Research Article

Soil Tillage and Planting Along the Contour on Sloping Land to Minimize the Potential for Erosion and Surface Runoff

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Abstract | Rainfall eroded surface soil by displacement of the topsoil, which is rich in organic matter. Additionally, soil pores are filled with runoff water, resulting in erosion and sedimentation at the tail. If the organic matter in the topsoil is washed away by rainfall, it becomes evident that agricultural productivity declines. In areas with steep slopes, loss of topsoil is associated with water flowing downhill. Based on these factors, the study was conducted to compare and analyze soil tillage and contour-oriented planting models with the aim of minimizing erosion and surface runoff. This research was carried out on land with a 23% slope and featured three treatments, i.e., N_0 (plots with soil loosening only), N_1 (erosion plots with contour-aligned soil bunds), and N_2 (erosion plots with bench terraces along the contour). All plots were planted with kale (*Ipomoea aquatica*) as ground cover. According to the research findings, soil management on sloping land is best achieved through a conservation approach involving contour-aligned planting and the creation of bench terraces, which can reduce the likelihood of erosion and surface runoff. According to the results, the erosion plot with bench terraces (N_2), during the fourth week of kale planting and the final observation period, experienced the highest rainfall (29.21 mm) but recorded the lowest erosion (0.56 tons/ha) and surface runoff (5.45). In addition to bench terraces, kale exhibited more optimal growth with a 25.22 cm canopy and 12.7 leaves per plant, compared to soil loosening without conservation techniques (plots with soil loosening only). Through the implementation of appropriate soil management and planting adapted to soil characteristics and land suitability for crop canopy development, the utilization of sloping land for agriculture must be able to support sustainable farming.

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Introduction

Indonesia is a country with a tropical climate and high rainfall intensity. One of the areas with abundant rainfall in Indonesia is Sorong City, West Papua. According to data from the BMKG (Badan Meteorolgi, Klimatologi, dan Geofisika) in 2021, rainfall in Sorong city has been on rise year after year.

An analysis of rainfall data in the 2020 conducted by Fajeriana and Wijaya (2020) revealed that Sorong city falls into climate type A (very wet). High rainfall has a positive impact on ensuring the abundant availability of water, which is vital for supporting agriculture in Indonesia. However, the downside of high rainfall is the potential for various issues to arise. One significant concern is that areas with steep slopes and a lack of conservation techniques are at a high risk of erosion due to the intense rain. Moreover, surface runoff resulting from heavy rainfall can transport the eroded materials downstream.

Rainfall that lands on the soil surface leads to erosion by breaking down soil aggregates and eroding the topsoil, which is a layer rich in organic matter. This organic matter contains numerous macro and micro nutrients essential for plant growth and yield. Therefore, if the organic matter in the surface layer of the soil is destroyed or washed away by rainwater, it is certain that agricultural land productivity will decrease. The risk of erosion on agricultural land typically begins with activities such as deforestation and cultivation on sloping terrain. Opening up sloping land for agriculture, following the slope direction for land use, and continuous planting of a single crop without crop rotation, as well as soil compaction, all contribute to the increased risk of soil erosion in an area. Erosion control can be achieved through the implementation of soil conservation measures. Effective soil conservation depends on proper land management, including efforts to cover the land with suitable ground cover and implementing appropriate plowing or soil management techniques (Tambunan, 2018). On steeply sloped land, the loss of topsoil occurs concurrently with the flow of water downward or toward lower areas. The surface layer of soil, known as topsoil and rich in nutrients, is gradually depleted by the water flowing over it. To optimize agriculture on sloping land, numerous efforts have been undertaken to minimize erosion. Various soil and water conservation techniques are employed in agricultural settings, including mechanical, vegetative, and chemical methods. Mechanical techniques primarily involve technical approaches to conserving agricultural land, such as the creation of terraces, mounds, or soil bunds, among others. Chemical conservation, on the other hand, involves the application of surplus chemicals to enhance the soil's biophysical properties, typically using a soil conditioner. Vegetative conservation entails planting different levels of vegetation on steep slopes to mitigate erosion. In essence, soil conservation aims to reduce runoff, thereby mitigating erosion and enhancing the soil's ability to sustain agriculture sustainably (Arsyad, 2009). While the practice of creating soil bunds is common on agricultural land with steep slopes, it's important to note that this practice may not always align with established theories. In Sorong city, for instance, many agricultural lands still employ soil bunds along the slope direction, deviating from conventional approaches.

Several previous studies have explored farming on sloping land to minimize, and even prevent, the potential for erosion and surface runoff. Specifically, these studies have focused on the effectiveness of soil processing and planting along the contour, which can significantly reduce the risk of erosion and surface runoff in Sorong city. These findings serve as valuable references for farmers seeking to optimize their agricultural practices on sloping terrain. Despite being a developing city, Sorong city still offers ample agricultural land with diverse slopes. Given the diverse land characteristics and high rainfall in the region, there is a pressing need to enhance and manage the optimization of agricultural land. However, it's worth noting that tillage techniques in this area often do not adhere to proper conservation practices. For example, some farmers continue to create mound terraces that follow the natural slopes. This practice persists because farmers believe that constructing bench terraces or soil bunds following the contour may lead to disease in cultivated plants. Nonetheless, it's important to recognize that tillage and planting in the direction of the slope on steep terrain can increase the risk of erosion and excessive runoff, ultimately reducing the soil's capacity for yield (Utami, 2001).

This study was conducted to compare and analyze tillage and planting models oriented along the contour. The objective was to identify effective methods for minimizing erosion and surface runoff, with the ultimate goal of maximizing vegetable crop production. Additionally, these findings can serve as recommendations for a farming system tailored to sloping land, ensuring not only high yields but also the mitigation of erosion and surface runoff. This approach aims to safeguard the integrity of agricultural soil by preventing the erosion and depletion of the topsoil layer, which is essential for retaining soil nutrients.

Materials and Methods

The research was conducted from December 2022 to April 2023 at the Experimental Farm of the Faculty of Agriculture, located on campus 2 of Muhammadiyah University Sorong in Klablim Village, East Sorong District, Sorong city. Soil sample analysis was performed at the Soil Physics and Conservation Laboratory as well as the Soil Chemistry and Fertility Laboratory, both under the Department of Soil Science in the Faculty of Agriculture at Hasanuddin University, Makassar. The study utilized various tools, including clinometers, ring samples, tape measures, soil drills, knives, plastic bags, rubber bands, label paper, zinc barriers, closed plastic containers (gutters) for collecting surface runoff water, hoses, and jerrycans for collecting land surface runoff water from the Chin-ong meter. (The Chin-ong meter is a surface runoff channel installed in the channel surface runoff plot to measure discharge and erosion). Additionally, analytical scales, measuring cups, mineral water bottles for erosion sample storage, funnels, filter paper for filtering erosion samples, zinc sheet holders, a digital camera, computer equipment, and stationery were used. The study required materials such as land suitable for kale (*Ipomoea aquatica*) cultivation with a 23% slope, kale seeds, manure, and rainfall data.In this study, 3 treatments were made:

N_0 = control (plots with soil loosening only).

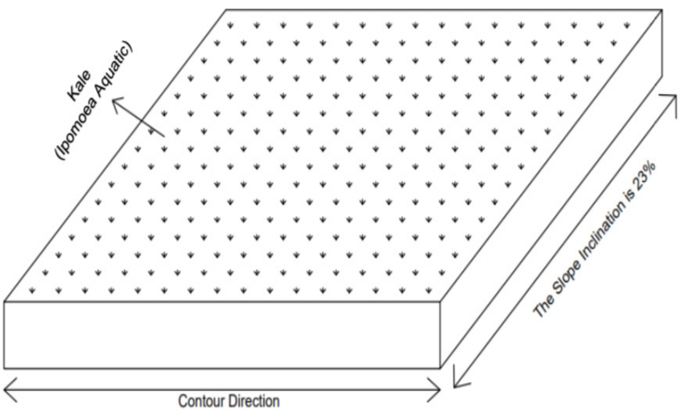

Figure 1: *Plot N_0 (erosion plots with soil loosening only).*

N_1 = plot with soil bunds along the contour direction.

The selection of land was based on consistent criteria, ensuring that each treatment plot had the same dimensions (4 meters in length and 4 meters in width), soil conditions, area, and slope (which was 23%). After clearing the land, goat manure was applied to each treatment plot at a consistent rate, with the same quantity of manure for each plot, two days after clearing. The research involved cultivating kale (*Ipomoea aquatica*) on sloping land using tillage and planting techniques oriented along the contour to mitigate the potential for erosion and runoff. To capture sedimentation resulting from erosion and surface runoff, buckets were strategically placed at each end of the plot. Additionally, sedimentation pipes were installed to direct the runoff towards the buckets. These buckets were tightly sealed to prevent direct rainwater inflow, similar to the Ching-ong meter device, ensuring that only sedimentation and surface runoff from the treatment plot entered the buckets.

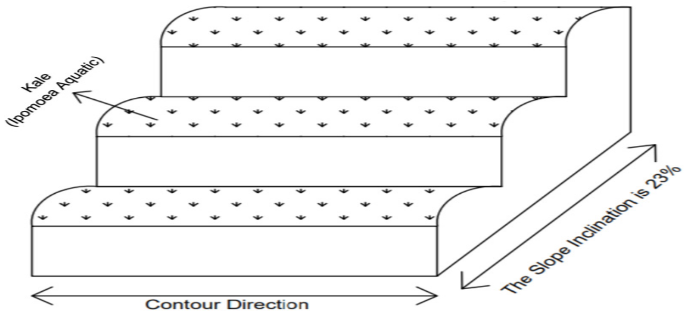

Figure 2: *plot N_1 (erosion plot with soil bunds along the contour direction).*

N_2= Erosion plot with bench terraces along the contour.

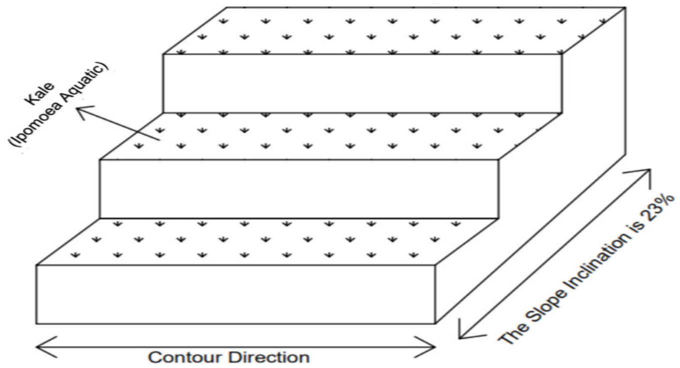

Figure 3: *plot N_2 (erosion plot with bench terraces along the contour).*

Data collection

Preparation stage: The preparation stage involves several activities:

Secondary data collection and compilation (Literature study): This process aims to gather various types of information regarding the research location's general conditions and relevant study materials from previous research.

Field observation: Field surveys and observations were conducted to directly assess field conditions and select a research location with the same slope and plot area.

Secondary data: Data on rainfall, temperature, and humidity in the study area were collected from BMKG Sorong city. This data was used to determine the climate type based on Schmidt-Ferguson and Oldeman classifications. Additionally, the collected rainfall data served as a basis for comparing rainfall measurements obtained in the field on the day of rain events.

Sampling of intact and disturbed/Composite soil samples: Soil sampling involved two types:

Intact soil samples: These were obtained using ring sample and used for analyzing soil physical properties such as texture, bulk density, particle density, porosity, saturated hydraulic conductivity (KHJ), and water content.

Disturbed or composite soil samples: These were collected for analyzing soil chemical properties, specifically C-organic content.

Observation variable measurement

Surface runoff measurement: Surface runoff measurement was conducted on each erosion plot. The measurement occurred following the calibration of the gutters attached to each erosion plot. This calibration process aimed to determine the precise volume of surface runoff captured by the gutter. To measure runoff, observations were made after a rain event by assessing the volume of the sedimentation in the gutter after it had been homogenized through stirring. The volume of surface runoff was determined by measuring the height, length, and width of the suspension within the gutter.

It's worth noting that gutter calibration was unnecessary in this study because PVC boxes were used for gutters, and their volumes were clearly defined. After gutter installation, the Ching-Ong meter was also installed. The Ching-Ong meter served as a backup in cases where the gutters couldn't accommodate all the runoff water.

$$RO\ 1 = p \times l \times t$$
$$RO\ 2 = V\ chin / Ar \times 100$$
$$TRO = (RO1+RO2)/L$$

Where: TRO = total surface runoff (liters/m2); RO 1= surface runoff on gutter (liters); RO2 = surface runoff in Ching-ong meters (liters); Vchin = volume of water in the bucket (liters); p = gutter length (meters); l = gutter width (meters); t = gutter water height (meters); Ar = Ching-ong meter average calibration factor (%); L = erosion plot area (m^2).

Erosion: Erosion and surface runoff are measured after the rain incident by knowing the volume of water in the gutter, which is the volume of surface runoff. Erosion was measured by weighing the material dissolved in the gutter by stirring the solution contained in the gutter so that it was homogeneous, then 500 ml samples were taken with 2 repetitions, then filtered to separate the water from the dissolved soil, then the filter results were in the oven at 105° C for 24 hours, and then weighed to determine the weight of eroded soil. The equation for the amount of eroded land according to (Sari, 2011) is:

$$A1= (RO\ 1 / Vsp) \times BKsp$$
$$A2= (RO\ 2 / Vsp) \times BKsp$$
$$Ap= A1+A2/100$$

Where: Ap = weight of total soil sediment = amount of erosion (tonnes/ha); A1 = gutter sediment weight (g/m2); A2= Ching-ong meter sediment weight (g/m2); RO 1 = gutter surface runoff (liter/m2); RO 2= surface runoff Ching-ong meter (liters/m2); Xr = average calibration result; Vsp = volume of sub-sample water in aprons or buckets (liters); BKsp = dry weight of the subsample in the apron or bucket (gr).

Analysis of rain data rainfall data measurements were carried out using a manual rainfall gauge and an Ombrometer placed on the study area. Observation and measurement of rainfall are carried out for each incident of rain every week after planting the kale (*Ipomoea aquatica*) until harvest by measuring the amount of rainwater stored in the manual rainfall gauge in units of milliliters (ml), which is then converted into units of millimeters (mm) by dividing by the area of the rainfall gauge with the equation: Rainfall (mm)= Rainfall (ml)/Ombrometer Area (cm) x 10.

Table 1: *Analysis of soil physical and chemical properties.*

Plots	Soil texture			CO (%)	BD (g/cm³)	PD (g/cm³)	P (%)	Ksat (cm/hour)	GWL (%)
	% Sand	% Silt	% Clay						
N_0	14,25	36,17	49,58	2,61	1,43	2,37	39,66	24,73	32,28
N_1	14,38	35,60	50,02	2,83	1,46	2,32	37,07	25,95	33,47
N_2	14,72	36,05	49,23	2,69	1,42	2,36	39,83	25,76	32,79
Average	14,45	35,94	49,61	2,71	1,44	2,35	38,85	25,48	32,85

CO, organic; BD, bulk density; PD, particle density; P, porosity; Ksat, saturated hydraulic conductivity; GWL, soil water content.

Observation of the growth of kale (*Ipomoea aquatica*). Growth observations were carried out by measuring the height of the plants and counting the number of leaves every week, starting from week 1 after planting until week 4 (four) weeks after planting. The plant samples measured were 10 plants per treatment plot. This is done because of the correlation between erosion and runoff that occurs when the kale (*Ipomoea aquatica*) plants grow. In other words, to determine the extent to which plant growth reduces erosion and surface runoff that occur in the soil.

Results and Discussion

Characteristics of soil physical and chemical properties

The results of soil tests in the laboratory are carried out to determine the physical and chemical characteristics of the soil that affect the size of the erosion and surface runoff that occur. The physical properties of the soil measured included: soil texture, C-organic soil, saturated hydraulic conductivity (KHJ), bulk density, specific gravity, porosity, and water content. The results of observations of the physical properties of the soil for each treatment plot are presented in Table 1.

From the analysis of the soil's physical and chemical properties, it is determined that the soil in the research area has a relatively high clay content, approximately 49.61%, and an organic carbon content (C-organic) of 2.71%. The soil exhibits a porosity of 38.85%, a bulk density of 1.44 g/cm3, and a particle density of 2.35 g/cm3. Bulk density serves as an indicator of soil density; a higher bulk density indicates denser soil, which means it is more challenging for water to pass through or for plant roots to penetrate. Bulk density is directly proportional to particle density but inversely proportional to soil porosity. In other words, as bulk density increases, particle density also increases, but soil porosity decreases. Moreover, a higher clay content in the soil leads to a reduction in the number and size of pores within the soil.

Soils with a high clay content are indicative of advanced weathering and are typically dominated by clay colloids. In the surface layer of these soils, you often find residues from previous plant material. Soils with high clay content have a relatively strong consistency or cohesion, making it more challenging for erosion, abrasion, and surface soil disruption to occur compared to sandy soils. This is because soils with high clay content exhibit strong adhesion properties. However, due to their strong consistency and low porosity, these soils experience difficulties in infiltration, leading to increased surface water pooling or even runoff. In other words, while erosion may be low, surface runoff tends to be high. Additionally, because of their clay texture, these soils have a high water-holding capacity, with a groundwater content of 32.85% and a saturated hydraulic conductivity of 25.48 cm/hour. The moisture content at field capacity is significantly influenced by soil texture. Clay texture has a higher water-holding capacity compared to sandy soils due to differences in particle size, allowing it to retain more water. The volume of water that soil can retain is influenced by various factors, including texture, structure, organic matter content, and pore distribution. Organic materials, with their high microporosity, can retain more water. Therefore, soils with a higher organic matter content and a greater proportion of micropores, such as fine-textured clay soils, typically have a greater water-holding capacity. Soil compaction can negatively impact a soil's water-holding capacity by compacting the soil and collapsing its pores (Schoonover and Crim, 2015).

Low saturated hydraulic conductivity values can be attributed to soils with a high clay content (Yu *et al*., 2016). Soil characteristics, including permeability, infiltration rate, water-holding capacity, particle distribution, aggregate stability, susceptibility to dispersion and erosion, transportability, structure, and humus content, collectively contribute to the soil's erodibility factor. Hydraulic conductivity, a property common to vascular plants, soils, and rocks, determines how easily a fluid, typically water, can flow through pore spaces or fractures. It is influenced by the inherent permeability of the material, the degree of saturation, and the density and viscosity of the fluid. The movement of water through saturated material is described by the saturated hydraulic conductivity (SHC) (Kirkham, 2005). Hydraulic conductivity represents the amount of water that can infiltrate the soil daily under the influence of gravity or a unit hydraulic gradient. Additionally, hydraulic conductivity exhibits temporal variability influenced by a complex interplay of factors, including soil physical and chemical properties affecting aggregate stability, climatic conditions, land usage, plant canopy and root dynamics, tillage methods, and the activities of soil organisms (Fuentes *et al*., 2004). High total soil porosity, which indicates the rate at which water can percolate into the soil, contributes to high hydraulic conductivity values (Ajibola *et al*., 2018).

Correlation of rainfall with erosion and surface runoff

Data on rainfall and air temperature for the past 10 years were processed to determine the climate and regional categories according to:

- Schmidt-ferguson classification, namely the Klablim village and Sorong city, including climate type A, the schmidt-ferguson classification, which places Klablim village in Sorong city in climate type A, indicating a very wet climate
- Oldeman's climate type classification, which categorizes Klablim village as climate type C, suitable for cultivating paddy rice.

Rainfall data for each week's rainfall events averaged for the month of March, which is the month for planting kale (*Ipomoea aquatica*) as well as observations of erosion and surface runoff occurring in the treatment plots, can be seen in Table 2.

The erosion process that occurs can be described as follows: when it rains, rainwater droplets fall and hit the topsoil layer of the soil, causing damage or destruction to the soil aggregates. The disrupted soil aggregates undergo transformation and translocation, where separated soil particles fill in the soil pores. When the soil pores become blocked, soil drainage and infiltration are reduced. Water that cannot be absorbed by the soil becomes surface runoff (RO). Surface runoff with sufficient force can transport and deposit soil (sedimentation) (Fajeriana and Risal, 2023). From the research conducted, it is known that the conservation technique for sustainable agriculture on sloping land, specifically the plots with bench terraces along the contour (N_2), is the best solution. This technique is capable of reducing or minimizing the potential for erosion and decreasing surface runoff. Additionally, contour-oriented planting for crops can also reduce erosion and surface runoff compared to bare soil without vegetation. The more abundant and denser the vegetation, the more it helps reduce erosion and surface runoff on sloping land. Research (Pradhanang *et al*., 2017) analyzed the effectiveness of constructing bench terraces with contour-oriented planting in reducing surface runoff and soil erosion on sloping land in Nepal. The results of the study showed that the construction of bench terraces with contour-oriented planting could reduce surface runoff by up to 67% and soil erosion by up to 83% compared to land that was not implemented with this technique (Lamour *et al*., 2017). The application of conservation techniques involving the construction of bench terraces with contour-oriented planting is an effective solution to reduce surface runoff and erosion on sloping land. This technique can help preserve soil fertility, improve water retention, and enhance long-term agricultural productivity (Gebremariam *et al*., 2018).

Table 2: *Weekly average rainfall, erosion, and surface runoff measurements.*

Plots	Rainfall (mm)				Erosion (ton/ha)				Run-off (liter/m²)			
	Week after planting (WAP)											
	1	2	3	4	1	2	3	4	1	2	3	4
$_N0$	27,63	27,82	28,44	29,21	0,79	0,72	0,70	0,65	8,29	7,52	7,52	6,98
N_1					0,73	0,67	0,65	0,58	6,35	5,57	5,57	5,5
N_2					0,72	0,65	0,63	0,56	6,24	5,49	5,49	5,45

N_0 (erosion control plot with soil loosening only), N_1 (plot with soil bunds along the contour direction), N_2 (erosion plots with bench terraces along the contour).

The higher the rainfall, the greater the potential for erosion and surface runoff. Rainfall with high intensity and soil that quickly becomes saturated can result in significant surface runoff, even on moderately steep slopes. Water will flow on the soil surface when the amount of rainfall exceeds the soil's ability to infiltrate water into deeper layers. Erosion, on the other hand, occurs because the soil particles in the topsoil are destroyed or damaged and are subsequently carried away by surface runoff. Erosion rates will be high if there is a large volume and velocity of surface runoff.

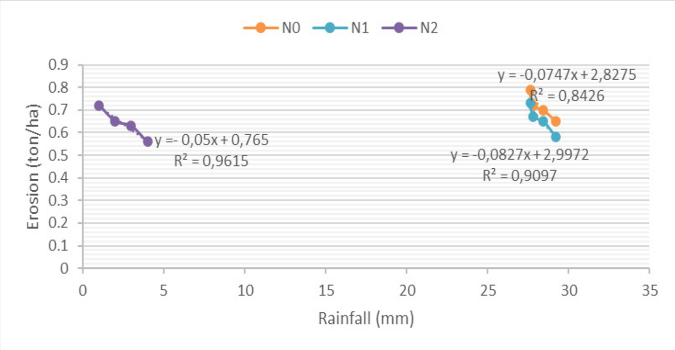

Figure 4: *Correlation of rainfall and erosion.*

From Figure 4, it is evident that there is a linear relationship between rainfall and erosion, characterized by a negative correlation. In other words, when rainfall is high, erosion tends to increase on sloping land. However, the implementation of conservation techniques, specifically soil management and contour planting, results in a reduction in erosion over time, even as rainfall intensity increases. The application of these conservation techniques enhances water infiltration and effectively mitigates erosion and soil loss, even in the face of elevated rainfall (Zhang *et al.*, 2019). Conservation practices play a crucial role in improving water infiltration, reducing surface runoff, and preserving soil structure integrity, all of which contribute significantly to erosion control (Wu *et al.*, 2021).

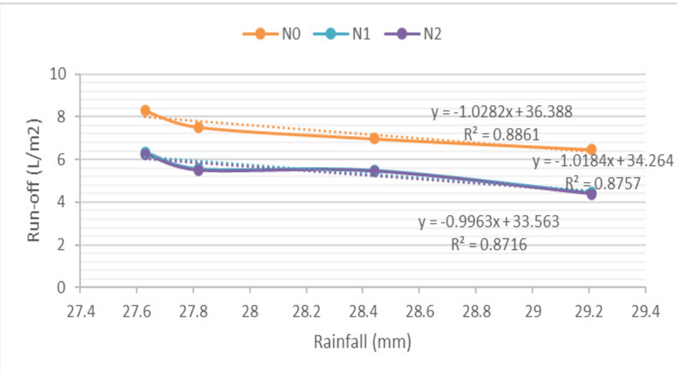

Figure 5: Correlation of rainfall and run-off.

From Figure 5, a negative correlation between rainfall and surface runoff is evident, indicating that an increase in rainfall leads to a decrease in surface runoff. In typical circumstances, higher rainfall would be expected to result in more water falling onto the soil surface, filling the soil pores. When these soil pores become saturated, surface runoff typically occurs. Groundwater runoff occurs when rainfall is absorbed by the soil; however, if all the soil pores become filled with water and the rain continues, the excess rainwater will flow over the soil surface. This happens when the soil cannot absorb water quickly, such as when there are impermeable soil layers or when the soil is already saturated with moisture (Black *et al.*, 2010). In this study, three different conservation models were applied: N_0 (plots with soil loosening only), N_1 (plot with soil bunds along the contour direction), and N_2 (plots with bench terraces along the contour). As a result, even with varying rainfall patterns, surface runoff decreased over time in line with the growth of the crops each week. Increased rainfall can lead to a reduction in surface runoff, especially when the land has been restored using appropriate conservation techniques (Huang *et al.*, 2019). Land restoration actions such as vegetation planting, soil management, and bench terracing can reduce surface runoff and enhance water infiltration (Chen *et al.*, 2020).

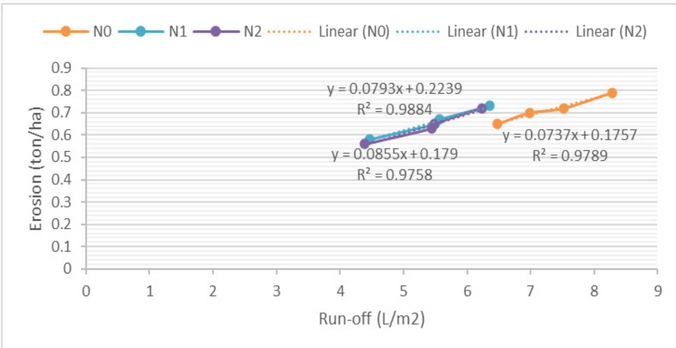

Figure 6: Correlation of run-off and erosion.

From Figure 6, it can be observed that there is a relationship between surface runoff and erosion in each treatment, showing a positive correlation between x (run-off) and y (erosion). The higher the surface runoff, the greater the erosion that occurs. The linear relationship between surface runoff and erosion with R^2 values for each treatment is as follows: N_0 (R^2= 0.9789), N_1 (R^2= 0.9884), and N_2 (R^2= 0.9758). The relationship between surface runoff and erosion is that an increase in surface runoff leads to an increase in erosion. When surface runoff increases, the flowing water on the soil surface can carry soil particles, sediments, and other materials, resulting in greater soil erosion. Soil saturation and increased rainfall can lead to significant surface runoff and higher soil erosion [21].

Factors influencing the relationship between surface runoff and erosion include; (1) Rainfall intensity: Prolonged intense rainfall increases surface runoff, thereby increasing the risk of erosion; (2) Vegetation: Plants and vegetation growing on the soil surface can help reduce erosion by retaining water and reducing the rate of surface runoff; (3) Topography: slope steepness also affects erosion. Steeper slopes tend to have larger surface runoff and increased erosion; (4) Land management practices: Proper land management practices, such as planting cover crops, terracing, or contour bunds, can help reduce surface runoff and control erosion.

Correlation of Kale (Ipomoea aquatica) plant growth variables with erosion and run-off

The presence of vegetation on the soil is one form of conservation on sloping land to minimize erosion and surface runoff. Ground cover plants help reduce the impact of rainfall so that it does not directly hit the soil.

Table 3: *Variables of Kale (Ipomoea aquatica) plant growth from week 1 to week 4 after planting.*

Plots	Plant height (cm)				Number of leaves (leaf blades)			
	1 WAP	2 WAP	3 WAP	4 WAP	1 WAP	2 WAP	3 WAP	4 WAP
N_0	5,13	11,2	18,66	26,06	5,3	7	8,1	11,2
N_1	5,32	12,83	20,02	24,87	5,7	7,3	9,2	12,5
N_2	5,4	12,88	21,3	25,22	5,7	7,5	9,3	12,7

Source: Average data measurements in the field.

From the data in Table 3, it is evident that in treatment N_2 (plots with bench terraces along the contour), the growth of Kale (*Ipomoea aquatica*) plants is more optimal, with a height of 25.22 cm and a total of 12.7 leaves in the 4th week after planting. This indicates that the nutrient elements present in the soil are sufficient for the growth of Kale. Additionally, because bench terraces are a conservation technique capable of minimizing erosion and surface runoff effectively, the organic material in the topsoil remains preserved. Based on the data on the growth of Kale, a regression analysis is subsequently conducted to measure the statistical relationship between the growth variables of Kale and the values of erosion and surface runoff that occur.

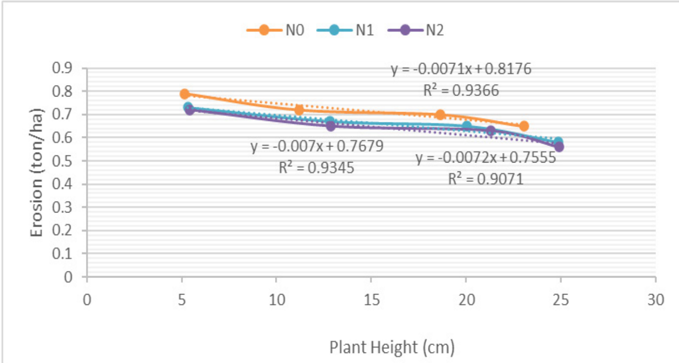

Figure 7: *Correlation of plant height and erosion.*

From Figure 7, it can be observed that there is a relationship between plant height and erosion in each treatment, indicating a negative correlation. The taller the plants, the lower the amount of erosion that occurs. The linear relationship between surface runoff and erosion with R^2 values for N_0 (R^2 = 0.9345), N_1 (R^2 = 0.9366), and N_2 (R^2 = 0.9071), respectively. Therefore, it can be concluded that each increase in Kale (*Ipomoea aquatica*) height will reduce the amount of erosion. R^2 values approaching 1 indicate that the land cover above the soil can withstand the destruction of the soil surface by rain. When the soil is covered by plants, rainfall does not directly hit the soil but undergoes interception, where the falling rain hits and passes through the bodies of the plants growing on the soil. This reduces the process of soil erosion or erosion caused by rainfall, in other words, reducing erosion (Panagos *et al*., 2015). Taller agricultural plants with dense coverage can help reduce soil erosion. Tall plants can reduce the speed of surface runoff, trap soil particles, and strengthen soil structure, which in turn reduces erosion rates (Saha *et al*., 2018; Renschler *et al*., 2002).

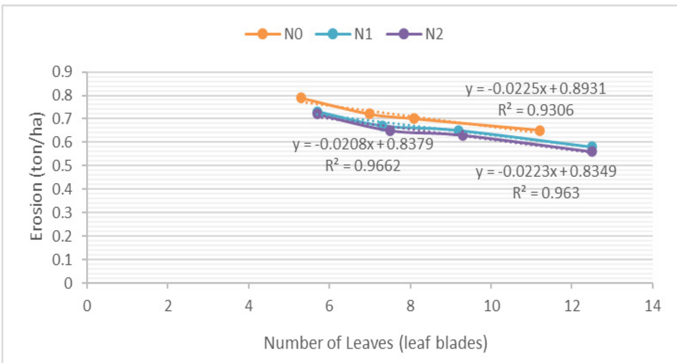

Figure 8: *Correlation of number of leaves and erosion.*

From Figure 8, it can be observed that there is a relationship between the number of leaves and erosion in each treatment, indicating a negative correlation. The more leaves the Kale (*Ipomoea aquatica*) plant has, the less erosion occurs. The linear relationship between surface runoff and erosion with R^2 values for N_0 (R^2 = 0.9306), N_1 (R^2 = 0.963), and N_2 (R^2 = 0.9622) shows that a higher number of leaves results in denser land cover. When rain occurs, the leaves of the plants help slow down the rainwater and prevent it from directly impacting and damaging the surface soil aggregates. (Ghadiri *et al*., 2005) studied the relationship between the number of leaves and erosion and found that a greater number of leaves in agricultural crops or natural vegetation, along with higher vegetation density and leaf count, provides increased protection against soil erosion. This is because the leaves can absorb the impact of raindrops, reduce surface water velocity, and shield the soil surface from the direct impact of rainfall (Sandercock *et al*., 2015).

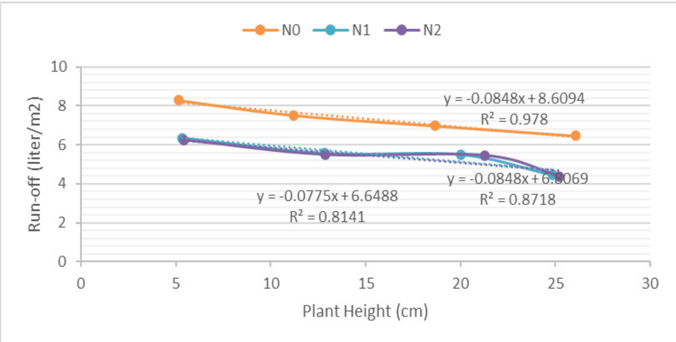

Figure 9: *Correlation of plant height and run-off.*

From Figure 9, it can be seen that there is a relationship between plant height and surface runoff in each treatment, which shows a negative relationship. The taller the plant, the lower the amount of surface runoff that occurs. Linear relationship between plant height and surface runoff with R^2 values of N_0 (R^2= 0.978), N_1 (R^2 = 0.8718), and N_2 (R^2= 0.8141). This indicates that the land cover that is above the ground is able to hold back the rate of rainwater. When the soil is overgrown with plants, when it rains, it doesn't directly hit the ground, but there will be an interception on the body of the kale (*Ipomoea aquatica*) plant. Water that seeps into the plant body will change its rate when rainwater hits the plant body, which will slow down the rate of water touching the ground so that it will give time for water to be absorbed into the soil. The slower rate of water will absorb more easily into the soil, so that surface runoff decreases as it increases. plant height. The taller the plant, the more water it retains through interception, evaporation, and root absorption. This reduces the amount of water flowing as surface runoff (Zhang *et al*., 2017) and taller plants can also help reduce surface runoff by increasing water uptake by plants, reducing the velocity of surface runoff, and preventing erosion (Li *et al*., 2019; Huang *et al*., 2020).

From Figure 9, it can be observed that there is a relationship between plant height and surface runoff in each treatment, showing a negative correlation. The taller the plants, the lower the surface runoff that occurs. The linear relationship between plant height and surface runoff with R^2 values for N_0 (R^2 = 0.978), N_1 (R^2= 0.8718), and N_2 (R^2= 0.8141) indicates that the land cover above the soil can slow down the rate of rainfall. When the soil is covered with plants, especially kale, rainwater does not directly impact the soil; instead, it is intercepted by the plant's canopy. Water that drips onto the plant's canopy undergoes changes in velocity as it reaches the plant's surface. This slowing down of water velocity allows more time for the water to be absorbed into the soil. Additionally, the slowed water velocity is more easily absorbed into the soil, resulting in reduced surface runoff as plant height increases. The taller the plants, the more water they can hold through interception, evaporation, and root uptake. This reduces the amount of water flowing as surface runoff (Zhang *et al*., 2021). Taller plants can also help reduce surface runoff by increasing water uptake by the plants, reducing surface water velocity, and preventing erosion (Li *et al*., 2019; Huang *et al*., 2020).

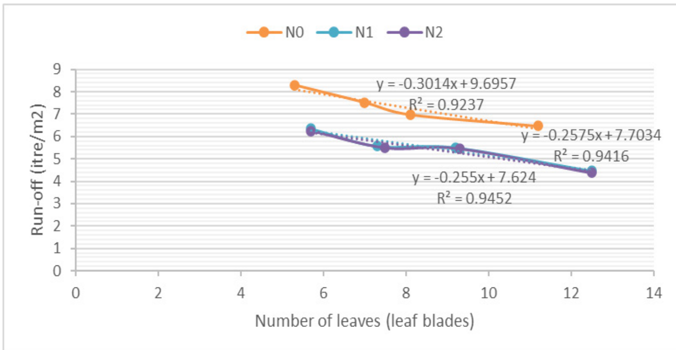

Figure 10: *Correlation of number of leaves and run-off.*

From Figure 10, it can be observed that there is a relationship between the number of leaves and surface runoff in each treatment, indicating a negative correlation. The greater the number of leaves, the denser the land cover, which in turn reduces the amount of surface runoff. The linear relationship between the number of leaves and surface runoff with R^2 values for N_0 (R^2 = 0.9237), N_1 (R^2 = 0.9416), and N_2 (R^2 = 0.9452) indicates that as the number of leaves on the plants increases, the land becomes more densely covered. Additionally, as the plants grow and develop, their root systems also expand, creating larger macropores in the soil for optimal infiltration. The greater the number of leaves on the plants, the denser the land cover, and the better the land's ability to retain rainfall. This reduces the amount of surface runoff (Shiferaw *et al*., 2016; Abouabdillah *et al*., 2018; Li *et al*., 2021).

Conclusions and Recommendations

Based on the study's findings, it is evident that employing tillage on sloping land, along with conservation techniques such as planting along the contour and constructing bench terraces, is more effective in minimizing the potential for erosion and surface runoff. According to the study's results, the erosion plots with bench terraces along the contour (N2) experienced the highest rainfall in the 4th week after planting Kale (Ipomoea aquatica), measuring 29.21mm, with an erosion rate of 0.56 tons/ha, and the lowest surface runoff (5.45 L/m2), in comparison to the treatment involving only soil loosening without conservation techniques (N0/plots with soil loosening only) and plot with soil bunds along the contour direction (N1). Additionally, in conjunction with the establishment of bench terraces, kale (Ipomoea aquatica) plants exhibited more optimal growth, reaching a plant height of 25.22 cm and producing a total of 12.7 leaves. Utilizing sloping land for agricultural cultivation must prioritize the principles of sustainable agriculture, including the appropriate implementation of tillage and crop selection based on soil characteristics and plant growth suitability.

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Novelty Statement

- This research aims to optimize sustainable agriculture on sloping land by cultivating the land and planting along the contour.
- The higher the rainfall, the higher the erosion and surface runoff, but if the conservation method is applied, the erosion and surface runoff will decrease.
- The research was conducted in Sorong, Papua Barat Daya, Indonesia, an area known for its high rainfall and varying terrain slopes.
- This article provides recommendations for soil management and the cultivation of kale (*Ipomoea aquatica*) that can be effectively implemented by farmers on sloping land.

Author's Contribution

Nurul Fajeriana: The lead author conducts research, processes and analyzes data, and writes a draft of the manuscript.
Akhmad Ali: Helped in making treatment plots, planting, and data collection.
Retno Puspa Rini: Create 2D images of erosion research plots using AutoCAD.

Conflict of interest
The authors have declared no conflict of interest.

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