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Evaluation of soil erosion hazards, causes and control measures at Uwani–Amokwe Community, UDI L.G.A, Enugu State

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Abstract
Globally, soil erosion menace has been a major problem threatening man's environment, the consequent effect had been degrading the environment, making it unfit for agricultural production and sustenance of infrastructure. In view of this teething problem, the soil erosion menace at Uwani–Amokwe community was critically examined and assessed, the renaissance survey revealed developed and developing gullies, linear incisions, impassable roads, poor drainages, poor agricultural produce, harvests etc. A mechanical analysis of soil composition revealed sandy loam soil which naturally does not support adequate vegetation; the erosivity index as determined from meteorological data is 75.84mm/hr and orchestrated 0.06m/s discharge; the cone-penetrometer test indicated liquid limit of 24% beyond which working the soil will be damaged; the reduced levels/ elevation indicated gentle slope towards the gully heads for the worsened selected gully units and adequate capacity trapezoidal channel and culverts were designed to handle the discharge.

Keywords: evaluation, soil erosion, hazards, causes, control measures

1. Introduction

Soil erosion is about the most important issue with man's environment. It varies in magnitude depending on the causative agent and nature of the environment.

It can be caused by the noticeable agents of wind, water or anthropogenic activity or a combination of any two or more of those agents.

The consequent problem emanating from soil erosion havoc is commonly draught, food shortage or outright hunger since the world population is fast growing in geometric progression and not arithmetic progression, destruction of the aesthetics of cities, farms, crops, livestock, washing away of buildings and sometimes loss of life.

Soil erosion by water exists in sheet/rill, raindrop/splash, stream bank and gully- the most devastating and always crying for restoration. Erosion by wind is not easily classified by type but rather by mode of soil particle movement; suspension, siltation and deposition.

The roles of anthropogenic activities in soil erosion are centered on farming practices, sand/ gravel mining operations, borrow –pits, urbanization etc.

It is therefore the need to address some of the above mentioned problems, orchestrated on the environment of Udi LGA of Enugu State that brought this research into focus.

Erosion may be defined as the gradual wearing away of the earth's surface by the agents of water, wind or anthropogenic elements. In Nigeria, the erosion caused by water is more spectacular than the other agent. It is closely followed by wind.

The World Bank (1990) recognized three main environmental problems facing Nigeria: soil degradation and loss, water contamination and deforestation.

In addition, six other problem areas were specified: gully erosion, fishery loss, coastal erosion, wildlife and biodiversity losses, air pollution and the spread of the water hyacinth.

According to World Bank, gully erosion contributes to each of the three main problems and causes damage with an annual cost to the nation (Nigeria) estimated at $100 million in 1990.

In Southeastern Nigeria, Akamigbo *et al*., (1987) [1] reported that the worst hit areas by gully erosion include; Enugu-Onitsha expressway, Enugu- Nsukka road, Udi, Awgu, Ezeagu, Oji River, Isi-Uzo.

In Anambra- Aguata, Nnewi, Njikoka, Ihiala, Awka, Idemili and Abia State- Bende, Ohafia, Arochukwu, Item, Nkporo are not equally spared.

Imo and Ebonyi states are also suffering the same fate, though not on the same echelon with the aforementioned states.

The culminating doom is that in South-Eastern Nigeria, food production is at low ebb, calling for intensive efforts and financial commitment to have arable lands to produce at all.

Infrastructural developments were not spared, while homes, many highways, electric and telephone lines which cost billions of naira to build, are all at the mercy of erosion in many parts of Nigeria (Asadu, 1990) [2].

In summary erosion in South-Eastern Nigeria is yearning for attention and perhaps this was why the National Assembly is about to enact a law on the establishment of a commission to handle this ugly monster of this geo- political zone and country.

Mechanism of Erosion

The soil erosion process is accomplished in three successive ways; detachment transportation and deposition.

Detachability- This refers to the ease or relative ease with which a particle could be detached. This is a function of the erosive agent; water, wind or anthropogenic element. It is a function of particle size as larger particles are easier to detach than smaller particles.

Bonding strength between particles, canopy/ vegetative cover, moisture content and climatic factors have also a role to play here.

Transportation- The transportability of detached particles also depends on its size; small particles are easily transported than larger particles.

Deposition- This completes the erosion process, detached, transported and deposited particle undergoes erosion.

Erosion Control Methods

The two major erosion control methods include;

Agronomic/ Biological Method; this could be categorized into

- Natural Vegetation and Ground litter
- Crop residue / Mulching
- Wind breaking barriers

Engineering/ Mechanical Methods

- Contour cultivation: this means carrying out all tillage operation such as ploughing, harrowing, ridge making, weeding etc across the slope.

The essence of this is to reduce velocity of runoff flow downhill

- Terracing: this refers to making terraces or ditches at constant intervals across the slope.

This will further reduce velocity of flow downhill by reducing the catchment area yield of runoff to each channel.

Other Engineering works: these will include culverts, chutes, spillway discharges, diversions, gully head dams, silt trap dams, gabions, gabion mattresses, gabion sausages brushwood dams, net dams, wire bolsters, water courses etc.

However, the choice of any or combination of the aforementioned depends on the objective in view; to restore original hydraulic balance or to create new conditions in the watershed.

2. Research Methodology

2.1 Study Area

The study area for this research is Uwani – Amokwe, located in Udi Local Government Area of Enugu State. Enugu City is located 0°28'N and longitude 07°33E at the altitude. Subjectively, the renaissance survey of the community revealed; fragmented parcels of land, impassable roads, especially within the residential location, even though few portions of the road-networks were macadamized; undermined building foundations, spectacular in market squares; foundations, sediment deposits at road-junctions and narrow roads; cave –ins and linear incisions, and above all developed, developing and worsened gully erosion sites. It is this devastated and ravaged environment that brought this research work into focus, since economic and social activities are already at stake.

Fig 2.1: Gully Unit a (Agulu Uwani Road)

Fig 2.2: Gully Unit B (Enuguodousu Road)

Fig 2.3: Gully Unit C (Ojukwu Agulu Road)

Fig 2.4: Gully Unit D (St. Patrick Road)

2.2 Determination of Catchment Area

Four worsened Gully Units were selected as representatives of the research area and catchment areas for those sites determined. Survey instruments used for fieldworks include; Dumpy level, Venire theodolite, Ranging poles, Tapes. Pins, Arrows, Spades/ hoes, Matches.

The aim of this exercise was to determine elevations/ heights and subsequently compute the area yielding the offensive runoff.

It was commenced with a survey assistant holding a ranging staff at the edge of the gully head and another survey assistant holding another ranging staff 20m away. The Dumpy level was mounted at the midway and readings of Backsight (BS) and Foresight (FS) taken and recorded in a record book. Before readings were taken, the leveling screws were properly adjusted and spirit bubble of the instrument was brought to the centre of its run. Also, the first point i.e. the edge of the gully where the ranging staff was mounted was assumed Benchmark (BM100), adding this BM100 to the height of the instrument/collimation and subtracting the FS reading indicated the next turning point (Tp).

This exercise was carried out for up to five stations before closure along each survey line and readings recorded in the record register accordingly.

The same exercise was carried out for each of the selected 4 gully units and readings taken and recorded in the record register. Figures 2.1, 2.2, 2.3 and 2.4 indicate the gullies whose catchment areas were surveyed.

The venire theodolite was used to traverse the marked out catchment areas of the of gully units to indicate vertical and horizontal angles but that was after sensitive adjustments were made.

The ranging poles served the purpose of ranging –in the staff to avoid slanting staff and maintain a straight line. The tapes were used to measure distance. The arrows served the purpose of the necessary markings and intersections were done with pins.

Spades and hoes were used for removing obstructing stumps, anthills and leveling positions for instrument mounting. The matches were used to clear bushes along survey lines, for staff and instrument mountings.

2.3 Determination of Rainfall Intensity

Rainfall data was obtained from National Weather Station Oshodi Lagos. Next was the collected data vis-a-vis that on which Nwoke H.U, Nwaogazie I.L and Okoro, B. C (2012) carried out a "Dimensional analysis " in consideration of the local conditions of South Eastern Nigeria indicated insignificant difference, and hence the choice of their work for the added advantage of dimensional analysis. The works of the eminent scholars are stated below;

Table 2.2a: Rainfall data for Enugu

Average mount (mm)	**10.02**	**25.06**	**31.0**	**32.34**	**31.35**	**51.31**	**53.55**	**62.32**
Duration (hr)	0.2	0.33	0.5	0.67	0.83	1.0	1.5	2.0
Intensity (mm/hr)	50.10	75.94	62.00	48.38	37.81	53.31	35.10	31.19

Table 2.2b: Rainfall data for Owerri

Average mount (mm)	**15.91**	**21.65**	**20.72**	**27.76**	**32.05**	**70.39**	**61.17**	**82.18**
Duration (hr)	0.2	0.33	0.5	0.67	0.83	1.0	1.5	2.0
Intensity (mm/hr)	70.55	65.82	57.44	41.44	38.61	70.39	40.78	41.09

Table 2.2c: Rainfall data for Onitsha

Average mount (mm)	**11.73**	**15.4**	**24.92**	**29.45**	**28.04**	**50.55**	**54.26**	**60.12**
Duration (hr)	0.2	0.33	0.5	0.67	0.83	1.0	1.5	2.0
Intensity (mm/hr)	58.63	46.67	49.83	43.96	33.79	50.55	28.17	30.06

***Source*:** Nwoke H.U, Nwaogazie I.L and Okoro B.C (2012)

2.4 Determination of Runoff Coefficient

This was determined from the table 2.3 below proposed by Chow, VT (1962)

Table 2.3: Runoff coefficient for Urban Areas

Type of Drainage Area	Runoff Coefficient
Industrial Light areas	0.5 – 0.80
Heavy Areas	0.6 – 0.90
Parks / cemeteries	0.10 – 0.25
Play grounds	0.20 – 0.35
Rail road areas	0.20 – 0.40
Unimproved areas	0.10 – 0.30
Streets	0.70 – 0.95
Drives and walks	0.75 – 0.85
Roofs	0.75 – 0.95

2.5 Soil Classification

The soil for the research area was classified using mechanical analysis.

The equipment used include; Matchets, Soil Auger, Scale balance, Sieve shaker and Textural triangle Soil samples collection were achieved using ELE 510 soil Auger and ELE 109 Auger handle which increased leverage to enable driving augar into the soil, since this activity was carried out in the dry season, pulverization and proper mixing of soil samples were carried out with bare hands and leaves, roots, stones and other foreign materials were expunged with ease.

A set of 5 sieves with diameter ranging from ½ - 4mm were stacked in a manner that the diameters / aperture of the sieves cascade. A sample weight of 70g was weighed out with the analytical scale balance and deposited on the topmost sieve on

the stack rack, before placing on sieve shaker.
After 15 minutes, the quantity still remaining on top of each sieve was weighed out respectively and computed in percentages. The weight of the collected soil in the collection pan was weighed too. The various percentages deposited on the sieves and collection pan were traced in the USDA Textural triangle, the point of intersection adjudges the soil type.

2.6 Liquid Limit Determination
The cone penetration apparatus was used. The cone penetrometer used, ELE 530 is composed of stainless steel of 35mm long with a smooth polished surface at an angle of 30º. The equipment also has adjustable provision for cone height in relation to specimen for every operation. To carry out the test requires putting soil in standard containers, gently tampered and left for about 3 weeks. Varying quantities of water were also added to various containers in order to vary their moisture contents and simulate natural conditions. The moisture content of each container was determined using the ELE 514 cell and moisture meter. The cone penetrometer plunger was then brought against all the cups in rotation and readings of penetration indicated on the cone penetrometer dial gauge recorded. The recorded penetrations were then plotted against the moisture contents of those cups. Following, was drawing a straight line through plotted points and the cone penetration corresponding to 20mm is the liquid limit of the soil.

2.7 Soil moisture content determination
Moisture content was determined using Cacer's Principle (1993) 10g of soil was weighed to 0.001g accuracy into dry moisture Can of known weight (W_1).
The total weight of the air dry soil sample plus Can (W_2) was recorded.
Drying at 105^0C for 24hours was achieved with Genlab mechanical oven and was allowed to cool in a desiccator.
The dried soil sample plus Can were reweighed and recorded (W_3).

$$\%\text{ moisture content (MC)} = \frac{W_2-W_3}{W_3-W_1} \times \frac{100}{1}$$

2.8 Soil Bulk Density Determination
Bulk Density was determined using core method as described by Grossman and Reinsch (2002) [7].
A double-cylinder, drop-hammer sampler with a core was used to remove a cylindrical core of soil. The sampler head contains an inner cylinder and it was driven into the soil with blows from a drop hammer. The inner cylinder containing an undisturbed soil core was then removed and trimmed to the end with a knife to yield a core whose volume can easily be calculated from its length and diameter. The weight of this soil core was then determined after drying in an oven at 105°C for about 18-24 hours.

$$BD = Ms/Vt\ (gkm^3)$$

Where
BD = Bulk density,
Ms = $\frac{\text{Mass of oven dried soil}}{\text{Volume of soil (taken as volume of the cylinder)}}$

2.9 Soil Porosity Determination
Total porosity was computed from the bulk density as described by Vomocil (1965) [20].
The calculation is as follows

$$Tp = 1 - \frac{BD}{PD} \times \frac{100}{1}$$

Where,
Tp =Total porosity,
BD=Bulk density (g/cm3),
PD=particle density (2.56g/cm3)

2.10 Soil pH Determination
Soil pH was measured using 1:2.5 soil water and KCl ratio as described by Hendershot *et al* (1993) [8].
20g of soil was into two separate plastic sample bottles. 50ml of distilled water and 50ml of KCl in each of the plastic sample bottle were added. (This gave a soil water and KCl ratio of 1:2.5). It was allowed to stand for 30minutes and occasional stirring with a glass rod was done so that the solution equilibrates with the entire soil sample.
The Jenway 3505 hand held pH meter was first calibrated with standard buffer solutions (Buffer 4.0 and 7.0 pH) and the pH values of the soil in each plastic sample bottles were recorded.

2.11 Exchangeable K and Na Determination
Exchangeable K and Na was extracted using 1N neutral ammonium acetate (NH_4OAC) and determined photo metrically using flame photometer (Thomas, 1982).
5g of soil sample was weighed into container and 50ml of 1N NH_4OAC was added. With a mechanical shaker, it was vibrated for 1hour and decant into a beaker.
The filter selection of flame photometer was set to either Na or K and aspirated with de-ionized water for 15 minutes in order to allow the operating temperature to stabilize.
The nebulizer tube was inserted into the sample container and the aspiration rate was between 2 and 6ml/minute.
The meter readings from standard solutions and concentration of sodium and potassium were obtained.

2.12 Exchangeable magnesium and calcium determination
Exchangeable Magnesium and Calcium was determined using Ethelene Diamine Tetra-acetic Acid (EDTA) (Thomas, 1982).
5g of soil sample was weighed into container and 50ml of 1N NH_4OAC was added. With a mechanical shaker, it was vibrated for 1hour and decant into a beaker.
5ml of the aliquot was pipette into a conical flask and 50ml of distilled water added.
Also 4ml of ammonium buffer solution and 5ml 1N NaOH were added 3 drops of calcon indicator were added and titrated with EDTA solution from red to a clear blue colour.
Blank titration was carried out in the same manner and subtracted from the sample reading.
Calculation

$$Ca + Mg\ (g/kg) = \frac{\text{Xml x volume of solution}}{\text{10 x aliquot x sample mass}}$$

Where;
Xml= titre value – blank titre,
volume of solution= 50ml,

aliquot= 5ml,
sample mass= 5g

2.13 Organic carbon and Organic Matter Determination

Organic carbon was determined using the wet oxidation method (Nelson and Sommers, 1996) and organic matter determined by multiplying organic carbon with 1.724 (Van Bemmellin factor).

A representative sample was taken and grinds to pass through 0.5mm sieve.

2g of soil sample was weighed in duplicate and transfer to 250ml erlenmeyr flask 10ml of 1N K_2 Cr_2 O_7 solution was pipette accurately into each flask and swirl to disperse the soil.

20ml Conc. H_2SO_4 was added rapidly using an automatic pipette, directing the stream into the suspension. The flask was gently swirls immediately until soil and reagents were mixed, then swirl vigorously for 1 minute. The flask was allowed to stand on sheet of asbestos for about 30mins.

100ml of distilled water was added after standing for 30 minutes.

3-4 drops of indicator were added and titrated with 0.5N $FeSO_4$ solution. As the end point was approached, the solution took a greenish cast and then changes to dark green. At this point 2-4 drops of $FeSO_4$ were added until the colour changes sharply from green to red (Maroon colour) in reflected light against white background.

Blank titration in the same manner was carried out in order to standardize the dichromate.

Calculation:

% Organic C in soil =

$$\frac{(\text{Me } K_2\,Cr_2\,O_7 - \text{Me } FeSQ_4) \times 0.003 \times 100 \times f}{\text{g of air-dry soil}}$$

Where;
f (correction factor) = 1.33
Me = Normality of solution x ml of solution use

3. Results, design and discussion

3.1 Results

The results of the fieldworks and laboratory experiments are presented below a leveling / Elevation

Table 3.1a

LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL
1	1	100.2	1	2	103	1	4	112.1	1	5	116.1	1	6	116.7	1	7	111.6	1	8	102.0
2	1	100.4	2	2	104.5	2	4	114.5	2	5	116.2	2	6	116.2	2	7	111.6	2	8	103.5
3	1	100.2	3	2	105	3	4	115.3	3	5	116.3	3	6	111.9	3	7	100.5	3	8	104.0
4	1	100.2	4	2	108.2	4	4	114.6	4	5	117.2	4	6	118.4	4	7	103.1	4	8	105.0
5	1	105.1	5	2	116.5	5	4	116	5	5	116.4	5	6	118.5	5	7	111.2	5	8	106.5
6	1	105.2	6	2	117.2	6	4	113.7	6	5	116.3	6	6	117.0	6	7	104,5	6	8	106.5
7	1	100.4	7	2	111.4	7	4	114.8	7	5	111.8	7	6	116.9	7	7	115	7	8	104.8
8	1	100.2	8	2	113.5	8	4	115.8	8	5	115.0	8	6	111.1	8	7	116.7	8	8	102.7

Table 3.1b

LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL
1	1	110.8	1	2	110.1	1	4	114.0	1	5	111.2	1	6	108.2	1	7	103.1	1	8	111.0
2	1	111.2	2	2	110.4	2	4	113.1	2	5	110.1	2	6	108.3	2	7	104	2	8	101.5
3	1	111.1	3	2	110.8	3	4	115.4	3	5	110.8	3	6	107.2	3	7	102	3	8	102.4
4	1	111.2	4	2	111.0	4	4	111.2	4	5	110.1	4	6	108.4	4	7	103	4	8	105.1
5	1	111.0	5	2	110.8	5	4	111.3	5	5	110.6	5	6	105.5	5	7	107	5	8	105.0
6	1	111.5	6	2	111.2	6	4	110.1	6	5	110.4	6	6	106.4	6	7	109	6	8	105.2
7	1	111.0	7	2	111.5	7	4	111.2	7	5	110.2	7	6	103.1	7	7	101	7	8	104.1
8	1	111.5	8	2	111.0	8	4	111.3	8	5	110.0	8	6	105.0	8	7	105	8	8	103.2

Table 3.1c

LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL	LL	ST	RL
1	1	100.8	1	2	110.7	1	3	118.2	1	4	117.1	1	5	118.1	1	7	114.2	1	8	108.2
2	1	110.5	2	2	114.0	2	3	111.3	2	4	118.2	2	5	118.2	2	7	115.2	2	8	108.6
3	1	112.6	3	2	115.2	3	3	118.4	3	4	117.2	3	5	119.4	3	7	113.9	3	8	107.5
4	1	112.3	4	2	114.1	4	3	119.1	4	4	118.4	4	5	115.5	4	7	113.8	4	8	106.4
5	1	112.6	5	2	113.2	5	3	111.4	5	4	117.2	5	5	118.3	5	7	114.0	5	8	106.4
6	1	113.4	6	2	114.6	6	3	117.2	6	4	118.3	6	5	117.6	6	7	113.9	6	8	107.2
7	1	114.5	7	2	115.6	7	3	116.4	7	4	116.5	7	5	118.4	7	7	114.5	7	8	105.1
8	1	113.2	8	2	116.1	8	3	117.2	8	4	117.2	8	5	113.4	8	7	115.6	8	8	106.8

Table 3.1 d

Gully Unit D																				
LL	**ST**	**RL**	**LL**	**ST**	**RL**	**LL**	**ST**	**RL**	**LL**	**ST**	**RL**	**LL**	**ST**	**RL**	**LL**	**ST**	**RL**	**LL**	**ST**	**RL**
1	1	100.3	1	2	103.0	1	3	107.5	1	4	111.1	1	5	107.8	1	7	100	1	8	129.2
2	1	100.6	2	2	103.0	2	3	107.6	2	4	111.3	2	5	108.1	2	7	101.2	2	8	129.4
3	1	101.1	3	2	104.1	3	3	107.8	3	4	111.4	3	5	103.2	3	7	100.3	3	8	129.5
4	1	100.3	4	2	104.0	4	3	108.2	4	4	112.1	4	5	100.3	4	7	100	4	8	127.6
5	1	100.4	5	2	105.0	5	3	107	5	4	112.4	5	5	100	5	7	114	5	8	130.1
6	1	100.7	6	2	105.0	6	3	106	6	4	103.4	6	5	111.4	6	7	113	6	8	132.1
7	1	100.8	7	2	104.2	7	3	103.1	7	4	102.1	7	5	111.2	7	7	113	7	8	133.4
8	1	100.9	8	2	104.3	8	3	100.3	8	4	103.4	8	5	111.3	8	7	113	8	8	134.5

LL- Leveling Line, ST- Station, RL- Reduced Level/ Elevation

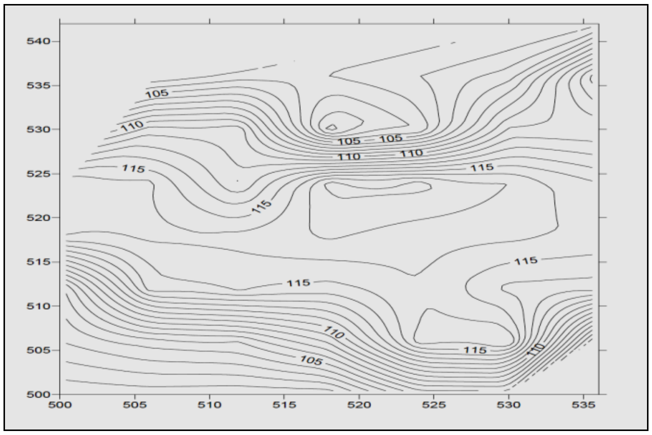


Fig 3.1a

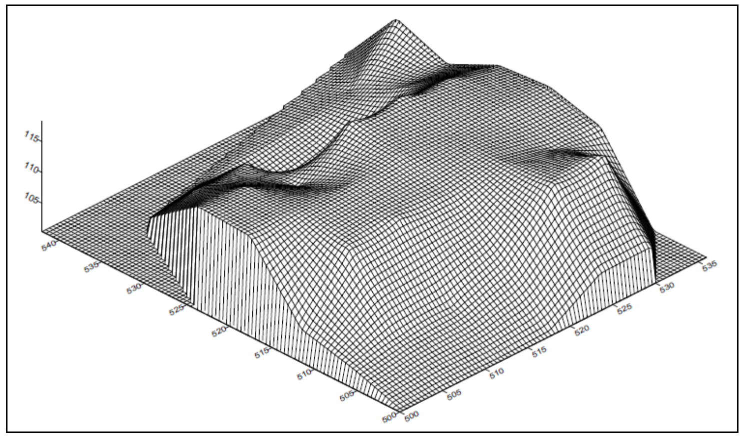


Fig 3.1.1

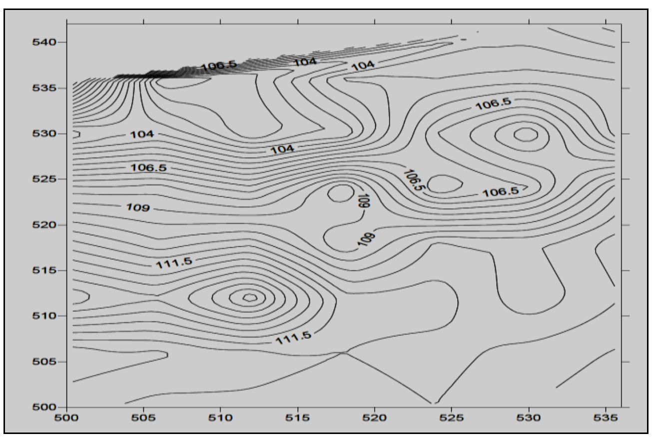


Fig 3.1b

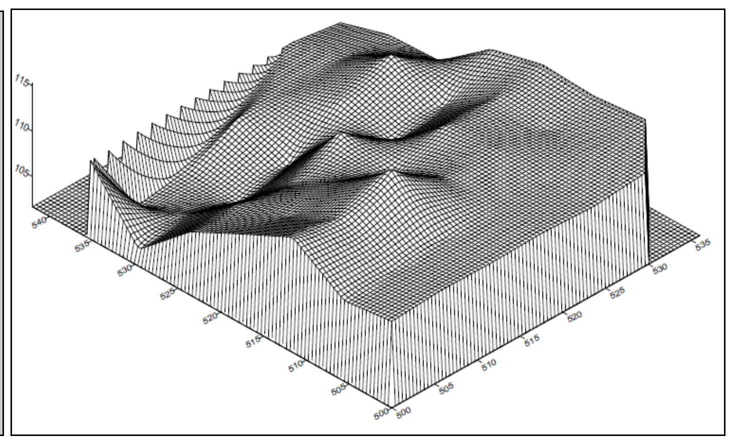


Fig 3.1.2

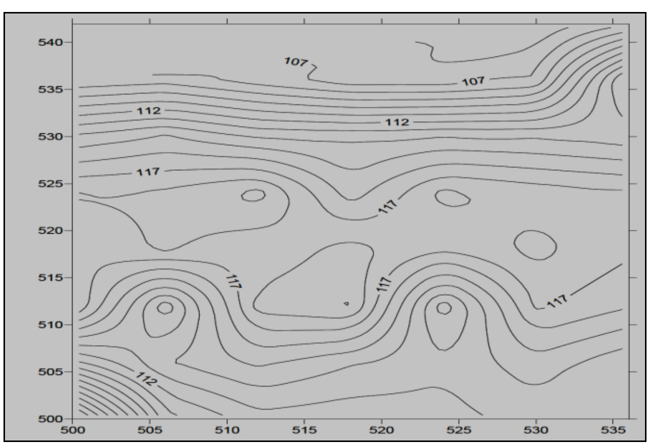


Fig 3.1c

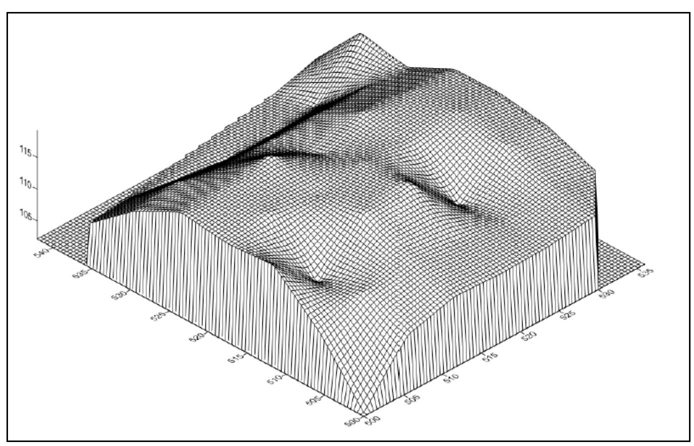


Fig 3.1.3

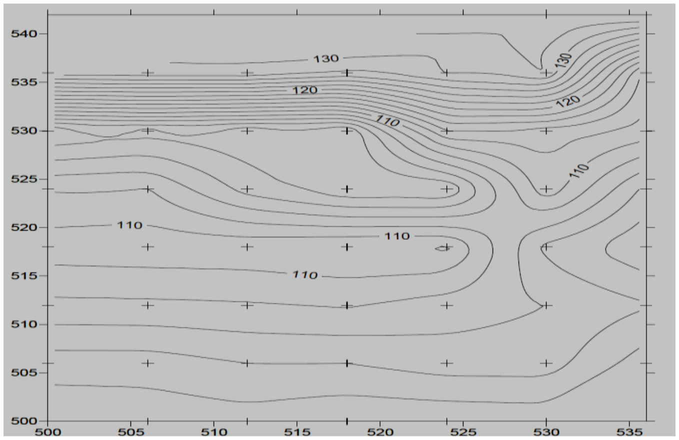


Fig 3.1d

Fig 3.1a - 3.1d: Shows the plotting of the elevations indicated in tables 3.1a – 3.1d

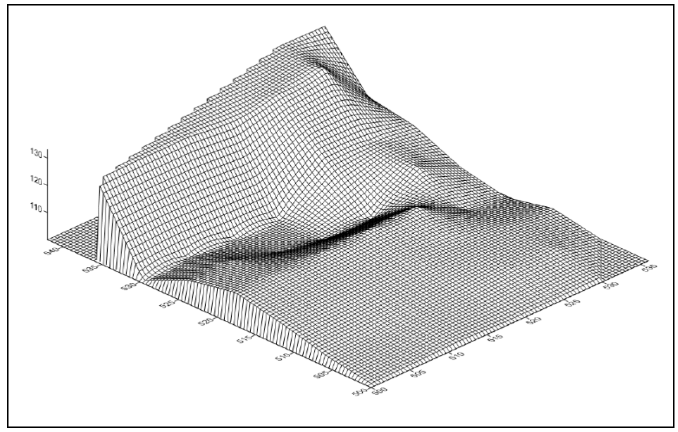
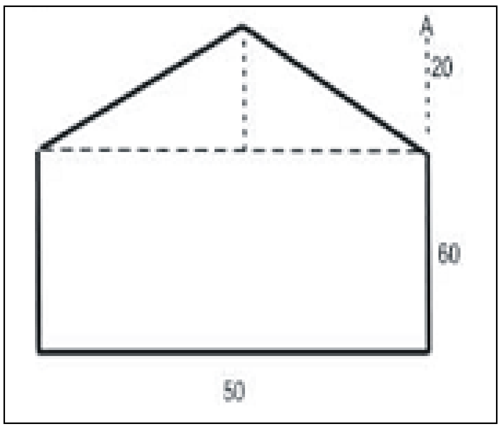


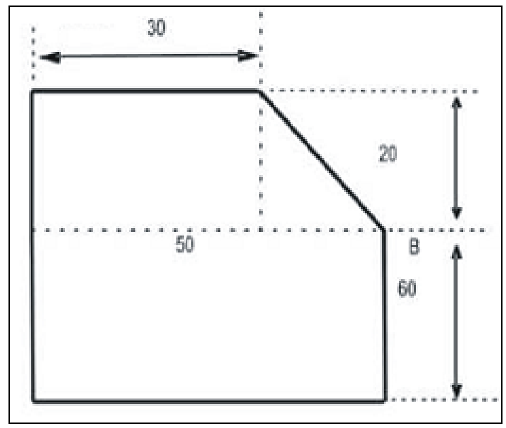
Fig 3.1.4

Fig 3.1.1 - 3.1.4: Shows the orthographic projection of the study area



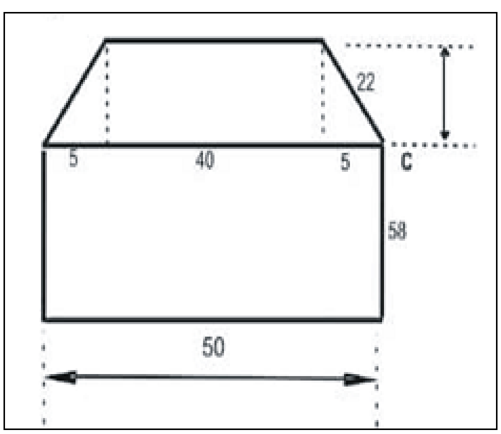
Area of Fig 3.2a =
½ base x height + L x W
½ (50 x 20) + (50 x 60)
= 500 +3000 = 3500m^2

Fig 3.2a



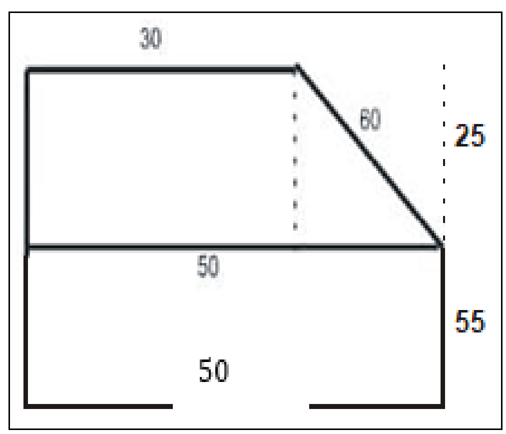
Area of Fig 3.2b =
½ sum of parallel sides x height + L x W
=½ (30 + 50) x 20 + (50 x 60)
= 800 + 3000 = 3800 m^2

Fig 3.2b



Area of Fig 3.2c =
½ (base x height) x 2 + (L x W) + (L x W)
= ½ (5 x 22)2 + (40 x 22) + (58 x 50)
= 110 + 880 + 2900 = 3890m^2

Fig 3.2c



Area of Fig 3.2 d
½ sum of parallel sides x height + L x W
½ (30 + 50) x 25 + (50 x 55)
= 1000 + 2750 = 3750 m^2

Fig 3.2d

Fig 3.2a-3.2d: Shows the catchment areas of the 4 selected Gully units

3.1.2 Rainfall Intensity for Uwani – Amokwe

The Dimensional analysis carried out by eminent researchers; Nwoke, H.U., Nwaagonzie, I.L and Okoro, B.C. in 2012 already revealed a rainfall intensity of 75.94mm/ hr for Enugu city as deduced from table 2.2a and Uwani – Amokwe is adjacent Enugu city, therefore adopt this 75.94mm /hr intensity for Amokwe since it is located in Udi and LGA which is about 15km from Enugu city.

3.1.3 Coefficient of Runoff (C) for Uwani – Amokwe

From the table proposed by Chov, TV (1962) runoff coefficient was presented for different soil surface covers, subjective examinations perceives Uwani Amokwe as a "Light area" and therefore a coefficient of runoff (c) of 0.80 is chosen (see table 2.2b).

3.1.4 Determination of Runoff Discharge (Q)

The rational formula is commonly adopted and it states

$$Q = CIA$$

Where,

Q = Runoff discharge, $m^{3/}s$
C = Runoff coefficient (c) dimensionless
I = Intensity of rainfall, mm/hr
A = Area of watershed, m^2

To compute discharge (Q) for the 4 gully units

C = 0.8
I = 75.94mm /hr
A = $3500m^2$, $3800\ m^2$, $3890\ m^2$ and $3750\ m^2$

$$Q1 = \frac{0.8 \times 75.94 \times 10^{-3} \times 3500}{60 \times 60} = 0.060\ m^{3/}s$$

$$Q2 = \frac{0.8 \times 75.94 \times 10^{-3} \times 3800}{60 \times 60} = 0.064\ m^{3/}s$$

$$Q3 = \frac{0.8 \times 75.94 \times 10^{-3} \times 3890}{60 \times 60} = 0.066\ m^{3/}s$$

$$Q4 = \frac{0.8 \times 75.94 \times 10^{-3} \times 3750}{60 \times 60} = 0.063\ m^{3/}s$$

3.1.5 Design of Trapezoidal Channel

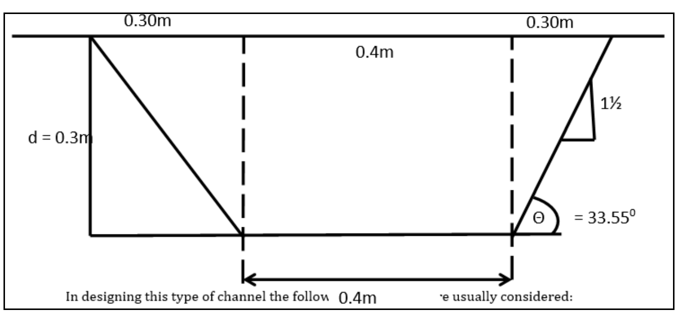


Fig 3.2e

In designing this type of channel the following parameters are usually considered:

1. Depth of the channel (m)
2. Cross – sectional area (m^2)
3. Bedslope
4. Bottom width
5. Velocity of flow in channels (m/s)

From the foregoing, the area of the watershed Hydraulic structure can be computed.

Also, from the continuity equation of open channels Q = VA.

Where;

Q = Peak rate of runoff of watershed
A = Area of hydraulic structures
V = Average velocity channel flow Recall,
Q = $0.060m^3/s$, $0.064m^3/s$, $0.066\ m^3/s$, and $0.063\ m^3/s$,
A = ?
V = 0.60 m/s, (see table below for soil texture of the research area)

Table 3.2: Permissible velocities for various soil textures

Type of soil	Maximum velocity (cm/sec)
Loamy sand	45
Sandy loam	60
Loam, silt loam silt	75
Clay loam	90
Gravel soil and clay	100

***Source*:** Michael and TP Ojha (2009)

Since: $Q = VA$

$$A = \frac{Q}{V}$$

Therefore,

$$A1 = \frac{0.060}{0.60} = 0.1m^2$$

$$A2 = \frac{0.064}{0.60} = 0.11\ m^2$$

$$A3 = \frac{0.066}{0.60} = 0.11\ m^2$$

$$A4 = \frac{0.063}{0.60} = 0.11\ m^{2,}$$

From the foregoing, the expected areas of the hydraulic structures to be constructed are; 0.1 m^2, $0.11m^2$, $0.11m^2$ and $0.11m^2$ for gullies A, B, C and D respectively. However, to save time and materials, it better to design one representative trapezoidal channel for every gully unit, since the discharges as, observable from the studied gullies, are almost the same.

Side Slopes

This was carefully selected to avoid sloughing. The table below shows maximum side slopes of open channels.

Table 3.3: Maximum side slopes of open channels

Soil	Side slopes – Horizontal Shallow channels up to 1.2m	Vertical Deep channel 1.2m
Peak and milk	Vertical	¼ : 1
Stiff (heavy) clay	½ : 1	1 : 1
Clay or silt loam	1: 1	1½ : 1
Sandy loam	1½ : 1	2 : 1
Loose sand	2 : 1	

Source: B.A. Etcheverry Copyright, 1931, McGraw – hill Book Company.

Since the soil is sandy loam, a value of 1½ : 1 was selected from the above table.

Bottom width: The bottom width for most efficient cross – section and minimum of excavation is determined by the formula.

$$b = 2d \tan {}^{\theta}/_{2} = 2d/\left[2 + (Z^2 + 1)^{1}/_{2}\right]$$

Where

b = Bottom, width (L)

d = Design depth (L)

θ = Sideslope angle (degrees)

z = Sideslope ration (L/1) (Horizontal / vertical)

Side slope = $1^{1}/_{2} = 1$

Tan θ = $\frac{1}{1^{1}/_{2}} = {}^{1}/_{1} \times {}^{2}/_{3} = {}^{2}/_{3}$

θ = tan - $^{2}/_{3}$ = 369 oral or = 21.144^0

θ = $\underline{21.144}$ = 33.55^0

Recall d= 0.3m

b = 2d tan $\frac{\theta}{2}$

= 2 x 03 x tan 33.55^0

= 2 x 0.3 x (tan 33.55^0 = 0.6631)

= 2 x 0.3 x 0.6 633

= 0.39798m Ω 0.40m

ii. Area of Trapezoidal channel

d = 0.3m

b = 2btan θ/2

= 2 x 0.3 x 0.6631

= 0.39798m Ω 04.m

A = ½ (Tw + Bw) D

= ½ (0.6 + 0.40) 0.3

= $0.15m^2$

Welted

Applying Pythagoras theorem

$y^2 = X^2 \times 2^2$

$y^2 = 0.3^2 + 0.1^2$

= 0.09 + 0.01

= 010M

P = 0.40 + (2 X 0.31) =1.02m

Rn = $\frac{A}{P} = \frac{0.15m^2}{1.02m}$

= 0.147m

3.1.7 Soil Type

The result of the mechanical analysis is as shown in table 3.2 below.

Table 3.4: Particle size distribution.

Particle(mm) size /sieve size	0.5–1mm	0.25–0.5mm	0.1–0.25mm	0.05–01mm	0.002-0.05mm	<0.002
Percentage (%) Composition	45	25	10	8	8	4

Tracing the various the percentages in the textural triangle in the USDA Textural triangles points at sandy loam.

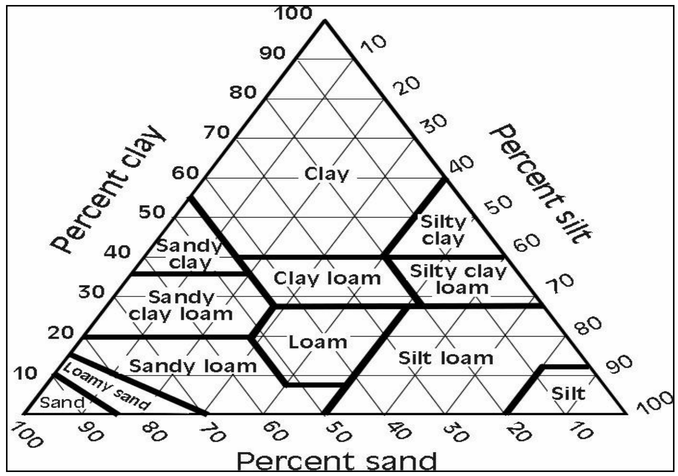


Fig 3.3: USDA Textural Triangle.

3.1.8 Liquid Limit Determination

The recorded penetrations against different levels of moisture are indicated in table 3.4 below.

Moisture content (%)	10	18	26	32	35	50	55	60	75
Cone (mm) penetration	13	17	29	38	42	46	30	58	65

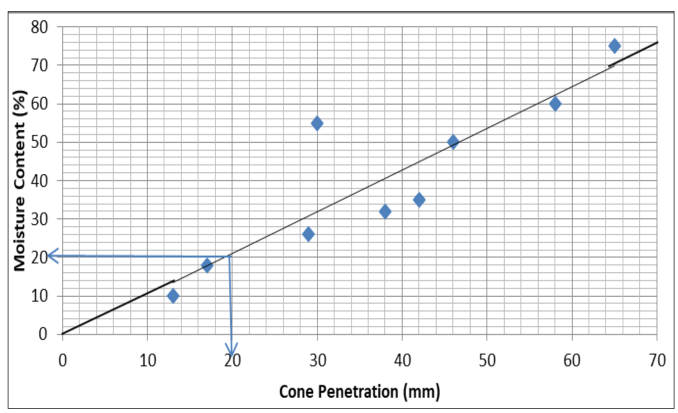


Fig 3.4: shows moisture content potted against cone penetration.

Table 3.5: Shows physicochemical properties of Uwani Amokwe soil

Soil Property	Gully Unit A Mean	Gully Unit B Mean	Gully Unit C Mean	Gully Unit D Mean
BD (g/cm^3)	2.2	1.6	1.8	2.0
MC (%)	10.5	10.6	10.3	10.9
Porosity	45.5	44	43.0	43
pH	5.8	6.0	5.4	6.3
Ca	6.3	8.3	9.5	5.9
Mg	3.1	3.8	2.3	2.8
K	3.7	2.3	1.4	2.0
Na	0.8	2.0	0.8	1.8
OC	0.5	0.4	0.6	0.4
OM	0.9	0.7	1.0	0.7

BD-Bulk Density, MC-Moisture Content, OC- Organic Carbon, OM-Organic Matter

3.7 Design of Culverts

A culvert is necessary at road junctions and usually consists of three to four spans and length of spans not more than 3 metres. The component of the culvert are: Abutment, wing walls, arches or desk slab, parapet, foundation, floor pitching
For the purpose of this design a box culvert is chosen.
Fig.3. 5 – below shows the geometry of box culvert design.

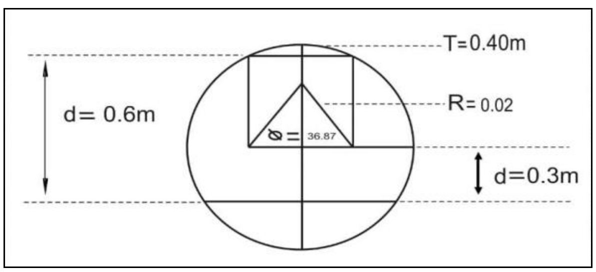


Fig 3.5

From the continuity equation
Q = AV
A = Q/V
Q = 0.06m3⁄s, discharge of watershed
V = 2.0m/s very few materials will stand velocities in excess of 1.5m/s
(A.M. Michael *et al*)
Therefore a velocity of 2m/s was adopted for the line pipe culvert

(i) A = 0.06/2.0 = 0.03m^2
In view of the computed area, the fishing equation can now be used to compute the various parameters of the culvert.

θ	=	Cos $^{-1\ (1 - yr)}$	………………..	i
Tw	=	r (1 – Cos θ)	………………..	ii
A	=	r2 (θ - Cos θ sin θ	………………..	iii
P	=	2r (θ)	………………..	iv
T	=	2r (sin θ)	………………..	v
Rh	=	A/P	………………..	vi

(ii) Since θ = Cos-1 (1 - yw⁄r)
Cos - (1- 0.0.06/0.3)
Cos -1 (1 – 0.2)
Cos-1 (0.8) = 36.87º

(iii) Area of flow (A),
A = r2 (θ - Cos θ Sin θ)
A = (0.3)2 (36.87 - Cos 36.87 x Sin 36.87)
= 0.09 (36.87) - 0.6755
= 0.09 (36.87 - 0.4980 x 0.7373)
= 0.09 (36.372) = 3.27m^2

(iv) Welted Perimeter (P),
P = 2r (θ)
= 2x 0.3 (36.87)
= 0.6 (36.87)
= 22.12m

(v) Top width of the water surface (T)
T = 2r (Sin θ)
T = 2 x 0.3 (Sin 36.87)
= 0.6 (0.7373)
= 0.44m

(vi) Hydraulic radius (Rn),
Rn = A/ P
= 3.27/22.12
= 0.15m

3.2 Discussion

Reduced levels/ elevations indicate a progressive rise from gully heads to terminal leveling points. This was why gravity flow down the gullies devastated downstream portions of the gullies. The implication is upwards and extensive ravaging of the gullies environment with time.
The computed discharge of about 0.06m^3/s is for each of the four gully units, even with variation in catchment areas, yielding offensive runoff suggests, a common design of engineering works for the entire area. However, if the erosion menace is allowed to aggravate with time, a more and extensive discharge control works would be needed.
The survey lines are at 10m equidistant in both horizontal and vertical directions, and hence compares heights. It is clearly observable that heights equidistant, from a contour line is usually of approximate difference of not more than 3, see tables 3.1a to 3.1d and figures 3.2a to 3.2d. The contour lines that traversed and marked out areas figs. 3.1b – 3.1d were marked out based on sharp drop in levels vis-à-vis progressive rise in levels. The sharp drop in level clearly indicates that gravity flow changes direction to inconsequential catchment other than the gully catchment under study. Also the catchment areas of gullies A, B, C and D were computed by adopting the appropriate geometric formulae.
The traced out contour lines defined grid lines for drain structures to reduce volume and cost of establishment of erosion control structures.
The mean soil bulk density for the four sampled gullies revealed 2.2, 1.6, 1.8 and 2.0g/cm^3 for gully sites A, B, C and D respectively. This may be attributed to the different sites that they exist.
Moisture content values for gully sites A, B, C and D showed 10.5, 10.6, 10.3 and 10.9% respectively. This indicates that gully erosion is more severe in the area because the soils are dominated by sandy materials, which makes it more

susceptible and consequent increase in gully erosion more especially the depths. This findings agreed with those of others studied by Yakubu, (2004) [22], Ofomata, (2007) [15] and Rahab, (2008) [19] and Mbaya (2012) who indicate that the dominance of sand proportion in most Nigerian savanna soils has accelerate gully erosion.

The average pH values for the four gully sites are 5.8, 6.0, 5.4 and 6.3 for gully site A, B, C and D respectively; This implied that the soil in the study area is moderately acidic The implication of this finding is that the soil of the study area may not be affected by micro-organisms that work on organic matter which might enhance the binding of soils to resists erosion and runoff impact

The overall pattern of exchangeable Ca, Mg and K for gully site A, B, C and D indicated 6.3, 8.3, 9.5 and 5.9 for Ca; 3.7, 2.3, 1.4and 2.0 for K and 3.1, 3.8, 2.3 and 2.8 for Mg respectively. They showed a general increase in mean values of the study area.

Exchangeable Na on the other hand showed an irregular increase and decreased in mean values of the gully walls. The mean values for gully site A, B, C and D in the area are 0.8, 2.0, 0.8 and 1.8 respectively. The possible variations might be due to mineral constituent of some waste disposal and the sewage that are washed away into these gully sites.

The implication of these findings to biological control of gully erosion, is that increase in Na can have negative effects on the soil fertility and hence retard the growth of plants such as vetiver grass and paniculata which are regarded as the most effective method of controlling gully erosion because of its affordability, accessibility and adaptability.

The results of soil organic matter content (OMC) showed that the mean values of gully site A, B, C and D are 0.9, 0.7, 1.0 and 0.7 respectively. The overall pattern of variation of organic matter content, revealed a downward increases in the organic contents. The possible causes of these might be attributed to leaching of the organic matter down the valley floors of the gully sites.

4. Conclusion

The outcome of the evaluation of soil erosion menace at Uwani Amokwe community is stated below

1. The erosivity index for the locality is 75.84m/hr which in combination with other factors (erodibility) pose erosion threat.
2. The soil type of the locality is sandy loam, which is highly vulnerable to erosion.
3. The result of cone penetrometer test is 24%, beyond which working the soil will damage it
4. An average discharge of $0.06m^3/s$ was computed for each of the 4 worsened gully units under study hence setting the stage for geologic erosion which is capital intensive in handling.
5. The elevation indicated progressive rise from gully head to the point of termination of the catchment area hence ensuring natural gravity drain towards the developed gullies.
6. A commensurate capacity trapezoidal channel and culvert were designed as engineering measure and recommend agricultural practices prescribed. Furthermore, the existing gullies should laid with gabions and gabion mattresses.
7. The physicochemical properties of Uwani Amokwe soil to be improved through good organic manure application.

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