Rate of Sediment Yield in the Conveyance Canals of Kano River Irrigation Project (Phase I) North-Western Nigeria

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Abstract

This study examined the rate of sedimentation in the conveyance canals of Kano River Irrigation Project (Phase I). Five canals were sampled from the total number of canals using systematic sampling technique. The base lines of the canals were taken to be the transect line, and all the samples were taken with reference to the transect line using simple random sampling. The method adopted was a combination of volumetric analysis and filtration method for field and laboratory work respectively. Variables investigated include canal discharge at pre and post siltation period, sediment texture, and sedimentation of the canals. Descriptive statistics with the use of tables (as means total and percentages) was used for the analysis and presentation of data collected on canals discharge, sediment texture and suspended and dissolved sediments. The deposit consists of a fine sand fraction (76.3%) with a small amount of clay and silt of about 12.04% and 11.66% respectively. The average canal concentration for the suspended sediment concentration was found to be 8474.4 ton per annum. Although result of student t-test revealed no difference between the present and potential discharge the canals discharge has reduced by 47%. And this in turn affected the farms by reducing the total designed irrigable hectares of land. Many factors are believed to have contributed to the increase of sediments in the canals which include movement of farm tractors across the canals, poor irrigation practice by the farmers, and lack of adequate maintenance. It is recommended among other things that: there should be effective maintenance and monitoring of the canals through regular disilting and cleaning the canals by the participant farmers and the government.

Keywords: Canals, siltation, discharge, texture, accumulation.

1.1 Introduction

Sedimentation and its complex process along the waterways of arid and semi-arid regions where various topographic and climatic factors are reportedly the contributory factors emerging as the major hydraulic considerations in project feasibility study (Hedayat, 2005). The study of sediment loads are crucial because they have major consequences on the hydraulic behavior of the waterways in terms of their morphology and transported loads that may have scouring effect in certain parts and establishment of sediment islands on the other (Shirin et al 2010, Ashkarian et al 2010). This, as various studies have indicated, can have grave consequences for the operational sustainability and performance efficiency of the water abstraction, conveyance and distribution system of the vital hydraulic structures that are fed by the flow originating from these natural sources (Sajedi et al 2010).

Sediments yield has been identified as the major cause of reservoir and canal sedimentation. Rate of sediment yield have been observed in temperate environments especially in Europe and North America, and general relationships established between the long term sediment yield of rivers and physical factors such as geology, relief, vegetation and land use, and with hydro meteorological factors (Andeson, 1969; Imeson, 1971; Gregory and Walling, 1973, Walling 1974). The data derived have been of tremendous value in water use planning. Observations on the rate and dynamics of sediment yield have been attempted from different surfaces under varying land uses with the aid of erosion plots (Kowal, 1970; Lal, 1988, Jeje, 1977; Oyegun, 1980; and Leow and Ologe, 1981). Glymph (1977); reported that some small reservoirs in the United States incure up to 25% storage loss annually as a result of sediment deposited in them. Dasma et al (1973); identified a similar phenomenon for reservoirs downstream of mining areas in the United State, while Platt (1971) reported similar occurrence in reservoirs downstream of logged areas in the United State.

In Nigeria, Imevore et al (1988) for example reported that some dams in Nigeria which include the one near Ile-Ife at Oko Odo had become totally silted up and turned into weed-infested marshes due to rapid urban development and farming activities at the headwaters of the lake. Another example is that of Efforn Alaye reservoir in former Ondo now Ekiti State of Nigeria, which would have completely silted up, but for perennial dredging. The situation in northern Nigeria where there is marked seasonality in rainfall is similar. For example, in his study of the extent of sedimentation in the reservoir of Kubanni River Zaria, Iguisi (1997) recorded a maximum depth of 5.2m as against the initial 8.5m which indicated a loss of about 3.3m (i.e about 30% loss in storage capacity) in 23 years and an average annual loss of depth of about 14.3cm. This is the result of eroded

materials transported and deposited on the reservoir floor, thus, sediment accumulation within the basin is very high. Yusuf & Igbinigie (2010) studied the relationship between Discharge and Sediment Loads of Samaru Stream, Zaria. Their findings revealed that the stream discharge is a response to rainfall seasonality.

The Kano River Irrigation Project Phase I is a large area with a proposed 22,000 hectares of land with lateral, distributory, and field canals to deliver water to farmlands. The project is entirely gravitational and canals are the conveyance system of the irrigation water. However, for over two decades, the canals particularly the distributory canals have been overgrow by an emergence of aquatic weeds belonging to the family Typhacea, and it is believed to be a direct response to siltation of the conveyance canals (Abdullahi, 2009). It is a common practice for the local farmers and fishermen in the Kano River areas to clear canals, drainage and channels by cutting and removing these plants for successful farming. Government on the other hand used to disilt the canals from time to time. None of these studies touched on the rate of sediment yield and its effect on the functioning of the irrigation canals of the project. Yet the muddy nature of the water in the canals indicates high concentration of sediments. It is because of this reason therefore, that this research focused on sedimentation problems in one of the largest irrigation schemes in West Africa, with a view to examine the rate of sediment accumulation and find out whether it constitutes part of the problem of the irrigation project.

1.2 Aim and Objectives

The aim of the study is to examine the rate of sediment yield in the canals, with a view to determine if it constitutes part of the problem of the irrigation project.
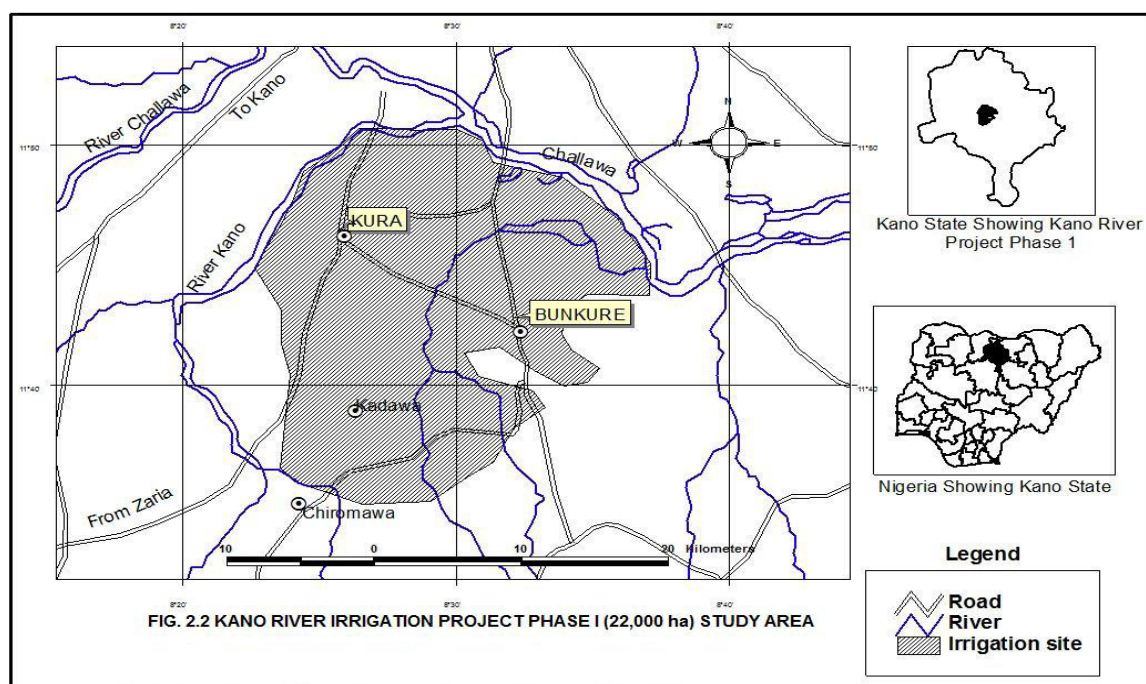
The objectives to achieve the aim are to:
   i.   Determine the suspended and dissolved sediment of the canal's discharge
   ii.   Determine the potential and present water discharge of the canals, and
   iii. Examine the rate of sediment accumulation in a sample of them

2.0 Materials and Methods

2.1 Study Area

Kano River Irrigation Project is divided by the River Shimar into East and West Branch. For the purpose of this study, the western branch of the project was selected and used as the study area. The Western Branch sectors falls within longitude 8^0 23' to 8^0 37' East and latitude 11^0 36' to 11^0 51' North. The cultivated area is situated in southern part of Kano State in Kura and Garun Malam Local Government Areas. It is 13, 630 hectares in extent and bound by the Kano River and Shimar River on the western and eastern side respectively. Water from the Tiga Dam is conveyed by (19 km) long Main Canal up to Garun Babba village where the division works have been constructed. (Hadejia Jama'are River Basin Development Authority Year Book 1994).

FIG. 2.2 KANO RIVER IRRIGATION PROJECT PHASE I (22,000 ha) STUDY AREA

Sources: Min. of Agric. Kano State. Redrawn @ the Dept. of Geog. Buk (2011)

2.2 Sampling and Site Selection

The Kano River Irrigation Project Phase I has 18 sectors each with a Distributory Canal (DCs) and Field Canals (FCs), besides the Main Canal (MCs). Distributory Canals (DCs) are the focus of the research, simply because they are the major canals affected by the sedimentation problem and they supply the field canals with water that supplies the farms. A sample of five distributory canals was taken using systematic sampling techniques from Kore, Agolas, Gori South, Gori North and Rakauna Sector.

The base line of the canals were taken to be the transect line and all the sampling points within the canal were taken with reference to the transect line. The number of sampling points within each canal is proportional to the length of the canal and 6 points were taken from Kore DC , 7 points from Agolas DC , and 5 points each from Gori South DC , Gori North DC , and Rakauna DC . A total of 28 points were selected for collection of bed loads and water sample using simple random sampling techniques.

FIG. 1.3 SECTORS AND CANALS IN THE STUDY AREA
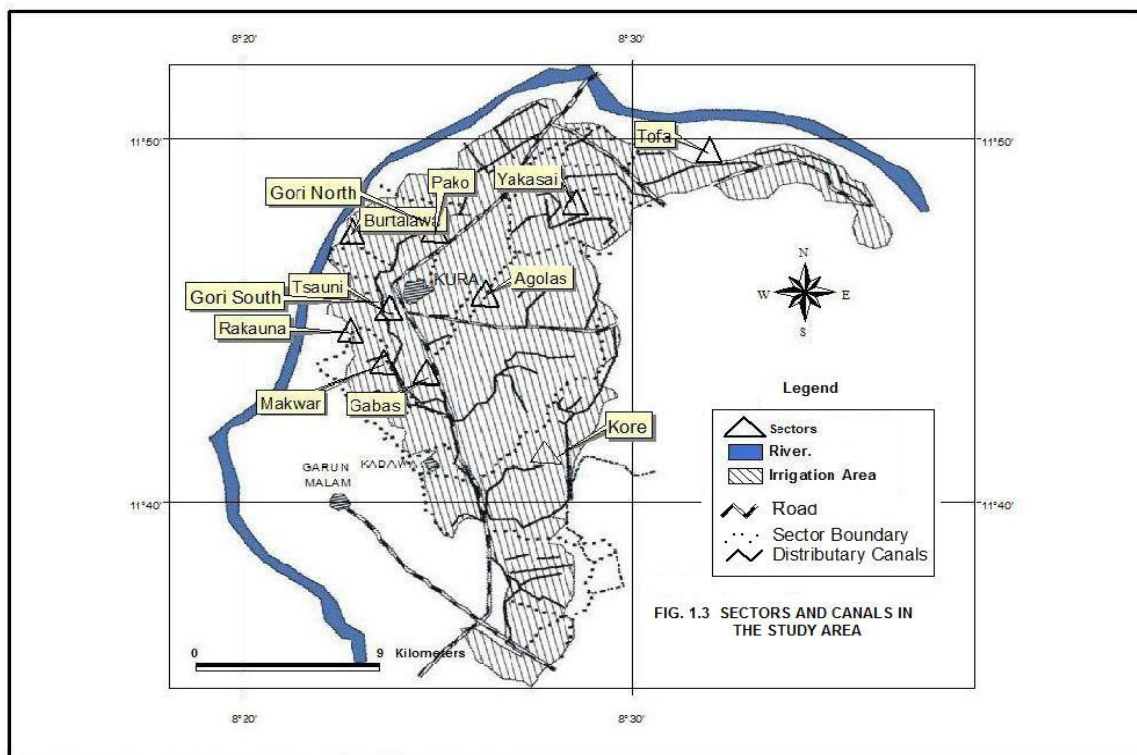
Sources: Min. of Agriculture and Natural Resources, Kano State

Figure 2. Kano River Irrigation Project Phase 1 (22, 000 ha) Showing Sampling Points.

2.3 Types of Data

The types of data collected are sediment deposits, sediments depth, canal width, depth and length, and water sample and water discharge.

2.4 Method of Data Collection

a. Collection of Bed Loads

The base line of the canal was used as the grid line to determine the depth of the deposit and its volume. The deposits were first exposed by closing the water in the canals for 48 hours and the lined portion with concrete was used. One meter excavation was made and the depth of the deposit was measured. The samples were taken from the sediment deposit from the points of study. The samples were properly mixed to represent the entire sediment. All the samples were taken at different points along the canals in order to have good representation of the sediment characteristics of interest. All the samples collected were put in clean polythene bags and numbers indicating the canal/sector each sample belonged were used to label each bag.

b. Collection of Water Sample

Plastic bottles of 350mls were used for collecting water samples. The bottles were held and deepened in the water in the manner approved for suspended sediment sampling. Each sample taken was put in a clean plastic bottle and leveled. Twenty eight samples were taken in two stages. The stage at which water was released and the stage at which water was closed having 15 and 13 samples respectively. Plate 1 shows the method of water

collection.

Plate 1. Immersing the Collecting Bottle to Collect Water Sample

2.5 Method of Data Analysis
2.5.1 Laboratory Analysis.
  2.5.1.1 Particles Size Distribution Analysis
The sediment samples collected were air-dried and big lumps were crushed with an aid of motar and pestle. They were then passed into a 2mm sieve and stored in polythene bags for final analysis. Hydrometer method was used for analyzing the particle sizes. 50 grams of 2mm sieved soil samples was weighed into a polythene bottle. To this, 25ml of Calgon (sodium hexametaphosphate) plus 400 ml tap water were added and shaked thoroughly on end-over-end shaker at 40 to 60 revolutions per minute lasting for 15 minutes. This was in the absence of a high speed stirrer container for proper shakened. The soil suspension was transferred into a 1 litre capacity cylinder and diluted and also stirred for 1 minute by the use of a plunger. The hydrometer was inserted and the readings were taken at two different times (4 minutes, 48 second and 5 hours) under a temperature of 32 ^{0}C. Mean values of sand, silt and clay were determined and textural class of the sediment deposit was obtained.
  2.5.1.2 Measurement of Suspended and Dissolved Sediment
Filtration method was used for the analysis. To this end, 20mls of the water samples was measured using a measuring cylinder. The measured sample was poured into a dry and weighed conical flask through a funnel filted with a folded filter paper which was also dry and weighed. The aliquot was allowed to drain into the conical flask through the filter paper. The solid suspended sediment was obtained by drying the filter paper in an oven at 180^{0}C. The difference between the weight of the filter paper plus the residues and the weight without the residues signify the quantity of the suspended sediment per 20mls. The filtrate in the conical flask was also dried in a hotplate at 120 ^{0}C to allow the water evaporates. This was allowed to cool later. The dissolved solutes were obtained by the difference between the weight of the flask with and without the residue. The dissolved and suspended sediment were then added to determine the concentration per liter using the formula described by Finlayson (1981). The canal yield was calculated by multiplying the present discharge with the sediment concentration. Four month's irrigation period was used to calculate the canal yield per annum simply because the time when the research was undertaken was during the dry season for only four month.
2.5.2 Statistical Analysis
Descriptive statistics with the use of tables (as frequencies and percentages) was used for the analysis of the collected data on sediment texture, canals discharge, suspended and dissolved sediments. The results were tabulated for easy assessment. Data on initial depth and present depth of the canals was subjected to students't-test to find whether there is a significance difference between the two. The difference was also used to estimate the effect of the sedimentation on the functioning of the canals. Also data on canal's discharge and sediment

concentration was subjected to correlation analysis to see if there is relationship.

3.0 Result and Discussion

3.1 Difference Between the Designed and Present Depth of the Canals

Analysis in Table 3.2 reveals that the sediment depth of the canals (3.72m) has reduced from the initial depth of 5.05m accounting for 77 percent reduction. Thus, the canals become shallow and can no longer accommodate the discharge designed for them. Field observation revealed that some silted section of the canals has become a cattle track where the Fulani rearers and farmers have almost converted some passage to permanent routes for them (See Plate 4.2). The result of inferential statistics showed that, there is significance difference between the designed depth and present depth of the canals at 5% level of significance, which has significantly reduced from 5.05m (100%) to 1.33m (23%). The remaining 77% of the depth was accumulated by sediment thereby affecting the function of the canals.

Table 1. Difference between the Designed and Present Depth of the Canals

Sectors	Design Depth (m)	Present Depth (m)	%	Mean Sediment Depth (m)	%
Kore	0.91	0.11	12	0.80	88
Agolas	1.06	0.36	34	0.70	66
Rakauna	0.78	0.08	10	0.70	90
Gori South	0.84	0.10	12	0.74	88
Gori North	1.46	0.68	47	0.78	53
Average	**5.05**	**1.33**	**23**	**3.72**	**77**

Source: Field Work, 2010.

3.2 Particle Size Distribution of the Canal's Sediment

The deposited sediments are characterized by a texture dominated by sand with small fractions of clay and silt as shown in Table 3.1. Sand fraction dominated the texture, followed by clay and silt. The low silt content may be attributed to the excessive washout of the particles by the flowing water. Since the particles are light in nature, they can move in suspension for a long period. Also, the clay fraction was found to be low, but slightly higher than silt fraction and this may be the reason why a thin layer of black deposit was seen between the layers of sand deposit in the process of excavation. Using textural triangle, the deposit was found to be within the range of loamy sand and sandy loamy soil. It is believed that the washout comes from the farm land upstream, and this agreed with the NEDECO (1976) report that the soil of the area was within the range of sandy loamy to loamy sand. And it is observed and agreed that soil erodibility tends to increase with greater silt content and decrease with greater sand and clay contents (Wischimier and Smith, 1958).

In addition, the texture provides a good environment for the growth of aquatic grasses. Indeed, Wischimier and Smith (1958) in Yusuf (2006) described such type of texture as favorable range for good roots penetration. This may be the reason why the canals are presently taken over by grasses. The structure is also loose and less compact. This shows that disilting will not be difficult.

Table 2. Particle Size Distribution of the Canal's Sediment

Sectors	Sand (%)	Silt (%)	Clay (%)	Total
Kore	74.3	24.3	1.4	100
Agolas	82.3	6	11.7	100
Rakauna	72.3	10	17.7	100
Gori South	78.3	8	13.7	100
Gori North	74.3	10	15.7	100
Average	**76.33**	**11.6**	**12.04**	**100**

Source: Field Work, 2010.

3.3 Suspended and Dissolved Sediment of the Canal's Discharge

Table 3 reveals that suspended sediments are lower in percentage than the dissolved ones, and this may be due to the fact that the higher the velocity and volume of water, the lower will be the sediment trapping efficiency of the canals, and this is true even in the flow of Natural River. The higher proportion of dissolved sediment may be attributed to insufficient water in the canals, and as such suspended sediment at that time were stable and static in a small volume which lacked energy to disperse them. Also, the movement of cattle and farm tractors across the canals is higher when the flow is static. These factors might have contributed to the variation in the canals' sediment concentration.

Water samples was collected under two different period (high and low discharge period), and the two samples tested gave different mean concentration per liter as shown in Table 4. The average annual sediment concentration under high discharge period was found to be 8474.4 tons, while that of low discharge period was found to be 9991.2 tons. This may be due to the fact that the higher the velocity and volume of water the lower will be the

sediment concentration in the canal discharge. Thus, the variation in the canal's concentration is connected with the water level in the canals and velocity at the time of collection. Collection under low discharge period was made at the time when the water in the canals was small and very steady or static. As such suspended sediments at that level were stable and static in a small volume which lacked enough energy to disperse them. Collection under high discharge period on the other hand is the period when the sediments were dispersed all over the canals in an unstable environment with a high velocity. Under such conditions the concentration would be low. These factors have contributed to the variation in the canals sediment concentration. The result of inferential statistics showed a strong relationship between water discharge and sediment concentration where the value obtained is 0.66.

The concentration obtained is believed to be a product of erosion and not from the irrigation water itself. The report of NEDECO (1976) shows that the irrigation water at the inception was without such suspended sediments. It can therefore be concluded that the sediment concentration of the canal is a function of both anthropogenic and natural factors. Deforestation, cattle activities and agricultural machineries are believed to be the anthropogenic factors, while the type of soil texture of the area to some extent contributed to the increase of sediment yield in the area. This is because the physical aspects of any region can determine the rate of siltation in the area, simply because whatever sediment is produced and transported depends on the magnitude of the various active and passive forces operating within the areas (Fournier, 1960).

Table 3. Suspended and Dissolved Sediment of the Canal's Discharge

Sectors.	Suspended (g/lit)	Dissolved (g/lit)	Total
Kore	1.2	1.2	2.4
Agolas	1.1	1.7	2.8
Rakauna	1.0	1.1	2.1
Gori South	0.9	1.0	1.9
Gori North	0.9	1.1	2.0
Average	**1.02**	**1.22**	**2.24**

Source: Field Work, 2010

Table 4. Sediment Concentration in Tons under High and Low Discharge Period

Sectors.	High Discharge Period			Low Discharge Period		
	Day (10 hours)	Month	Year (4 Month)	Day (10 hours)	Month	Year (4 Month)
Kore	124.7	3741	14964	157.7	4731	18924
Agolas	159.7	4791	19164	164.5	4935	19740
Rakauna	44.9	1347	5388	54.9	1647	6588
Gori South	11.6	1392	1392	18.2	546	2184
Gori North	12.2	1464	1464	21	630	2520
Average	**68.3**	**2547**	**8474**	**83.26**	**2497.8**	**9991.2**

Source: Field Work, 2010

3.4. Difference between Potential and Present Water Discharge

Table 5 revealed that the accumulated sediment has reduced the potential discharge of the canals by an average of 651.58 lit/sec or 47%. Thus, the canals become shallow and no longer accommodate the discharge designed for them. The result of inferential statistics however showed no significance difference between the potential and present canal's discharge at 5% level of significance, and this may be due to the small samples of canals taken. Had it been the samples taken are large, it would show a significance difference. Field observation on the other hand revealed that, some silted sections of the canals have become cattle tracks which the Fulani rearers have almost converted to permanent routes for them. Thus, the reduction of about 47% of the potential discharge is enough to ascertain that sediment deposits have accumulated in large volume in the canals' thereby reducing the designed capacity of the canals discharge. This is similar with the findings of U.S Geological Survey on reservoir sediment studies in Kansas where the results indicated decreases in total water-storage capacity at normal pool elevations due to sedimentation which ranged from less than 5 percent at Cheney Reservoir (south-central Kansas), Hillsdale Lake (northeast Kansas), and Webster Reservoir (north-central Kansas) to about 55 percent at Crystal Lake, a small impoundment in east-central Kansas. Decreases in storage capacity at Perry and Tuttle Creek Lakes (northeast Kansas) were in the range of 20 to 35 percent.

Table 5. Difference between Potential and Present Water Discharge

Sectors.	Potential (lit/Sec)	Present (Lit/Sec)	Difference	Reduction (%)
Kore	2633.76	1444.32	1189.44	45.16
Agolas	3030.24	1584.8	1445.44	47.70
Rakauna	594.72	283.2	311.52	52.36
Gori South	339.84	169.92	169.92	50.0
Gori North	311.52	169.92	141.6	45.45
Average	**1382.01**	**730.43**	**651.58**	**47.14**

Source: Field Work, 2010

4.0 Conclusion

The study examined the rate of sediment yield in the conveyance canals of Kano River Irrigation Project Phase I. The study has shown that irrigation canals can be made less effective by siltation/sedimentation where there is poor maintenance culture. It is obvious that over the years, the canals at the Kano River Irrigation Project have not received proper attention to remove the sediments from the canals. Rather, the problem of sedimentation is compounded by escalated erosion within and upstream of the irrigated plots by human and animal activities. This in turns affected the total hectares under cultivation and serious crises of irrigation water.

4.1 Recommendations

Based on the findings of the study, the following recommendations are given to reduce the problem of sedimentation to the minimum, as sedimentation is a natural phenomenon which can not be controlled in totality.

   i.   There should be effective maintenance and monitoring of the canals through regular disilting and cleaning of the canals by the government and participating farmers. Indeed, the Farmers association like Water Users Association (WUA) should be encouraged and enlightened to pursue disilting and cleaning of the canals at short intervals of about 6 month. To this end, they should be mobilized through enlightenment campaigns

   ii.   Efforts should be made to reduce erosion in the upstream areas through tree planting at the erosion catchments area and to prevent cattle using the canals and irrigated farms as transit routes.

   iii. Adequate and timely financial support should be given regularly to the Kano River Irrigation Authority by the government to maintain the irrigation structures and repair the equipments for desiltation.

   iv.   Participating farmers should always be consulted and their view sought when solving the problem of siltation.

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