



Effects of Soil Physical Properties and Slope Gradient on the Growth Performance of Hybrid Maize (ADF Ruby)

Innah Inayyah¹, Abdullah¹, Sudirman Numba¹

¹Universitas Muslim Indonesia, Indonesia

*Corresponding Author: Innah Inayyah

E-Mail: inayyah132@gmail.com



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Abstract

*The expansion of corn cultivation to dryland areas in the highlands increases the risk of soil degradation due to slope gradients, which can alter soil physical properties, increase erosion, and reduce crop productivity. This study aims to analyze the effect of slope gradient on the physical and chemical properties of soil, erosion potential, and the growth and yield of the hybrid corn (*Zea mays* L.) variety ADF Ruby in the highlands of Bima Regency, Indonesia. The study employed a field survey method across three slope gradient classes (8–15%, 15–25%, and >25%). Erosion potential was predicted using the Universal Soil Loss Equation (USLE), while data were analyzed using ANOVA, Pearson's correlation, and simple linear regression. The results showed that an increase in slope gradient did not significantly alter soil particle density, bulk density, and porosity, but it increased soil permeability from 3.85 to 9.03 cm h⁻¹ and predicted soil loss from 83 to 317 metric tons ha⁻¹ year⁻¹. The highest maize growth and yield were obtained on slopes of 8–15%, while soil permeability was very strongly negatively correlated with dry kernel weight ($r = -0.98$; $R^2 = 0.89$). The results of this study indicate that the effect of slope on corn productivity is mediated by changes in soil hydrological characteristics and an increased risk of erosion; therefore, soil and water conservation are key to the sustainable management of sloping dryland.*

Introduction

Corn (*Zea mays* L.) is one of the strategic food commodities that plays a vital role in supporting food security, the feed industry, and the supply of raw materials for agroindustry (Annisa et al., 2026; Noma et al., 2026; Ahmed et al., 2026). The sustained increase in demand for corn has driven the expansion of cultivation areas into upland drylands due to the increasingly limited availability of productive agricultural land in lowland areas. Although upland areas have great development potential, they are generally characterized by sloping topography, which increases their vulnerability to erosion, soil degradation, and declining productivity if not managed properly (Kumar et al., 2023).

Slope gradient is a topographic factor that influences hydrological processes and soil dynamics through changes in infiltration, surface runoff, and soil loss due to erosion (Syazili et al., 2026; He et al., 2026; Slamet et al., 2026; Yang et al., 2026). These changes directly affect soil physical properties, such as bulk density, particle density, porosity, permeability, and organic matter content, which play a crucial role in regulating water storage, soil aeration, root system development, and nutrient availability for plants. Therefore, variations in soil physical characteristics influenced by slope gradient have the potential to determine the growth and productivity of maize on sloping dryland (Borrelli et al., 2020; Hermiyanto et al., 2026; Mengiste et al., 2025).

Bima Regency, West Nusa Tenggara Province, is one of the nation's major corn-producing centers, with production largely taking place on dryland characterized by undulating to hilly topography. Corn cultivation in this region generally occurs on slopes of varying gradients, with the application of soil conservation measures still limited. These conditions increase the risk of erosion, which can degrade soil physical quality, reduce the soil's capacity to supply water and nutrients, and lead to decreased crop growth and yields. Given the region's importance as a corn-producing area, understanding the relationship between slope characteristics, soil physical properties, and crop productivity is crucial for supporting sustainable land management (Ewunetu et al., 2025; Abebaw et al., 2025; Latif & Abbas, 2025).

Various previous studies have shown that slope gradient affects erosion rates and soil physical characteristics, while other studies have emphasized the relationship between soil physical properties and plant growth (Umair et al., 2025; Hanif et al., 2024; Hun et al., 2026). However, most of these studies have examined each factor separately and thus have not been able to explain the interrelationships among topographic conditions, changes in soil physical properties, erosion potential, and plant growth responses within an integrated analytical framework. Furthermore, similar studies on maize cultivation systems in the dryland highlands of Bima Regency remain very limited, so scientific information that can serve as a basis for site-specific land management is not yet sufficiently available (Ravi et al., 2026; Schreiner et al., 2026; Afsari Bajestani et al., 2026).

This study offers an approach that integrates slope analysis, soil physical properties, erosion rate estimates using the Universal Soil Loss Equation (USLE), and analysis of relationships between variables through correlation and regression to explain the influence of land biophysical conditions on the growth and yield of ADF Ruby hybrid corn. This integrative approach is expected to provide a more comprehensive understanding of the mechanisms by which topography influences corn productivity, while also providing a scientific basis for the development of soil conservation strategies and sustainable dryland management (Wang et al., 2025; Dang et al., 2026; Ishfaq et al., 2025).

Based on this background, this study aims to analyze the effect of slope gradient variations on soil physical properties, estimate soil loss potential using the Universal Soil Loss Equation (USLE) method, and evaluate the relationship between soil physical properties, erosion potential, and the growth and yield of ADF Ruby hybrid corn on upland dryland in Bima Regency as a basis for formulating recommendations for sustainable land management.

Methods

This study was conducted on upland corn farmland in Bima Regency, West Nusa Tenggara Province, Indonesia, which is one of the major centers of corn production on sloping dryland. Annual rainfall in the study area ranges from 859 to 1,173 mm/year, with an average of approximately 993 mm/year, occurring from December through March, while the period from June to September is the dry season with very low rainfall; in fact, in some months there is no rain at all. These conditions indicate that the study area has a tropical savanna climate (Aw), characterized by a dry season that is longer than the rainy season. Analysis of the physical and chemical properties of the soil was conducted at the Soil Physics and Conservation Laboratory, Faculty of Agriculture, Mataram University. The research was conducted in 2026, encompassing field sampling, laboratory analysis, and data processing.

The study employed a field survey method using a quantitative approach based on stratification by slope class. This approach was chosen because topographic conditions are natural factors

that cannot be manipulated; thus, observations were made under actual land conditions that represent the characteristics of the study area. Slope classes were divided into three categories based on a modified USDA/FAO classification, namely: moderately steep (8–15%), steep (15–25%), and very steep (>25%).

Each slope class consists of three observation points selected using the purposive sampling method, resulting in nine main observation units: T1U1, T1U2, T1U3, T2U1, T2U2, T2U3, T3U1, T3U2, and T3U3. The selection of sample points was based on the uniformity of land use, plant species, land management conditions, and the representation of each slope class so that they could describe the biophysical conditions of the study site.

Soil samples were collected at depths of 0–30 cm, which corresponds to the effective layer for maize root system development. Two types of soil samples were used in this study: undisturbed soil samples, collected using a ring sampler for analysis of soil physical properties; and disturbed soil samples, collected as composite samples at each observation point for analysis of soil organic carbon.

The soil properties analyzed included bulk density (BD), particle density (PD), total porosity, permeability, and organic carbon (organic C). Bulk density and particle density were determined using the core method after oven drying at 105°C for 24 hours (Blake & Hartge, 1986). Total porosity was calculated using the following equation: Porosity.

$$\text{POROSITY} = (1 - \text{BD}/\text{PD}) \times 100\%$$

Soil permeability was measured using the constant-head permeameter method, as described by Klute and Dirksen (1986). Organic carbon content was analyzed using the Walkley Black method based on wet oxidation with potassium dichromate (Nelson & Sommers, 1996). Plant observations were conducted on 5 m × 5 m plots at each observation point. Each plot consisted of approximately 28–30 ADF Ruby hybrid corn plants as the unit of observation. The parameters observed included: plant height (cm) at 70 days after sowing (hst); number of leaves (sheets) at 70 hst; wet grain weight (g plant⁻¹) at 110 hst; and dry grain weight (g plant⁻¹) at 110 hst.

Potential soil loss was calculated using the Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978):

$$A = R \times K \times LS \times C \times P$$

where:

A = soil loss (metric tons ha⁻¹ year⁻¹)

R = rainfall erosivity factor

K = soil erodibility factor

LS = slope length and steepness factor

C = vegetation cover and management factor

P = conservation measures factor

The R factor value is calculated using monthly rainfall data for the 2022–2026 period based on the (Bols, 1978) equation. The K factor is obtained from soil property analysis, while the LS, C, and P factors are determined based on topographic characteristics, land use, and management practices at the study site. Soil loss values are then classified into erosion hazard levels according to Indonesia's soil conservation guidelines.

Data on soil physical properties were analyzed descriptively and presented in tabular form based on soil property classification criteria. Differences in maize growth parameters and yield among slope classes were analyzed using one-way analysis of variance (ANOVA) in SPSS, after confirming that the assumptions of normality and homogeneity of variances were met. If there were significant differences at the 5% significance level ($p < 0.05$), a post-hoc Honestly Significant Difference (HSD/Tukey) test at the 5% level was conducted to compare the means across slope classes.

The relationship between slope, soil physical properties, estimated soil loss, and maize growth parameters was analyzed using Pearson's correlation. Furthermore, the effect of soil physical properties on maize yield was analyzed using simple linear regression to obtain a mathematical model explaining the relationship between land biophysical conditions and the productivity of the ADF Ruby hybrid maize. All statistical analyses were conducted at a 95% confidence level.

Results and Discussion

Physical and Chemical Soil Characteristics

The results of the analysis of the physical and chemical properties of soil across various slope gradient classes are presented in Table 1. In general, an increase in slope gradient does not cause significant changes in particle density (PD), bulk density (BD), or soil porosity. Conversely, the parameter showing the most pronounced response is soil permeability, which tends to be higher on steep slopes than on gentler slopes. These findings suggest that the primary influence of slope gradient on soil quality is more closely related to changes in hydrological characteristics than to changes in the soil's fundamental physical properties. Thus, slope gradient plays an indirect role in controlling water availability, nutrient dynamics, and crop productivity through changes in water movement processes within the soil. This pattern is consistent with (Lv et al., 2024), who reported that topography acts as a controlling factor in water redistribution and changes in soil physical properties on sloped croplands. However, the high permeability observed in this study does not necessarily indicate better soil conditions, as it has the potential to accelerate water percolation beyond the root zone, thereby reducing the efficiency of water use by plants. Thus, the hydrological quality of soil on sloped land needs to be evaluated not only based on infiltration capacity but also on the soil's ability to retain moisture available to plants.

Table 1. Physical and Chemical Characteristics of Soil Across Various Slope Gradient Classes.

Slope Class	Sample Code	Particle Density (g cm ⁻³)	Bulk Density (g cm ⁻³)	Porosity (%)	Soil Structure	Permeability (cm h ⁻¹)	Permeability Class	Organic Matter (%)
Moderately steep slope (8–15%)	T1U1	2.05	1.03	49.76	Granular	5.32	Medium	1.72
	T1U2	2.03	1.1	45.81	Granular	3.19	Medium	0.66
	T1U3	2.01	1.08	46.27	Granular	3.04	Medium	0.77
	Mean ± SD	2.03 ± 0.02	1.07 ± 0.04	47.28 ± 2.10	Granular	3.85 ± 1.28	Medium	1.05 ± 0.58
Steep slope (15–25%)	T2U1	2.03	1.12	44.83	Granular	8.11	Somewhat fast	0.97
	T2U2	1.96	1.11	43.37	Granular	7.86	Somewhat fast	1.1
	T2U3	1.95	1.05	46.15	Granular	11.15	Somewhat fast	1.07
	Mean ± SD	1.98 ± 0.04	1.09 ± 0.04	44.78 ± 1.40	Granular	9.03 ± 1.83	Moderately fast	1.05 ± 0.07

Very steep slope (>25%)	T3U1	2.1	1.08	48.57	Granular	10.07	Somewhat fast	1.21
	T3U2	2.03	1.11	45.32	Granular	7.39	Somewhat fast	1.43
	T3U3	2.07	1.13	45.41	Granular	6.42	Somewhat fast	0.87

Note: The data are the results of an analysis conducted by the Laboratory of Soil Physics and Conservation, Faculty of Agriculture, Mataram University (2026). Values are presented as mean $\pm$ standard deviation (SD).

Particle density values at all study sites ranged from 1.95 to 2.10 g cm⁻³, while bulk density ranged from 1.03 to 1.13 g cm⁻³. This range still falls within the category that supports the development of maize root systems and shows no indication of soil compaction that could inhibit root growth. The stability of bulk density values across slope classes indicates that an increase in slope gradient does not directly affect soil density levels. This condition is believed to be due to similarities in soil type, land use, and management systems across all study sites, resulting in relatively uniform soil formation processes despite differences in slope class. According to (Blake & Hartge, 1986), mineral soils with a bulk density of less than 1.30 g cm⁻³ generally still possess good physical conditions to support root growth as well as water and air circulation within the soil

Soil porosity values ranged from 43.37–49.76%, with a relatively uniform average across all slope classes. This indicates that the soil's pore space is still sufficient to support water infiltration, gas exchange, microbial activity, and plant root system development. However, relatively similar porosity values do not always reflect the soil's ability to supply water to plants. The effectiveness of soil pore function is largely determined by the distribution between macro- and micro-pores, not merely by the magnitude of total porosity. Therefore, soils with nearly identical porosity may exhibit different hydrological behavior if their pore-size composition changes due to erosion or the leaching of fine particles. Unlike other physical parameters, soil permeability shows more pronounced variations across slope classes. Average permeability on steep and very steep slopes is higher than on moderately steep slopes, although the highest values are found in the 15–25% steep slope class. This indicates that an increase in slope gradient tends to enhance the soil's ability to allow water to pass through, although this relationship is not entirely linear.

These changes in permeability are closely related to the hydrological and geomorphological processes occurring on sloped land. The steeper the slope, the higher the energy of surface runoff capable of transporting fine-grained soil fractions, particularly silt, clay, and organic matter. The loss of fine fractions causes the soil to be dominated by macropores, allowing water to move more quickly toward deeper layers. As a result, infiltration occurs more rapidly, but the soil's water-holding capacity actually decreases because water drains more quickly outside the root zone. These conditions increase the risk of drought stress in plants, especially during rainless periods, while also increasing the potential for leaching of soluble nutrients such as nitrogen and potassium. Similar phenomena have been reported by (Fields et al., 2020), indicating that changes in the hydraulic properties of sloped land are primarily controlled by the redistribution of fine particles due to erosion.

Soil organic carbon content at the study site ranged from 0.66–1.43%, falling into the low-to-moderate category. Low organic carbon content is a common characteristic of dry, semi-arid lands, which have relatively high temperatures that accelerate the decomposition of organic matter and the mineralization of carbon in the soil (Deiss et al., 2020). In addition to climatic

factors, the loss of topsoil due to erosion also contributes to the low organic carbon content on sloping land (Abdo & Awad, 2021). Organic carbon plays a crucial role in the formation and stabilization of soil aggregates, thereby improving soil structure, increasing water-holding capacity, and maintaining a balance between macro- and micro-pores. Conversely, low organic carbon content causes soil aggregates to become less stable and more susceptible to dispersion and transport by surface runoff. (Szatmári et al., 2021) emphasize that organic matter is one of the primary factors controlling soil physical quality through its influence on aggregate stability and soil pore dynamics.

Overall, the research findings indicate that slope gradient does not directly alter the basic physical characteristics of the soil, such as particle density, bulk density, and porosity, but rather influences soil hydrological functions through changes in permeability and organic carbon content. These changes affect the soil's ability to supply water and nutrients to plants, thereby potentially reducing the growth efficiency and productivity of corn on steeper slopes. Therefore, the management of sloped land should focus not only on improving soil fertility through fertilization but also on implementing soil conservation techniques and adding organic matter to increase water-holding capacity, maintain aggregate stability, and reduce the risk of soil loss due to erosion. This approach is key to supporting the sustainability of corn cultivation on dryland in highland areas.

Analysis of Rainfall Erosivity (R) and Soil Erodibility (K)

Calculations using the Universal Soil Loss Equation (USLE) indicate that the rainfall erosivity (R) at the study site is $551 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ year}^{-1}$, while the soil erodibility (K) is 0.25 (Table 2). These two parameters are the main components in determining the magnitude of potential soil loss because they represent, respectively, the energy of rainfall as a trigger for erosion and the soil's susceptibility to the processes of detachment and transport of soil particles.

Table 2. USLE factors and erosion hazard levels for various slope classes

Slope	Slope Length (m)	Slope (%)	Annual Rainfall (mm/year)	R	K	L	S	C	P	Erosion A (tons/ha ⁻¹ /year ⁻¹)	TBE Class
somewh at steep	99	13.25	927.2	5 5 1	0. 2 5	1 . 5	0 . 4		1	83	Mode rate
Steep	114	33.37	927.2	5 5 1	0. 2 5	4 . 1	0 . 4		1	227	Steep
very steep	105	48.95	927.2	5 5 1	0. 2 5	5 . 7	0 . 4		1	317	Weig ht

Source: Erosion predictions were calculated using the Universal Soil Loss Equation (USLE) method.

The R-factor value was derived from an annual rainfall of 927.2 mm. Although the study area is classified as a dryland region with relatively lower rainfall compared to areas with a wet climate, the resulting rainfall energy is still significant enough to trigger erosion processes, particularly on sloped terrain. These conditions indicate that erosion potential is determined not only by the amount of annual rainfall but also by rainfall intensity, which determines the magnitude of raindrop kinetic energy (raindrop impact) and the formation of surface runoff. When rainfall intensity exceeds the soil's infiltration capacity, the excess water becomes

surface runoff capable of dislodging and transporting soil particles from the topsoil. These findings are consistent with those of (Roy & McDonald, 2015), who stated that rainfall intensity is the primary driver of surface runoff formation and soil loss on sloping land. Additionally, (Borrelli et al., 2020) reported that changes in rainfall patterns due to climate change increase the risk of erosion in various agricultural systems worldwide.

A soil erodibility value (K) of 0.25 indicates that the soil at the study site has a moderate susceptibility to erosion. The K factor is influenced by intrinsic soil characteristics, such as texture, structure, permeability, organic matter content, and aggregate stability. Previous analysis results show that the soil's organic carbon content is relatively low, while permeability tends to be higher on steeper slopes. The combination of these two conditions reduces the soil's ability to retain aggregates, making soil particles more prone to dispersion when subjected to the impact energy of raindrops. Thus, although the soil structure is still classified as granular, the low organic matter content acts as a limiting factor that increases the soil's susceptibility to erosion.

The role of organic matter in erodibility has been widely documented in various studies. Organic carbon acts as a binding agent between mineral particles, forming more stable soil aggregates and thereby increasing the soil's resistance to dispersion caused by rainfall impact. Conversely, a decrease in organic matter content causes aggregates to break apart more easily and increases the likelihood of particle transport by surface runoff. (Szatmári et al., 2021) demonstrated that organic carbon is a key component in maintaining soil aggregate stability, while (Deiss et al., 2020) reported that a decline in organic matter accelerates soil structure degradation and increases erodibility values.

The results of this study also indicate that the R and K factors do not operate independently but interact with one another in determining erosion potential. High rainfall energy will have a greater impact on soils with high erodibility, whereas soils with more stable aggregates tend to be more resistant to particle detachment. Therefore, the extent of potential soil loss on agricultural land is determined not only by climatic conditions but also by the soil's ability to dampen rainfall energy through its physical characteristics and organic matter content.

Overall, the analysis results indicate that the study site exhibits a combination of relatively high rainfall erosivity and moderate soil erodibility. These conditions indicate that agricultural land in the highlands of Bima Regency is highly vulnerable to soil degradation if not balanced by adequate conservation practices. Therefore, increasing organic matter content, contour-based soil management, and the application of vegetative and mechanical conservation techniques are crucial strategies for enhancing soil resistance to erosion while maintaining sustainable land productivity.

Growth and Production of Hybrid Corn

The results of the analysis of variance showed that slope gradient had a significant effect ($P < 0.05$) on all growth and yield parameters of the ADF Ruby hybrid corn, namely plant height, number of leaves, wet kernel weight, and dry kernel weight (Table 3). The results of the BNJ post-hoc test at the 5% level indicated that each slope gradient class exhibited a significantly different response. In general, all growth and yield parameters decreased as slope steepness increased. Moderately steep slopes (8–15%) produced the highest vegetative growth and productivity, while very steep slopes (>25%) showed the lowest values.

Table 3. Effect of slope gradient on the growth and yield of ADF Ruby hybrid corn

Slope Class	Plant Height (cm)	Number of Leaves (leaves per plant)	Fresh Kernel Weight (g plant ⁻¹)	Dry Kernel Weight (g per plant)	Slope Class
Moderately steep (8–15%)	225.33 ^c	13.26 ^c	216.98 ^c	173.88 ^c	Moderately steep (8–15%)
Steep (15–25%)	164.31 ^b	10.91 ^o	177.99 ^b	143.38 ^b	Steep (15–25%)
Very Steep (>25%)	158.33 ^a	8.57 ^o	171.47 ^a	139.19 ^a	Very Steep (>25%)
BNJ 5%	0.35	0.11	0.54	0.42	BNJ 5%

Note: Numbers followed by different superscript letters in the same column indicate significant differences based on the BNJ test at the 5% level.

Table 3 shows that plant height decreased from 225.33 cm on the moderately steep slope to 164.31 cm on the steep slope and 158.33 cm on the very steep slope. A similar pattern was observed for the number of leaves, which decreased from 13.26 leaves per plant to 10.91 and 8.57 leaves per plant. The decrease in both parameters indicates that increasing slope steepness significantly inhibits the vegetative growth of maize plants.

This response is closely related to changes in soil biophysical conditions, as described in Table 1. Steeper slopes have higher permeability, causing water to percolate more rapidly into deeper soil layers. This reduces water availability in the root zone and increases the risk of water stress during the vegetative phase. In addition, increased soil loss due to erosion leads to a reduction in the topsoil layer, which is rich in organic matter and nutrients, thereby limiting the soil's ability to supply nitrogen, phosphorus, and potassium. The combination of these two factors inhibits root system development, cell division, and stem elongation, which ultimately reduces plant height and leaf formation.

Physiologically, vegetative growth is highly dependent on the availability of sufficient water and nutrients to support photosynthesis and the formation of new tissue. Water deficiency causes a decrease in cell turgor pressure, resulting in slower cell division and elongation. At the same time, plants tend to reduce leaf formation as an adaptive mechanism to minimize water loss through transpiration. The reduced number of leaves further decreases the photosynthetic surface area, thereby reducing the plant's capacity to produce assimilates. These findings are consistent with those of (Ahluwalia et al., 2021; McCall et al., 2021), who reported that changes in soil hydrological conditions on sloped land directly affect the vegetative growth of maize through reduced water availability and nutrient uptake efficiency.

These differences in vegetative conditions are further reflected in crop yield parameters. Fresh grain weight decreased from 216.98 g plant⁻¹ on moderately steep slopes to 177.99 g plant⁻¹ on steep slopes and 171.47 g plant⁻¹ on very steep slopes. A similar pattern was observed for dry kernel weight, which decreased from 173.88 g plant⁻¹ to 143.38 g plant⁻¹ and 139.19 g plant⁻¹. The decrease in kernel weight indicates that increasing slope steepness not only inhibits vegetative growth but also reduces yield formation efficiency during the reproductive phase.

Low maize yields on steeper slopes result from the interplay between vegetative growth, soil hydrological conditions, and nutrient loss due to erosion. Plants with shorter heights and fewer leaves have more limited photosynthetic capacity, resulting in a reduced amount of

photosynthates that can be translocated to the ears during the grain-filling phase. On the other hand, high permeability and increased soil loss lead to reduced water and nutrient use efficiency, particularly for nitrogen and potassium, which play crucial roles in protein synthesis, starch formation, and carbohydrate translocation to the kernels. Consequently, dry matter accumulation within the kernels is less than optimal, resulting in a decrease in both wet and dry kernel weights.

These findings are consistent with studies by (Tuo et al., 2023), which show that water limitations, degradation of soil physical properties, and increased nutrient loss on sloped land lead to reduced photosynthetic efficiency and impaired grain filling, thereby decreasing corn productivity. Thus, slope gradient does not directly affect crop yield but rather through changes in soil hydrological characteristics, increased erosion rates, and a decline in root zone environmental quality factors that collectively inhibit growth and yield formation.

Overall, the results of this study indicate that slope gradient is the primary controlling factor of corn productivity on upland dryland through its influence on soil physical properties, erosion potential, and the availability of water and nutrients. The steeper the slope, the greater the risk of soil degradation, which leads to reduced vegetative growth and corn yields. Therefore, the application of soil conservation techniques such as contour farming, mulching, the addition of organic matter, and vegetative and mechanical conservation is a crucial strategy for improving water use efficiency, maintaining soil fertility, and supporting sustainable corn productivity on sloping dryland.

Simple Linear Correlation and Regression

A Pearson correlation analysis was conducted to evaluate the relationships between slope gradient, soil physical properties, erosion rates, and growth and yield parameters of the ADF Ruby hybrid corn. The results of the analysis show that all variables have very strong relationships, both positive and negative (Table 4). These patterns indicate that changes in the biophysical conditions of the land due to increasing slope are closely associated with changes in soil characteristics, increased soil loss, and reduced corn growth and productivity.

Table 4. Pearson correlation matrix between soil physical properties, erosion, and corn growth

Variable	Slope (%)	Soil Permeability (cm/hour)	Erosion Rate (metric tons/ha/year)	Plant Height (cm)	Number of Leaves (leaves)
Slope Gradient (%)	1				
Soil Permeability	0.85	1			
Erosion Rate (A)	0.99	0.75	1		
Plant Height	-0.96	-0.97	-0.91	1	
Number of Leaves	-0.97	-0.96	-0.93	0.99	1
Weight of Dried Peas	-0.95	-0.98	-0.9	0.99	0.99

Note: Positive values indicate a positive relationship, while negative values indicate a negative relationship. The interpretation of the correlation refers to the Pearson correlation coefficient.

Slope gradient shows a very strong positive correlation with the rate of erosion ($r = 0.99$) and soil permeability ($r = 0.85$). Conversely, slope gradient is negatively correlated with plant height ($r = -0.96$), number of leaves ($r = -0.97$), and dry kernel weight ($r = -0.95$). These results indicate that an increase in slope gradient tends to be accompanied by an increased potential for soil loss, while vegetative growth and corn productivity decline. These findings reinforce the results of previous analyses that slope is a major factor controlling changes in soil hydrological conditions and increasing the risk of land degradation.

Among all the observed physical properties of the soil, permeability showed the strongest negative correlation with dry grain weight ($r = -0.98$). This correlation indicates that the higher the soil permeability rate, the lower the resulting corn yield. From a hydrological perspective, excessively high permeability accelerates the movement of water to deeper soil layers, thereby shortening the water's residence time in the root zone. This condition reduces the efficiency of water and nutrient uptake particularly nitrogen and potassium, which play crucial roles in photosynthesis, ear formation, and grain filling. Consequently, dry matter accumulation within the grains decreases, leading to a reduction in dry kernel weight. These results are consistent with those of (Fields et al., 2020; Zhang et al., 2023; Qu et al., 2026), who reported that changes in soil hydraulic properties due to topographic variations are one of the main factors determining crop productivity on sloping land.

Correlation analysis also showed that plant height, number of leaves, and dry kernel weight had a very strong positive correlation ($r = 0.99$). These findings indicate that increased vegetative growth is followed by increased crop yield. Physiologically, plants with more optimal height and a greater number of leaves have a larger photosynthetic surface area, enabling them to produce higher amounts of photosynthates. These photosynthates are subsequently translocated to the cob during the grain-filling phase, thereby increasing dry matter accumulation in the kernels. This relationship reflects the concept of the source-sink relationship the interdependence between the capacity of vegetative organs as sources of photosynthates and reproductive organs as sinks for the storage of photosynthetic products. These findings support the results of studies by (Amas et al., 2022; McCall et al., 2021), which indicate that successful maize yield formation is strongly influenced by the quality of vegetative growth during the early stages of plant development.

To strengthen this relationship, a simple linear regression analysis was conducted between soil permeability as the independent variable (X) and dry kernel weight as the dependent variable (Y). The resulting regression equation is:

$$Y = 196.4 - 5.95X$$

With a coefficient of determination $R^2 = 0.89$. This equation indicates that every $1 \text{ cm} \cdot \text{h}^{-1}$ increase in soil permeability is followed by a decrease in dry kernel weight of approximately $5.95 \text{ g plant}^{-1}$. The negative value of the regression coefficient indicates that an increase in the soil's ability to allow water to pass through at the study site is associated with a decrease in corn productivity. From an agronomic perspective, this condition reflects a reduced ability of the soil to retain moisture in the root zone, resulting in decreased efficiency in water and nutrient use during the grain-filling phase.

A coefficient of determination of 0.89 indicates that approximately 89% of the variation in dry kernel weight can be explained by variations in soil permeability, while the remaining 11% is influenced by other factors not included in the model, such as rainfall distribution during the growing season, microclimate conditions, fertilizer efficiency, and biological variations in the

plants. Nevertheless, the high R^2 value indicates that soil permeability is a biophysical indicator closely related to corn productivity on sloping dryland (Maroeto et al., 2026).

Overall, the results of the correlation and regression analyses show that slope gradient indirectly affects corn productivity through changes in soil physical properties and increased erosion rates. Changes in soil hydrological characteristics, particularly increased permeability, lead to reduced availability of water and nutrients in the root zone, which in turn reduces vegetative growth and crop yield. These findings reinforce the notion that managing soil hydrological properties through increased organic matter content, contour farming, and the application of soil conservation techniques are important strategies for sustainably improving corn productivity on upland dryland in Bima Regency.

Conclusion

This study shows that slope gradient is the primary factor affecting the productivity of ADF Ruby hybrid corn through changes in soil physical properties and increased erosion potential. An increase in slope gradient does not significantly alter soil particle density, bulk density, and porosity, but it does increase permeability, which results in a reduced ability of the soil to retain water in the root zone. These conditions, combined with low organic carbon content, reduce the efficiency of water and nutrient supply to the plants. Analysis using the USLE method showed that increases in the slope length and steepness (LS) factors raised the predicted soil loss from the moderate to severe category, even though the rainfall erosivity (R) and soil erodibility (K) factors were relatively consistent across all study sites. These conditions contributed to reduced vegetative growth and corn yields on steeper slopes.

Correlation and regression analyses show that soil permeability has a very strong negative relationship with dry grain weight, while vegetative growth is positively correlated with yield components. These findings confirm that the effect of slope on corn productivity occurs indirectly through changes in soil hydrological characteristics and an increased risk of erosion. In practical terms, the results of this study indicate that corn cultivation on land with a slope of more than 15% requires the application of soil and water conservation techniques, such as contour tillage, the addition of organic matter, the use of mulch, and vegetative or mechanical conservation measures to reduce erosion, improve water and nutrient use efficiency, and sustain corn productivity on dry upland soils.

The results of this study suggest that the relationship between slope gradient, soil physical properties, and corn productivity should be understood as an interconnected system, in which changes in topography affect soil hydrological characteristics, increase erosion potential, and subsequently impact crop growth and yield. These findings reinforce the concept that corn productivity on dryland is not only determined by genetic factors such as variety or fertilization, but is also significantly influenced by soil physical quality and the effectiveness of land management. From a practical standpoint, the research findings indicate that corn cultivation on land with a slope of more than 15% requires the application of soil and water conservation techniques, such as contour tillage, the construction of simple ridges or terraces, the use of cover crops, mulching, and the addition of organic matter to improve soil aggregate stability, water-holding capacity, and nutrient use efficiency. The application of these conservation technologies is expected to reduce the rate of erosion while sustainably improving corn growth and yields on dryland in Bima Regency.

From an academic perspective, this study provides basic information on the relationship between soil physical properties, erosion, and corn productivity across various slope classes, which can serve as a reference for the development of sustainable corn cultivation systems in

tropical dryland regions. However, this study has limitations because observations were conducted during a single growing season and at a single research site. Therefore, future research is recommended to examine these relationships across different soil types and growing seasons, as well as to evaluate the effectiveness of various soil and water conservation techniques in enhancing corn productivity on sloped land.

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