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Full Length Research Paper

Evaluating soil erosion in the Benin metropolis, Edo State, Nigeria

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This research study examined the menace of soil erosion in the Benin metropolis. Based on this, the following objectives were analyzed: the causes of soil erosion by water in the Benin metropolis, the type of soil erosion and the management techniques of soil erosion in the Benin metropolis. To meet these objectives, data used for this study were collected from both the primary and secondary sources of data collection. To do this, the metropolitan city of Benin was divided into 12 areal units for easy collection of data. Also, the perception people have regarding soil erosion was sampled. For geologic or normal soil erosion, rainfall factor is the main cause of soil erosion followed by soil character. Whereas, for the accelerated factor of soil erosion, uncontrolled construction especially buildings is the major human factor of soil erosion followed by increased urban land use. The findings and recommendations were made on the need for gully reclamation, erection of retaining walls, use of erosion brakes, land use zoning system and above all construction of side drains and tunnel.

Key words: Climate, rainfall, geologic, factor, evapotranspiration.

INTRODUCTION

Soil erosion is the removal of soil resources from one location and then transported and finally deposited elsewhere. It may also be referred to as the wear and tear of the earth surface brought about by agents of denudation such as water, wind, glacier or ice as well as human activities. Soil erosion therefore is the physical removal of all parts of the soil by running water, wind or other agents of erosion and transportation (Aziegbe, 1997). Also, Chup (2007) stated that soil erosion is the partial or complete removal of surface soil. According to him, soil erosion is a denudation process which requires the presence of moving media such as running water, waves, wind and glacier.

The precise meaning of erosion is sometimes vague even to the earth scientist. Over the years, three categories of soil erosion have been identified and distinguished on the basis of the transporting medium (Aziegbe, 2006). They include: glacial erosion, which refers to the entrainment and transportation of materials in an ice matrix; deflation erosion, which refers to the entrainment and transporting of materials due to wind; and fluvial erosion which refers to the entrainment and transportation of materials due to water flow in the liquid phase (Aziegbe, 2006). This paper is restricted to fluvial erosion as it affects the physical landscape in the Benin metropolis.

After rainfall, surface flow will occur, this happens when the rate of precipitation exceeds the rate of percolation and evapotranspiration (Faniran et al., 2006). This may be in form of sheet or channel flow. There are many types of soil erosion by water. These are splash erosion, sheet erosion, rill erosion, gully erosion, tunnel erosion and stream bank erosion. Splash erosion or rain drop impact represents the first stage in the erosion process. Sheet erosion is responsible for extensive soil loss in both cultivated and non-cultivated environments. Rill erosion results from the concentration of surface water into deeper and faster – flowing channels while gully erosion is responsible for removing vast amount of soils and tunnel erosion is caused by the movement of excess water through dispersive subsoil.

Soil erosion could be normal or accelerated. Normal or geologic soil erosion refers to the slow removal of soils and other particles by the natural processes of denudation while accelerated soil erosion is man-induced. Rainfall is a key factor in soil erosion by water.

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First and foremost, raindrops cause rain splashes, some of the soil particles upon which it drops are moved both vertically and horizontally. The quantity removed is a function of the resistance of the soil in question and environmental influences on soils like temperature, evapotranspiration, amount of rainfall and topography. Also, soil texture, stability, intensity of rainfall and the drop velocity and size determine how much soil will be displaced by raindrop impact.

Study objectives

The objectives of this paper are to examine the main causes and types of soil erosion by water in Benin metropolis and the management techniques that will help to ameliorate them.

METHODOLOGY OF STUDY

Map of the Benin metropolis was drawn to show some of the areas that have been ravaged by soil erosion. The study area was divided into 12 different areal units or zones for easy collection of data (Figure 1). Data were obtained from both primary and secondary sources. Primary data were collected through the administration of questionnaires, while secondary data were sourced from records provided by the Ministries of Environment, Works and Transport and Local Government Councils.

A total of 600 questionnaires were administered randomly by sampling. A total of 50 questionnaires were administered in each zone or areal unit which are mainly erosion prone areas. The same number of questionnaires was administered in each zone since all of them are affected by one form of soil erosion or the other. Within each local zone, the simple random sampling technique was used to select areas that are affected by soil erosion while in each selected area, stratified sampling was used to select respondents for interviews. Out of the six hundred questionnaires distributed, five hundred and ninety eight were retrieved. This represents 99.7% response. Most respondents ticked more than one answer hence the number of respondents is 616 as shown in Table 2.

RESULTS AND DISCUSSION

Causes of soil erosion in the Benin metropolis

Soil erosion by water is mainly caused by two major factors. These are the geologic and accelerated factors. The geologic factors are mainly natural factors that cause soil erosion by water, which include rock type, topography and soil characteristics, while the accelerated soil erosion is man induced.

People's perception about physical factors of soil erosion

Physical factors are those natural factors that constitute most of the elements that make up our physical environment. Such factors include rainfall, soils, rivers, landscape, relative humidity, vapor, pressure and temperature. Physical factors are quite natural and so their impact is very high in causing soil erosion by water especially in subequatorial humid tropical climate like the study area. Most of these geologic factors of soil erosion by water in the Benin metropolis are briefly discussed below.

High rainfall which ranges between 2000 and 2200 mm annually is one of the major causes of soil erosion in the Benin metropolis (NIFOR, 2012). High intensity rainfall makes surface runoff to accumulate within a short time throughout the city. Benin metropolis is associated with lack of proper drainage system, runoff from several sections of the drainage basin accumulates on the land. The resultant effect is that severe flooding is experienced, many roads are silted up and rendered impassable and this has created life and property threatening situation to the entire inhabitants in the Benin metropolis as revealed by this study. In Table 1, among the assessment of the respondents' perception of natural causes of soil erosion, high rainfall constitutes the highest. The highest respondents being those who live in Ugbeku/Ihunmwinrin and environs with a response of 12 and 21.1%. Among the total responses as far as natural causes of soil erosion is concerned, high rainfall also ranked number one as shown in Table 1 with a respondents of 120 and a percentage of 19.5.

Soil characteristics are another major geologic cause of soil erosion in the Benin metropolis. The geology or characteristics of the soil type in the Benin metropolis can be classified as ferralitic soils on loose sandy sediments and the infiltration and percolation of water is a function of soil type which invariably affects the level of soil erosion in the study area. In Table 1, soil characteristics ranked second out of the total responses of natural factors that cause soil erosion in the Benin metropolis with a total response of 91 which constitute 15.1% of the respondents. Also, in Table 1, the people of Idumuinbioto, Evboriaria, Isenmwenro and environs have the highest respondents of 10 with 20%. Other responses are as spelt out in Table 1.

Topographical factor is yet another major geologic cause of soil erosion in the Benin metropolis. Both the length and steepness of land slope affects the rate of soil erosion by water. The two effects have been evaluated separately in research and are represented in the soil loss equation by L and S respectively. In field application, the two factors are considered as a simple topographic factor LS. LS is the expected ratio of soil loss per unit area from a field slope to that of a standard plot size under identical conditions (Goudie, 1981). Slope point is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or the runoff water enters a well defined channel that may be part of a drainage network or a constructed channel. In the

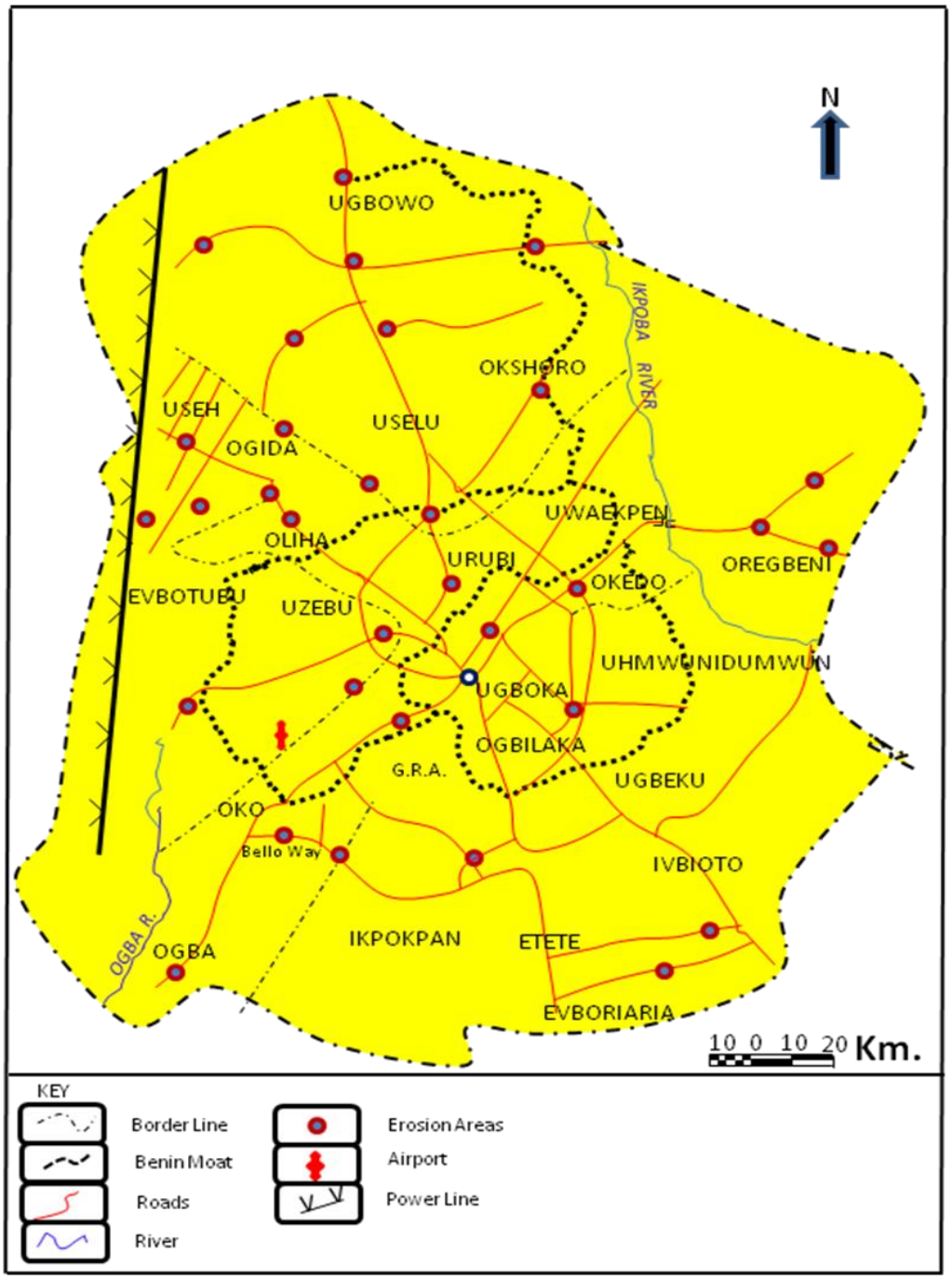

Figure 1. Location/division of areal units of erosion prone areas in the Benin metropolis.
A. Airport Road and Environs (Elema and Ighiwiyisi-Eweka, Evian Quarters).
B. Aruosa/Ogbelaka and Environs.
C. Uzebu Quarters and Environs.
D. Evbogida Quarters (Siluko Road, Teachers House, Erhunmwunse Street and Environs).
E. Benin Auchi Road (Eyaegie, Tamboga Road, Ogiso/Osunde Street and Environs).
F. Urubi Quarters (Adolor College Road, Eyeye Street, Eagle Furniture Road, Uselu Lagos Road).
G. Okhoro Quarters (Upper Lawani) and Environs.
H. Textile Mill Road and Environs (Uwelu Road, Cannan Street and Environs).
I. Uwelu/Ugbowo Axis and Environs (Uwasota, Ojo Axis, etc).
J. Idumuivbioto / Evboriaria / Senmwenro Environs (Dumez Road and Environs).
K. Ugbeku / Ihinmwinrin and Environs.
L. Benin Technical High School and Environs.
Source: Cartographic Studio A.A.U, Ekpoma, 2012.

Table 1. Assessment of the respondents perceived natural causes of soil erosion problems.

Causes	A	%	B	%	C	%	D	%	E	%	F	%	G	%	H	%	I	%	J	%	K	%	L	%	Total
Soil characteristics	7	13.7	6	11	7	14.9	8	14.8	8	16	7	13	8	15.4	7	15.2	8	16.7	10	20	9	15.8	8	16	93
High rainfall	10	19.6	9	16.7	10	21.3	9	16.7	10	20	10	18.5	10	18.2	11	23.9	9	18.7	11	22	12	21.1	9	18	120
Topographic factor	5	9.8	7	13	8	17	8	4.8	6	12	6	11	11	20	8	17.4	7	14.6	8	16	8	1.4	6	12	88
Erodibility factor	6	11.8	8	14.8	6	12.8	7	13	6	12	7	13	7	12.7	6	13	8	16.7	6	12	6	10.5	7	14	80
Vegetation	8	15.7	9	16.7	7	14	9	6	11	7	14	9	16.7	6	11	5	10.9	6	12.5	5	10	12.3	6	12	81
Land surface stability	7	13.7	8	14.8	5	10.6	9	16.9	7	14	10	18.5	8	14.5	4	8.7	5	10.4	4	8	8	14	8	16	83
Climate change	8	15.7	7	13	4	8.5	7	13	6	12	5	9.1	5	10.9	5	10.4	6	12	7	12.3	6	12.3	6	12	71
Total	51	100	54	100	47	100	54	100	50	100	54	100	55	100	46	100	48	100	50	100	57	100	50	100	616

Source: Field Survey (2013).

Table 2. Natural factors of soil erosion.

Causes	Number of Respondents	Rank	Percentage
High rainfall	120	1	19.5
Soil characteristics	93	2	15.1
Topographical factors	88	3	14.3
Land surface stability	83	4	13.5
Vegetation	81	5	13.1
Erodibility factor	80	6	13
Climate change	71	7	11.5
Total	616		100

Source: Field Survey (2013).

questionnaires administered, topographical factor ranked 3rd with a total response of 88 and 14.3% as shown in Table 1. In Table 1, the people of Okhoro, Lawani and environs constitute the highest respondents of 11 with 20%. Other details are as shown in Table 1.

Land surface stability in the Benin metropolis influences the rate of soil erosion in the area. It was observed that as a result of land surface stability or nature of soil in the study area, the rate of runoff is usually very high and the runoff is not adequately channeled in many parts of the study area which has resulted into destruction of roads, houses, properties and even farm lands. Soil quality, structure, stability and texture can be affected by the loss of soil. The breakdown of aggregates and the removal of smaller particles or entire layers of soil or organic matter weaken the structure and even change the texture. Textural changes can in turn affect the water holding capacity of the soil making it more susceptible to extreme condition such as drought. Among the natural factors that cause soil erosion by water in the area of study, land surface stability ranked 4th with total respondents of 83 and 13.5% as shown in Table 2. In the study area, the land surface has been exposed to direct impact of rain splash and runoff as a result of the different land use types in the area which exposed the surface.

Vegetative and residual cover protects the soil

from raindrop impact and splash and tends to slow down the movement of surface runoff and then allows excess surface water to infiltrate. Soil erosion potential is increased if the soil has no or very little vegetative cover of plants and or crop residues (Faniran, 1986). The study area, being an urban center is associated with scanty vegetative cover which makes the place susceptible to soil erosion by water. The impact of soil erosion on plant or residual cover depends on the type, extent and depth of cover. Vegetation and residue combinations that completely cover the soil and which intercept all falling raindrops at and close to the surface are the most efficient in controlling soil. Partially incorporated residues and residual roots are also important as these provide channels that allow surface water to infiltrate into the soil. However, vegetation ranked 5th among the physical causes of soil erosion by water. This is with total respondents of 81 with 13.1% as shown in Table 2.

Erodibility factor which is also a natural cause of soil erosion in the Benin metropolis is defined as the resistance of the soil to both detachment and transport. Erodibility varies with soil texture, aggregate stability, stream length, infiltration capacity and organic chemical content (Ofomata, 2009). Soil erodibility factor also represent the ease with which a soil is eroded. It quantifies the cohesiveness of a soil and its resistance to detachment and transport. In Table 2, erodibility is a major natural factor that causes soil erosion in the Benin metropolis. The highest response is recorded with those living around Aruosa, Ogbelaka and environs and those living at Uwelu, Ugbowo axis and environs. They constitute total respondents of 8 with 14.8 and 16.7% respectively. Erodibility factor ranked 6th as a natural factor that causes soil erosion in the Benin metropolis with a total respondents of 80 and 13%.

The problem of soil erosion by water is not usually well pronounced on gently sloping surface, where sedimentation rather than erosion may be the problem. This is because erosion is a function of slope angle. In the study area, field observations of slopes reveal that they are of different forms, depending on the degree and pattern of steepness. The recognized slope forms in the Benin metropolis are convex, concave, cliff and constant slopes. These slope types present in the study area make soil erosion by water more prevalent in the area.

Climate change which has resulted to warmer atmosphere temperatures observed over the past decades is expected to result into extreme rainfall events. Studies on soil erosion suggest that increase rainfall amounts and intensities will lead to greater rates of erosion. Soil erosion rates are expected to change in response to changes in climate for a variety of reasons. The most direct is the change in the erosive power of rainfall. However, Table 2 shows that climate change is one of the major natural causes of soil erosion. It ranked seventh with total respondents of 71 and a total of 11.5%. Details of the responses are shown in Table 2.

Climate change has equally resulted because of the different human activities in Benin metropolis which has invariably disrupted natural features.

People's perception about human factors of soil erosion

Over the years, it has been argued that man is the principal actor in causing most of the ecological problems like soil erosion. This is caused by the activities of man to meet his daily needs. The interference of man with the natural environment in a bid to restore and enhance the quality of the environment has not yielded fruitful results compared to the damaged done to the environment. The activities of man such as uncontrolled construction of buildings, indiscriminate grading of urban roads, bush burning, mining, farming activities, increasing urban land use and indiscriminate removal of vegetation have all resulted into soil erosion by water in the area of study.

In the Benin metropolis, the quest for man to engage in the construction of buildings, factories and roads have greatly resulted to soil erosion by water in the area. The impact of road construction can be clearly seen in the deep gullies that are created along the roads. This is also because most of the roads are constructed without side drains especially adjoining streets in the metropolitan city. Also, open cast mining especially of sand in the area has greatly resulted into soil erosion by water. Tables 3 and 4 show human factors that can result into soil erosion by water in the study area.

The various human factors that can lead to soil erosion in the study area are: uncontrolled construction of buildings with total respondents of 119 or 20.3% as shown in Table 3. In Table 3, the people in the different zones responded as shown with respondents of 11 being the highest, while the percentages are at variance because of the different answers provided by the people. The details of this are however spelt out in Tables 3 and 4. The uncontrolled construction of buildings constitutes the highest degree of 73 which is closely followed by increasing urban land use with a total degree of 60.1. In the Benin metropolis, houses are compacted in virtually all the spaces and once rain falls on top of these roofs they are made to gather around houses to form channels. These channels later form a single stream or channel if the rains persist and if the intensity is high. The Benin moat which cut across the Benin metropolis has been built upon by some individuals and cooperate organizations without recourse to the danger it poses especially to soil erosion and flood in the study area. Simply because of high demand for vacant lands, drainage channels have been built upon across the metropolis.

Management and control measures of gully erosion in the Benin metropolis

The warmer atmospheric temperatures observed over the

Table 3. Assessment of the respondents' perceived human causes of soil erosion problems.

Causes	A	%	B	%	C	%	D	%	E	%	F	%	G	%	H	%	I	%	J	%	K	%	L	%	Total
Uncontrolled construction of buildings	11	20.8	10	20	9	17.3	8	17	12	25	11	22.4	10	20	9	19.6	10	20.8	11	23.9	10	19.6	8	17	119
Road construction	5	9.4	6	12	8	15.4	6	2.8	5	10.4	8	16.3	9	18	7	15.2	8	16.7	4	8.9	10	19.6	7	14.9	83
Farm systems	6	11.3	4	8	5	9.6	5	10.6	6	12.5	7	14.3	10	20	8	17.4	8	16.7	6	13	9	17.6	9	19.2	83
Increase urban landuse	10	18.9	9	18	9	17.3	10	21.3	8	16.7	8	16.3	6	12	7	15.2	7	14.6	8	17.4	8	15.7	8	17	98
Indiscriminate removal of vegetation	8	15.1	7	14	8	15.4	8	17	9	18.8	8	16.3	5	10	6	13	6	12.5	7	15.1	6	11.8	4	8.5	82
Low elevation of neighbourhood	9	17	8	16	9	17.3	7	14.9	4	8.3	3	6.2	4	8	5	10.9	5	10.4	6	13	5	9.8	6	12.8	71
Commercial activities	4	7.5	6	12	4	7.7	3	6.4	4	5.3	4	8.2	6	12	4	8.7	4	8.3	4	8.7	3	5.9	5	10.6	51
Total	53	100	50	100	52	100	47	100	48	100	49	100	50	100	46	100	48	100	46	100	51	100	47	100	587

Source: Field Survey (2013).

Table 4. Human factors of soil erosion.

Causes	Number of Respondents	Rank	Percentage
Uncontrolled construction of buildings	119	1	20.3
Increasing urban landuse	98	2	16.7
Farming systems	83	3.5	14.1
Road construction	83	3.5	14.1
Indiscriminate removal of vegetation	82	5	14
Low elevation of neighborhood	71	6	12.1
Commercial activities	51	7	8.7
Total	587		100

Source: Field Survey (2013).

past decades are expected to lead to a more vigorous hydrological cycle, including more extreme rainfall events. Studies on soil erosion suggest that increased rainfall amounts and intensities will lead to greater rates of erosion. Soil erosion rates are expected to change in response to changes in climate for a variety of reasons. The most important reason is the change in the erosive power of rainfall. Other reasons include changes in soil moistures due to shifting precipitation regimes and evapotranspiration which changes infiltration and runoff ratios; a shift in landuse may be necessary to accommodate new climate regimes and that soil erodibility changes due to decrease in soil organic matter concentrations in soils that lead to a soil structure that is more susceptible to erosion and increased runoff due to increase soil surface sealing and crusting (Pruski and Nearing, 2002).

Gully erosion like many other environmental crises is not without its own mitigating measures. The measure involved in the management is known as soil conversation. The effects of soil conversation process points to the fact that soils

Table 5. Measures to avert the problems of gully erosion in the Benin metropolis.

Control measures	Number of Respondents	Percentage
Landuse zoning	86	14.4
Side drains and conduit	84	14.1
Good budgeting allocation	84	14.1
Erosion brakes	76	12.7
Identifying erosion area	72	12.0
Concrete walls	54	9.0
Man's influence on land	46	7.7
Mapping the area	42	7.0
No response	54	9.0
Total	598	100

Source: Field Survey (2013).

can be restored, even quickly with large technical inputs. However, the result of an erosion process is so diverse and can get out of hand if not checked on time. In the Benin metropolis, the economic cost of managing and controlling soil erosion is very high and well beyond the reach of an average individual, especially gully erosion. On the control measures that can be put in place by the residents in the study area, Table 5 clearly explains this.

In Table 5, among the measures that one can adopt to remedy the problem of soil erosion, land use zoning system has a total response of 86 and 14.4%. This shows that if land use zoning system is adopted in the area of study, it will help to ameliorate the problem of soil erosion to a great extent. This is closely followed by construction of side drains and conduits and good budgeting allocation which have a total response of 84 and 14.1% each. Undoubtedly, most of the gullies created by flood in the area of study require huge sum of money to solve. For example, the EDPA gully sites, the Queen Ede Secondary School road erosion site amongst others. This is why most of the sites are beyond the local and state governments. In most cases they use joint accounts to remedy most of the erosion sites in the study area. The cost of constructing drains, tunnels and conduits are so high that most of the projects at times are abandoned after collecting mobilization fee. Other control measures that one can put in place to remedy soil erosion are as shown in Table 5. Most respondents did not respond hence we have total respondents of 54 or 9.0% for 'no response'.

CONCLUSION AND RECOMMENDATIONS

In this research work, the following statements summarized the major findings:

- The different types of soil erosion in the Benin metropolis that degrade the landscape are rain splash erosion, sheet erosion, rill erosion and gully erosion. The erosion sites identified were over 50. The soil erosion sites have greatly ravaged the landscape in the study area.
- The causes of soil erosion in the study area range from physical to human factors. The physical factors include: rainfall, rock type, topography, vegetation and soil character while the human factors are all forms of human activities that have resulted into soil erosion such as uncontrolled construction of buildings, indiscriminate grading of urban roads, mining, farming activities, indiscriminate removal of vegetation and unregulated landuse types.

In combating soil erosion, a lot of factors have been adduced. The most common methods put in place are gully reclamation, retaining walls, use of erosion brakes, landuse zoning system and above all construction of side drains and tunnel where necessary. Grade stabilization which is a method designed to stabilize the grade or control cutting in natural and artificial channels is also used. Sediment control basins will help to reduce the amount of sediment eroded from the field. Also, tile drains which involve construction of conduit such as field tile, pipe or tubing that are installed beneath the ground surface to collect and convey drainage water.

As revealed by this study, higher aggregates materials such as very fine sand, silt, clay and organic matter are easily removed by the raindrop splash and runoff water; greater raindrop energy or runoff amount is required to move the larger sand and gravel particles. Above all, this study reveals that in terms of population, the high density areas and the medium density areas are not ravaged by gully erosion as these areas are well drained by side drains and tunnels. However, the low density areas, the open spaces and rural areas in the metropolitan city are well affected by soil erosion. The less regards to these areas by the authorities concerned have resulted into abandonment of residential buildings, surface degradation, occurrences of diseases, mudding water surfaces and disruption of traffic and normal socio-economic activities in these areas. Also the undulating terrains of the study area deprive the city of its natural trenches and geomorphic basins which would have received rain and flood waters widespread on its landscape. Hence the landscape has been greatly ravaged by runoff induced soil erosion.

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