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LAND DEGRADATION MONITORING PROGRAMME OF THE NATIONAL ENVIRONMENT AND HUMAN SETTLEMENTS SECRETARIAT MINISTRY OF ENVIRONMENT AND NATURAL RESOURCES KIAMBU DISTRICT, KENYA THE FIRST PILOT STUDY (Preliminary Report)

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OBJECTIVES

This pilot study, begun in July, 1981, is the first stage in developing a methodology to provide basic information on soil erosion to planners, district officials and operating ministries in Kenya. The results of this programme will provide some of the crucial environmental data that will help NES to execute its mandate to monitor the state of the national environment. The specific objectives of the Erosional Monitoring Programme are to:

- develop a methodology that can rapidly be applied and used in the diverse environmental settings found throughout Kenya;
- quantify the amount of erosion occurring in rural areas;
- identify the general rural environmental settings in which erosion is a major problem;
- develop a simulation technique to determine if proposed activities will be deleterious to the existing land resource base, and, if so, what changes in land use plans might be suggested to minimize negative impact; and,
- this should help the NEHSS to suggest priorities for remedial action and appropriate strategies to use.

As one intent of the Secretariat is to make this information available to any ministry concerned with ameliorating land degradation; the data provided will be in a format that can be utilized in designing general safe criteria for land use planning as well as for legislative purposes.

Personnel and Governmental Organizations Involved in the Pilot Study

The success of the pilot study required the cooperation of numerous organizations and individuals that had first-hand experience and knowledge of the soil erosion situation within Kiambu District. No matter where future

monitoring programs will occur in Kenya, the need exists to obtain the crucial cooperation of the individuals living and working in the area if information is to be rapidly and accurately gathered.

Several individuals cooperated with this project and insured its success. Particular appreciation is given to Mr. P.M. N'jenga who acted as liaison with Ministry of Agriculture personnel in Kiambu District and assisted this project continuously throughout the field portion of this project. The following were particularly helpful:

Mr. Kobia - formerly District Commissioner Kiambu District (now P.C. Western Province) and the seven district officers in Kiambu District
Mr. Kibage - District Agricultural Office
Mr. P.M. N'jenga - Kiambu Crop Specialist, District Office
Kiambu Divisional Extension Agricultural Officers -
- Mr. Stephen K. Ng'ososei (Gatundu)
- Mr. K.C. N'getich (Githunguri)
- Mr. H.P. Obade (Kiambaa)
- Mrs. G.N. Maingi (Kikuyu)
- Miss G.W. Kamakia (Lari)
- Mr. Keinduiwa (Limuru)
- Miss Amenya (Limuru)
- Mr. J.M. Karanja (Thika)

Dr. Lawrence Ulsaker - Kenyan Agricultural Research Institute allowed NES to utilize the laboratory facilities to dry and weigh the soil samples

Almost all of the farmers interviewed in Kiambu were very much concerned with the problem of soil loss and realize the need to minimize it. In the whole District, no farmer was ever unwilling to cooperate with the project. In particular, the following farmers need to be mentioned as they both permitted measurements of soil loss to be made on their farms and watched the equipment placed on their farms. In addition, they provided us with numerous agricultural insights on the environmental problems affecting their farms and how they deal with them.

Mr. Hiuhi; Mr. F. Gichuki; Mr. C. Njiriri; Mr. R. Kangeth; Mr. P.K. Kinundu; Mr. Njenda; Mrs. P.M. Gachigua; Mr. N. Kinyita; Mr. P. Kimani and Mr. G. Gichuki; Mrs. T.W. Kago; Mr. K. Mugatha; Mr. K. Njugunaj; Mr. R. Mwithuria.

Data Collection Approach

Kiambu District, Central Province was chosen as the first pilot area. Data gathered in this pilot study are aimed primarily at developing the methodology to permit NEHSS to rapidly assess existing and potential land degradation throughout the nation. Kiambu has many advantages for this initial inquiry. First there are a diverse number of physical environmental settings found within the district ranging from humid to almost semi-arid; flat to extremely steep; and rich volcanic highly resistant soils to poor clay highly erodable soils. In addition there are diverse human-economic situations ranging from large estates to small individual farms less than 1/8 of an acre in extent; part-time and full-time commercial and subsistence farms; farms largely export oriented to farms oriented to the domestic market including the Nairobi market; nonirrigated and irrigated farms; farms long established and farms in newly settled areas some of which are largely unplanned and others which are in government developed schemes. Finally the proximity of Kiambu to Nairobi minimizes the logistic problems during the first year when unexpected problems should occur in greater frequency than in future years.

Little soil erosional data were available at the onset of this study. Given the relatively weak data base for soil loss throughout Kenya, one critical need for this study is to develop a rapid approach that can evaluate soil loss in a resource context within the constraints of the Kenyan situation. This is crucial if the objectives of this study are to be met and information is to be made available to farmers. The strategy decided upon to evaluate the soil resource for Kiambu was to first simulate soil loss for the whole district under 'natural' vegetation conditions. The justification for this approach is that this is the condition under which the soils formed. This simulated soil loss is assumed to approximate the normal or geologic

erosion and represents a non-degrading soil condition under natural conditions. The simulated values are assumed to be the minimal soil loss values possible.

A major purpose of this study is to apply the methodology being developed to determine if soil degradation exists in Kiambu, and if so, its magnitude and areai extent. Thus it is necessary to compare actual soil loss (data collected in the field) with the simulated 'natural' soil loss. As the ratio between actual soil loss to the 'natural' soil loss increases, degradation increases. Areas where large ratio values exist are potential problem areas in terms of high soil loss for agricultural purposes and high sediment production for that could limit projects. The assessment of 'natural' soil loss for Kiambu District was completed December, 1981. This information is available at the Natural Resources Division National Environment and Human Settlements Secretariat (Nairobi) and Internation Development Program, Clark University (Worcester).

The assessment of actual soil loss took place over a six month period from January to July, 1982. The initial phase of the assessment was a reconnaissance of the district to determine the agro/economic settings found in the area as well as to observe the obvious soil erosion and conservation practices. The purpose of the reconnaissance was to insure that each of Kiambu's major environmental settings would be included in the sample of soil loss measurements during the 1982 long rains. In each of the seven divisions, a divisional agricultural officer, and often a D.O. and district agricultural officer accompanied NEHSS personnel on the initial erosion survey. The complete spectrum of conditions ranging from major problem areas to well managed areas from their perspectives were examined. Conversations with the farmers and landowners added insights into reasons for crop selection, conservation

practices and other factors affecting land utilization. During this phase vegetation types (including crops) and location, topography, gully location and conservation practices were noted.

The next phase of the investigation was the installation of equipment to measure soil loss in the diverse settings found in Kiambu to determine their relations to environmental conditions. Beginning in the middle of February four automatic recording raingages were installed; one in Lari, Kikuyu, Kiambu and Gatundu Divisions. These gages measure both the quantity and intensity of precipitation. In addition, data from the existing raingage at KARI was made available for our use. After the completion of raingage installation, 27 soil traps were placed in individual fields that constitute a sample of the environmental conditions found throughout Kiambu.

At the end of March, the rains began. Precipitation data and soil loss data for the whole 1982 rainy season from the 29th of March to 30th of June were continuously collected and recorded. In addition 5 soil samples were sent to N.V. Philips in Almelo, Netherlands to determine the major mineral properties of the soils found in Kiambu in order to approximate the erodability of the soils. Simultaneous with the measurement of soil loss, all the major gullies found in the district were measured and the environmental situation in which the gullies were situated was noted. These measurements were done by both NEHSS personnel and the division agricultural officers. With the cessation of the rains, the analysis of the data began.

DATA ANALYSIS

Four types of soil erosion were identified in Kiambu District during the pilot study. These are: soil loss (sheet wash) resulting from agricultural activities; gully erosion resulting largely from runoff of roads; erosion resulting from small individual quarry operations; and massive hillslope failure resulting from tree clearing on very steep slopes and tea/agricultural crop substitutions. While the primary focus of this study is on soil loss resulting from agricultural activities, the other three types of erosion are briefly discussed since they all affect the soil resource.

Soil Loss-Agricultural Activities

All soil loss data were collected using the installed soil traps (Figure 1, photo). Table 1 lists a summary of the total soil loss for the 27 field sites during the 1982 long rainy season. From an agricultural perspective if soil loss is less than the soil tolerance*, the soil loss is considered acceptable. Soil tolerance rates in the United States range between 4.5 M tons/hectare/year for poorer soils to 11.2 M tons/hectare/year for the best soils. Little quantitative information is available for soil loss tolerance for Kenyan soils and Kiambu District in particular, but likely the majority of soils in Kiambu have tolerance less than 6.5 M tons/hectare/year. The simulated 'natural' soil loss values already derived for Kiambu District are assumed to represent the likely tolerance of the soils. Because of the variable nature of soil tolerance from area to area, it is important to remember when examining the soil loss figures in Table 1 that the sites having lower values do not imply that soil degradation is less of a problem than field sites having higher values. The range of these simulated values is less than

* Soil tolerance is the upper amount of erosion that can take place without soil degradation occurring.

TABLE 1

Total Soil Loss in Long Rainy Season 1982 by Site

Site	Slope	Major Land Use	Soil Loss 29/3/82-30/6/82 MT/hect/rainy season
1K	3°	Coffee	less than 1.0
2K	18°	Coffee	1.6
3K	22°	Coffee	1.1
4Y	20°	Cabbage	3.9
5Y	11°	Cabbage	1.2
6Y	12°	Maize	39.6
7L	45°	Potatoes	25.8
8L	20°	Mixed Vegetables	10.3
9L	20°	Pyrethrum	7.8
10L	15°	Maize	11.5
11L	20°	Cabbage, Potatoes	6.2
12L	16°	Mixed Vegetables	9.7
13M	14°	Plums	1.1
14M	11°	Pears, Grass	less than 1.0
15M	15°	Pears	1.5
16R	3°	Tomatoes	less than 1.0
17R	10°	Bananas, Beans	5.3
18R	11°	Coffee	less than 1.0
19R	4°	Maize	16.5
20R	6°	New Coffee, Beans	13.1
21G	20°	Maize	57.4
22G	20°	Maize	24.7
23G	9°	Mixed Vegetables	11.2
24G	12°	Coffee	4.1
25T	9°	Beans	22.9
26T	9°	Beans	11.4
27T	10°	Chick Peas	6.5

K = Kiambaa
T = Thika
G = Gatundu
R = Githunguri
L = Lari
M = Limuru
Y = Kikuyu

Range of accepted soil loss tolerance in U.S. 4.5 to 11M tons/hectare/year.

1.0 to 6.5 metric tons per hectare per year. Thus all soil-loss values greater than 6.15 M tons/hectare/year clearly represent problems.

The range of soil loss measured during 1982 was between 57.4 and less than 1.0 metric tons/hectare/year. The field having the 57.4 loss is clearly a major problem site. Major efforts to lower the soil loss need to be taken immediately in this area. The sites having less than 1.0 metric tons of soil loss are areas of excellent farming practices. Evident in summary Table 1 are a few basic relations between crop type and soil-loss for Kiambu District that merit future consideration in soil erosion control programs. Perennial crops consistently have the lowest soil loss (less than 1.0 M.T. to 4.1 M.T.); lands cultivated under maize produce the largest soil losses (11.5 M.T. to 57.3 M.T.); within a given farm, fields in cash crops in each division have lower soil losses than other crops.

Many fields in the Lari Escarpment area and in the nearby parts of Limuru Division under pyrethrum have visual indications of experiencing excessive soil loss. Thus, the 7.8 soil loss for site #9 is likely to be excessive for soils in this area. The simulated value for this area is 2.3. This substantiates the visual evidence of soil degradation (actual soil loss is higher than 'natural' soil loss). This is one bit of evidence that the simulated values are valid and meaningful for the assessment of land degradation. Sheet wash is clearly a problem in many fields under pyrethrum as evident by the coarse texture found on the surface of the soils. A large percentage of the soil's clay and silt components have been removed from the surface. Abandoned fields, no longer being cultivated, that previously were in this crop are found scattered in some parts of these areas. This gives evidence of the relatively low tolerances of soils in the pyrethrum zone. Data in Table 1 (sites 7-12) indicate that the food crops are generally resulting in even

higher erosion under these environmental conditions found along the Escarpment. It is important to note that tree crops when introduced on lands having high erosion under other crops, appear to be an effective erosion control (sites 13,14,15). With just the opposite being the dominant trend in some parts of Kiambu, especially Gatundu Division, it is expected that erosion will significantly increase as trees are cleared for agricultural purposes.

Because raingage coverage was not present in all divisions of Kiambu, it is necessary to group the seven divisions into four groupings (Figure 2 -map) for further analysis (Lari Grouping includes Lari and Limuru; Gatundu Grouping includes Gatundu and Githunguri; Kikuyu Grouping includes Kikuyu; and Kiambaa includes Kiambaa and Thika).

As a primary purpose of this pilot study is to develop a methodology that can rapidly assess soil erosion, an analysis of variance was used to examine the relations among crop type and conservation practices on soil loss. Tables 2 through 6 present this information for the four groupings individually and for Kiambu District as a whole. Type of crop cover and conservation methods for all the groupings are significant except in the Lari Grouping. And even in this grouping, if the crops had been classified solely between annual and perennial crop type and conservation method they would have been significant.

Some extremely meaningful relations that will be used in the development of the methodology for rapid soil loss assessment became evident from the analysis of variance (Table 7). First perennial crops are very good indicators of less than average soil loss. Second cash crops are also good indicators of less than average soil loss. These relations are found throughout all of Kiambu to be generally valid. In the Kikuyu Division (Table 3) this is clearly examplified where erosion rates for coffee and vegetables, both important cash crops, produce the lowest soil losses. Not evident from this data

TABLE 2

Analysis of Variance for Kiambaa Grouping (1982)
Crop types, Conservation Practices, Soil Loss

Kiambaa Grouping

	Significance	Mean soil loss/trap	Number of observations
Crops			
Coffee		87.7	30
Mixed Vegetables and Maize	0.008	3.4	30
Crop and Conservation			
Coffee:			
Mulching		less than 0.1	1
Terrace and Mulching		less than 0.1	10
Terrace, Mulching and Cutoffs		5.42	19
Mixed Vegetables and Maize:			
Terrace or Mulching and Cutoffs		87.7	30

TABLE 3

Analysis of Variance for Kikuyu Grouping (1982)
Crop types, Conservation Practices, Soil Loss

Kikuyu Grouping

	Significance	Mean soil loss/trap	Number of observations
Crops			
Coffee		7.4	31
Beans-Maize		396.0	10
Mixed Vegetables (cash crop)	.007	19.8	19
Crops and Conservation			
Coffee:			
Terrace or Mulching		7.4	31
Beans/Maize:			
Cutoff or Intercropping		396.0	10
Mixed Vegetables:			
Terrace or Mulching		19.8	19

TABLE 4

Analysis of Variance for Gatundu Grouping (1982)
Crop types, Conservation Practices, Soil Loss

Gatundu Grouping

	Significance	Mean soil loss/trap	Number of observations
Crops			
Bananas and Coffee		20.3	30
Beans/Maize		289.4	40
Mixed Vegetables	.09	232.2	20
Crops and Conservation			
Bananas and Coffee:			
Terrace or Mulching		20.3	30
Beans and Maize:			
Terrace or Mulching		289.4	40
Mixed Vegetables:			
Intercropping or Cutoff		110.0	10
Terrace or Mulching		354.4	10

TABLE 5

Analysis of Variance for Lari Grouping (1982)
Crop types, Conservation Practices, Soil Loss

	Lari Grouping Significance	Mean soil loss/trap	Number of observations
Crops			
Pyrethrum		17.5	30
Beans and Maize		34.0	20
Mixed Vegetables	0.3*	35.0	10
Crops and Conservation			
Pyrethrum:			
Terrace or Mulching and Cutoff		16.1	20
Terrace, Mulching and Cutoff		20.5	10
Beans and Maize:			
Intercropping or Cutoff		34.0	20
Mixed Vegetables:			
Intercropping or Cutoff		35.0	10

*Not significant

TABLE 6

Analysis of Variance for Kiambu District (1982)
Crop types, Conservation Practices, Soil Loss

Kiambu District (all groupings combined)

	Significance	Mean soil loss/trap	Number of observations
Crops			
Coffee		10.3	91
Pyrethrum/Banana		17.5	30
Beans and Maize		231.7	70
Mixed Vegetables	.0007	101.2	79
Crops and Conservation			
Coffee:			
Mulching		0.1	1
Mulching or Terracing		13.7	61
Terracing and Mulching		0.1	10
Terracing, Mulching and Cutoff		5.42	19
Banana and Pyrethrum:			
Terrace or Mulching, Cutoff		20.5	10
Terrace and Mulching		16.1	20
Beans and Maize:			
Intercropping or Cutoff		154.7	30
Terrace or Mulching		289.5	40
Mixed Vegetables:			
Cutoff or Intercropping		72.5	20
Terrace or Mulching		135.2	29
Terrace or Mulching and Cutoff		87.7	30

TABLE 7

Summary Table of Stepwise Regressions

	R^2	
Lari Grouping		N = 60
Crop Cover	0.22	
Conservation Factor	0.27	
Average Weekly Duration of Rain Event	0.31	
Slope	0.39	
Max 30 minute duration	0.41	
Gatundu Grouping		N = 90
Slope	0.12	
Total Precipitation	0.21	
Average Weekly Rainfall Intensity	0.28	
Crop Cover	0.31	
Conservation	0.34	
Kikuyu Grouping		N = 60
Conservation	0.17	
Total Precipitation	0.25	
Average Weekly Intensity	0.32	
Crop Cover	0.35	
Slope	0.37	
Kiambaa Grouping		N = 60
Crop Cover	0.15	
Average Weekly Duration	0.25	
Conservation	0.27	
Maximum Precipitation in a Single Event	0.33	

is the finding that on the vegetable fields most oriented to the Nairobi (cash) market, the soil loss is less than on the other fields. The use of irrigation to increase the length of the growing season reduces the soil loss on these fields. One likely explanation for this is that at the start of the rainy season, these fields already have a good vegetation cover and thus the soil is partially protected from rain drop impact. Third, excessive conservation practices on cash crops indicate moderate soil loss (see Table 2, Table 4, Table 5). This apparent contradiction is easily explained. With the expansion of cash crops on to more marginal lands in Kiambu District, a need exists to use more conservation than on the better lands. But because conservation practices only reduce soil loss, greater erosion still occurs than on the better lands that require less conservation. In Kiambu for agricultural lands the occurrence of mulching and terracing is the best indicator of low soil losses. Fourth, a hierarchy in crop types exists related to soil loss. Coffee is the best cash crop in terms of the soil loss relation (Table 6). However, it should be noted that tea is even better than coffee, but no soil loss data were recorded in tea fields in this study as the low soil loss from tea is well documented. Wattle and other trees also produce less soil loss than coffee. Maize and beans two primary food crops are good indicators of high soil loss in Kiambu. To further explore the predictive relations between visual indicators and soil loss a series of stepwise regressions were undertaken.

To explore the predictive relations between the visual indicators such as crop type, precipitation attributes and slope steepness, with soil loss, four stepwise regressions were run for each of the four area data groupings. Prior to running the regressions it was necessary to assign numerical values to the various crop and conservation practices that exist in the area. Utilizing the

findings of the analysis of variance, values for crops were assigned as follows:

Coffee and tree crops	5	(low erosion indicator)
Bananas and pyrethrum	4	
Vegetables (excluding beans/peas)	3	
Beans and peas	2	
Maize	1	(high erosion indicator)

Values for conservation practices were assigned as:

Mulching and terracing	5	(low erosion indicator)
Terracing or mulching	4	
Terracing, mulching, and cutoffs	3	
Intercropping	2	
Other	1	(high erosion indicator)

Table 7 lists the significant (at the 0.05 level) variables for each of the four area groupings. In the Gatundu Grouping, which is the area having the overall steepest terrain in Kiambu, the slope factor contributes the greatest explanation to soil loss. In Kiambu and Lari the crop cover is most important. In Kikuyu conservation practices provide the greatest explanation (Table 8). While not discussed previously, the stepwise regression results all indicate the importance of precipitation properties affecting soil loss. The most important result of the regression analysis for the purpose of this pilot study is that the values assigned to the crop cover and conservation practices result in meaningful relations. This quantification procedure can thus be used in the development of the methodology for assessing soil loss.

TABLE 8

Crucial Factors in Soil Loss

	Pp	Slope	Crop	Conservation
Gatundu		X		
Kiambaa			X	
Lari			X	
Kikuyu				X

Gully Erosion

Gully erosion primarily occurs in three environmental settings in Kiambu: at culverts associated with road drainage; along footpaths; or near school play fields and market areas. Only in one area in Kiambu was any serious rill formation noted that could be traced solely to agriculture. This was in the Ngoliba Settlement Scheme (Thika Division). In this Scheme the soils, unlike most other soils found in the district, have a high clay content. A general practice at Ngoliba is to build terraces and cut off trenches where most of the eroded soil is trapped. On the better farms, between rains, the soil is removed from the trenches and spread over the fields from which the soil originated (Table 1, sites 25, 26, 27). Clearly this is a very labor intensive activity and with increasing labor costs this activity is decreasing resulting in greater actual soil loss.

The other gully erosion related to agriculture is along footpaths. The location of the footpath is a clear indicator of above average erosion potential. When gullies or rills are noted on the footpath or the area juxtaposed to the path, this is direct evidence of excessive erosion. But this problem appears to be under control in a large percentage of the district. Farmers are cognizant of the footpath-erosion problem and are both terracing (steps) and planting grass on footpaths at the step. The existence of steps and grass on footpaths are good indicators of low soil losses emanating from the footpaths.

Gullies that originate from the surface runoff of large bare areas, such as market areas, diversion ditches associated with gabions, and road runoff ditches or culverts present a growing problem throughout the whole district. Unfortunately the ability to control these major gullies lies beyond the capabilities of the farmers whose land is being washed away. Table 9 lists

TABLE 9

Gullies in Kiambu District (only greater than 2 meters wide)

Gully	Location	Age	Length (meters)	Average Depth/Width (meters)	Maximum Depth/Width (meters)	Origin
Kiambaa						
Buriria	Ndumberi		40	2.0 x 1.5	12 x 3.4	
Gachingiri	Ndumberi		45	2.5 x 2.5	9 x 3.3	
D.B. Gulley	Ndumberi		87	3 x 2	13.8 x 3.1	
Gacarage	Tinganga		62	6.2 x 3.1	24.6 x 4.3	
Kanunga	Kiambaa/ Ndumberi		51	4.3 x 2.5	15.7 x 3.0	
Gatundu						
Ngenda	Ngenda		45	1.5 x 2.5		School, Shopping Center
Kiamwangi	Kiganjo		30	2.5 x 2.5		Road Culvert
Nduthini	Ngenda		20	2.5 x 2.0		
Karinga	Ndarugu		25	1.5 x 2.2		School
Nyamu	Chania		125	2.0 x 2.5		School, Road Culvert
Kikuyu						
Gikuni	Kabete		200	3.5 x 4.0	10 x 15	
Muthure	Mugugu	8	240	1.1 x 2.1	2 x 2.4	Road Culvert
Thogoto	Kinoo		150		12 x 15	Road Culvert
Kinoo	Kinoo		200	2.0 x 2.0		
Chura	Kabete		100	2.0 x 2.0		
Thika						
Ngoliba I	Gatuanyaga		50	2 x 3.0		
Ngoliba II	Gatuanyaga		100	2 x 3.5		
Munyu	Gatuanyaga		75	2.5 x 3.0		
Munyu	Gatuanyaga		80	2.5 x 3.0		
Juja	Juja		100	2.5 x 4.0		
Lari						
Kagwi	Gatamaiyu		200	2.0 x 2.5	3.0 x 3.5	Market
Gachoire	Gatamaiyu		80	2.0 x 3.0	3.5 x 2.5	
Kamuchege	Gatamaiyu		100	2.5 x 3.0	2.8 x 3.2	Market, Road
Giant Ibonia	Escarpment		32	1.5 x 3.0	3.1 x 7.0	
Rare Village	Escarpment		62	1.1 x 2.0	1.5 x 3.0	
Mugatha	Escarpment		250	6.0 x 4.0	7.0 x 5.0	
Mbauni	Escarpment		30	2.0 x 2.5	2.5 x 3.0	
Mbathi	Escarpment		42	2.0 x 2.5	3.0 x 3.5	
Karinga	Escarpment	10	395	2.3 x 2.2	3.4 x 4.0	Road Culvert

the major gullies (over 2 meters wide) identified and measured during the period of this pilot study. It is important to remember that most gullies in Kiambu are less than 2 meters wide and thus are not on this table. These generally 'small' active gullies are primarily resulting from road runoff and according to the Divisional Extension Officers will be over 2 meters wide in the near future if corrective measures are not quickly initiated.

The soil loss from the large gullies contribute a large amount of sediment besides removing land from agricultural production. For example Karinga Gully (Table 9) has resulted in the removal of over 1,970 cubic meters of earth. The total quantity of soil loss from gullies less than 2 meters wide due to their higher frequency and active growth likely is greater than the total soil loss from the large gullies.

The general method of gully control in the area has been gabion construction. This appears to be a relatively ineffective and costly approach for gully control in Kiambu. First the gabion only protects the immediate gully upslope from it. Second, often water goes around the gabion or overflows the top. Two examples illustrate the problems with gabions. In Thika Division, Ngoliba Location a large gully resulting from road runoff had a large gabion constructed in 1981 during Soil Erosion Week. By the end of the 1981 rainy seasons, a gully downslope from the gabion had formed over 30 meters in length and 2 meters deep. The gabion had resulted in filling up the gully above it for 7 meters, but clearly did not stop active gully growth. Another example in a different setting occurs along the dirt road near the Riara Coffee Factory (Kiambaa). Here a series of small gabions have been built along a drainage ditch paralleling the road in an attempt to stop erosion in the drainage ditch. The effect of the series of gabions has been to force the water from the ditch onto the road surface. The result is that gullies are

now forming on the road itself. The need is to prevent runoff from becoming concentrated to such a magnitude that gully formation even occurs. Once the gully has formed, the effort should be in reducing the runoff at the source. The gabion does not do this. Since in most places the runoff and gully formation occur in different locations, a need for co-operation between more than one government agency will be required.

With the primary purpose of this study being to assess soil erosion, the existance of gabions and gullies are both very good indicators of severe soil erosion. Gullies that are not grassed and show side collapse are other visual indicators of high erosion. Similarly the presence of road culverts and diversion ditches are other visual indicators of high erosion.

Quarries

On steep slopes or in areas that are relatively dry for Central Province, quarrying activity by individuals often is an economic activity. For example, in Thika Division in the Gatunyaga and Munyu Areas numerous very small quarry operations are found. For most of the individuals working the small quarries this activity is their major cash producing labor as farms in these areas are not cash oriented. In Gatundu Division small quarries are found along many of the steep slopes in Wamwangi Area. These small quarries are found throughout the whole District except in the areas of large coffee and tea estates. Wherever they exist, due to the disruption of surface material, soil erosion is large. Thus, the presence of a quarry is a very good visual indicator of high soil loss on the slopes that are affected by this activity. Quarrying is a source of high local sediment production, especially in steep areas which have streams occupying the immediate valley bottoms.

Slope Failure

The only area in which slope failure resulting from agricultural activities was noted was near Mundoro in upper Gatundu (Figure 3, photo). Throughout upper Gatundu agricultural expansion is rapidly occurring in areas previously under tree cover. In many parts the slopes are greater than 45°. In the area where the slope did fail it destroyed a tea field. Now because of the unstable slope, other fields will collapse and a rural road is threatened.

From visual evidence it appears that even terracing and the best agricultural crop, namely tea, in these areas of steep slopes produce excessive erosion, and in extreme cases even slope failure. Where food crops are grown soil loss is even greater. In the years to come as the tree cover is destroyed, this area will undergo ever increasing erosion. Whenever slopes are greater than 45°, tree cover should be encouraged. Cleared lands on steep slopes over 45° (100%) is another indicator of high erosion regardless of the crop cover.

Preliminary Results

Through the analysis of the data collected as well as the general reconnaisance of the District including discussions with the farmers, estate managers, The District Commissioner, district officers, and agricultural officers, a set of visual indicators that are related to soil loss has been identified. The types of crops, conservation practices, slope steepness, engineering works (culverts, gabions, school yards, markets), and quarry activities are all identified as crucial factors that affect soil erosion and at the same time can be quickly observed. As substantiated by the stepwise regressions, the

values assigned for crop type and conservation practices are a valid quantification of these phenomena.

The general findings for Kiambu at this stage of the analysis are that cash crops usually result in low erosion. This is likely because the farmers have placed them on their better lands. Perennial crops, everything else being equal, result in lower erosion than annual crops. Maize generally is the crop that causes the greatest soil loss. Irrigation is a good indicator of lower erosion for a given crop than if it were grown without irrigation. Conservation practices reduce erosion, but areas that have been required to practice maximum conservation have moderate soil losses. This moderate soil loss occurs despite the major conservation practices since the lands which have major conservation inputs are generally of a poorer quality than the areas of only moderate conservation practices. Thus, while the conservation reduces soil loss, it is still greater than on the better lands with less intense conservation activity. Thus, the types of conservation practiced are good visual indicators of soil loss. Newly settled areas, as they are located on poorer agricultural lands, have greater soil loss than the older farmed areas. Unless conservation practices are stongly enforced in these newly settled areas, the number of productive years of these lands will be relatively short.

Gully erosion is increasing in Kiambu, but generally it's the result of non-agricultural activities and cannot be controlled by the farmers whose lands are being gullied. Gully formation in Kiambu is primarily the result of drainage diversions resulting from road and building construction. Gabion construction is largely ineffective in controlling this type of gully initiation. A need exists for the various ministries involved (especially Agriculture and Public Work Roads) to co-operate on this problem. Evidence exists that gully formation will increase in Kiambu unless there is immediate action.

The ever increasing deforestation of steep slopes is creating new areas of land disequilibrium. This activity will not only result in new erosion and sedimentation acceleration; but in some places it will destroy the land resource for future generations and thus destroy the long term agriculture and silvaculture potential of the areas. Impacts on the water resource likewise result from the deforestation. Clearly more extreme flow regimes of the streams will result. Streams will both flood more often and dry up more often due to the changes in runoff and infiltration relations. Finally, quarry activities cause local erosional problems. Unless this activity is controlled additional agricultural lands will be lost.

Suggested Basic Remedial Land Degradation Actions and Controls

If the preliminary findings in Kiambu are determined to be representative of conditions throughout Kenya, a need to modify existing practices will be required to insure the continuous productivity of the rural Kenyan sector. A few major requirements are evident from Kiambu. Clearly a need exists to modify the design of roads. In particular, road surface runoff control must include the juxtaposed lands along the roads as well as the road surface. The current practice of permitting excess road runoff to initiate major gullies has to be arrested quickly.

Second, control on crop selection needs to be attempted. If maize is to continue to be planted, new practices need to be implemented to minimize its high erosional potential. Agricultural officers need to determine the best procedures and then demonstrate these new procedures to the farmers. The need to require the mulching of maize fields is one likely possibility.

Third, the clearing of tree cover at least from the very steep slopes (40°) must be halted. Not only is soil loss high on these slopes, but actual slope failure can occur. A program to encourage perennial crops whenever possible should be developed.

Fourth, in newly settled areas as well as sites currently being cleared for agricultural expansion, the soil loss rates are above average. Also, as more cash crops are planted on marginal lands, even with additional conservation practices, soil loss rates are above normal. It appears that all of the good agricultural lands in Kiambu are already under cultivation. Therefore any agricultural expansion in Kiambu is likely to result in only short term use of the newly cultivated lands before land-degradation becomes severe. At a minimum, agroforestry needs to be considered as a possible option for increasing agricultural output if complete tree cover is not a viable option.

Finally, the building of gabions as an erosional control needs to be re-examined. Not only is it costly, it appears to have only limited success. There is a need to control the cause of the gully formation at the source.

Ongoing Analysis

Ongoing analysis will be completed by the end of November.

1. Development of simulation of actual soil loss for Kiambu.

2. Assessment of the state of land degradation for Kiambu (ratio between actual and natural soil loss.

3. Production of land degradation and/or actual soil loss maps for Kiambu if NEHSS requests this.

4. Development of initial check list to predict soil erosion rapidly using visual indicators and simulation data.

Future Work

1. Pilot study in another environmental setting, 1983 rainy season.

2. Test validity of checklist methodology for predicting soil loss in the 1983 pilot study area (compare collected data to checklist methodology derived data).