TITLE: INVESTIGATION INTO CAUSES OF GULLYING AND GULLY CONTROL IN KANDARA DIVISION OF MURANGA DISTRICT."

AUTHOR:

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PROJECT REPORT SUBMITTED TO THE UNIVERSITY OF NAIROBI IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR POST-GRADUATE DIPLOMA IN IRRIGATION AND SOIL CONSERVATION

YEAR: 1980/81

SUPERVISOR: MR. D.B. THOMAS

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INVESTIGATION INTO CAUSES OF GULLYING AND GULLY CONTROL IN KANDARA DIVISION OF MURANGA DISTRICT.

SUMMARY

Gullying is intense in many arid and semi-arid parts of Kenya due to erosive climatic conditions, rugged terrain, development projects like roads and overgrazing. The same problem of gullying is extending into good agricultural lands due to human and livestock increases in population and other land development activities. Several land and water development schemes have been carried out without evaluating their impact on the environment. The lack of properly planned run off disposal systems has led to defective drainage which has resulted in roadside gullies. With a high rate of population growth in the developing world and Kenya in particular, an attempt should be made to solve the problem of gullying so that agricultural production may keep pace with population increase.

The paper discusses the causes and problems of gullying in Kandara division, Muranga Location, Kenya. Survey results and field observations are given. The paper also gives the present gully control practices and their effects. Recommendations of practices to prevent and control different types of erosion in general and gully erosion in particular and to preserve land for the future are summarised.

ACKNOWLEDGEMENTS

The author would like to acknowledge the help of Mr. D.B. Thomas in supervising the study and the personnel of the Ministry of Agriculture Kandara Division in helping to collect the data used in this paper. The author also gratefully acknowledges the ready assistance of D.A.A.D. his sponsors, and that of Mr. and Mrs. Dr. Kituuka.

1. INTRODUCTION

A. major problem facing the areas already under cultivation in Muranga district is the seriousness of soil degradation and loss of soil fertility due to indiscriminate misuse of agricultural lands. Several practices in agriculture today have resulted in misuse and degradation of previously fertile land (F.A.O. soils bulletin 33). Bad cropping patterns, unsuitable cultivation techniques, misuse of tractor power, cultivation of marginal and submarginal lands and faulty drainage systems. Soil erosion is intense in many areas of developing countries because of erosive climatic conditions, rugged terrain, and heavy land use, yet little quantitative information is available about the pattern of erosion (Dunne and Ogweny 1976).

The high rate of population growth, both human (Anon 1975) and livestock (Anon 1976.) has resulted in over exploitation of natural resources to meet the ever-increasing demand for cash crops food, fodder and fuel. The increased competition on the same lands for these needs is resulting in wide-spread damage to agricultural lands. Thus increasing misuse of na'tural resources poses one of the greatest threats to better land use management and the problem is compounded by competing demands from different sectors for expanding development and industrial activities on similar types of land. Construction of several roads has made the problem more acute. Accelerated erosion may take place following road construction on forested lands. Experience by F.A.O. in developing countries has often shown that roads are the major source of erosion. Effects however vary considerably depending on the geologic, climatic, land form, soil and vegetation properties of the area or country in question and upon the care taken to reduce erosion in all phases of the road development project. In the attempt to solve some of the erosion problems, many mistakes have been made resulting in failures and worsening of the situation. Detailed knowledge of the nature and distribution of land in an area are the basic pre-requisites of any conservation programme. Therefore land inventories must be interpreted in practical terms, significant to the basic requirements of all land-users and planners. Soil conservation must be extended both to grazing land and agricultural land (F.A.O. bulletin 33, Recommendations of working groups). Thus the objective of this paper is to find out the major causes of gullying and their control in Kandara Division, the effectiveness -of the reclamation on gullies and alternative actions to prevent any further gullying and erosion in general in the area. The Paper considers the present situation of gullies and the steps that should-be taken to improve the situation. In addition the present gully control measures are evaluated and comparisons made. Lastly a solution is sought to prevent land degradation caused by gullies resulting from foot-paths.

2.0 LITERATURE REVIEW

Gullying has been severe for centuries but its impact on regional and national economy has only been actutely felt during recent decades. In response to the same, a substantial amount of work has been done on causes, reclamation and control of gully erosion and soil erosion in general.

2.1 Dunne (1977) studied patterns of soil erosion in Kenya. In the study methods of quantifying erosion rates and sediment yields of Kenyan rivers were reviewed. Hill slope measurements of erosion using controlled plot experiments to provide quantitative information on the controls of soil erosion in Kenya were made. He concluded that there are many gaps in our knowledge of the magnitude, distribution, and controls of soil erosion in the tropics and that we do not know a great deal about the degree to which various conservation techniques presently reduce the soil loss. Lastly he stated that in view of the present concern about desertification, it would be worthwhile to collect some quantitative information to form an objective basis for decision making about soil conservation.

2.2 Hennemann (1975) noticed that in areas where people have destroyed natural vegetation in order to have new arable land, soil degradation on slopes followed. Bare slopes deprived of their protective cover become unstable when exposed to the unhampered impact of rainfall and soil erosion spreads fast.

2.3 Wenner (1980) wrote about gully erosion and the preventive measures. In the cau-ses he did not say more than gullies develop particularly in soils between clay and sand. He however wrote alot on the preventive measures for gully erosion. In gully control he suggested diversion ditches, check dams of different types and carpet of piled stones and straw. The advantage with the structures he suggested is that they are cheap and.- are available locally. As regards to their effectiveness, they have failed and succeeded in some cases. For example within Kandara area they worked well at Kiguoya gully (see map p.24) but they did not work as well at Kiriko gully.
#

2.4 Rapp (1972) studied soil erosion and reservoir sedimentation in Tanzania. The main purpose of the project was to obtain reliable information on the types, extent and contemporary rates of erosion and reservoir sedimentation in Tanzania. It was hoped that such information might form a more rational basis for future schemes of soil and water conservation in critical areas in Tanzania and other countries with similar ecological conditions. Sediment survey of silting reservoirs was carried out. The sedimentation rate in each of the reservoirs under experiment was determined by repeated surveying of cross-profiles. Inventories of the erosion features in the catchments were made by means of air photo interpretation and field checking. Rainsplash and sheet wash were the most important types of erosion in the areas studied. Gullies were appearing in district zones on the upper pediment slopes near the foot of the inselbergs in the Dodoma catchments. He concluded that erosion has many marked effects on the flow of water and sediment in streams. He added that erosion/sediment systems have to be studied together in natural catchment basins, under different environmental conditions and different types of land use to clarify the mechanisms and rates of active processes. Rapps work is very relevant to the problems of sedimentation in Kenya. There is evidence that gullies are often the main source of sediment reaching reservoirs. In Kenya the Masinga reservoir on the Tana River is receiving huge amounts of sediments from gullies in Muranga.

2.5 Much more work has been carried out on erosion studies in developed than developing countries. Blong (1970) studied the development of discontinuous gullies in a pumice catchment in Australia. He gave the general sequence of gully formation as:-

1. Initiation of one or more small scarplets or knick points on the relatively flat pumice valley floor during periodic surface water flow.
2. Head ward retreat.
3. Down valley extension.
4. Eventual widening of gully.
5. Increase in gully floor gradient.
6. The possible recurrance, a number of times of the sequence of event postulated above. Blong states that many present gullies are attributed to environmental changes consequent on land development. Majority of gully head-cuts retreat under the action of ephemeral surface water flow resulting from high intensity rainstorms. However some headcuts may be further influenced by sub-surface water flow, seepage and undermining. He observed that once trenching has begun further down, valley extension, knickpoint retreat and deepening takes place. Widening occurs where

down valley extension is prevented and/or where rapid adjustment to increased discharge is necessary. Hudson (1971) however has an opposite view about gully floor gradient. He states that for the velocity to remain constant the gully floor gradient must decrease. Blong refers to the general overall slope of gully while Hudson seems to be confined to the slope of the head only. It should be noted here that despite differences in climate and soils between Kenya and Australia where Blong did the study, his findings are useful and can be used for the Kenya conditions.

2.6 Bradford and Piest (1977) made a study of gully wall stability in loess-derived alluvium. The study was aimed at investigating the triggering mechanisms that initiate gully wall failure in loess-derived alluvium. They examined the relevancy of hydrology, soil morphology and soil mechanics to understand gully slumping. Conventional limit equilbrium slope stability were of little value in predicting failure volumes or in understanding the failure mechanics. The geometry and time of failure were greatly influenced by the structural features of loess derived alluvium and by the dependence of the shear strength on the pore water pressure within the soil. Bradford et al (1978) stated that a characterization of the failure sequence of gully head walls and bank is necessary to predict gully erosion rates and to develop controls. He gave a model for the sequential nature of gully growth in the thick loessial area of western Iowa. The failure sequence includes a popout or alcove failure near the toe of a near-vertical wall, columnar stoughing of the overhanging material and finally the transport of eroded material downstream. The initial failure at the base of the wall is a result of weakening of the soil material by wetting. The gully bank failure sequence and geometry in the western Iowa loess region was compared to gully erosion studies the glacial drift region of north western Missouri and in the Piedmont of South Carolina. In conclusion, terraces were shown to control gully erosion through reduction in run off. The need to investigate lower cost management methods for stabilising bank slumping were also recommended.

2.7 Heede (1977) did some work on gully control structures and systems. He divided the mechanics of gully erosion into down cutting and head cutting. Down cutting of the gully bottom leads to gully deepening and widening. Head cutting extends the channel into unguliied headwater areas and increases the stream net and its density by developing distributaries. Thus, effective gully control must stabilize both the channel gradient and channel headcuts. Heede stated that measures taken outside the channel also aid revegetation process in the gully. Improvements on the watershed that increase infiltration and decrease overland flow and spread instead of concentrating flow, would benefit gully healing process. Normally however, improvements can be attained quicker within gully than outside, because of concentration of treatment and availability of higher soil moisture in the defined channel. In addition to vegetation, porous check dams, loose rock, wire bound loose rock were among the control structures suggested. For the head cut control rock walls reinforced by wire mesh and steel posts were recommended.

2.8 Logan (1968) states that gullying is symptomatic of the advanced stage of erosion where the destruction has proceeded in depth and large quantities of soil have been removed.. He adds that in order to logically discuss measures to control gully erosion, it is first necessary to consider the processes involved and the underlaying causes. Logan quotes Miller (1950) who suggested that the mechanism of gullying may be divided into three main processes viz:.(i) waterfall or headward erosion (ii) vertical erosion or deepening (iii) lateral corrision or widening. All three processes may be taking place in the one gully and at the same time. Gully erosion may commence through vertical corrosion by headward erosion. Lateral cutting maintains the banks of the gully in a steep and unstable condition and is often responsible for the production of large quantities of silt.

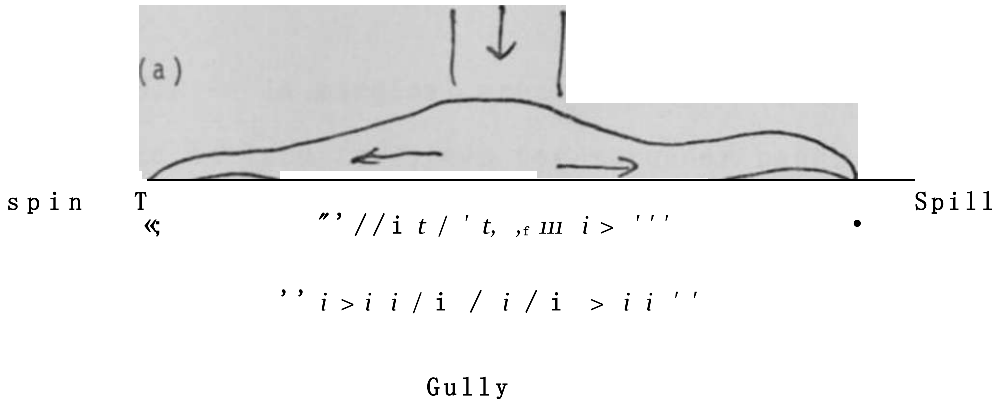
2.8.1 Gullying may result from (a) destruction of the protective cover in natural flow lines by cultivation or over-grazing. This allows the concentrated flow to act on the unprotected soil surface and so initiate erosion, (b) cultivation of sloping lands. This can increase the amount of run off and also render the soil easily movable, (c) concentration of water by tracks, roads, fences and cultivation. (d) increase of flow in drainage lines by land use factors that increase run-offs.

2.8.2 Treatment of the catchment with measures that will reduce runoff is important in gully control. Measures include soil conservation, good management practices. In some instances it is possible to divert runoff that is causing gullying on to stable areas. Care must be taken in such cases that the new disposal area does not gully.

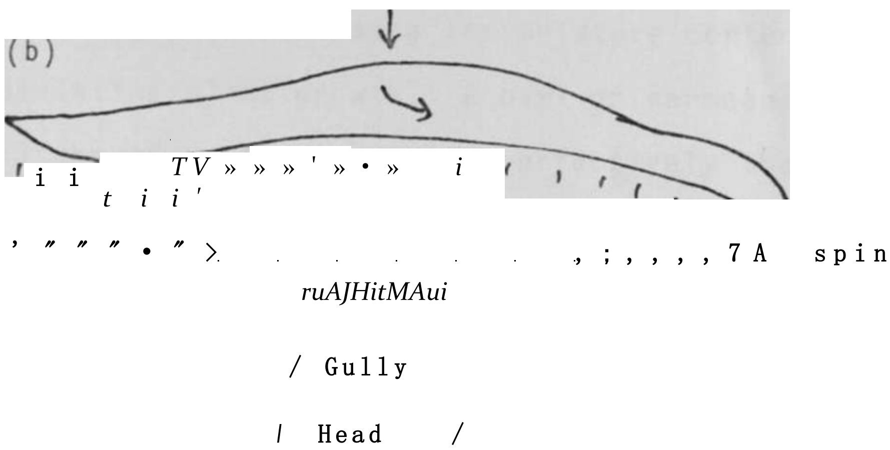
2.9 Quilty (1973) studies gully control structures and absorption banks in marginal cropping areas of western New South Wales.

Gully control structures as par Quilty are major water retention or diversion works used to check erosion which has progressed beyond the sheet and rill erosion states to the development of actively eroded gullies. These gullies may carry off the run off from catchments of the order of hundreds or in extreme cases, thousands of hectares. A bank to control run off of such magnitude is a major structure and excavation and construction may therefore entail the movement of several thousand cubic metres of soil.

2.9.1 Quilty observed that the first major consideration is siting of the structure. He gave the alternatives of siting of the structures above the gully head, in the gully itself or to one side of the main flow line with a bank constructed to divert runoff into a constructed waterway. (See page 15 for illustrations). When sited above the gully head the structure prevents further upslope progress of the gully. The gully is then reclaimed by filling or by battering the sides along the entire length.



Gully check sited in the gully and spilling at both ends



Gully check sited above the gully head and spilling at one end only.

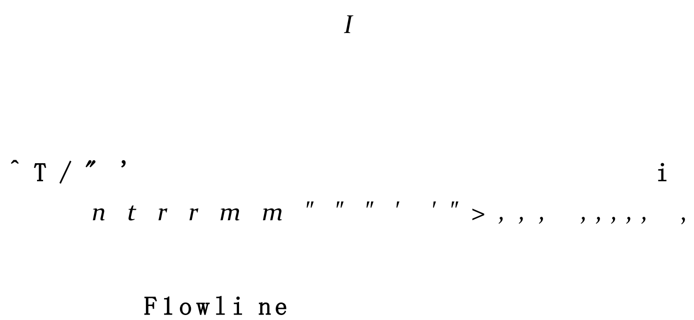


Fig. 1

Diversio'n bank across a flow line turning water into a ground tank. Arrows indicate the direction of flow. Quilty suggested that in all cases survey was necessary before control structures could be constructed in the gully.

2.9.2 In marginal areas absorption banks are used on land too steep for spreader banks and ditches. They are used on more gentle slopes to co control run off which is too rapid or too large for spreader banks to handle effectively. Apart from preventing erosion by restricting runoff, the absorption banks is designed to store as much water as possible so that this water ultimately unfiltrates into the soil, increasing its moisture content and stimulating plant growth. A bank on permeable sandy soil therefore functions more effectively than a bank on heavy impermeable clay. The fornTer allows rapid infiltration of moisture whereas the latter may hold water for indefinite periods so that the growth of useful pasture species is unpeded.

From Quilty's work it is evident that absorption and diversion banks work well in the area he studied. Check dams don't seem to be very popular in the area as they are in Kenya. The idea of diversion banks is difficult in Kenya due to land fragmentation which calls for co-operation of very many farmers if a ditch is to pass through their farms. Thus where there are alternatives like check dams, they are used.

2.10 Tuckfield (1964) studied six gullies in the northern part of the New Forest, Hampshire, U.K. for three years. Plans and long profiles of four and cross profiles of one were drawn at yearly intervals. He observed that gullies originated during very heavy rain in the superficial deposits on convex slopes in healthland areas where the vegetation has been destroyed by man. Gullies grew by coalescing of a number of incipient gullies. Head steps often 3 feet high developed wherever sections coalesced. One gully, 200 feet long developed in 2 years during which period over 1000 cubic feet of material were removed. In another gully 900 cubic feet were removed during one abnormally wet year.

2.10.1 Tuckfield made the same observations like Heede (1977) and Logan (1968) made on growth of the gully. He observed that the gully grew by headward extension, and deepening. He noted that during and after running water sometimes undercuts the gully sides thus widening the channel. In summer the exposed material in the gully sides dried and cracked or crumbled and the forest animals contributed to the widening process.

2.10.2 Tuckfield concluded that exceptionally heavy rainfall was necessary to initiate the process and to maintain it. In the absence of further abnormally heavy rain storms, widening process tended to produce stable cross profiles which allowed vegetation to grow again and prevented further erosion.

2.11 - Ologe (1972) studied gullies in the Zaria area of the North Central State of Nigeria. The aim of the study was to investigate the processes of scarp recession at the headward termination of the gullies. The study showed that headscarp recession took place through recurrent undermining and collapse of gully wall material. The process involved in undermining which closely controlled the rate of recession depended on surface runoff water for their operation. He stated that therefore erosion within the headscarps was limited to short periods during and immediately after runoff producing storms.

The methods used in measuring the amount of recession which took place were determined by the character of the headscarps and the nature of erosion within them.

2.12 Megahan (1977) observed that accelerated erosion may take place following road construction on forested lands. He recommended measures designed for prevention of erosion than control. He recommended land use planning with respect to road construction.

All sources tend to agree on the causes and development of gullies and their findings are relevant to the problems of gullying in Kenya.

However with gully control structures the story is different. For example the methods proposed by Heede (1977) for control of gullies are too expensive to apply in our situation. On the other hand Wenners' suggestions are both too temporary and their effectiveness has not been consistent. Cheap but effective gully control structures are needed for the Kenya situation because of financial limitations faced by both the Government and farmers. Most of the commonly recommended practices of gully control are neither economically feasible nor practically applicable under the socio-economic and financial resources of the small farmers.

BACKGROUND TO STUDY AREA

3.0 Rainfall in Kandara

The mean annual rainfall for Kandara is about 1000 mm. Much of this rain comes between March and June and the rest falls between September and November. Much of the rainfall, particularly in March and June is associated with storms of high intensity.

Vegetation

The area has been influenced by prolonged human use in form of grazing, burning, shifting cultivation or selective cutting. The natural forest vegetation has been repeatedly cultivated. Present vegetation consists of cultivated land pasture and planted trees, food and cash crops. Food crops include maize, beans, bananas, green vegetables and cash crops are coffee and some sugar cane.

PROCEDURES

4.0 Investigations were carried out to find out the causes of gullying, the extent to which gullying has taken place and the present measures taken to control it. The necessary information was obtained from inverviews with government staff and farmers and by surveying gullies using survey equipment. All the gullies in the area were studied in general but two were studied in detail and these are found at Kabati and Kiriko.

4.1 Interview with Government staff and Farmers

Mr. A. Too who works as a Technical Officer with the Ministry of Agriculture, Kandara Division was interviewed to obtain information generally on farming, soils, climate, causes of gullies, gully control and future plans to stop gullying. With the help of the agricultural staff, farmers in the area were also interviewed to get information on when gullies were formed, the causes of gullying, effects of gullying if any to their farming and their opinions on the whole matter.

4.2 Survey of gul ly

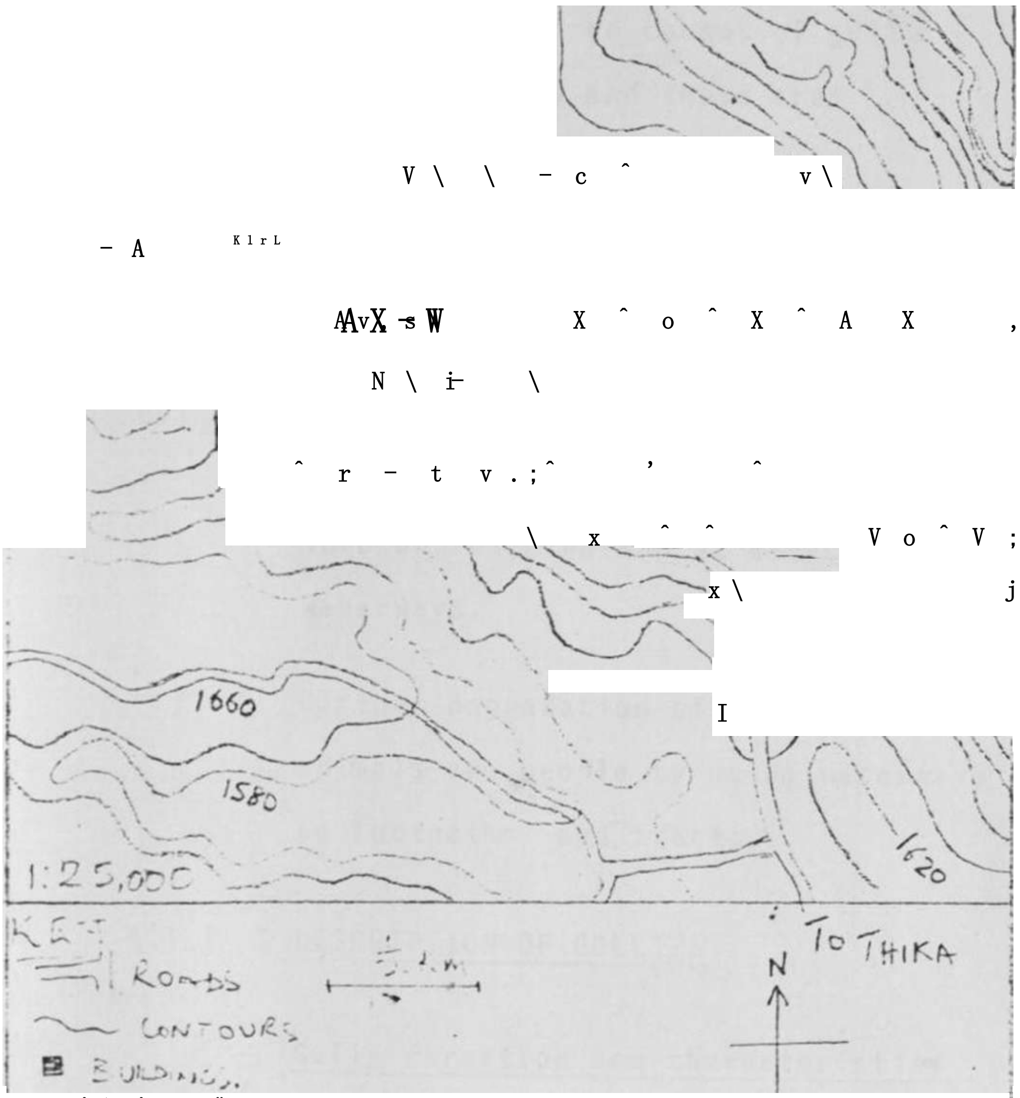
, An attempt was made to estimate the amount of soil lost from the two gullies. The method used was as follows: Long profiles of the land surface where the gullies area were taken at intervals of 5 metres. At the same distances cross profiles were taken, the profiles being selected so that each was typical of a certain length of the gully. The Volume removed from each gully length was then found by multiplying the cross-sectional area by the length. By addition the total volume removed from each gully was found. Although it is realised that the degree of accuracy in the calculations is not very high, at least some idea of rate of erosion by this process in this area is given. In addition, observations of control structures used were made to find out the type, numbers, spacing and their cost and effectiveness. Sites were inspected for alternative measures for control and prevention of further gullying.

4.3 Observations on soils

The soils are deep, well drained dark red clay soils. Top soils are thick and rich in organic matter. The A horizon is dark brown to dark reddish brown with a crumby or subangular blocky structure. The thickness varies from 10 to 60 cm. The porosity is well developed and internal drainage is high and soils are of high agricultural value.

Observations on topography and land use:-

Kandara area is hilly with slopes between 20-30%. Land is used for growing coffee and maize mainly. Coffee is grown on terraces where as maize is not.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1620
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KEY
ROADS
CONTOURS
BUILDINGS
TO THIKA
N

Fig. 2

5.0 RESULTS OF INVESTIGATIONS

5.1 CAUSES OF GULLYING IN KANDARA

In Kandara, three causes of gully erosion were identified and these are:

(a) Excessive concentrations of runoff from uncontrolled road drainage into badly designed waterways.

(b) Increased runoff from cultivated areas under low standards of management into unprotected and at times cultivated waterways.

(c) Further degradation of waterways by animals and people by using waterways as footpaths and tracks.

5.1.1 DESCRIPTION OF GULLIES

Gully formation and characteristics

Gullies are cuts over 0.3 m wide and greater than 0.6 m deep formed by running water or sliding.

5.1.2 Gully formation

Running water cuts a narrow, shallow trench in the ground. The trench slowly deepens and the deep, narrow shape of the rill encourages high velocities and in an attempt to reach a shallower gradient, the bare soil of the rill erodes. A sudden difference in ground level thus occurs at the head of the rill which accelerates erosion and the formation of a gully. The gully then deepens, widens and extends up the catchment-areas as it undermines and thus causes the gully head to collapse. Erosion continues until runoff quantities and velocities are once again in balance with the soil type, the gradient and the established vegetative cover in the gully.

5.2.0 KABATI GULLY

Kabati gully is situated about km from Kandara town on the right hand side of the road to Gacharage.

5.2.1 Gully length

Kabati gully is about 125 m in length with ground slope of 20%.

5.2.2 Catchment area

The catchment area for Kabati gully is about 0.67 ha of which the road contributes over 70%. The slope of land is about 20%.

5.2.3 Causes of erosion

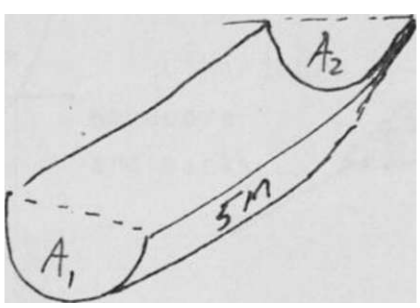
From the observations made on the site and from the information obtained from Mr. Too and Mr. Kiruri of the Kandara Agricultural division offices, the Kabati gully was caused by water running off the newly constructed road. Concentrated run off from the road drainage coupled with absence of grass cover in the poorly protected natural waterway used as a footpath caused the initiation of gullying.

A long profile and cross-sections of Kabati gully are shown in figures 8 and 9.

5.2.4 Volume of soil lost

The volume of soil lost as a result of gullying was calculated. Example of the method used is illustrated below.

Fig. 3



Areas of two cross-sections 5M apart were calculated and their average taken.

Volume of soil lost was calculated using formula:

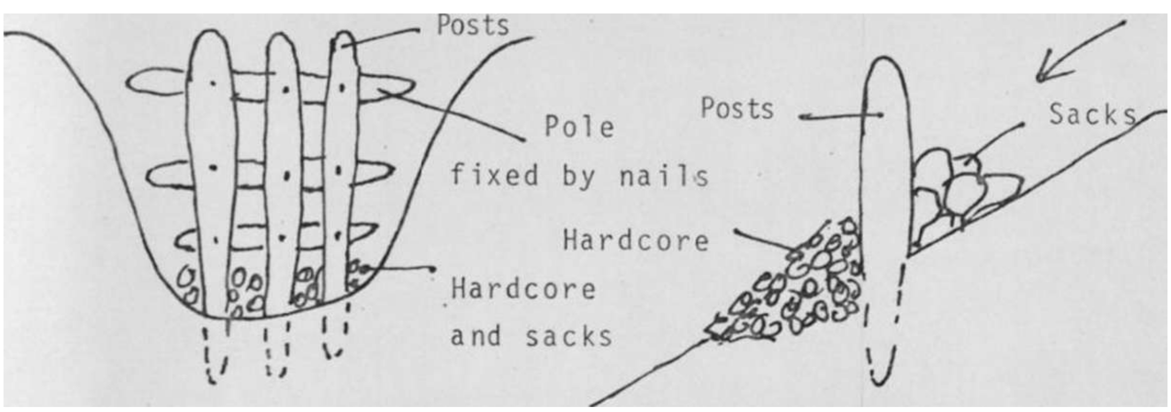
$$= \frac{(5m \times A_1 + A_2)\,M^3}{2}$$

By adding the volumes from different sections the total volume removed from gully was obtained. This was roughly 356.85 M^3 as shown in table 1 on page 35.

5.2.5 Control structures

Check dams have been constructed in the gully to cause siltation. A total of 21 check dams have been constructed along the whole length of the gully and their spacing is between 6-10 metres depending on slope. Check dams are constructed from posts and rufters, hardcore and sacks filled with soil. Posts were lined up across the gully at right angles and were joined together by rafters. Sacks full of soil were deposited behind the posts on the

Fig. 4



upstream side and hardcore deposited on the downward stream side of the poles.

In addition to the gully control structures side walls have been planted with grass, cynodon dactylon in particular and napier grass.

Fig. 5

Figure shows head of Kabati gully. Road in background and road drainage can be seen.

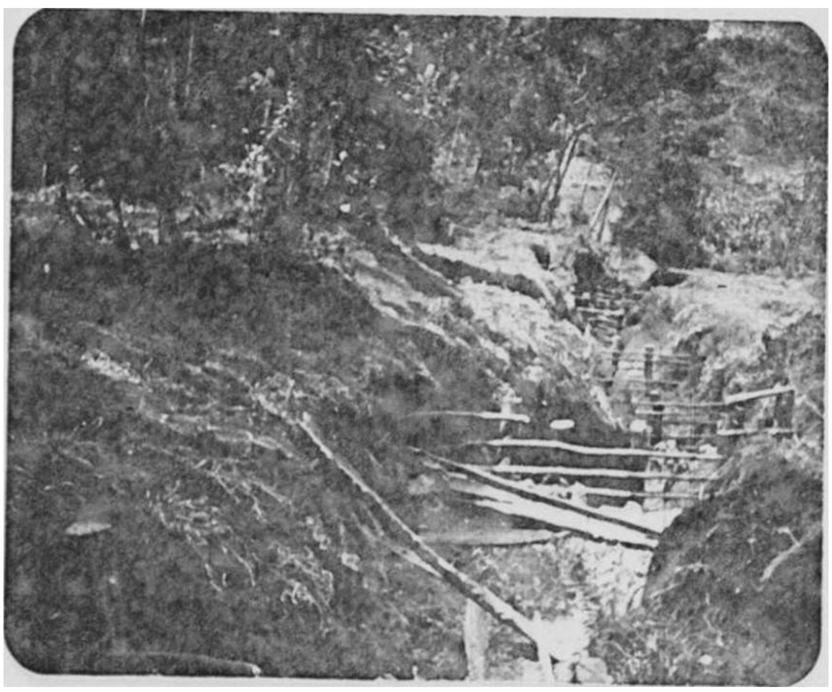


Fig. 6

Kabati gully showing control structures and footpath on the right. Note the grass establishing behind the check dam.

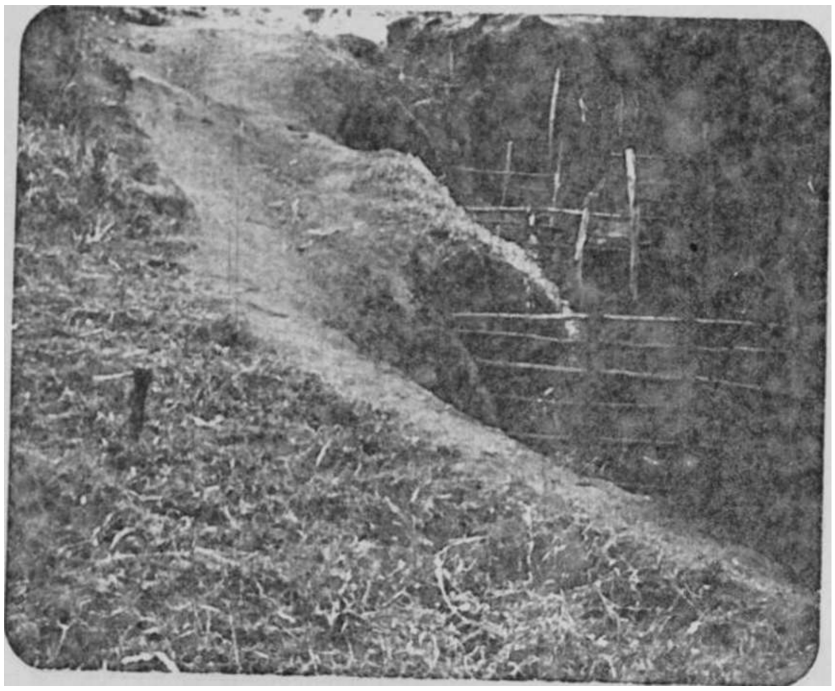
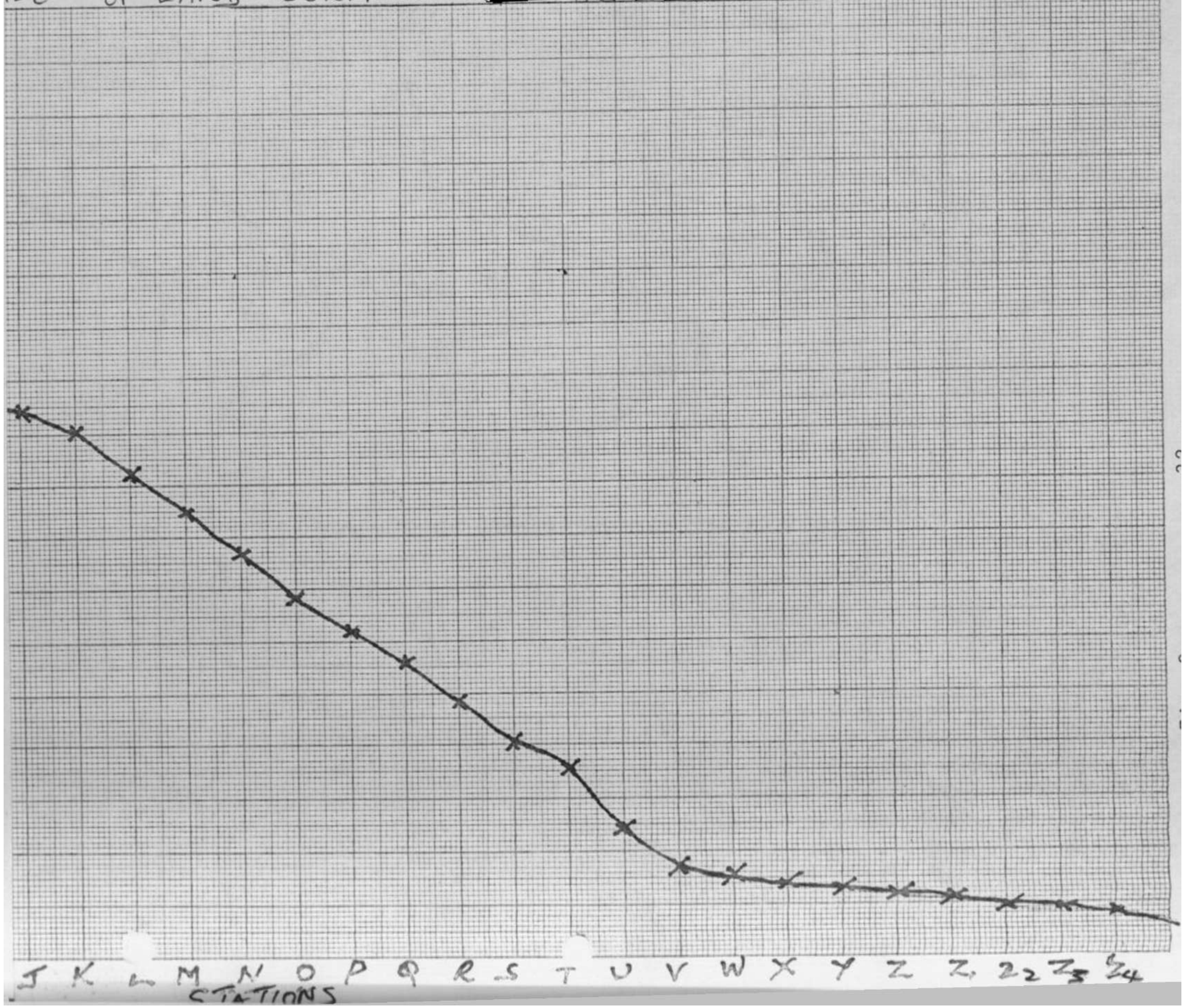
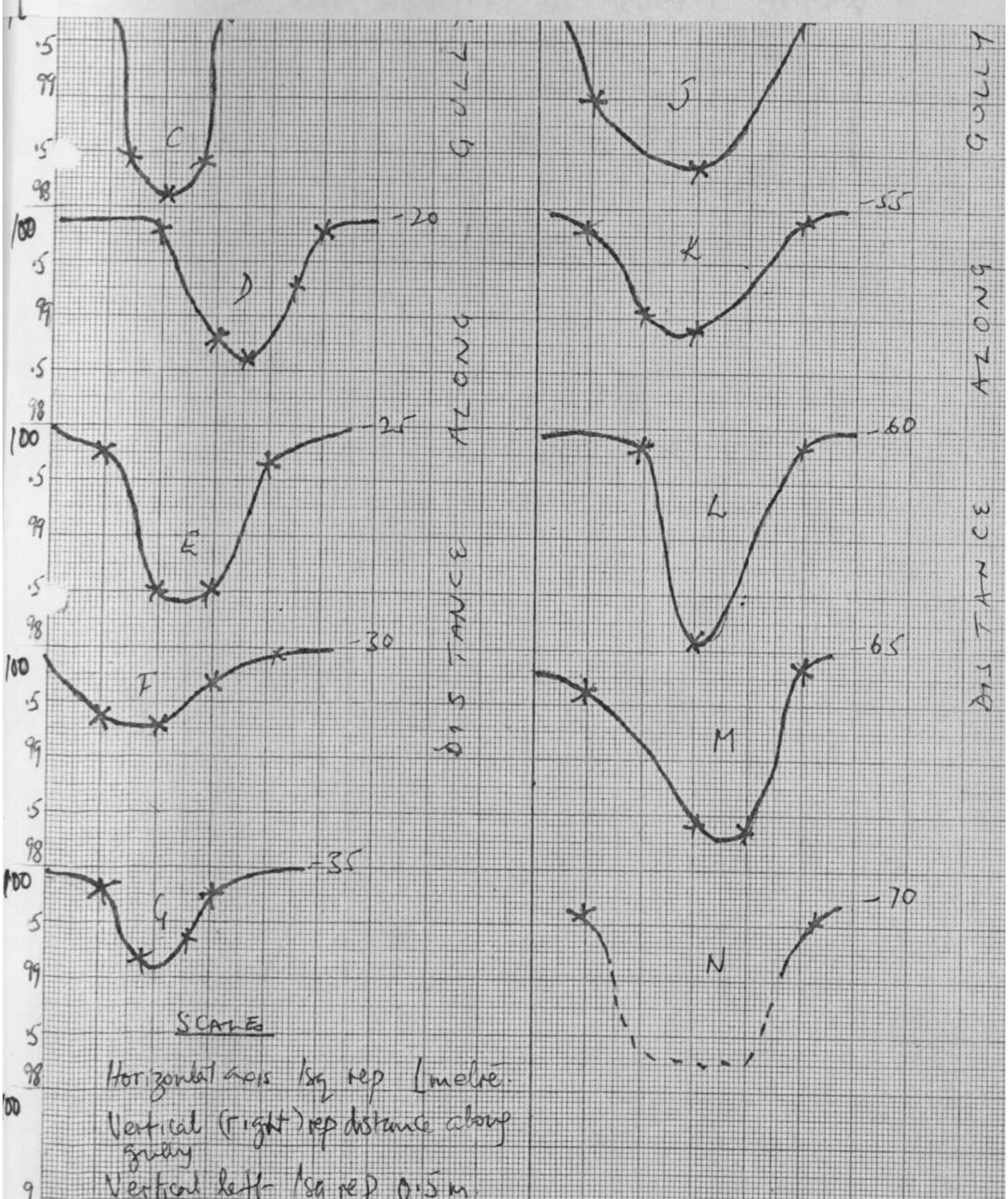


Fig. 7

Kabati gully showing footpath on the left and extent of gully lower down the gully.

ILE OF LAND SURFACE [redacted]

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-35
-55
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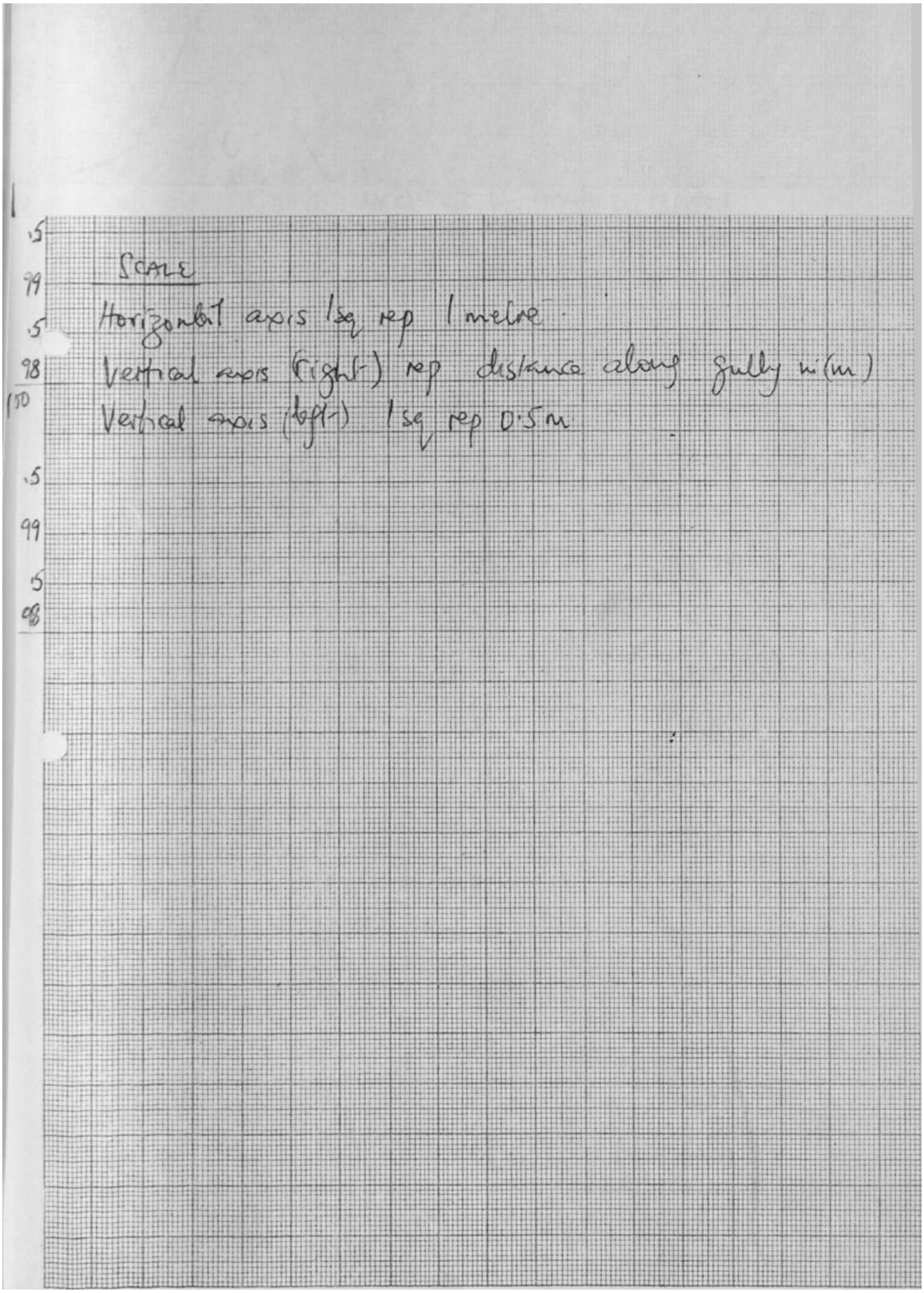
-65
-70
DISTANCE ALONG GULLY
SCALES
Horizontal axis 1sq rep 1metre.
Vertical (right) rep distance along gully
Vertical left 1sq rep 0.5m.

Fig. 9


.5
99
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150
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99
.5
98
SCALE
Horizontal axis 1sq rep 1 metre
Vertical axis (right) rep distance along gully in (m)
Vertical axis (left) 1sq rep 0.5m

Fig. 10

Table 1: Volume of soil lost from Kabati gully.

KABATI GULLY

STATION	CROSS-SECTIONAL AREA IN M^2	AVERAGE CROSS-SECTIONAL AREA IN M^2	VOLUME OF ’ TM M3 , IN M LOST
Head		2	10
A	2	2	10
B	2	2.5	12.5
C	3	2.5	12.5
D	2	2.25	11.25
E	2.5	2	10
F	1.5	1	7.5
G	1.5	0.9	4.5
H	3	2.75	13.75
I	2.5	3.25	16.25
J	4	3.5	.. 17.5
K	3	3	15
L	3	3	15
M	3	3.5	17.5
N	4	3.75	18.75
O	3.5	3.25	16.25
P	3		TOTAL 208.25
Q-Z1	31.72	3.172	158.60
			GRAND TOTAL 366.85

Kabati gully occupies about 390 M of land. JgES1VH ©

Table 2:

5.2.6 Cost of gully control at Kabati gully

	Shs.	Cts
Posts and poles	2,000	00
57 ton lorries of stones	20	00
Labour costs	4,000	00
Sacks	600	00
	10,620	00

5.2.7 Effectiveness of structures

At the time of the study the structures had just been installed about 4 months earlier and so their effectiveness could not be properly assessed. However those structures at the head of the gully had trapped sediment behind them.

5.3.0 KIRIKO GULLY

Kiriko gully is situated in Kiriko village about 1.5 km from Kandara shops. The gully is about 6 years old but has been partially reclaimed and grass is establishing along the whole stretch of the gully. See map on page 24 and Fig. 12 on page 40.

5.3.1 Gully length

Kiriko gully is about 80 m long.

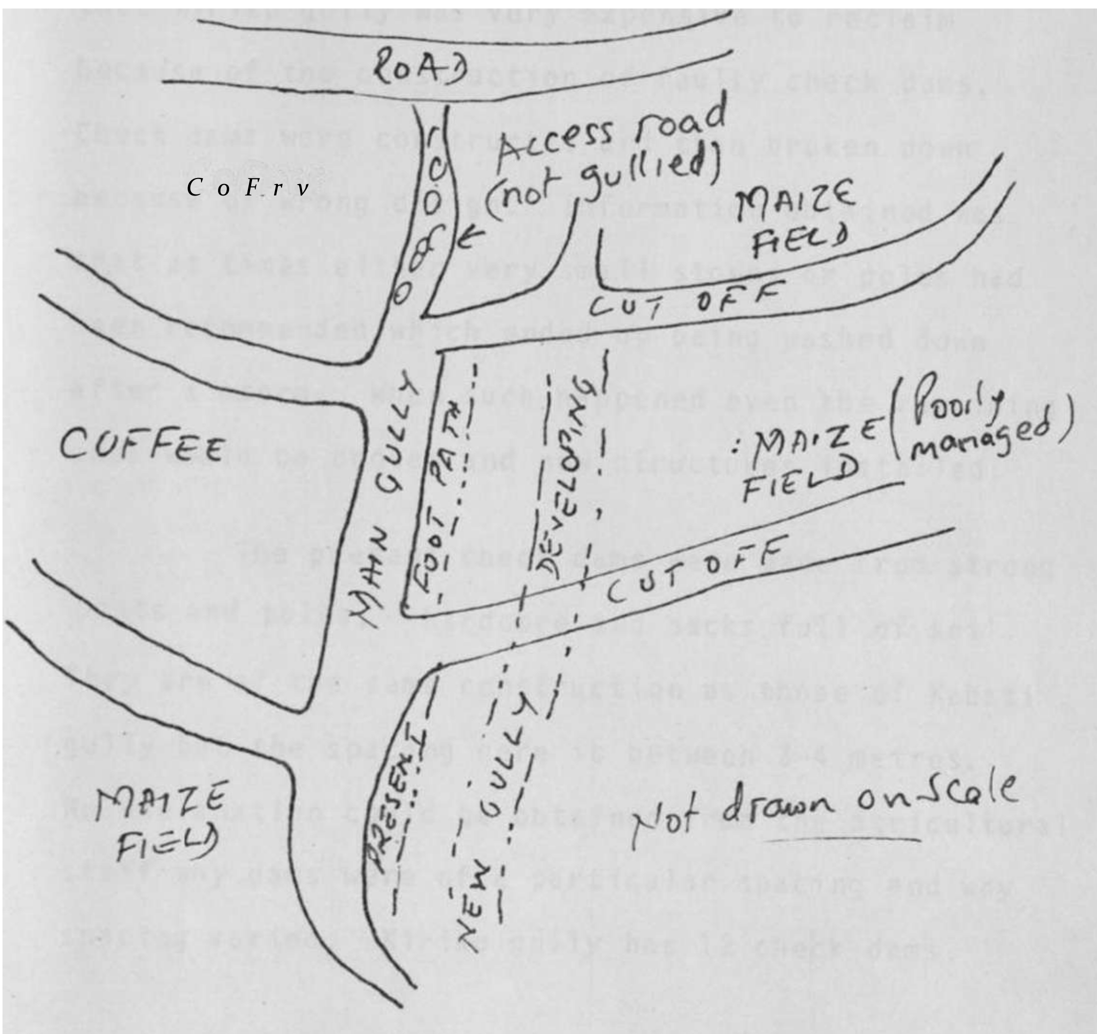
5.3.2 Catchment area

The catchment area is about 1.2 hectares. Slope of land is 25%.

5.3.3 Causes of Kiriko gully

Kiriko gully was formed by disposing off water into a natural waterway, which was at the same time being used as an access road. The diagram below illustrates the situation at Kiriko gully.

Fig. 11



5.3.4 Volume of soil lost from Kiriko gully

. The same procedure was used to calculate the volume of soil lost in Kiriko gully as was used in the Kabati one. Total volume is about 194.9 M^3. Long profile and cross-profiles of Kiriko gully are shown in figures 13 and 14. The long profile of the land surface is shown in fig.13. It should be noted that gully is being reclaimed.

5.3.5 Gully control structures

Check dams were used to control the gully. Information obtained from the Agricultural staff was that Kiriko gully was very expensive to reclaim because of the construction of faulty check dams. Check dams were constructed and then broken down because of wrong design. Information obtained was that at times either very small stones or poles had been recommended which ended up being washed down after a storm. When such happened even the remaining ones would be broken and new structures installed.

The present check dams were made from strong posts and poles, hardcore and sacks full of soil. They are of the same construction as those of Kabati gully but the spacing here is between 3-4 metres. No explanation could be obtained from the agricultural staff why dams were of a particular spacing and why spacing varied. Kiriko gully has 12 check dams.

Due to silt deposits that have taken place, grass is being established. The grass is napier grass mainly

KIRIKO GULLY

STATION	CROSS SECTIONAL AREA M^2	AVERAGE CROSS SECTIONAL AREA M^2	VOLUME OF SOIL M^3 . ncT n LUbl
A	1.5	1.75	8.75
B	2	2.75	13.75
C	3.5	3.75	18.75
D	4	3.5	]7.5
E	3	2.5	12.5
F	2	2	10
G	2	1.6	8
H	1.2	1.85	9.25
I	2.5	2.75	13.75
J	3	2.5	12.5
K	2	2.25	J1.25
L	2.5	2.75	13.75
M	3	2	10
N	i 1		5
O	1	0.75	3.75
P	1.5	1.75	8.75
Q <	2	1.25	6.25
R	0.5	0.37	<u>1.85</u>
S	0.25		194.9

TOTAL 194.9 M^3

Table 2: Volume of soil lost from Kiriko gully

Kiriko gully occupies 200 M^2 of land.

Fig. 12

Figure shows check dam in Kiriko gully. Note the gentle slopes and the establishment of grass both on the slopes and within the gully.

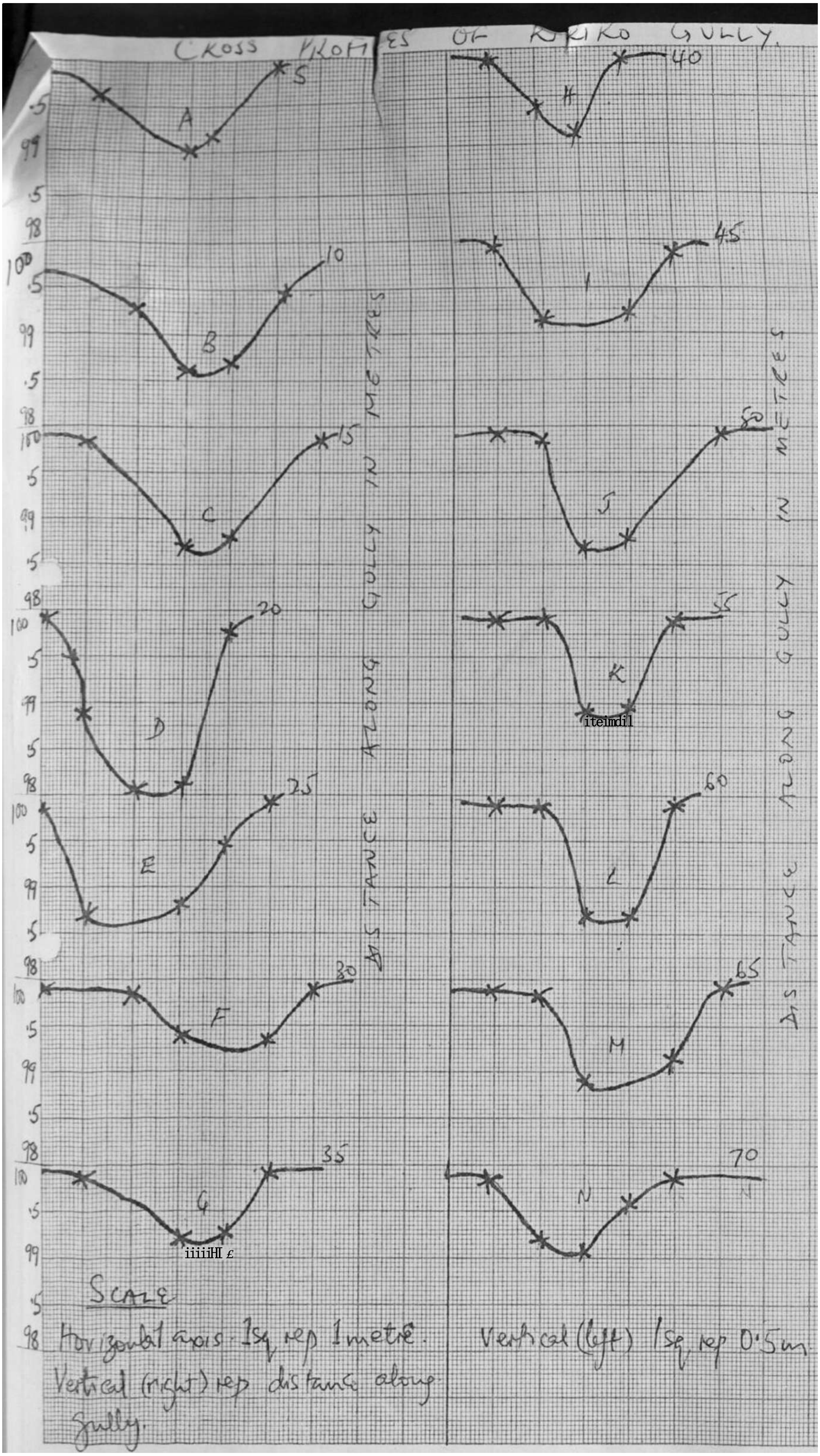

DISTANCE ALONG GULLY IN METRES
SCALE
Horizontal axis 1sq rep 1 metre.
Vertical (left) 1sq rep 0·5m
Vertical (right) rep distance along gully.

Fig. 14

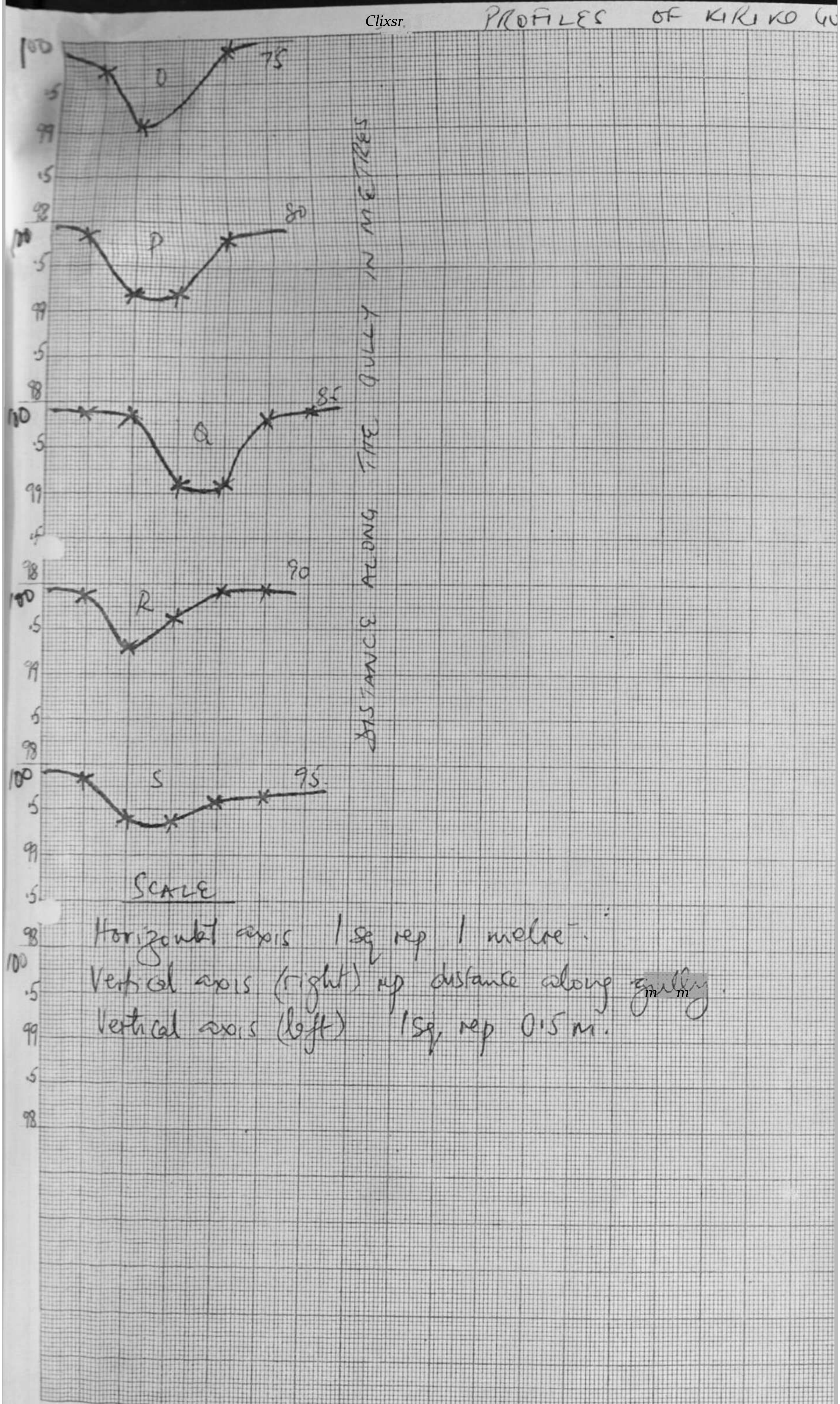

PROFILES OF KIRIKO GU
DISTANCE ALONG THE GULLY IN METRES
O
P
Q
R
S
75
80
85
90
95
SCALE
Horizontal axis 1 sq rep 1 metre.
Vertical axis (right) rep distance along gully.
Vertical axis (left) 1 sq rep 0·5 m.

Fig.15

5.3.6 Cost of Kiriko gully control

As already stated the Kiriko gully has been expensive to control due to bad design and planning. The materials and cost outlined below are just part of the total materials and cost used Full records could not be obtained.

Table 4:

	Shs.	Cts
12,7 ton lorries of hardcore	9,600	00
Poles and posts	3,000	00
Sacks	1,200	00
Nails	50	00
Labour costs had no records		
	13,850	00

Records however show a figure of 25,000 including labour.

5.3.7 Effectiveness of control structures

After several different trials, the control have become effective. The gully is recovering and grass is establishing on the trapped sediment behind the control structures and also along gully walls.

5.4.0 KA6UTHI-KIGUOYA GULLY

, In Kiguoya village of Kaguthi sublocation on Thika-Gacharage road another gully was formed but has been reclaimed. See map on page 24.

5.4.1 Gully length, width and depth

Kaguthi gully is about 130 m long, about 0.5 m wide and 1 m in depth. Slope of the land is between 20-30%.

5.4.2 Causes of gullying at Kaguthi

The Kaguthi gully was caused by excessive concentrations of run off from a road culvert which dug a very deep hole at its month which ended down the farms as a gully.

5.4.3 Gully reclamation at Kaguthi

Check dams made of stones, posts poles and tree branches were used to control the gully. Apart from the month of the culvert most of the gully stretch has silted up and grass has established.

5.4.4. Cost of gully control

Records were not available to show how much has been spent on material for gully control at Kaguthi. However it was estimated that labour took about 4000/-.

5.5.0 GULLYING ALONG MUNYORI-KANDARA ROAD

Gullies are developing on either side of Munyori-Kabati Road. These gullies were noticed to have been caused by excessive concentations of runoff from uncontrolled road drainage. Gullied areas are shown on the map. Trickle flows from the road cut a narrow, shallow trench or rill between the coarse clumping grasses on the road side. The deep, narrow shape of the rill encourages high velocities and in an attempt to reach a shallower gradient, the bare soil of the rill erodes. Due to lack of properly planned water disposal more gullies are forming. These gullies threaten both the stability of roads and the good farming land in the neighbourhood.

6.0 DISCUSSION

Recognition of the type of erosion occuring on an area and knowledge of factors controlling erosion are important in avoiding problem areas and in designing control measures, (Heede 1977). Taking the Kabati gully the major cause was road drainage. There are a variety of practices available to reduce the erosional impact of road construction.

These are:-

(1) High erosion hazard areas should be avoided for example very steep hills, unstable soils.

(2) Erosion on areas that are disturbed by road construction should be minimised by a variety of practices des-'igned to reduce erosion.

(3) Lastly off-site impacts of erosion should be minimised.

6.1.1 Gullies have caused serious problems to farmers in the area. As already mentioned there is is land shortage in Kandara and the population there is high. Gullies have extended in length and width. They have therefore reduced the already small sized farms to smaller farms. Soils removed from gullies have ended in streams and rivers and this has caused sedimentation which can easily result in flooding. In fact dams like Masinga are suffering from the same effects. The cost and time taken to reclaim gullies are also very high and the practice cumbersome. Some gullies have occurred in middle of small farms, thus making the whole farming activities almost impossible. Farmers have realised the problem but in some cases they can not do much. For the majority of farmers the recommended conservation practices are not economically feasible under their financial resources. The problem is complicated further by the fact that any conservation praceice would have to involve so many poor farmers due to land fragmentation. One of the solutions would be application of cover crops and mulch farming techniques for soil and water management in Kandara.

The government participation in terms of finance and personnel should not be overlooked either and for farmers full co-operation too.

6.1.2 Waterways and Waterway planning

Waterways are an integral part of the road construction. Natural depression and waterways without shaping and protection are not safe to accommodate extra runoff concentrated by the road. On average a hectare needs 100 m of- water way, Sheng (1977). Proper water disposal should be planned during road construction. Wherever water flows over unprotected soil it may pick up and carry along soil particles. If such flows are concentrated by natural topography or works of man like roads, gullies may develop that destroy valuable farm land like those of Kandara division.

6.1.3 Water way design

Stabilization of waterways is necessary in Kandara area where runoff from roads and natural watersheds occurs. Terracing is necessary to reduce runoff in the area. Vegetated diversion channels should also be constructed across the slope to serve as diversion channels. Diversion ditches divert water away from active gullies and farm buildings, protect bottom land from overflow and intercept runoff when it is not desirable or otherwise possible to control runoff because of topography, land owership or other reasons. In Kandara gullies under some conditions trees, shrubs and logs may be more suitable for gully control than grasses and legumes. Natural re-vegetation may be stimulated by diverting flow and fencing livestock out of the areas. A gradual succession of plant species native to the region may become established. Plantings of recommended species like Chl orisgayana and Kikuyu grass can speed up revegetation. Variety in plantings will reduce the danger of destruction by disease and climatic ex tremes.

6.1.4 Channel shape

Vegetated waterways may be constructed to be parabolic or trapezoidal in crarss-section. The top width of the channel together with its cross-sectional shape and depth determine its cross-sectional area of flow. The wetted perimeter is the length of contact of the water with the bottom and sides of the channel. The area and wetted perimeter together with'the slope of the channel and the nature of the channel lining determines its flow capacity. The parabolic channel is similar in cross section to a natural waterway. Under the normal action of channel flow, deposition and bank erosion, trapezoidal and triangular sections tend to become parabolic. Parabolic channels should be selected for natural drainage ways, and trapezoidal or triangular cross-sections adopted where the entire channel must be excavated .

6.1.5 Vegetation for waterways

The vegetation selected for a given water-way is governed by soil and climatic conditions, duration, quantity, and velocity of'runoff , time required to develop a good cover and ease of establishment, availability of seed or plant materials, suitability for utilization by the farmer as a seed or hay crop, and spreading of vegetation to adjoining fields. In Kandara the recommended grasses include napier grass, nandi setaria, guinea grass, star grass and ki kuyu grass.

6.1.6 Design velocity of flow

The design velocity of flow of a vegetated water way should be such that neither scouring nor sedimentation will take place. The maximum permis* sible velocity in.the channel is dependent upon the type, condition and density of vegetation and the erosive characteristics of the soil. Velocity of flow in an open channel may be calculated by application of the manning formula.

V = r|s|	V = velocity in M^2/sec.
	R = Hydraulic radius in M.
n	S = Bed slope of channel in metre/metre.
	n = channel roughness coefficient.

The velocity is an average velocity within the channel. The velocity in actual contact with the vegetation or within the channel bed is much lower than the average velocity.

6.1.7 Channel flow capacity

The discharge or capacity of a channel may be calculated from the equation:

Q = CIA T5U	C = runoff coefficient.
	I = rainfall intensity in mm per hour.
	A = watershed area in ha.
	Q = design peak runoff rate in M^3/sec.

6.1.8 Maintenance of waterways

The condition of the vegetation is dependent not only on design and construction but also on subsequent management. Vegetation in waterways that are used as trials or lanes for livestock or vehicles will often be damaged to the point of waterway failure.

Plow furrows ending against the vegetated strip should be staggered to prevent flow concentration down the edges of the water course. High runoff during the period vegetation is being established may result in small gullies. These should be filled in and the grass re-established or the channel may need to be reshaped and reseeded. Water should be diverted to another channel during the period that grass is being established. Sedimentation should be discouraged in vegetated waterways by proper conservation treatment of the watershed above. Accumulated sediment should be removed to avoid damage to the vegetation and to prevent localised erosion. This practice however should not be confused with gully reclamation. . In gully reclamation sediment shouldn't be removed because it is necessary for gully recovery.

6.2.0 Foot paths and waterways

A solution has to be sought to combine footpaths with waterways without causing erosion. In Kandara the particular problems of waterways design relate to:

(a) # Shortage of land so that channel width when designed has to keep to the minimum.

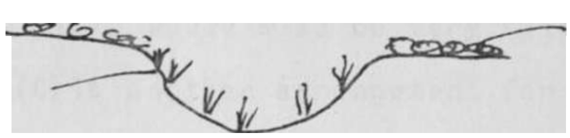
(b) Steep slopes which make it difficult to design narrow grassed waterways without drop structures.

(c) Plot boundaries run up and downslope and footpaths and tracks run on boundaries where waterways may be needed.

Below are cross-sections of suggested structures of footpath and waterway complex:-

(a)

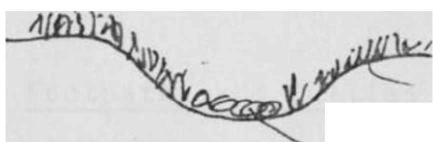
Grassed waterway



Stone lining for footpath

Footpath alongside waterwa-y.

(b)

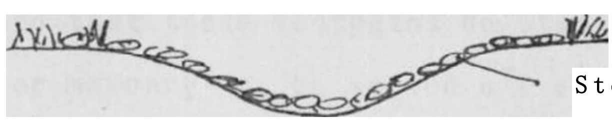


Grass.

Stone lining for footpath

Footpath in middle of waterway.

(c)



Stone lining

All waterway is footpath.

Fig. 16

Arrangement (a) in figure 16 is suitable where there is a possibility of flooding or where large volumes of water run through the waterway. Secondly such arrangement can be done to iminimize costs of construction and materials.

Where the runoff volumes are low and gentle and where funds are available arrangement (b) can be made. This would also be very suitable on steep slopes. (C)is another arrangement for minimising costs where slopes are steep and where runoff comes seasonally. In such a case arrangements have to be made to use alternative footpath during periods of high runoff. Arrangement (a) would suit Kandara situation because of its low cost of construction.

6.2.1 Footpaths and gullies

People have used the neighbouring area in places where footpaths and access roads have caused gullying. As a result new gullies or present gullies will extend into those paths. It is therefore recommended that these footpaths be stabilised by concrete or masonry or be sealed off altogether by fencing.

6.3.0 Control Structures

Check dams have proved successful in controlling further erosion in Kiriko gully and Kaguthi gully in Kiguoya village. It is expected that they will control erosion in the Kabati gully. So far these check dams are the cheapest to construct when their effectiveness is taken under consideration. Because the Kabati check dams were new, it was not easy to evaluate their effectiveness. If they do not succeed, other alternative measures can be taken*

The alternative measures are:-

(1) If funds are available, a metal pipe or pipes can be installed to carry all the water from the road to the river valley. Along side, a footpath can be constructed.

(2) At Kabati the whole gully can be cemented plus the footpath if the finances allow.

(3) Rocks and stones can be laid along the whole

length of the gully.

(4) . Loose rock check dams can be used-

6.3.1 <u>Hire bound loose rock and loose rock dams</u>

Loose-rock dams are not reinforced and can be used to control gullies. These are not recommended in Kandara because more rock is needed than when loose rock and posts are used. As for wire-bound loose rock, the disadvantage here is that posts are cheaper when used for binding than the wires. In addition when wire bound loose rock dams are used, there is temptation of stealing the wire by villagers and thus destroy the dam. For the same reason where posts are used, they should be firmly fixed so that removing them is difficult.

6.3.2 <u>Head cut control</u>

Head custs should be stabilised though in Kandara no gully showed headcut control measures. Loose rock can again be used for headcut control in Kandara gullies. If loose rock is used porosity is required to avoid excessive pressures plus some type of filter that leads the seepage gradually from smaller to the larger openings in the structure. The wall of the headcut must be sloped back so the rock can be placed against it.

6.3.3 General design criteria

The quality, shape, size and size distribution of the rock used in construction of a check dam affect the success and life span of the structure. Thus the rock that disintegrates rapidly when exposed to water and atmosphere will have a short structural life while only small rocks when used in a dam, may be removed by water flow. Therefore right sizes of stones have to be used. An effective rock gradation would call for a distribution of size classes as follows:-

10-14 cm	25%
15-19 cm	20%
20-30 cm	25%
31-45 cm	30%

Source is "Gully control structures and systems'by Heede (1977).

One important point in design of check dams is to concentrate flow in the centre of the structure and to build walls into bank with high shoulders to avoid cutting around. This was not evidenced anywhere in the control structures of gullies in Kandara, It should be carried out and foundations should be strong. This can be achieved by using rock as foundation.

Figure shows check dam.

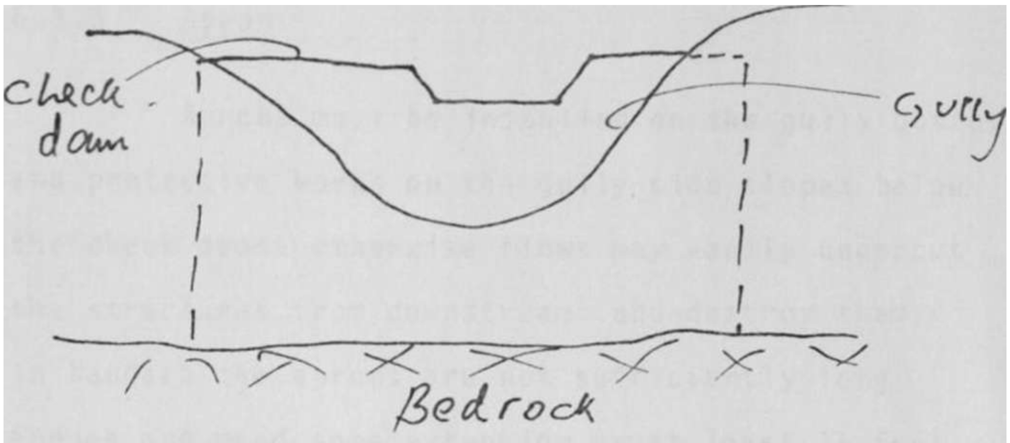


Fig. 17

6.3.4 Spacing

Requirements for spacing depend on the gradients of the sediment deposits expected to accumulate above the dams, the effective heights of the dams, the available funds and the objective of the gully treatment. If for instance, the objective is to achieve the greatest possible deposition of sediment, then widely spaced, high dams would be constructed. On the other hand, if the objective is mainly to stabilize the gully gradient, then the spacing would be relatively close and the dams low. The latter was the objective in Kandara and the spacing seems quite alright.

6.3.5 Apron

Aprons must be installed on the gully bottom and protective works on the gully side slopes below the check dams, otherwise flows may easily undercut the structures from downstream and destroy them. In Kandara the aprons are not sufficiently long enough and need some extension by at least 1J feet.

6.3.6 Bank protection

Investigations have shown that check dams may be destroyed if flows scour thegully side slopes below the structures and produce a gap between the dam and the bank. Water below a check dam is turbulent and eddies develop that flow upstream along each gully side slope as cutting forces.

Where possible banks should be planted with grass for protection. Possible grasses include napier grass, nandi setaria, guinea grass, star grass and kikuyu grass. The grass has to be established in dry season otherwise it can be washed away. Since gully banks are eroded, fertilizers might be necessary to enable grass to establish. Where gully sides are very steep effort should be made to make them more gentle. .

6.4.0 Watershed treatment

In Kandara little or no watershed treatment has been carried out as an aid to gully control. Measures taken outside the channel can also aid revegetation processes in the gully. Improvements on the watershed that increase infiltration and decrease overland flow, and spread instead of concentrate this flow, will benefit gully healing processes. Normally however improvements can be attained quicker within the gully than outside, because of concentration of treatment and availability of higher soil moisture in the defined channel. There are several watershed restoration measures to aid gully control.

These are some of the measures that should be carried out in Kandara division. They are:-

(1) Seeding and planting with and without land preparation and fertilization.

(2) Vegetation cover conversions.

(3) Engineering works such as reservoirs, water diversions, benches, terraces, trenches and furrows.

Erosion is generally severe on cultivated uplands and a variety of practices can be applied to prevent erosion and to restore and improve productivity.

Contour cultivation, contour ridges and grass strips may be more feasible and co-operation between individual farmers is essential especially for the surplus water disposal systems, such as waterways interception and diversion ditches and for irrigation facilities. On steeper slopes where the above simple conservation practices will be insufficient to stop erosion, bench terracing will probably be the most effective practice. Well laid-out bench terraces even on slopes of up to 35% can prevent erosion, increase water infiltration and should be considered as the most important practice in developing countries. Generally slopes of up to 25% should be the limit for bench terracing for rotation crops. Effective soil conservation on agricultural uplands is most important because these lands are a major source of erosion,' runoffs and siltation. Low lands also need conservation. It would be unwise to start soil conservation activities on the lowlands without'having done so first on the uplands. The main soil and water conservation practices on lowlands are concerned with maintaining and improving soil fertility by good farm management. This will include in the case of irrigation, proper levelling and application of water, prevention of alkalinity and creation of swampy conditions.

6.4.1 The possibility of diverting all runoff elsewhere is not easy in Kandara for some reasons. Kandara has shortage of land and steep slopes. Where there is shortage of land and where slopes are very steep it becomes very difficult to plan and design safe water disposal systems. Under such circumstances people are not willing to spare reasonable portions of their land for water systems, In some cases if a diversion channel has to cross several farms, it becomes difficult because not all farms might co-operate. So it is recommended that improvements be done on the existing waterways to carry runoff.

Land consolidation and prevention of new fragmentation and co-operation between in individuals and villages are indispensable for planning implementation and maintenance of watershed management.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The causes of gullying in Kandara Division are uncontrolled road drainage, degraded waterways, badly designed physical conservation measures increased runoff from cultivated areas under low standards of management and the presence of footpaths and access roads on water ways in some cases. It is therefore necessary to evaluate critically every land and water development scheme of its impact on the land. It is necessary to observe critically the reaction of the environment to road construction and exploitation of land by poor management. Conclusions should be drawn for better land use from these observations and records kept.

7.1 Footpaths and access roads should either be closed or they should also be properly planned and protected so that erosion does not occur. Conservation measures to control gullying should not stop in the gully itself but should be extended to the whole catchment area. Therefore reliable reference data maps, photographs, descriptions must be obtained for land and water development projects, so that it is possible to compare the situation before, during and after implementation of a plan. By means of repeated comparisons or monitoring, initial mistakes can be recognised and corrected.

7.2 As for the gully control structures there are many gaps in the knowledge of the magnitude, distribution and control of soil erosion in the area. A little is known about the degree to which various gully control structures presently reduce soil loss. Information in this paper about the control structures is about check dams only made of rocks and posts and sacks of soil. In view of the present concern it would be worthwhile to collect some more quantitative information about gully control in other areas to form an objective basis for decision making about gully control structures in Kandara.

Lastly treatment of the catchment with measures that will reduce runoff is important in gully control.

APPENDIX

Table 1 :

LONG PROFILE SURVEY OF LAND SURFACE OF KIRIKO GULLY

STATION.	DISTANCE (M)	BACK SITE	INTERMED SITE	FORE SITE	HEIGHT OF COLLI-MATION	REDUCED LEVELS	REMARKS
		1.32			101.32	100	On B.M.
A	o	0.12		3.19	98,25	98.13	TURNING POINT
B	5		1.60			96.65	
C	10	0.36		3.11	95.5	95.14	TURNING POINT
D	15		1.62			93,88	
E	20		2.80			92.7	
F	25	0.68		3.80	92.38	91 .7	TURNING POINT
G	30		1.76			90.62	
H	35		2.61			89.77	
I	40	0.17		3.60	88.95	88.78	TURNING POINT
J	45		1.27			87.68	
K	50		2.44			86.51	
L	55	0.72		3.60	86.07	85.35	TURNING POINT
M	60		2.00			84.07	
N	65		3.05			83.02	
o	70			3.64	82.61	82.43	TURNING POINT
P	75	0.18	1.39			81.22	
Q	80			2.80		79.81	
		3.55		23.74		79.81	
CHECK		-23.74				-100.00	
		-20.19				-20.19	

The arithmetic check:-

(B.S.) F. S.) = Last R.L. - First R.L.

Table 2:

CROSS-SECTION SURVEY OF KIRIKO GULLY

INST. STN.	STAFF STN.	DISTANCE (M)	B.S.	I.S.	F.S.	HEIGHT OF COLLI-MATION	R.L. (M)	REMARKS
A	A1	0	1.23			101.23	100	B.M.
	A2	1		1.57			99.66	
	A3	3		2.19			99.04	
	A4	3.5		1.95			99.28	
	A5	4			0.81		100.42	
B	B1	0	1.11			101.11	100	B.M.
	B2	3		1 .73			99.38	
	B3	4		2.48			98.63	
	B4	5		2.40			98.71	
	B5	6			0.63		100.48	
C	CI	0	1.04			101.04	100	B.M.
	C2	1		1.12			99.92	
	C3	3		2.28			98.76	
	C4	4		2.17			98.87	
	C5	6			0.42		100.62	
D	D1	0	1 .06			101.06	100	B.M.
	D2	1		2.15			98.91	
	D3	2		2.98			98.08	
	D4	3		2.91			98.15	
	D5	4			0.68		100.38	
E	El	0	0.91			100.91	100	B.M.
	E2	1		2,15			98.76	
	E3	4		2.10			98.81	
	E4	5			0.30		100.61	
F	F1	0	0.95			100.95	100	B.M.
	F2	2		0.61			100.34	
	F3	3		1.52			99.43	
	F4	5		1.61			99.34	
	F5	7			0.32		100.63	
G	G1	0	0.97			100.97	100	B,M.
	G2	1		0.92			100.05	
	G3	3		1.92			99.05	
	G4	4		1.92			99.05	
	G5 •	5			0.06		100.91	

Table 2:

CROSS-SECTION SURVEY OF KIRIKO GULLY

INST. STN.'	STAFF STN.	DISTANCE (M)	6.S.	I.S.	F.S.	HEIGHT OF COLLI-MATION	R.L.(M)	REMARKS
H	HI	0	1.02			101.02	100	B.M.
	H2	1		0.84			100.18	
	H3	2		1.59			99.43	
	H4	3		1.86			99.16	
	H5	4			0.00		101.02	
I	11	0	0.40			100.40	100	B.M.
	12	1		0.32			100.08	
	13	2		1.26			99.14	
	14	4		1.12			99.28	
	15	5			0.00		100.40	
J	J1	0	1.38			101.38	100	B.M.
	J2	2		0.89			100.49	
	J3	3		2.66			98.72	
	J4	4		2.70			98.68	
	J5	6			0.61		100.77	
K	K1	0	1.10			101.10	100	B.M.
	K2	1		0.84			100.26	
	K3	2		0.49			100.61	
	K4	3		2.28			98.82	
	K5	3.5		2.14			98.96	
	K6	4			0.29		100.81	
L	LI	0	2.25			102.25	100	B.M.
	L2	1		2.10			100.15	
	L3	1.5		2.00			100.25	
	L4	2		3.56			98.69	
	L5	3		3,51			98.74	
	L6	4			1.80		100.45	
M	M1	0	0.74			100.74	100	B.M.
	M2	1		0.74			100	
	M3	2		0.82			99.92	
	M4	3		1.76			98.98	
	M5	5		1.60			99.14	
	M6	6			0.39		100.35	

Table 2:

CROSS-SECTION SURVEY OF KIRIKO GULLY

INST. STN.	STAFF STN.	DISTANCE CM)	B.S.	I.S.	F.S.	HEIGHT OF COLLI- MATION	R.L.(M)	REMARKS
N	N1	0	2.04			102.04	100	B.M.
	N2	1		2.18			99.86	
	N3	2		2.73			99.31	
	N4	3		2.97			99.07	
	N5	4		2.42			99.62	
	N6	5			1.83		100.21	
0	01	0	0.66			100.66	100	B.M.
	02	1		0.92			99.74	
	03	2		1.60			99.06	
	04	4			0.66		100.	
P	PI	0	1 .55			101.55	100	B.M,
	P2	1		1.53			100.02	
	P3	2		2.40			99.15	
	P4	3		2.27			99.28	
	P5	4			1 .75		99.8	
Q	Q1	0	1.11			101.11	100	B.M,
	Q2	1		1.02			100.09	
	Q3	2		2.05			99.06	
	Q4	3		2.05			99.06	
	Q5	4		1.20			99.91	
	Q6	5			1.11		100	
R	R1	0	2.52			102.52	100	B.M.
	R2	1		2.36			100.16	
	R3	2		3.13			99.39	
	R4	3		2.91			99.61	
	R5	4		2.18			100.34	END OF
	R6	5			2.13		100.39	GULLY
S	51	0	2.71			102.71	100	B.M.
	52	1		2.95			99.76	CHANNEL
	53	2		3.28			99.43	
	54	3		3,36			99.35	
	55	4			3.07		99.64	

Table 5:

PROFILE SURVEY OF LAND SLOPE AT KABATI GULLY

STATION	DISTANCE CM)	BACK SITE	INTEMED SITE	FORE-SITE	HEIGHT OF COLLI-MATION	REDUCED LEVELS (M)	REMARKS
-	-	1.93			101.93	100.00	On B.M.
A	0	0.24		3.10	99.07	98.83	TURNING POINT
B	5		0.40			98.67	
C	10		1.5			97,57	
D	15	0.4		2.80	96.67	96,27	TURNING POINT
E	20		1.13			95.54	
F	25	0.4		2.50	94.57	94.17	TURNING POINT
G	30	0.44		3.98	91.03	90.59	TURNING POINT
H	35		1.64			89.39	
I	40	0.26		3.28	88.01	87.75	TURNING POINT
J	45		1.73			86.28	
K	50	0.6		3.00	85.61	85.01	TURNING POINT
L	55		2.20			83.41	
M	60	0.32		4.10	81.83	81.51	TURNING POINT
N	65		2.22			79.61	
0	70	0.58		3.86	78.55	77.97	TURNING POINT
P	75	0.56		2.58	76.53	75.97	TURNING POINT
Q	80	0.24		2.33	74.44	74.20	TURNING POINT
R	85		1.96			72.48	
S	90	1.01		4.1	71.35	70.34	TURNING POINT
T	95	0.27		2.28	69.34	69.07	TURNING POINT
U	100	0.22		2.41	67.15	66.93	TURNING POINT
V	105	1 .0		2.24	65.91	64.91	TURNING POINT
W	110		1.0			64.91	
X	115		1.29			64,62	
Y	120		1.61			64.30	End of Gully
Z	125		1.76			64.15	
z_1	130		1.88			64.03	
z_2	135		1.96			63.95	
z_3	140		2.10			63.81	
z_4	145			2.34		63.57	
IECK_		8.47		44.9		63.57	
		-44.90				-100.00	
.		-36.43				- 36.43	

Table 2:

CROSS-SECTION SURVEY OF KIRIKO GULLY

INST. STN.	STAFF STN.	DISTANCE (M)	B.S.	I.S.	F.S.	HEIGHT OF COLLI-MATION	R.L. (M)	REMARKS
A	A1	0	1.53			101.53	100	B.M.
	A2	0.5		1.56			99.97	
	A3	1		1.82			99.71	
	A4	2		2,81			98.72	
	A5	3		2.77			98.76	
	A6	4		2.02			99.50	
	A7	5			1.63		99.9	
B	B1	0	1.61			101.61	100	B.M.
	B2	2		2.13			99.48	
	B3	3		2.91			98.7	
	B4	3.5		2,01			99.6	
	B5	4			1.53		100.08	
C	CI	0	0.98			100.98	100	B.M.
	C2	1		1.09			99.89	
	C3	2		2.80			98.18	
	C4	3			1.12		99.86	
D	D1	0	1.87			101.87	100	B.M.
	D2	2		1.66			100.21	
	D3	3		3.00			98.87	
	D4	3.5		3.22			98.65	
	D5	4			1.82		100.05	
E	E1	0	1.39			101.39	100	B.M.
	E2	1		1.56			99.83	
	E3	2		2.84			98.55	
	E4	3		2.81			98.58	
	E5	4			1.61		99.78	
F	F1	0	1.50			101.50	100	B.M.
	F2	1		2.02			99.48	
	F3	2		2.18			99.32	
	F4	3			1.78		99.72	

Table 2:

CROSS-SECTION SURVEY OF KIRIKO GULLY

INST. STN.	STAFF STN.	DISTANCE (M)	B.S.	I.S.	F.S.	HEIGHT OF COLLI-MATION	R.L. (M)	REMARKS
G	G1	0	1.43			101.43	100	B.M.
	G2	1		1.54			99.89	
	G3	2		2.24			99.19	
	G4	4			1.54		99.89	
H	HI	0	1.68			101.68	100	B.M,
	H2	1		1.68			100	
	H3	3		2.72			98,96	
	H4	5		2.72			98.96	
	H5	6			1.56		100.12	
I	11	0	2.03			102.03	100	B.M.
	12	1		2.15			99.88	
	13	2		3.60			98.43	
	14	3		3.54			98.49	
	15	4			1.67		100.36	
J	J1	0	1.58			101.58	100	B.M.
	J2	1		2.50			99.08	
	J3	3		3.11			98.47	
	J4	5			1.54		100.04	
K	K1	0	1.38			101.38	100	B.M.
	K2	1		1.46			99.92	
	K3	3		2.48			98.90	
	K4	5			1.35		100.03	
L	LI	0	1.62			101.62	100	B.M.
	L2	2		1.64			99.98	
	L3	3		3.67			97,95	
	L4	5			1.25		100.37	
M	Ml	0	1.33			101.33	100	B.M.
	M2	1		1.69			99.64	
	M3	3		2.85			98.48	
	M4	4		2.95			98.38	
	M5	5			1.59		99.74	

Table 2:

CROSS-SECTION SURVEY OF KIRIKO GULLY

INST. STN.	STAFF STN.	DISTANCE (M)	B.S.	I.S.	F.S.	HEIGHT OF COLLI- MATION	R.U(M)	REMARKS
N	N1	0	1.80			101.80	100	B.M,
	N2	1		2.22			99.58	
	N3	No Reading		3.9				Depth at this point was 2.5 M.
	N4				1 .93		99.87	
0	01	0	1.62			101.62	100	B.M.
	02	2		2.05			99.57	
	03	3		3.21			98.41	
	04	4		3.50			98.12	
	05	5		3.50			99.23	
	06	6		2.39	1 .62		100	
P	PI	0	1.34			101.34	100	B.M.
	P2	1		1.40			99.94	
	P3	2		2.50			98.84	
	P4	3		2.92			98,42	This was on check dam.
	P5	4			10.2		100.32	

Table 2:

CROSS-SECTION SURVEY OF KIRIKO GULLY

STATION	WIDTH OF GULLY	DEPTH OF GULLY	
Q	3 m	2,8 m	
R	3.3 m	3.1 m	
S	4 m	3.3 m	
T	3.5 m	3 m	
U	4 m	3.4 m	
V	4.1 m	3.5 m	
W	3.9 m	3.6 m	
X	3 m	2.5 m	
Y	2 m	2 m	
Z	1 .92 m	1 m	End of gully and begining of a small channel which ends at the steam.

Calculated area of the catchment = 0.67 ha.

REFERENCES

1. Anon (1975), Food Statistics, Twenty-fifth Bulletin, Directorate of Economics and Statistics, Ministry of Agriculture and Irrigation, New Delhi.

Anon (1976a) Eleventh Census, 1972, Livestock (Information updated to 18.1.76) Directorate of Economics and Statistics, New Delhi.

3. Barber, R.G. Thomas, D.B. (1975), A Proposed New Design Procedure for steep back-slope terraces in the semi-arid areas of Machakos district.

4. Beasley, R.P. (1972), Erosion and Sediment Pollution Control. Iowa State University Press, Annes Iowa.

5. Blong, R.J. (1970), The development of discontinous gullies in a Pumice catchment. J. American Science Vol.268 p.369.

6. Bradford, J.M., Piest, R.F., (1977), Gully wall stability Loess-derived alluvium. J. Soil Science Society of America Vol .41 , p.115.

7. Bradford, J.M., Piest, R.F. (1978) Failure sequence of gully head walls in Western Iowa. J. Soil Science Society of America, Vol.42, p.323-328.

8. Dimbley, G.W., (1962) Development of British heathlands and soils, p.40-41.

9. Dunne, T. (1976b) Intensity and Controls of Soil erosion in Kajiado District Kenya. Consultancy Report to the Kenya Wildlife Management Project, Nairobi Soils Bulletin 33, F.A.O. Rome.

10. Dunne, T., Ongweny, G.S.O. Studying patterns of Soil erosion in Kenya. Soils Bulletin 33, F.A.O. Rome.

11. Dunne, T., Ongweny, G.S.O. (1976) A new estimate of the rate of sedimentation in reservoirs on the Upper Tana river Kenya. The Kenyan Geographical Journal. December, 1976.

12. Eugene etˆ ajˆ (1976), Highway erosion control and prediction.

13. 'Heede, H.B., (1977), Gully control structures and systems, Conservation Guide I F.A.O. Rome.

14. Henneman, G.R. (1975), Erosion in the Kisii-West Area, Kenya.

15. Hudson, N. (1971), Soil Conservation. Cornell University Press, Ithaca, New York.

16. Logan, J.M., (1968), The Design of earth structures for Soil Conservation in Eastern New South Wales. J. Soil Conservation N.S.W. Oct. 1968 p.186-209.

17. Ologe, O.K., (1972), Gullies in the Zaria area: A Preliminary study of headscarp recession. Savanna, a Journal of the Environmental and Social Sciences published at Ahmadu Bellow University Zaria. Vol.1 No. 1 p.55-66.

18. Quilty, J.A. (1973), Gully Control structures and absorption banks. J. Soil Conservation Service N.S.W. Vol. 29 (1973), p.3-13.

19. Rapp, A., (1972), Soil erosion and reservoir sedimentation case studies in Tanzania. Soils Bulletin 33, F.A.O. Rome. P.123-131.

20. Sheng, T.C., (1977), Protection of Cultivated Slopes, Conservation Guide I. F.A.O., Rome, p.147-171 .

21. Staples, R.R. (1933), Reports of the runoff and soil tests at Mpwapwa in semi-arid Tanganyika.

22. Temple, P.H., (1972), Soil and Water Conservation policies in the Ulluguru Mts. Tanzania.

23. Tuckfield, C.G., (1964), Gully erosion in the New Forest Hampshire. J. American Science, Vol.262-, p.795-805.

24. Walter, F.M., (1977), Reducing erosional impacts of roads. Conservation Guide I F.A.O., Rome, p.237-259.

25. Wenner, C.G., (1980), Soil Conservation in Kenya.