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Estimates of Nutrient Loss from Gully Erosion and its Economic Implications Around Tsokundi Area, Taraba State, Nigeria

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ABSTRACT

Gully erosion, a severe form of land degradation, results in significant losses of soil nutrients. These losses reduce agricultural productivity and imposing substantial financial burdens on farmers. Three locations were selected at Tsokundi ward, Wukari Taraba State for the study. Three locations in the Tsokundi area of Wukari, Taraba State, Tsokundi, Gidan Idi and Avyi-Agbon, were surveyed for gully erosion between June and November in 2022 and 2023, respectively. Soil samples collected from gully sites were analyzed for some physical and chemical properties. The Nitrogen, Phosphorus and Potassium contents were used to estimate nutrient losses and the associated financial implications based on the prevailing market prices of fertilizers. Analysis of variance (ANOVA) was used to evaluate the data and significant differences between means were determined using the t-test at the 5% probability level ($p \leq 0.05$). The results showed that gully erosion resulted in Nitrogen, Phosphorus and Potassium losses equivalent to 0.05–5.8 bags of fertilizer, with the associated financial losses ranging from ₦90 to ₦145,000 in 2022. In 2023, nutrient losses due to gully erosion were equivalent to 0.02–2.17 bags of fertilizer, resulting in estimated financial losses ranging from ₦460 to ₦238,840. The study recommends the implementation of effective erosion control measures to reduce further losses of essential soil nutrients with the view to minimizing the financial burden on farmers in the study area.

Keywords: Gully erosion, nutrient depletion, soil fertility loss, economic evaluation, land degradation.

1. INTRODUCTION

Gully erosion causes a serious environmental problem in Nigeria. This results in high nutrient loss and economic implications (Tekwa *et al.*, 2013). The problem is exacerbated by human activities such as deforestation, unsustainable land-use practices and poor waste management, all of which accelerate the formation and expansion of gullies (Montgomery, 2017). These translate to the formation and expansion of gully channels. The extent of gully erosion in Nigeria called for immediate and effective remedy to curtail the increasing environmental degradation and economic losses which threaten food security and the well-being of Nigerians. The nation grapples with approximately 3,000 gullies, predominantly in the

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southeastern region, where affected areas have nearly tripled from 1,021 km² in 1976 to 2,820 km² in 2006. In the northeastern region of Nigeria, a study was carried out in Mubi Local Government Area, Adamawa State. The study reported an alarming annual soil loss of over 31,000 tons due to gully erosion, stripping the land of vital nutrients essential for agricultural production. This degradation results in significant economic losses because nutrient-rich topsoil is essential for sustaining crop productivity (Tekwa *et al*., 2013).

A study conducted in Mubi Local Government Area, Adamawa State, reported that annual soil loss due to gully erosion ranged from approximately 159,574 to 725,345 kg/ha. This translates to an average annual loss of 32.33 kg of Nitrogen, 2.17 kg of Phosphorus and 18.5 kg of Potassium per hectare. Economically, the annual cost of soil loss in the region is estimated at between ₦1,278,000 and ₦1,335,000. This includes nutrient depletion costs, which alone range from ₦48,000 to ₦353,000 per year (Tekwa *et al*., 2013). These figures indicate staggering and disheartening economic consequences. In southeastern Nigeria, gully erosion inflicts a massive $100 million in economic losses every year. The impact on local farming is devastating, with some areas seeing crop yields plummet by 30% to as much as 90% (Climate Change News, 2020). In Malawi, soil erosion and nutrient loss have been estimated to cost up to 11 % of the Gross Domestic Product annually. The reported negative impacts of gully erosion called for an urgent need for comprehensive soil conservation and erosion mitigation approach (FAO 2018; Boardman *et al*., 2020). Although there is absence of Gross Domestic Product loss figures for Nigeria, the prevailing extensive land degradation shows severe economic consequences.

Apart from the immediate loss of arable land, gully erosion causes the destruction of critical infrastructure, displaces communities, and threatens the livelihoods of local populations (FAO, 2018). The devastating toll that gully erosion takes on both the environment and human lives makes one thing clear: we urgently need better, more sustainable ways to fight it and relieve the pressure on these communities. To address the severe nutrient loss as well as the economic threats posed by gully erosion, multifaceted methods such as the implementation of comprehensive land-use planning and management practices should be adopted. These will effectively control surface runoff thereby reducing gully formation. Similarly, the adoption of awareness and engagement of local communities in erosion control initiatives will ensure the sustainability of intervention measures (Pimentel & Burgess, 2013). Also, educating residents about the causes and consequences of gully erosion will foster proactive participation in prevention and remediation efforts. Another approach entails strengthening of policies and institutional frameworks to enforce regulations against unsustainable land-use practices thereby promoting environmental conservation and providing financial and technical support for erosion management projects.

Even though the damage caused by gully erosion around the Tsokundi area of Taraba State is plain to see, we still don't know exactly how many vital soil nutrients are being lost, or what this truly costs the local economy. Therefore, this study intends to achieve the following objectives: (i) to determine the amounts of nutrient losses from gully erosion around Tsokundi area, Wukari Local Government, Taraba State. (ii) to assess the economic implications of nutrient losses in the study area. Addressing these objectives, the study will provide insights into the severity of nutrient depletion due to gully erosion and its economic consequences. This will ultimately contribute to a more effective land conservation policies and sustainable agricultural practices.

2. MATERIALS AND METHODS

Location and Extents

To get an accurate picture, our research looked at nine (9) specific sites across three different locations around the Tsokundi district area. The study looked at three specific locations Tsokundi, Gidan-Idi, and Avyi-Agbon all located within the Wukari Local Government Area of Taraba State (Figure 1). Wukari is in the Southern Guinea Savannah, North-East of Nigeria. Tsokundi lies between latitude 7^0 51′ 0′′ N and 7^0 53′ 0′′ E and longitude 10^0 0′ 0′′ N and 10^0 2′ 0′′ E (Gani *et al*., 2022).

Climate and Vegetation of the Study Area

The local landscape is dominated by tall grasses, including elephant grass *(Pennisetum purpureum), Stylo (Stylosanthis gracilis)*, Itch weed *(Roetbolia cochinchensis)*, Gamba grass *(Andropogon gayanus)* etc. The trees are scanty and include the Gmelina (*Gmelina arborea*), *Daniella oliveri, Prosopia Africana*, *Azadirachta indica, Vitex donian, Vitellaria, Parkia biglobosa*, etc. The shrubs include camel foot (*Piliostigma thonningii*) and African giant milkweed (*Calotropis procera*), etc. The area receives an average of 1,300 mm of rainfall each year, with typical temperatures swinging between 20°C and 37°C. The sites are characterized by a tropical climate (Gani *et al*., 2022).

Field Studies: Survey of gully erosion sites and soil sampling

The field surveys were conducted across two full rainy seasons, tracking the gully erosion from the very first rainfall to the end of the wet season each year. Each of the three locations comprised three sites, whereby each gully erosion channel was carefully observed and measured. Channels with depths of ≥ 0.46 m were noted as a gully (Balasubramanian, 2017). Disturbed soil samples were collected from 0 – 30 cm depth at each gully site using a soil auger. Intact core samples of the undisturbed soil were collected using core rings and then carefully wrapped in plastic sheets to protect them. The collected soil samples were spread out on plastic sheets and plant roots were pricked out before packaging them up and sending them off to the lab. Labeled bags were used to package the loose soil samples from each site. The samples were subsequently air-dried for seven (7) days and passed through a 2 mm sieve in preparation for physical, hydraulic and chemical laboratory analyses.

Laboratory Studies

After sampling from the study sites, both disturbed and undisturbed soil samples were available. The undisturbed core samples were analyzed in the laboratory to determine soil bulk density and water-holding capacity. Meanwhile, the prepared loose samples were used to determine particle size distribution, pH, total Nitrogen, soil organic Carbon and available Phosphorus. Laboratory analyses also evaluated the soil's chemical properties, including exchangeable bases (Calcium, Magnesium, Potassium and Sodium), Sodium Adsorption Ratio and Cation Exchange Capacity. Particle size distribution was determined using the Bouyoucos hydrometer method (1927), while the corresponding soil textural classes were determined using the standard soil textural triangle. The bulk density was measured using the core method as described by Blake and Hartge (1986). Soil water-holding capacity was determined by calculating the ratio of water retained within the core sample relative to its oven-dry weight (Dane & Topp, 2002). The total porosity was obtained using the procedure outlined by Obi (2000).

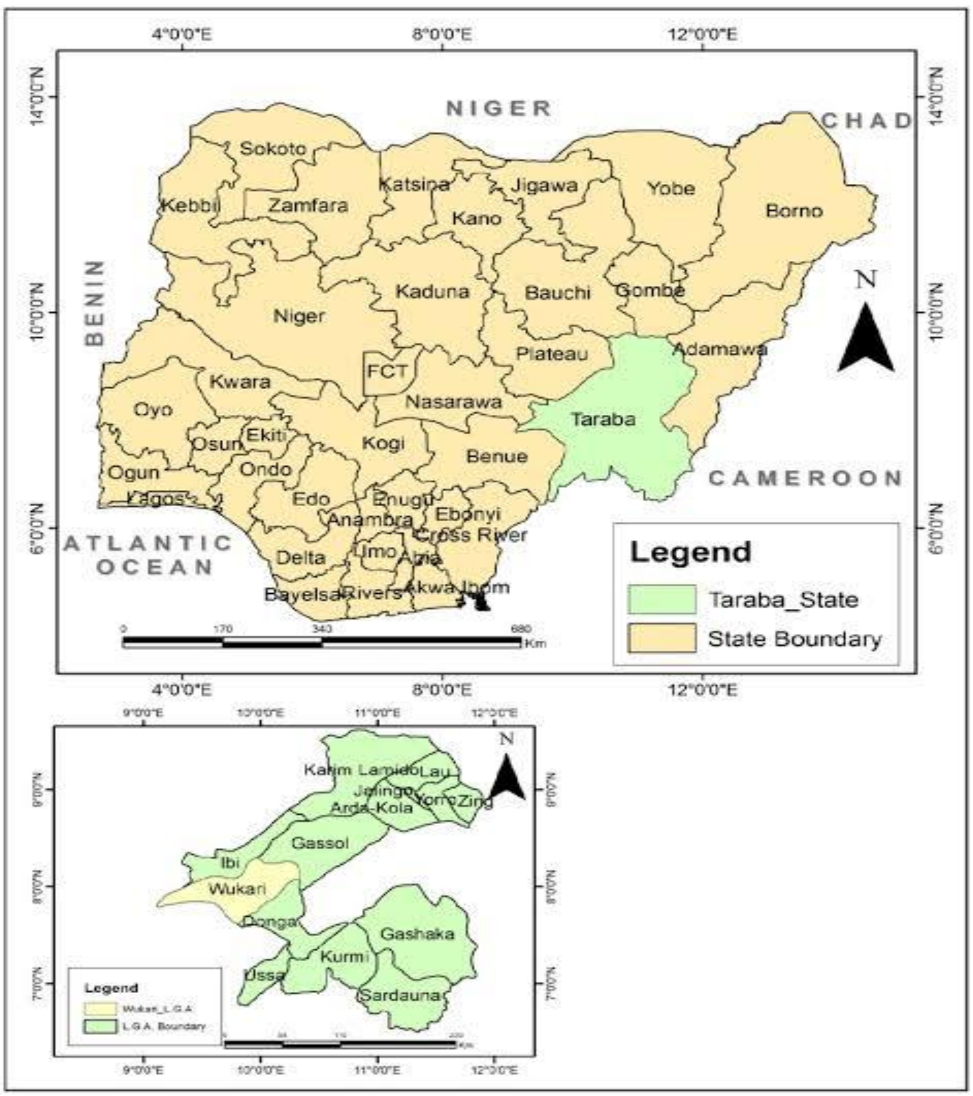

Figure 1. Map of Nigeria showing the showing the study area

The total Nitrogen was measured using the macro Kjeldahl method (Bremner and Mulvaney, 1982). Soil organic Carbon was determined via the Walkley–Black wet digestion method (Nelson and Sommers, 1982). The resulting values were subsequently converted to total organic matter by multiplying by the standard Bemtri factor of 1.724. Soil pH was determined by mixing the soil samples with deionized water in a 1:2.5 ratio (Kalra, 1995). The solution was stirred thoroughly and allowed to equilibrate before measurement with a glass electrode pH meter. Soil available Phosphorus was measured using the procedure outlined by Olsen (1982). Exchangeable bases (Calcium, Magnesium, Potassium and Sodium) were determined using the 1 M ammonium acetate (NH_4OAc) extraction method at pH 7.0, as described by Thomas (1982). Soil Cation Exchange Capacity was determined according to the method described by Chapman (1965), whereas the Sodium Adsorption Ratio was calculated following the procedure outlined by Rhoades (1982).

Estimation of Nutrient Elemental Loss

Nutrient loss was estimated adopting the method described by Nandwa (2007). This is because the method provides a systematized approach of assessing soil nutrient depletion, particularly in Africa agricultural systems.

Nitrogen estimates (kg) = Wsl (kg) × analytical Nitrogen (%) ÷ 100 ……………. (1)

Phosphorus estimates (kg) = Wsl (kg) × analytical Phosphorus (ppm) ÷ 1,000,000 mg …… (2)

Potassium estimates (kg) = Wsl (kg) × analytical Potassium (cmol (+) kg^{-1}) × 0.39 g/kg ÷ 1000 g ……(3)

Where;

Wls = weight of soil loss nutrient loss as per fertilizer bag (50 kg) equivalents:

(i). Nitrogen estimates: 100 kg Urea = 46 % (46 kg Nitrogen)

X kg Urea = weight of Nitrogen (kg) lost

X kg Urea = 100 kg Urea × weight of Nitrogen (kg) lost

Therefore, fertilizer bags equivalent = X kg urea ÷ 50 kg.

(ii). Phosphorus estimates: 100 kg SSP = 18 % P_2O_5 (18 kg Phosphorus)

X kg SSP = weight of Phosphorus (kg) lost × 2.29

X kg SSP = 100 kg × weight of Phosphorus (kg) lost × 2.29 ÷ 18 kg P_2O_5

Therefore, fertilizer bags equivalent = X kg SSP ÷ 50 kg.

(iii). Potassium estimates: 100 kg MOP = 60 % K_2O (60 kg) potassium

X kg MOP = weight of Potassium (kg) lost × 1.20

X kg MOP = 100 kg MOP × weight of Potassium (kg) lost × 1.20 ÷ 60 kg K_2O

Therefore, fertilizer bags equivalent = X kg MOP ÷ 50 kg.

Where;

SSP = Single Super Phosphate

MOP = Murate of Potash

2.29 = Conversion factor from Phosphorus to P_2O_5

1.20 = Conversion factor for Potassium to K_2O

Statistical Analysis

Data on the estimated elemental nutrient loss of Nitrogen, Phosphorus and Potassium for each of the study year and site was analyzed using a generalized linear model of statistix 9.1 in a Completely Randomized Design (CRD). Analysis of Variance (ANOVA) was carried out and means were separated using T-test at $p \leq 0.05$ probability level. Additionally, tables of results were used to present some of the analyzed results.

3. RESULTS AND DISCUSSION

Physical Properties of the Gully Sites

The results of the physical properties of the studied sites are shown in Table 1. Sand content varied across locations, ranging from a minimum of 60.00% at the Tsokundi water board station to a maximum of 74.20% at Akun-Avyi. Silt content varied by location, ranging from a minimum of 21.53% at Akun-Avyi to a maximum of 27.80% at the Gamwe gully site. The highest clay content was recorded at the Tsokundi Road, Jalingo Road, Ashikan, Akun-Avyi, and Gowniwi sites, each of which exhibited a corresponding silt content of 4%. Meanwhile, the remaining gully sites recorded the minimum clay content at 3%. The soil at all investigated gully sites was classified as a sandy loam texture. Soil bulk density values ranged from a minimum of 0.65 g/cm^3 at the Tsokundi water board gully site to a maximum of 1.49 g/cm^3 at the Jalingo Road site. The highest total soil porosity (56.20%) was recorded at the Tsokundi Road and Tsokundi water board sites, whereas the minimum value was obtained at the Acho-kundi site (33.28%). Soil moisture levels varied significantly across the study areas, ranging from a low of 6.37% at the Tsokundi Water Board site to a high of 23.27% at the Ashikan site.

Chemical Properties of the Gully Sites

The results (Table 2) of the chemical properties showed that soil pH in both water and Potassium chloride ranged from strongly acidic (at the Tsokundi water board and the Ganwe in KCl) to slightly acidic (Brady and Weil, 2016). The Akun-Avyi site recorded the highest amount of soil organic matter at 1.59%, whereas the Gidan-Idi hospital gully site dropped to the lowest level at just 0.85%. Because the soils are low in organic matter (Brady and Weil, 2016), they are highly susceptible to being detached by water. This erosion washes away the soil particles and subsequently leads to a loss of essential nutrients. Total Nitrogen levels ranged from a low of 0.58% at both Gidan-Idi and Acho-kundi to a high of 0.64% at Gowniwi and the Tsokundi Water Board site. Meanwhile, Tsokundi road recorded the lowest Phosphorus (7.89 mg/kg) and the highest value was obtained at Jalingo road (10.03 mg/kg). The results of the chemical analysis indicate that the soils were low in Nitrogen, Phosphorus and Potassium (Marschner, 2012). Soil total exchangeable bases ranged from 0.78 at the Gidan-Idi hospital and Jalingo road to 1.30 at the Ganwe gully site.

Table 1. Soil physical properties of the gully sites

Study Location	Sand (%)	Silt (%)	Clay (%)	BD (mg cm^3)	Total porosity (%)	Moisture content (%)	Textural class
Tsokundi Road	70.69	25.27	4.00	0.80	56.20	22.33	SL
Gidan-Idi Hospital	70.72	26.28	3.00	1.10	50.00	21.08	SL
Jalingo Road	73.60	22.40	4.00	1.49	45.00	21.71	SL
Ashikan	72.20	22.53	4.00	0.72	39.00	23.27	SL
Akun-Avyi	74.20	21.53	4.00	0.93	37.17	22.15	SL
Acho-kundi	71.23	25.80	3.00	1.43	33.28	22.74	SL
Gamwe	70.20	27.80	2.00	0.85	49.42	7.55	SL
Gowniwi	71.43	23.80	4.00	0.84	49.81	7.22	SL
Tsokundi Water Board	60	26.40	3.00	0.65	56.20	6.37	SL

BD = bulk density, SL = sandy loam

The cation exchange capacity ranged from 4.81 cmol/kg at Gamwe to 5.39 cmol/kg at the Ashikan. Meanwhile, the highest Sodium adsorption value (18.38 %) was obtained at the Acho-kundi and the lowest (11.55 %) was at the Gowniwi. The combination of low Nitrogen, Phosphorus and Potassium levels alongside a high Sodium Adsorption Ratio indicates that the soil is highly vulnerable to erosion. Strongly sodic Sodium dsorption ratio denotes soil structural damage, reduced water infiltration and nutrients imbalances (Rengasamy, 2002). These occurrences lead to ponding of water subsequently resulting to runoff which detach and transport soils and nutrients. Therefore, sustainable remediation practices should be adopted at the various gully sites to prevent further deterioration of the existing gullies.

Soil Nutrient Loss Estimates

Nitrogen loss estimates

The results of analysis of Nitrogen loss of the study area are presented in Table 3. The results showed that Nitrogen loss differed significantly among the study locations in both years. In 2022, Jalingo Road soils experienced the highest Nitrogen loss at 0.38 kg. This was followed by Gowniwi (0.36 kg), Gamwe (0.26 kg) and Ashikan (0.13 kg), while Acho-kundi recorded the lowest Nitrogen loss at 0.10 kg. However, Nitrogen loss was moderate at Tsokundi Road (0.73 kg) and Gidan-Idi Hospital (0.87 kg), but jumped significantly at the Tsokundi Water Board, which recorded a loss of 1.95 kg. The elevated Nitrogen loss observed in the Jalingo Road soils can be attributed to specific soil characteristics, namely a high porosity of 45% and a large sand fraction of 73.60%. Furthermore, the results imply that Nitrogen loss may intensify across the majority of the sites if appropriate intervention measures are not taken. The 2023 results indicate that the general trend of Nitrogen loss was largely consistent across the study areas, except for Tsokundi Road and Jalingo Road soils, where the patterns differed slightly.

Table 2. Chemical properties of the Studied Sites

Study Location	pH (H_2O)	pH (KCl)	O.M	N (%)	P	Ca	Mg	K	TEB	CEC	SAR (%)
					→			Cmol/kg	←		
Tsokundi Road	5.75	5.15	1.12	0.65	7.89	0.50	0.26	0.36	1.12	4.90	13.63
Gidan-Idi Hospital	5.62	5.07	0.85	0.58	9.08	0.12	0.27	0.53	0.92	5.36	13.84
Jalingo Road	5.83	5.06	0.95	0.60	10.03	0.13	0.23	0.42	0.78	5.22	16.65
Ashikan	5.93	5.30	0.93	0.62	8.43	0.01	0.32	0.45	0.78	5.39	15.30
Akun-Avyi	5.77	5.20	1.59	0.61	8.23	0.13	0.26	0.47	0.86	5.02	11.9
Acho-kundi	5.75	5.25	1.46	0.58	9.03	0.09	0.32	0.52	0.93	5.19	18.38
Gamwe	5.65	4.76	1.50	0.59	7.97	0.53	0.32	0.45	1.30	5.04	13.71
Gowniwi	5.75	5.20	1.52	0.64	8.37	0.12	0.33	0.50	0.95	4.81	11.55
Tsokundi Water Board	5.65	4.82	1.29	0.64	8.54	0.09	0.27	0.42	0.79	5.02	17.69

KCl = potassium chloride, O.M = organic matter, N= nitrogen, P= potassium, Ca= calcium, Mg= magnesium, K= potassium, TEB= total exchangeable bases, CEC= cation exchange capacity, SAR= sodium adsorption ratio.

Phosphorus loss estimates

The results of analysis of P-loss in terms of P_2O_5 are presented in Table 4. The results showed that the P_2O_5-losses differed significantly ($p<0.05$) among the study location only during year 2022. In year 2022, the Gidan-Idi hospital soils had the highest P_2O_5-losses (9.43 kg) compared to the other locations such as the Ashikan (1.04 kg), the Tsokundi water board (2.24 kg) and the Akin-Avyi (2.97 kg) with the lowest P_2O_5-losses. However, the Jalingo road (4.13 kg), the Acho-kundi (8.63 kg), the Gowiniwi (4.18 kg) and the Tsokundi road (3.37 kg) recorded considerably higher P_2O_5 losses. The observed higher P_2O_5-losses at the Gidan-Idi hospital might have been caused by some soil properties such as sand fraction (70.72%) and high porosity (50.00%) in the soils. The results further imply that P_2O_5-losses might worsen in most of the sites if proper conservation measures are not implemented in the study area.

Potassium loss estimates

The K-loss estimates in terms of K_2O are presented in Table 5. The results showed that K_2O-losses differed significantly ($p<0.05$) among the study locations only in the year 2023. In 2023, the Tsokundi road had the highest K_2O-losses (9.57) compared to the other locations such as the Gowiniwi (1.20), the Ashikan (1.09) and the Gidan-Idi hospital road (3.22) with the lowest K_2O estimates. Hence, other locations such as the Acho-kundi (9.37), the Jalingo road (8.50), the Gamwe (7.68), the Tsokundi water board (6.81) and the Akin-Avyi (3.27) recorded considerably higher K_2O losses. The higher K_2O-loss at Tsokundi road might have been due to the effect of soil bulk density (0.80), porosity (56.20%) and sand fractions (70.69%). The results also imply that K_2O losses might worsen in most of the sites if proper management practices are not implemented in the study sites.

Cost of Estimated Fertilizers (Bags)

The results on cost of N, P and K fertilizer bags across the study area are presented in terms of urea, SSP and MOP.

Cost of Nitrogen (urea) fertilizer (bags)

The results (Table 3) showed that cost of urea fertilizer bags differed among the study locations in both years. In 2022, the Jalingo road had the highest cost estimates (₦2,160) compared to the other locations such as the Ashikan (₦90), the Acho-kundi (₦90) and the Gamwe (₦180) with the lowest N-fertilizer cost estimates. Meanwhile, the Tsokundi road (₦540), the Tsokundi water board (₦1,620), the Gidan-Idi hospital (₦540), the Akin-Avyi (₦360) and the Gowniwi (₦360) had moderate cost estimates. The observed higher cost of urea at Jalingo could have been due to higher N-losses in the sites. The results imply that cost of urea might worsen in most of the study locations with time.

In 2023, the Gidan-Idi hospital had the highest (₦13,800) cost of urea compared to the other locations such as the Gowniwi (₦1460), the Acho-kundi (₦690) and the Gamwe (₦920) with the lowest cost estimates. On the other hand, the Tsokundi road (₦5,290), the

Jalingo road (₦4,830) and the Akin-Avyi (₦1,150) had moderate N-loss cost estimates. This higher cost of urea at the Gidan-Idi hospital could be attributed to high N-loss in equivalent fertilizer bags that resulted from high soil and nutrient losses. The results imply that cost might worsen in the future due to hike in fertilizer prices (Table 3).

Cost of Phosphorus (SSP) fertilizers (bags)

The results (Table 4) showed that the cost of SSP fertilizer differed among the study locations in both years. In 2022, the Ashikan had the highest cost of SSP (₦103,250) compared to locations such as the Tsokundi (₦37,000), the Gidan-Idi hospital (₦48,500), the Acho-kundi (₦34,250), the Akin-Avyi (₦35,000) and the Gowniwi (₦38,750) with the lowest. However, the Jalingo road (₦98,500), the Gamwe (₦54, 250) and the Tsokundi water board (₦69,250) recorded moderately. The higher cost of SSP at the Ashikan could have been due to low content of P_2O_5 (1.04) in the soils. The results imply that the cost of SSP might escalate at most of the study locations over time if proper conservation practices are not implemented.

Table 3. Analysis of nitrogen loss estimates

Location	Mass of soil loss (kg)		Analytical N content (%)		Weight of N content (kg)		Equivalent urea fertilizer bags		Cost of urea fertilizer bag (₦)		T-test for cost of N-loss between 2022 and 2023
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	
Tsokundi Road	344.14	732.61^{a}	0.65	1.04^{a}	0.73^{ab}	4.76^{a}	0.03^{ab}	0.23	540	5290	4154.7
Gidan-Idi Hospital	95.70	242.01^{ab}	0.58	0.98^{b}	0.87^{ab}	1.40^{ab}	0.03^{ab}	0.6	540	13800	706.47
Jalingo Road	279.59	524.80^{ab}	0.60	0.84^{b}	2.71^{a}	3.30^{ab}	0.12^{a}	0.21	2160	4830	1111
Ashikan	15.49	131.50^{b}	0.62	0.85^{b}	0.13^{b}	0.81^{b}	0.005^{b}	0.06	90	1380	1111
Akun-Avyi	45.36	134.76^{b}	0.61	0.84^{b}	0.38^{b}	0.81^{b}	0.02^{b}	0.06	360	1380	752.33
Acho-kundi	13.38	100.26^{b}	0.58	0.78^{b}	0.10^{b}	0.58^{b}	0.005^{b}	0.03	90	690	497.47
Gamwe	25.14	106.83^{b}	0.59	0.78^{b}	0.26^{b}	0.63^{b}	0.01^{b}	0.04	180	920	1110.5
Gowniwi	19.29	73.31^{b}	0.64	0.83^{b}	0.36^{b}	0.47^{b}	0.02^{b}	0.02	360	460	174.67
Tsokundi Water Board	185.06	240.87^{ab}	0.64	0.84^{b}	1.95^{ab}	1.51^{ab}	0.09^{ab}	0.05	1620	1150	-50.947
SE (±) p≤0.05	169.14	270.47	0.1146	1.7429	1.0981	1.7429	0.0487	0.1146			

Table 4. Analysis of phosphorus loss estimates

Location	Mass of soil loss (kg)		Analytical P content (%)		Weight of P_2O_5 content (kg)		Equivalent SSP fertilizer bags		Cost of SSP fertilizer bag (₦)		T-test for cost of P-loss between 2022 and 2023
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	
Tsokundi Road	344.13^{a}	732.62^{a}	7.89^{f}	12.18^{b}	3.37^{ab}	5.90^{a}	8.50^{a}	1.48^{ab}	37,000	238,000	18.480
Gidan-Idi Hospital	95.70^{a}	242.01^{ab}	9.08^{b}	9.91^{bc}	9.43^{ab}	2.17^{a}	2.38^{a}	1.97^{ab}	48,500	66,640	47.810
Jalingo Road	279.59^{a}	524.80^{ab}	10.03^{a}	9.98^{bc}	4.13a^{b}	5.23^{a}	6.97^{a}	3.94^{a}	98,500	195,160	91.500
Ashikan	15.49^{a}	131.50^{b}	8.43^{cd}	10.05^{b}	1.04^{b}	1.09^{a}	2.67^{a}	4.13^{b}	103,250	74,760	10.857
Akun-Avyi	45.36^{a}	134.76^{b}	8.23^{c}	12.26^{b}	2.97^{b}	4.12^{a}	7.47^{a}	1.40^{ab}	35,000	209,160	37.413
Acho-kundi	13.38^{a}	100.26^{b}	9.03^{b}	18.26^{a}	8.63^{b}	8.97^{a}	2.20^{a}	1.37^{ab}	34,250	61,600	37.727
Gamwe	25.44^{a}	106.83^{b}	7.97^{f}	10.55^{b}	3.07^{b}	8.40^{a}	8.53^{a}	2.17^{b}	54,250	238,840	37,633
Gowniwi	19.29^{a}	73.31^{b}	8.37^{d}	12.27^{b}	4.18^{ab}	6.07^{a}	7.02^{a}	1.55^{b}	38,750	196,560	-14.613
Tsokundi Water Board	185.06^{a}	240.87^{ab}	8.54^{cd}	12.27^{b}	2.24^{ab}	2.06^{a}	6.00^{a}	2.77^{ab}	69,250	168	44.560
SE (±) p≤0.05	169.14	270.47	1.674	5.184	0.2407	1.672	5.184	1.674			

Cost of Potassium (MOP) fertilizer (bags)

The results (Table 5) showed that the cost of MOP fertilizer bags differed among the study locations in both years. In 2022, the Gownwi recorded the highest MOP (₦145,000) followed by the Ashikan (₦109,250). The next was the Tsokundi road (₦85,750), the Acho-kundi (₦93,250), the Jalingo road (₦85,750). However, the Tsokundi water board (₦69,500), the Ganwe (₦76,750), the Atkin-Ayi (₦32,750) and the Gidan-Idi hospital (₦58,500). However, the Tsokundi water board (₦35,500) had the lowest cost estimates. The higher cost of MOP fertilizer at the Gowniwi and the Ashikan could have been due to the high loss of K_2O in the soils as evidenced in the equivalent fertilizer bags in the soils. This occurrence agrees with the report of Tekwa *et al*. (2013), who observed similar trends in soil implications at Mubi, Adamawa State.

The results further imply that the cost of MOP might be higher over time if not controlled. In 2023, the Acho-kundi had the highest MOP (₦214,110), followed by the Ganwe (₦201,690), the Atkin-Ayi (₦122,310), the Tsokundi road (₦112,320) and the Jalingo road (₦92,610). However, the Gowniwi (₦67, 500), the Tsokundi road (₦43,200), the Gidan-Idi hospital (₦54,810) and the Ashikan (₦38, 610) had the lowest MOP cost estimates.

Table 5. Analysis of potassium loss estimates

Location	Mass of soil loss (kg)		Analytical K content (%)		Weight of K_2O content (kg)		Equivalent MoP fertilizer bags		Cost of MoP fertilizer bag (#)		T-test for cost of K-loss between 2022 and 2023
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	
Tsokundi Road	344.13	732.62^{a}	0.10^{a}	0.36	0.11	9.57^{a}	3.83^{ab}	4.16	95,750	112,320	101.99
Gidan-Idi Hospital	95.70	242.01^{ab}	0.19^{a}	0.53	0.05	3.22^{ab}	2.34^{a}	2.03	58,500	54,810	-8.3700
Jalingo Road	279.59	524.80^{ab}	0.09^{b}	0.42	0.08	8.50^{ab}	3.41^{ab}	3.43	85,750	92,610	83.483
Ashikan	15.49	131.50^{b}	0.19^{a}	0.45	0.04	1.09^{ab}	4.37^{b}	1.43	109,250	38,610	37.523
Akun-Avyi	45.36	134.76^{b}	0.19^{a}	0.47	0.02	3.27^{ab}	1.31^{b}	4.53	32,750	122,310	118.86
Acho-kundi	13.38	100.26^{b}	0.19^{a}	0.51	0.02	9.37^{b}	3.73^{b}	7.93	93,250	214,110	53.263
Gamwe	25.44	106.83^{b}	0.17^{a}	0.45	0.02	7.64^{b}	3.07^{ab}	7.47	76,750	201,690	89.630
Gowniwi	19.29	73.31^{b}	0.18^{a}	0.50	0.01	1.20^{b}	5.80^{b}	2.50	145,000	67,500	55.403
Tsokundi Water Board	185.06	240.87^{ab}	0.16^{a}	0.42	0.04	6.81^{ab}	2.78^{ab}	1.60	69,500	43,200	35.639
SE (±) p≤0.05	NS	270.47	NS	NS	NS	0.0403	1.031	NS			

4. CONCLUSION

This study assessed nutrient loss caused by gully erosion and its economic implications in the Tsokundi district of the Wukari Local Government Area, Taraba State. The results showed that nutrient loss from gully erosion was equivalent to losing between 0.05 and 5.8 bags of fertilizer per site. In 2022 economic terms, this translated to a cost ranging from as little as ₦90 to as much as ₦145,000 In 2023, nutrient losses were equivalent to 0.02 to 2.17 bags of fertilizer, resulting in monetary losses ranging from ₦460 to ₦238,840. The economic estimates represent the combined effect of specific soil properties and gully features that influence the processes of soil loss and gully formation. The present study recommends the adoption of erosion mitigation measures to reduce further loss of soil essential nutrient so as to reduce and the financial burdens on the farmers in the study area.

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Author Contributions

Ijasini John Tekwa: Conceptualization, design and execution of research work, statistical analysis and writing of manuscript. Angyu Micah Dantani: Manuscript drafting, proofreading and online submission of manuscript.

Informed consent

Not applicable.

Conflicts of interests

The author declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Ethical approval & declaration

Not applicable. This article does not contain any studies with human participants or animals performed by any of the authors.

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Data and materials availability

All data associated with this study are present in the paper.

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