 b	67.51
R3	543.14 b	61.78	40.86 b	71.22	5.86 b	60.13
R4	485.94 b	65.80	37.74 b	73.42	6.08 b	58.67

Note:
R0= treatment without silt pit;
R1=treatment with silt pit;
R2=treatment with silt pit+ mulch;
R3=treatment with silt pit+ mulch+ biopori tube;
R4= treatment with silt pit+ mulch+ biopori tube+vertical plant tube.
* The numbers followed by different letters on the same line are significantly different at the 5% level of DMRT.
** The Organic C and soil nutrient loss reduction, counted by the Organic C and nutrient on silt pit treatment and control comparison.

Table 3. The silt pit effect on loss nutrient economic valuation.

Treatment	C-Org Loss (Rp)	P_2O_5 Loss (Rp)	Total N Loss (Rp)	Total Economic Loss (Rp.)
R0 (without silt pit)	6.353.894	1.079.648	123.088	7.556.631
R1 (silt pit)	1.858.839	300.192	39.790	2.198.822
R2 (silt pit+ mulch)	1.842.851	256.889	39.986	2.139.727
R3 (silt pit+ mulch+ biopore tube)	2.428.683	310.700	49.077	2.788.461
R4 (silt pit+ mulch+ biopore tube+vertical plant tube)	2.172.911	287.010	50.874	2.510.797

directly. All treatments (silt pit with mulch, biopore, vertical planting, and all three combinations) gave the same response toward the peanut bean and dried pods. The peanut bean and dried pods yield in R1 and R2 treatments were higher than other treatments, including control. The dry biomass showed a different response on bean and dried pods. The R1 and R4 treatments produced higher dry biomass than other treatments (R0, R2, and R3). The R2 treatment resulted in the same response as control (R0). It can be shown in Figure 2.

The increasing yields of dried seeds and dried pods on R1 and R2 treatments and the dry biomass yield (on R1 and R4 treatments) showed that silt pit application and its integration could improve crop yields. Thus, the silt pit could implement in the peanut farming system on dry soil. This research tested the integration of peanut as the main crop with silt pit technology and vertical planting. The vertical planting was cayenne pepper with two kinds of treatment. It stated that cost and working time-limited soil and water conservation applications (Sartori *et al.* 2019; Brausmann and Bretschger 2018; and Schiefer *et al.* 2015) low-budget soil conservation must be developed. The common budget conservation development is only implemented for vegetables and secondary crops. The cayenne pepper was applied in this experiment because of its unstable price during the research period. The determination of cayenne pepper as intercrops was based on Jariyah's research which stated that the construction of soil conservation was often constrained due to cost and time. Therefore, it is necessary to make soil conservation that is minimal in cost. Soil conservation can be pursued with vegetable crops and secondary crops (Jariyah, 2014). Moreover, the current price of red cayenne pepper has a high value, which reached Rp. 70,795

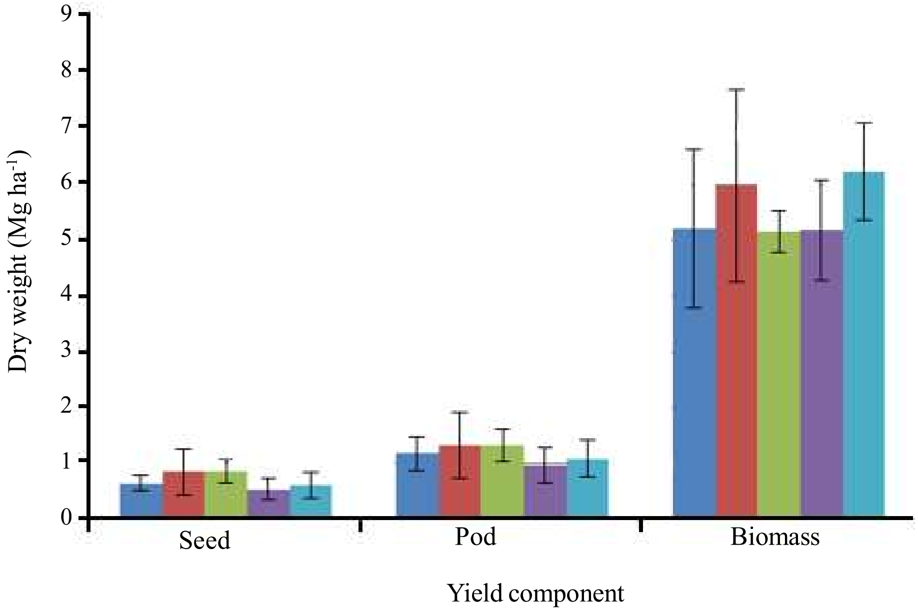

Figure 2. The silt pit treatment effect on peanut yield component in Sukamantri Village sub-region Tamansari Bogor district Province of West Java. ■ : R0 (treatment without silt pit), ■ : R1 (treatment with silt pit), ■ : R2 (treatment with silt pit+ mulch), ■ : R3 (treatment with silt pit+ mulch+ biopori tube), ■ : R4 (treatment with silt pit+ mulch+ biopori tube+vertical plant tube).

per kg (Kementan RI 2017). This study was planted with red cayenne pepper and consisted of two treatments. The first treatment (M1) used cow manure as growing media, while the second (M2) used green manure. Nugroho (2017) research on silt pits combined with crude palm oil fresh fruit bunches waste significantly reduces the impact of soil erosion while increasing root growth in rubber plants in South Sumatra. The B/C analysis showed that both treatments were feasible. Both of them were worth more than one. The highest analysis value was precisely in the M2 treatment. The cayenne pepper as vertical plants produced an average 48 grams yield per tree in the first three months. The vertical tubes per silt pit were two tubes filled with five plants, so the average production per silt pit was 480 grams each. The B/C analysis showed that the results from both of them were more than one. The decent B/C ratio value could motivate farmers to take conservation actions (Betela and Wolka 2021; Mcharo and Maghenda 2021; Sriprapakhan *et al.* 2021; DeVincentis *et al.* 2020). The highest B/C value occurred in the M2 treatment (Table 4). That treatment was the silt pits made and filled with green manure. The highest value occurs because there was a green manure's role. It increased the uptake of nutrients due to surface runoff, and the peanut production became high. Sutarno's research also found that the application of vertical mulch to the micro catchment system accommodated surface runoff effectively and absorption capacity, and this modification was easy for farmers. The B/C value was also greater than conventional soil treatments (Sutarno 2004). A study to predict the model to estimate the erosion rate with good accuracy showed the same results. It was proven that the application of silt pits in date palm plantations was able to reduce the effect of surface runoff and the erosion rate by 88.55% (Devianti *et al.* 2020). Both treatments feasible to develop (Shrestha *et al.* 2018).

Incremental B/C Ratio

The analysis of the technology effect applied in this study on farmers' revenue is approached by the concept of Incremental B/C Ratio. The incremental B/C analysis analyzed the effect of silt pit technology application. The incremental B/C analysis described that peanut farming was feasible before and after implementing the silt pit technology (Table 5). The formula was:

$$Incremental\frac{B}{C}Ratio = \frac{(TR_{\mathrm{AR}} - TR_{\mathrm{BR}})}{(TC_{\mathrm{AR}} - TR_{\mathrm{BR}})}$$

Notes :

TR_{AR} = Total farmer's revenue after technology
TR_{BR} = Total farmer's revenue before technology
TC_{AR} = Total farmer's cost after technology
TC_{BR} = Total farmer's cost before technology

If the value of the Incremental B/C Ratio was more significant than 1, the farmer's revenue with the application of silt pit technology increases, while if the value was less than 1, the farmer lost. Using the green manure treatment was better than cow

Table 4. The B/C analysis result on the combination of silt pit and cayenne pepper, with various treatments.

Treatment	Yield (Kg)	Price (Rp per kg)	Cost (Rp)	Benefit (Rp)	B/C
Cow Manure (M1)	172	70,795	5,497,680	6,653,936	1.21
Green Manure (M2)	175	70,795	5,362,680	7,037,197	1.30

Source: Primary data processed (2017)

Table 5. The Incremental B/C ratio on silt pit treatment with various treatments.

No	Treatment	Total revenue before technology applied (Rp)	Total revenue after technology applied (Rp)	Total cost before technology applied (Rp)	Total Cost after technology applied (Rp)	Incremental B/C Ratio
1	Cow Manure (M1)	21,729,155	27,642,845	1,949,000	7,427,450	1.079
2	Green Manure (M2)	21,729,155	28,010,590	1,949,000	7,292,450	1.175

Source: Primary data processed (2017)

manure treatment. This treatment should indeed be applied, namely the silt pits operation combined with the litter and biopore dual function and green manure media. The conservation taken by farmers will increase profits where the incremental ratio value showed the number of 1.175. It indicated that post-implementation of silt pits' dual-function technology could increase farmers' profits by 0.175 units. The farmers made 1.175 times the profit for each unit cost incurred. The value of the incremental B/C ratio is expected to encourage farmers to apply biopore dual function of biopore technology with green manure media. Irawan (2016) research support this analysis. The results showed that farmers with a high dependence on farming yield tend to adopt soil conservation technology more quickly than farmers who have income variations outside of farming. The application of silt pits technology on sloping land in this study could be appropriately developed at the farmer level. Based on that value, the silt pit technology could be recommended for farmers. The farmer will be motivated to conserve their soil (Komarek *et al.* 2019; Beardmore *et al.* 2019). The right technology to implement is the silt pit plus technology combined with mulch, double function biopore with green manure.

CONCLUSIONS

The runoff in the control experiment was 113.05 mm (9.0% from 1,249.61 mm rainfall). The lowest runoff occurred on all treatments (R1, R2, R3, and R4) and significantly differed from control (R0). The highest runoff-decreasing occurred on R4 treatment, which pressed down 29.38% runoff. The highest value of erosion-decreasing occurred on R2 as 68.74% and followed by effectiveness in reducing the loss of 71% Organic C, 76% available P, and 67% Total N. The dry seeds peanut yields was around 0.54 - 0.86 Mg ha^{-1}, dried pods production was 0.96 - 1.33 Mg ha^{-1}, and dry biomass was 5.16 - 6.23 Mg ha^{-1} and not significantly different between all treatments. The most beneficial soil conservation action for farmers was silt pit innovation technology applied with mulch biopore with mature green media because the incremental B/C ratio showed number 1.175. It became a beneficial indicator for farmers. Based on this research, the silt pit technology innovation is recommended for the farmer. It is very advantageous in two aspects of soil conservation: environmental conservation and economic aspect. The best technology was integrating silt pit with biopore and vertical planting.

ACKNOWLEDGMENTS

Thanks to Prof. Dr. Muhidin, who helped review the manuscript. The team acknowledges the Agency Agricultural Research and Development, Ministry of Agriculture, for the research funding through the Strategic Agricultural Research, Assessment and Development Cooperation Scheme KP4S (project No. 76.87/PL.040/H.1/04/2017.K). Also, all parties, including LPPM Nusa Bangsa University, supported this research either in the field or laboratory.

REFERENCES

Abdulaali HH, CTB Sung, AH Abdulaali, MR Kamal and R Ismail. 2020. Optimization of silt pit dimensions and the water supply period in oil palm plantation by artificial neutral network estimation. *EnvironmentAsia* 13: 53-66. doi: https://doi.org/10.14456/ea.2020.5.

Borrelli P, K Paustian, P Panagos, A Jones, B Schutt and E Lugato. 2016. Effect of good agricultural and environmental conditions on erosion and soil organic carbon balance/ : A national case study. *Land Use Policy* 50: 408-421. doi: https://doi.org/10.1016/j.landusepol.2015.09.033.

Beardmore L, E Heagney and CA Sullivan. 2019. Complementary land use in the Richmond River catchment: Evaluating economic and environmental benefits. *Land Use Policy* 87: 104070. doi: https://doi.org/10.1016/j.landusepol.2019.104070.

Betela B and K Wolka. 2021. Evaluating soil erosion and factors determining farmers' adoption and management of physical soil and water conservation measures in Bachire watershed, southwest Ethiopia. *Environmental Challenges* 5: 100348. doi: https://doi.org/10.1016/j.envc.2021.100348.

Bhan S and UK Behera. 2014. Conservation agriculture in India – Problems, prospects and policy issues. *Int Soil Water Conserv Res* 2: 1-12. https://doi.org/10.1016/S2095-6339(15)30053-8

Bohluli M, CTB Sung, AHM Hanif and ZA Rahman. 2014. Silt pit efficiency in conserving soil water as simulated by HYDRUS 2D model. *Pertanika J Trop Agr Sci* 37: 321-330.

Brausmann A and L Bretschger. 2018. Economic development on a finite planet with stochastic soil degradation. *European Economic Review* 108: 1-19. doi: https://doi.org/10.1016/j.euroecorev.2018.06.006

Devianti, Y Yunus, R Bulan, TD Sartika and A Sitorus. 2020. Silt Pit Application In Tropical Palm Dates Plantation/ : Case Study In Aceh Province, Indonesia. *Int J Sci Technol Res* 9: 42-48.

DeVincentis AJ, SS Solis, EM Bruno, A Leavitt, A Gomes, S Rice and D Zaccaria. 2020. Using cost-benefit analysis to understand the adoption of winter cover cropping in California's specialty crop systems. *J Environ Manage* 261: 110205. doi: https://doi.org/10.1016/j.jenvman.2020.110205

Donjadee S and T Tingsanchali. 2016. Soil and water conservation on steep slopes by mulching using rice straw and vetiver grass clippings. *Agr Nat Resour* 50: 75-79. doi: https://doi.org/10.1016/j.anres.2015.03.001

Dumanski J. 2015. Evolving concepts and opportunities in soil conservation. *Int Soil Water Conserv Res* 3: 1-14. doi: https://doi.org/10.1016/j.iswcr.2015.04.002.

Ebabu K, A Tsunekawa, N Haregeweyn, E Adgo, DT Meshesha, D Aklog, T Masunaga, M Tsubo, D Sultan, AA Fenta and M Yibeltal. (2019). Effects of land use and sustainable land management practices on runoff and soil loss in the Upper Blue Nile basin, Ethiopia. *Sci Total Environ* 648: 1462-1475. doi: https://doi.org/10.1016/j.scitotenv.2018.08.273

Endale DM, TL Potter, TC Strickland and DD Bosch. 2017. Sediment-bound total organic carbon and total organic nitrogen losses from conventional and strip tillage cropping systems. *Soil Till Res* 171: 25-34. doi: https://doi.org/10.1016/j.still.2017.04.004.

GAO X-song, Y XIAO, L-ji DENG and Q-Quan Li. 2019. Spatial variability of soil total nitrogen, phosphorus and potassium in Renshou County of Sichuan Basin, China. *J Integr Agric* 18: 279-289. doi: https://doi.org/10.1016/S2095-3119(18)62069-6

Golosov V and V Belyaev. 2013. The history and assessment of the effectiveness of soil erosion control measures deployed in Russia. *Int Soil Water Conserv Res* 1: 26-35. doi: https://doi.org/10.1016/S2095-6339(15)30037-X

Gonzalez JM. 2018. Runoff and losses of nutrients and herbicides under long-term conservation practices (no-till and crop rotation) in the U.S. Midwest: A variable intensity simulated rainfall approach. *Int Soil Water Conserv Res* 6: 265-274. doi: https://doi.org/10.1016/j.iswcr.2018.07.005

Irawan E. 2016. Adoption Model of Falcataria-Based Farm Forestry: A Duration Analysis Approach. *J Ekonomi Pembangunan: Kajian Masalah Ekonomi Dan Pembangunan* 17: 28. doi: https://doi.org/10.23917/jep.v17i1.1633.

Jacobs SR, L Breuer, K Butterbach-Bahl, DE Pelster and MC Rufino. 2017. Land use affects total dissolved nitrogen and nitrate concentrations in tropical montane streams in Kenya. *Sci Total Environ* 603-604: 519-532. doi: https://doi.org/10.1016/j.scitotenv.2017.06.100.

Jariyah NA. 2014. Partisipasi masyarakat dalam rehabilitasi lahan dan konservasi tanah (RLKT) di Sub DAS Keduang, Kabupaten Wonogiri, Jawa Tengah. *J Penelitian Sosial Dan Ekonomi Kehutanan* 11: 211-221. (in Indonesian).

Kementan RI. 2017. Pasokan dan Harga Aneka Cabai Nasional dan Wilayah Papua Barat Aman dan Stabil. https://www.pertanian.go.id. (in Indonesian).

Komarek AM, H Kwon, B Haile, C Thierfelder, MJ Mutenje and C Azzarri. 2019. From plot to scale: ex-ante assessment of conservation agriculture in Zambia. *Agric Syst* 173: 504-518. doi: https://doi.org/10.1016/j.agsy.2019.04.001

Kuzucu M and F Dökmen. 2015. The Effects of Tillage on Soil Water Content in Dry Areas. *Agric Agric Sci Proc* 4: 126-132. doi: https://doi.org/10.1016/j.aaspro.2015.03.015

Liu J, C Zang, S Tian, J Liu, H Yang, S Jia, L You, B Liu and M Zhang. 2013. Water conservancy projects in China: Achievements, challenges, and way forward. *Glob Environ Change* 23: 633-643. doi: https://doi.org/10.1016/j.gloenvcha.2013.02.002.

Liu KL, J Huang, DM LI, XC Yu, HC Ye, ZH Hu, QH Huang and MH Zhang. 2019. Comparison of carbon sequestration efficiency in soil aggregates between upland and paddy soils in a red soil region of China. *J Integr Agric* 18: 1348-1359. doi: https://doi.org/10.1016/S2095-3119(18)62076-3.

Lord R and R Sakrabani. 2019. Ten-year legacy of organic carbon in non-agricultural (brownfield) soils restored using green waste compost exceeds 4/ per mille per annum: Benefits and trade-offs of a circular economy approach. *Sci Total Environ* 686: 1057-1068. doi: https://doi.org/10.1016/j.scitotenv.2019.05.174

Mankasingh U and G Gísladóttir. 2019. Early indicators of soil formation in the Icelandic sub-arctic highlands. *Geoderma* 337: 152-163. doi: https://doi.org/10.1016/j.geoderma.2018.09.002

Masnang A, Aisyah, A Jannah, Namriah and Resman. 2016. Efektivitas interval rorak dalam mencegah penurunan produktivitas tanah di lahan sentra kakao. Prosiding Kongres Nasional Perkumpulan Masyarakat Gambut Indonesia (HGI) Ke VII dan Seminar Pengelolaan Lahan Sub-Optimal Secara Berkelanjutan, BBSDLP, Bogor. 573 p. (in Indonesian)

Masnang A, N Sinukaban, Sudarsono and N Gintings. 2014. Study of Run-off and Erosion Rate on Various Land Use in The Upper Jenneberang Sub Watershed. *J Agroteknos* 4: 32-37.

Mcharo M and M Maghenda. 2021. Cost-benefit analysis of sustainable land and water management practices in selected highland water catchments of Kenya. *Sci Afr* 12: e00779. doi: https://doi.org/10.1016/j.sciaf.2021.e00779

Moradi A, TC Boon Sung,GK Joo, MHA Husni and IC Fauziah. 2015. Effect of four soil and water conservation practices on soil physical processes in a non-terraced oil palm plantation. *Soil Till Res* 145: 62-71. doi: https://doi.org/10.1016/j.still.2014.08.005.

Nugroho PA. 2017. Pembangunan rorak dan aplikasi tankos di areal perkebunan karet (the study of silt pits establishment and empty fruit bunch application in rubber plantation). *Inovasi* 14: 155-161. (in Indonesian).

Ping LY, CT Boon Sung, GK Joo and A Moradi. 2012. Effects of four soil conservation methods on soil aggregate stability. *Malaysian J Soil Sci* 16: 43-56.

Pratiwi and AG Salim. 2013. Aplikasi Teknik Konservasi Tanah dengan Sistem Rorak pada Tanaman Gmelina (Gmelina arborea Roxb.) di KHDTK Carita, Banten. *J Penelitian Hutan dan Konservasi Alam* 10: 273-282.

Reinwarth B, R Petersen and J Baade. 2019. Inferring mean rates of sediment yield and catchment erosion from reservoir siltation in the Kruger National Park, South Africa: An uncertainty assessment. *Geomorphology* 324: 1-13. https://doi.org/10.1016/j.geomorph.2018.09.007

Rizinjirabake F, DE Tenenbaum and P Pilesjö. 2019. Sources of soil dissolved organic carbon in a mixed agricultural and forested watershed in Rwanda. *Catena* 181: 104085 https://doi.org/10.1016/j.catena.2019.104085.

Rop K, GN Karuku, D Mbui, N Njomo and I Michira. 2019. Evaluating the effects of formulated nano-NPK slow-release fertilizer composite on the performance and yield of maize, kale, and capsicum. *Ann Agric Sci* 64: 9-19. doi: . https://doi.org/10.1016/j.aoas.2019.05.010.

Saida, Abdullah, E Novita and M Ilsan. 2016. Sustainability analysis of potato farming system at sloping land in Gowa Regency, South Sulawesi. *Agric Agric Sci Proc* 9: 4-12. doi: https://doi.org/10.1016/j.aaspro.2016.02.107

Sartori M, G Philippidis, E Ferrari, P Borrelli, E Lugato, L Montanarella and P Panagos. 2019. A linkage between the biophysical and the economic: Assessing the global market impacts of soil erosion. *Land Use Policy* 86: 299-312. doi: https://doi.org/10.1016/j.landusepol.2019.05.014.

Schiefer J, GJ Lair and WEH Blum. 2015. Indicators for the definition of land quality as a basis for the sustainable intensification of agricultural production. *Int Soil Water Conserv Res* 3: 42-49. doi: https://doi.org/10.1016/j.iswcr.2015.03.003

Shrestha P, SE Hurley and BC Wemple. 2018. Effects of different soil media, vegetation, and hydrologic treatments on nutrient and sediment removal in roadside bioretention systems. *Ecol Eng* 112: 116-131. doi: https://doi.org/10.1016/j.ecoleng.2017.12.004

Shrestha RP and PJ Ligonja. 2015. Social perception of soil conservation benefits in Kondoa eroded area of Tanzania. *Int Soil Water Conserv Res* 3: 183-195. https://doi.org/10.1016/j.iswcr.2015.08.001

Sriprapakhan P, R Artkla, S Nuanual and P Maneechot. 2021. Economic and ecological assessment of integrated agricultural bio-energy and conventional agricultural energy frameworks for agriculture sustainability. *J Saudi Soc Agric Sci* 20: 227-234. doi: https://doi.org/10.1016/j.jssas.2021.02.001

Sukarman and A Dariah. 2014. *Tanah andosol di Indonesia karakteristik, potensi, kendala, dan pengelolaannya untuk pertanian*. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. Bogor. 137 p. (in Indonesian).

Sutarno. 2004. *Analisis Kelayakan Finansial Penerapan Modifikasi Sistem Microcatchment Pada Usahatani Lahan Kering*. IPB (Bogor Agricultural University). 86 p. (in Indonesian).

Wahyuni S, P Purwanto and J Bako Baon. 2015. Runoff Water in Cocoa Plantation as Affected by Rorak Number and Mulch Type. *Pelita Perkebunan (a Coffee and Cocoa Research Journal)*, 31: 196-207. doi: https://doi.org/10.22302/iccri.jur.pelitaperkebunan.v31i3.206.

Wang F, X Mu, R Li, L Fleskens, LC Stringer and CJ Ritsema. 2015. Co-evolution of soil and water conservation policy and human-environment linkages in the Yellow River Basin since 1949. *Sci Total Environ* 508: 166-177. doi: https://doi.org/10.1016/j.scitotenv.2014.11.055

Zhang, W., Tang, X. Y., Xian, Q. S., Weisbrod, N., Yang, J. E., and Wang, H. L. 2016. A field study of colloid transport in surface and subsurface flows. *J Hydrology* 542: 101-114 doi: https://doi.org/10.1016/j.jhydrol.2016.08.056