A STUDY OF DESIGN, CONSTRUCTION AND BANK STABILIZATION OF FANYA JUU TERRACES AT KABETE, KENYA

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DECLARATION

This project is my original work and has not been presented for a P.G. Diploma in any other University.

Masereke 19-5-1983

Eric M. Masereka Date

This project has been submitted for examination with my approval as University Supervisor

D B Thomas 19th May 1983

D. B. Thomas, BA; Dip. Agric (Cambridge); MSc Agric. Eng. (Reading). Date

DEDICATED TO

MY PARENTS AND ALL MY FRIENDS

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SUMMARY

The application of fanya juu terraces for soil and water conservation in high and low rainfall areas is on the increase. Fanya juu terraces have become popular because they are easy to construct, less infertile subsoil is exposed during the construction and when compared to bench terraces, less labour is required for construction. But for fanya juu terraces to be effective, proper design, bank stabilization and maintenance are necessary.

The study of design, construction and stabilization of fanya juu terraces was carried out at the University of Nairobi's Faculty of Agriculture Farm at Kabete, Kenya, between 18-10.82 and 18-1-83 on nitosol soils. The suitability of the design of fanya juu terraces for retaining maximum runoff expected in specified period of time put forward by Thomas et al (1980) was studied. Labour required for the construction and land taken up by terraces were also studied. Seven grass species were planted on the banks of the constructed terraces. These species were visually evaluated for establishment and ground cover at the end of the project. Stone wall was the control.

From the study, it was observed that the expression formulated by Thomas et al (1980) gives a good guidance for designing fanya juu terraces. But data on infiltration and rainfall intensity is necessary. If the construction of fanya juu terraces is phased over a period of time, the labour requirement can be within the capabilities of small scale farmers. Average land lost from crop production in

construction of fanya juu terraces was found to be 15%. If this area is used for bana grass production - a species which was observed to be high herbage yielder, about 45 t/ha green fodder can be obtained. This can be fed to livestock. Bank protection, stabilization and maintenance were observed to be necessary for fanya juu terraces.

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1.0 INTRODUCTION

The care of the soil is essential to the survival of human race. It provides most of the food required, fibres for clothing and wood for building material. And yet in some parts of the world, the soil has been so damaged by mismanagement that it will never again be able to produce food, let alone fibres and other industrial crops, at least not in the foreseable future. This mistreatment has led to soil erosion on vast scale, that is, the physical loss of the upper layer of topsoil, the most vital part necessary for healthy plant growth. Once this top layer has been lost, it has for all practical purposes gone for good. For example, even under natural conditions of cover, it takes from 300 to 1000 years or more to generate one inch of top soil and it would need 3000 to 7000 years to generate sufficient [illegible] (Barrett, [illegible]).

The world population is increasing at an alarming rate. This means the production of food, fibre and [illegible] must also be increased. This would mean expansion of cultivable areas, intensifying production by introducing high yielding varieties and introduction of new technology in agricultural production. But

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1.0. INTRODUCTION

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The world population is increasing at an alarming rate. This means the production of food, fibre and wood must also be increased. This would mean expansion of cultivable areas, intensifying production by introducing high yielding varieties and introduction of new technology in agricultural production. But opening up more cultivable areas offers the least solution to the problem as most of the countries especially in Asia have little or no room for expansion. This leaves only one alternative: to conserve the natural resources as much as possible.

Water,soil and solar energy are the three most important resources of any nation (Barber, 1981). These have to be conserved if life is to continue. Soil conservation is the application of all measures necessary to conserve the whole complex of land and water resources (Constantinesco, 1976).

In this project a study was carried out on the design, construction and bank stabilisation on one of type of terraces used in soil and water conservation - fanya juu terrace.

The objectives of the study were:

1) To design fanya juu terraces for control of soil and water losses at Kabete.
2) To construct fanya juu terraces by hand and determine labour requirements.
3) To examine alternative ways of bank stabilisation and select the most promising for statistical comparison and evaluation.
4) To establish selected treatments for bank stabilisation in a randomised block design and carry out a preliminary evaluation.
5) To draw up detailed plans for comprehensive long term evaluation of the selected treatments.

The fanya juu terrace has been chosen for the study because its use in soil and water conservation has increased both in areas with little rain and in areas with much rain. Fanya juu terraces which are similar in principle to steep backslope terraces used in U.S.A. have several advantages:

i) They are easy to construct

ii) Less soil is cut and moved than when bench terraces are made

iii) They can store excess runoff until it infiltrates

iv) They reduce the slope length and eventually slope angle

v) Due to farming operations and erosion, fanya juu terraces eventually form bench terraces.

In the construction of fanya juu terraces, the size of the ridge to be formed above the bank is important. The storage depth of this ridge should be enough to store expected runoff without overflow which would lead to breaking down of the ridge and the bank. If too much soil is cut to make the ridge, more labour would be required and this would increase construction costs. Also more area on the ridge would be exposed to infertile soil. In this study, an expression to estimate the amount of the soil which can make a desired height of the ridge was formulated.

The design arrived at, was applied in construction of 224 m of fanya juu terrace at Kabete, Kenya, between 18-10.82 and 1-11-82. Efficiency of the tools used, labour requirements and land taken up by the terraces which would be used for crop production were assessed.

Protection measures on newly built terraces and thereafter their maintenance are essential to success of overall terracing programme (Sheng, 1977). In this project, seven grass species and stone wall as a control were planted on the constructed four fanya juu terraces of 56m long each in RBD to assess their suitability for bank protection and stability. The selected species were:

1) *Setaria anceps* (Nandi grass)
2) *Panicum coloratum* var. *makarikariensis*
3) *Brachiaria brizantha*
4) *Tripsacum laxum* (Guatemala grass)
5) *Paspalum notatum* (Bahia grass)
6) *Panicum trichocladum* (Donkey grass)
7) *Pennisetum purpureum* x *P. americanum* (Bana grass)

Different species were chosen for the project because they vary in bank stabilisation, persistence, herbage production and competition for moisture with crops grown on the terraces.

2.0. LITERATURE REVIEW

2.1. Importance of soil and water conservation

The importance of soil and water conservation is seen in the definition - it is "the efforts to change the trend in basic productive capacity of land upward from what it would otherwise be (including holding it constant when otherwise its trend would be downward)" (Held and Clawson, 1965). Soil Conservation increases productivity and in long-run income. This is shown in table 1 of the results of a study made by "Soil Conservation Service" on 503 mid-Western farms - Upper Mississippi Valley Region in U.S.A. (Foster, 1965).

Neglect of soil conservation practices in the past led to a fall in food, fibre and shelter production which in turn led to the fall of civilisations. Mesopotamia was once a land of dense population and great cities. All that now remains are scattered villages, and the ruins of the great cities, which had been hidden by deep blankets of erosional debris for centuries (Stallings, James, Henry, 1967). Other civilisations that had the same fate include that of Judea, China and the Nile Valley. Opening up of vast areas of land resulted into loss of estimated 1000 million acres of land in U.S.A. by 1930 (Constantinasco, 1976). It can therefore be observed that soil conservation is of paramount importance and the study of soil and water conservation should be pursued if soil degradation has to be reduced.

Table 1. Average Production and Income of 252 Soil Conserving Farms and 251 Farms Without Soil Conservation

	252 soil conserving farms	251 farms without soil conservation	Difference
Size of the farm (acres)⟶	170.6	170.8	-0.2
Yields of crops per acre			
Corn - bu.	50.9	44.3	+6.6
Soybean - bu	21.7	19.9	+2.8
Oats - bu	52.4	48.5	+3.9
Wheat - bu	22.0	18.7	+3.3
Hay - tons	2.01	1.99	+0.02
Livestock production per animal			
Cattle - lbs	9458	7054	+2404
Sheep - lbs	666	600	+ 66
Hogs - lbs	13462	10882	+2580
Poultry - lbs	845	725	+ 120
Eggs - doz.	1779	1521	+ 258
Milk - lbs	92200	86100	+6100
Production income			
Per farm	$6877	$5923	+$954
Per acre	$40.31	$34.68	+$5.63

From Table 1, soil conservation practices increased production per farm by 16.11% and per acre by 16.23%.

2.1.1. Terraces as soil erosion control and water conserving structures

Terraces are one of the physical structures used for controlling soil erosion and conserving moisture in the soil. Some authors insist that physical structures should be only applied when cultural measures are not adequate. Other authors say that the two types of measures are complementary. But Hudson (1979)thinks the physical structures should come first. Mechanical protection of the soil is the foundation and it must come first, to be followed later by the better farming (Hudson, 1979).

Experiments carried on in Wisconsin state in U.S.A. gave results of increase in crop yields due to terracing of 10% to 15% (Foster, 1965). This means within the first four years the increase in yield would pay for the construction costs.

Level terraces increase the time for runoff to infiltrate into the soil. This is very important in areas with low rainfall. The increase in soil moisture can increase yield. DowKer (1963), working in Machakos, showed that an increment of as little as 50 mm in seasonal rainfall could make a difference of up to 1100 kg/ha in yield of maize. In Baringo District micro-basins have been shown to trap moisture which can support the growth of vegetation in the semi-arid areas.

2.1.1.1. Application of the fanya juu terrace in soil and water conservation

This is the type of terrace constructed by digging a trench on contour or at a slight gradient and throwing soil uphill to form a bank which can be stabilised with planting of grass. This type of terrace is similar to grassed backslope except that fanya juu has steeper backslope. This type of terrace has an advantage of combining erosion and farming operations to form bench terrace (Jacobson, 1962). Observations in West Tarkio project in Iowa showed that terraces of this type had almost formed bench terraces in 20-30 years (Jacobson, 1962). Wenner reports that in erodible soil, constructed fanya juu terraces can develop into level bench terraces in 2-6 years. Using data from Gitau (1980), Wenner reports a decrease of the original slope of land by 4.5% after 2 years and 7% after 4 years due to fanya juu terraces in Nyeri District (Wenner, 1980).

Because fanya juu terraces trap silt, and can easily and cheaply be constructed, they have been employed in Gituamba river catchment, Kiambu District - Kenya to reduce sediments in water supply systems for Nairobi. In areas of low rainfall like Machakos District in Kenya, this type of terrace has been recommended.

2.2. Design of fanya juu terraces

Fanya juu terraces are usually designed for water storage. The expected depth of storage should be considered in the design of fanya juu terraces.

Spacing of fanya juu terraces like other types of bench terraces is based on the formula recommended in Kenya (Wenner,1980):

$$VI = \left\{ \frac{\%s}{a} + b \right\} 0.3 \quad \ldots\ldots \quad (1)$$

where VI = vertical interval in metres
s = slope
a = rainfall factor and
b = erodibility factor

In Kenya: a = 4
b = 2

$$HI = \frac{VI \times 100}{\% \text{ of slope}} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

HI = Horizontal interval

D. B. Thomas, R. G. Barber and T. R. Moore (1980) taking into consideration the soil infiltration rate, rainfall intensity in a specified time and slope of the land, came out with a formula for estimating depth of storage above the bank.

$$d = \sqrt{2A/\ (\cot\alpha + 1)} \quad \ldots\ldots\ldots \quad (3)$$

where A = cross-sectional area of storage in m^2
d = depth of storage in m
α = slope angle of the land

This expression was arrived at on the assumption of channel front slope of 45^{o}. This is not always the case in practice. The design was:

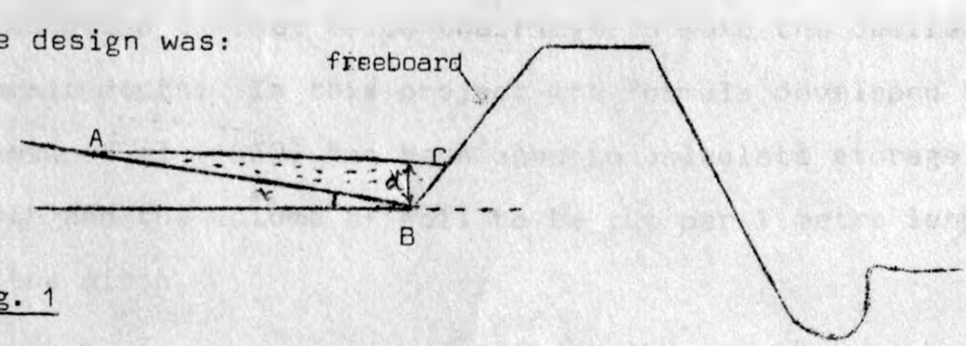


Fig. 1

Area of ABC (water of storage) = $A = \frac{1}{2}d^2 \ (\cot\alpha + 1)$..(4)

Larson working on Grassed Backslope Terraces (which are similar to fanya juu) came up with several formulae and with a design suitable for mechanisation (Larson, 1971). In his design, the factors which affect the volume of runoff that can be accumulated in a given storm are not considered. This makes the design unsuitable for conditions in Kenya. The design was:

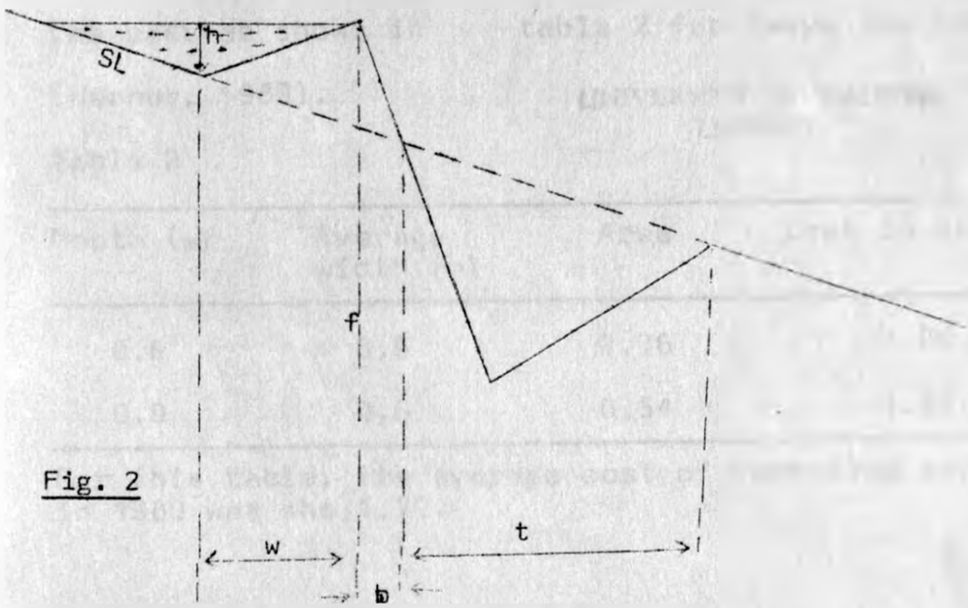


Fig. 2

$$h = f - S_L W \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

h = storage depth

In the same publication, Larson discusses Grassed Backslope Terrace where excavation is done above the ridge in addition to that below the ridge to make the desired storage depth. In this project the formula developed by Thomas et al (1980) has been used to calculate storage depth and the volume of soil to be cut per 1 metre length of the ditch.

2.3. Construction of fanya juu terrace

The amount of soil to be cut determines the labour and the cost of construction. It also determines the cutting rate of the soil. A man can cut 3.8 to 4 m^3 of dirt in eight hours of cut (Sheng, 1977). The cost of digging also depends on the type of the soil, availability of labour and the quality of tools used (Wenner, 1980). The size of the ditch is directly proportional to the cost as shown in table 2 for fanya juu terraces (Wenner, 1980).

Table 2

Depth (m)	Average width (m)	Area	Cost in shs/m
0.6	0.6	0.36	1.05
0.9	0.6	0.54	1.35

For this table, the average cost of terracing per metre in 1980 was shs 1.20.

2.4. Protection and stabilisation of banks (risers) of fanya juu terraces

Materials that are used for protecting and stabilising terrace banks include stone and grass. The grass should be stiff-stemmed that gives a good cover (Wenner,1980).The best species in areas with plenty of rain is Napier grass (*Pennisetum purpurenum*)or Bana grass (*P. purpureum* × *P. typhoides*) (Wenner, 1980).

Work has been done on several grasses as bank protectors and stabilisers. Dalal (1966) in a trial of 8-grasses gave results of suitable species in descending order of value as: Panicum, Brachiaria, Cynodon and Paspalum species. In the same year Piot (1968) found out that *Stylosanthes gracilis* and *Melinus tenussia* were suitable for stabilising young soils on slopes not exceeding 65%. *Cynodon dactylon* and *Pennisetum clandestinum* gave the best results on well developed soils. Byrant (1966) in his work found out that species with outstanding value in soil conservation are *Chloris gayana, Panicum coloratum, Cenchrus ciliaris, Pennisetum clandestinum* and *Medicago sativa.*

In Upper Harton Valley in N.W. New South Wales/Watt, working in trials for 7 years, the grasses: *Chloris gayana, Panicum coloratum - Makarikari* and *Eragrotis species* gave the best establishment, persistence and ground cover (Watt, 1978). In Nepal in stabilising waterways, it was found *Pennisutum polystachyon* was superior to *P. purpureum* in fresh fodder yields, basal area coverage and retaining silt deposition in surface runoff in high rainfall areas (Sachdere, 1976).

In studies carried on effects of various grasses used for revegetating slopes at Fengshan Tropical Horticultural Experimental Station by Chang (1970) showed that:

1) Soil loss and runoff were much reduced compared to bare slopes.
2) Soil loss was least with Bahia and Centro and runoff was least with Guinea grass and Centro.

3) Soil moisture content under Bahia and Centro was higher than bare ground but for Guinea and Paspalum lower than bare ground. After 80 day dry period, the soil moisture content was in the order: Bahia > Paspalum > Centro > Guinea grass

Fresh herbage yields were:

4.67 kg/m^2 per year for Guinea grass, 2.76 kg/m^2 for Bahia and 2.1 - 2.7 kg/m^2 per year for Centro.

So it was concluded that Bahia grass was the most and Guinea and Centro the least promising species.

The grass used on the banks should be that which gives a good cover to reduce raindrop erosion. Chang (1970) working on effect of ground-cover on surface runoff from experimental plots, the results showed that increased cover resulted in the curvilinear decrease in runoff frequency. 75% ground cover was found to be critical value. Above it runoff was slight and increased rapidly below it.

2.5. Competition of the grasses

Grasses on the banks compete with crops for moisture, minerals, light and space. This has led to farmers not protecting the banks with grass. Thomas (1956) working in Machakos, reported the competition effect extending up to 6 feet from the bank. This disadvantage is more noticed in areas with low rainfall. But if the grass is used as a fodder, the decrease in crop yield may be compensated for.

2.6. Notes and literature on characteristics and other uses of grasses used in this project

Important characteristics of grasses that are used for protecting and stabilising banks include: growing habits, climatic requirements, soil requirements, herbage production and palatability to animals.

2.6.1. *Setaria anceps* (Nandi grass)

This is a perennial grass. It can remain on the banks for several years. It has erect stems and a tufted habit that concentrates runoff, therefore close spacing is necessary. It is a tropical grass and therefore suitable for high potential areas of Kenya. With a height of 1-2 m, it can have shading effect on short crops like beans (Bogdan, 1977). This grass grows well within altitude range of 600-2600 m. The rainfall requirement is 750 mm and up to 500 mm where temperatures are low (Bogdan, 1977).

Bogdan (1977) reports that *Setaria anceps* does well in a variety of soils except those of alkalinity or acidity. He also reports that it is tolerant to temporary flooding and water-logging. It can therefore be important for protecting waterways and channels. He also reports that in Kenya, South Africa and Australia, it is an important fodder crop.

Bogdan (1977) working in E. Africa, observed that *Setaria anceps* can best be propagated vegetatively. He recorded 90% establishment. In Kenya *Setaria* grass is undersown to maize after the maize is 70-100 cm (Poultney,1963).

Because the grass is a good tiller, its herbage production is high. Boonman (1971) counted 1900 tillers/ m^2. The highest cut yield was got when cutting was at an interval 3-7 weeks (Bogdan, 1977). He suggested the cutting at 15 cm from the ground. In Queensland pure stand of *S. anceps* cut at 15 cm from the ground yielded 27.5 - 28.2 t DM/ha.

Bredon and Horrell (1961) considered *S. anceps* as a grass of low nutrition value. Hacker and Jones (1962) gave 8.7% CP value. In Kenya data for 16 samples gave 5.1 to 19.4% CP, and the quality of herbage from high to low (Dougall, 1960). Quality therefore depends on the stage of growth.

Animals respond well to *S. anceps*. In Kenya 332 kg/ha live weight gain by cattle were obtained in the first year. In the second year the gain was 190 kg/ha (Hacker and Jones, 1969). 2000 lts. of milk/ha were obtained from cows grazed on *S. anceps*.

Setaria anceps needs a lot of moisture in the soil and it does not do well in dry areas. This means that this grass is likely to be a competitor for moisture with the crops. As a grass it requires Nitrogen. Other elements which it may compete for include Sulphur, Potassium and Iron.

2.6.2. *Brachiara brizantha*

This is a perennial tufted grass with erect stem but can creep. This gives it a property of reducing erosion, on the banks. It requires at least 800 mm of rainfall, therefore unsuitable for dry areas. It can be propagated from seed or vegetatively. Crude protein is rated at 10.7% in dry matter (Edwards and Bogdan, 1957).

2.6.3. Bana grass

It is a hybrid of *P. purpureum* and *P. americanum*. It is propagated by splits or stem cuttings. Herbage yields of up to 168 t/ha and 283 t/ha were reported (Jodhum, 1965). In Thailand yields as low as 34 t/ha were reported.

Working on herbage quality, Narayaman and Dabadghoa (1972) reported 25% of CP, 12% sugars. Daftar and Zende (1968) reported CP of 22.8% in young grass of 14 days old and 5.3% in 72-day old herbage. Dry matter digestibility was reported by Pritchard (1971) to be 65.6% for the leaf and 58.4% for stem and leaf-sheaths.

2.6.4. *Paspalum notatum*

This is a creeping perennial plant with stolons and stems firmly pressed to the ground. This keeps soil in place, and is therefore important for soil conservation on banks. It can grow up to height of 100 cm (Bogdan, 1977). It therefore has little shading effect on the crops. The grass is suitable for tropics (Bogdan, 1977). Kawamwa and Yamasaki (1972) suggested temperatures 20-25°C gave maximum tillering. Moderate rainfall is enough. It is resistant to drought because of long roots (Bogdan, 1977). The grass was observed to be tolerant to flooding. 36 days of continuous flood produced no harmful effect (Schroder, 1966). Because the grass easily establishes, forms dense cover and persists, it was recommended for bank cover.

Herbage yields of *P. notatum* are low. 17 t DM/ha were obtained in Australia from heavily fertilised and irrigated crop (Shaw et al., 1965). In Cuba yields of 14 tDM/ha were recorded from stands which had been sprinkler irrigated (Perez, 1970).

Paspalum notatum has fairly high nutritive value. Rodel and Boultwood (1971) and Montgomery et al (1972) reported CP of 14% iny oung herbage but 8-10% in old herbage. This is important in determining cutting time. The total DM digestibility as determined by Milford (1968) ranged from 40 to 53%.

2.6.5. <u>*Panicum trichocladum* - Donkey grass</u>

It is a trailing perennial plant with slender branched stem with many nodes. The creeping base roots form from the nodes. It grows in East, South and Central Africa. It requires rainfall of at least 850 mm (Bogden, 1977). He reports that in some areas of Kenya, it is considered particularly suitable for calves and therefore grown by small farmers.

Leaves which are picked by animals contain 17.5% CP. and 0.29% of P. in wet season. This is enough to secure the growth of young cattle but in dry season, the values drop to 8.5% CP. and 0.10% P (van Voorthuisen, 1971).

2.6.6. *Panicum coloratum* var. *makarikariense*

In his trials in Machakos, Thomas (1956) rated the cover got from *P. makarikariense* on banks as 'fair' and persistence as 'good'. The grass has been known to form a good pasture. It can withstand flooding. Anderson (1970) observed 100% survival of young plants after 20 days of flooding. In the same trials, Thomas (1956) observed that this species was very competitive for moisture with crops.

In the same trials, Thomas rated *P. coloratum* var. *makarikariense* herbage production as 'high'. High values of 23 t DM/ha/year have also been reported (Bogdan, 1977).

Herbage quality is high. CP content 10.3 - 10.7% was observed (Bryant, 1967). Butterworth (1967) quoting Myburgh of S.A. gave CP of 7.1% to 7.6% and CF content of 34.1 - 35.2% in samples used in digestibility with sheep. The herbage is very palatable to cattle and sheep (Bogdan, 1977).

2.6.7. *Tripsacum laxum* - Guatemala grass

The plant is large tufted or spreading and can grow up to 3.5 - 4.5 m. It can therefore have shading effect on crops. It is propagated by tuft division or stem cuttings.

In Brazil a single second cut gave 68 T fresh herbage or 12 t DM/ha (Zuniga et al., 1965). Similar high yields were obtained in Thailand (Holm, 1972) from a well fertilised crop. Bogdan (1977) quotes that in a trial by Pereira et al (1966) in Brazil a yield of 70 t. of green material/ha. in wet season and 4 t. in dry season were obtained. In Kenya (Kenya Report, 1970), yields ranged from 11.2 to 26.2 t. DM/ha. The real value depended on frequency of cutting, the lowest being obtained at 2-month intervals between the cuts and highest at 8-month intervals.

CP contents in the leaves in *T. laxum* ranged from 6.3 to 13.7% depending on the frequency of cutting. Bogdan (1977) quoting Dirven (1962), working in Surinam, determined the CP as 6.1% in leaves and 4.6% in stems and CF in leaves was 40.4%.

3.0. MATERIALS AND METHOD

The method included: survey, construction of the fanya juu terraces and experiment layout.

3.1. Survey

Instruments used were:

1) 30 m tape measure
2) Quickset level
3) Levelling staff
4) Range rods
5) Pegs

45 x 70 m plot was marked off. Survey procedures outlined by Sheng (1975) were followed. Across the general slope of the land, contours 10 m apart were staked (HI = 10 m) by reading the same reading along the contour at an interval of 15 m using a quickset. Four 70 m long contours were staked.

Using a quickset level and levelling staff, slope of the marked off plot was found as described by Wenner (1980) at four points and the average slope was found to be 14%. A cutoff drain, 0.4% gradient, was surveyed and staked on the upper side of the experiment using a quickset level and levelling staff.

3.1.1. Spacing

The surveyed general slope = 14%

$$VI = \left\{\frac{\%S}{4} + 2\right\} \times 0.3 \text{ m}$$

$$= \left\{\frac{14}{4} + 2\right\} \times 0.3 \text{ m} = 1.65 \text{ m}$$

$$HI = \frac{VI \times 100}{\%\ slope}$$

$$= \frac{1.65 \times 100}{14}$$

$$= 11.8\ m$$

For construction, HI of 10 m was used.

3.1.2. Volume of soil to be cut

In claculating the volume of the soil to be cut per 1 metre, the following were considered:

1) storage depth (d)

2) the riser height

The volume to be cut per 1 metre was calculated to be 0.54 m^3/m as shown later in the terrace design.

3.2. Construction of fanya juu terrace

A team of five men was hired to cut the terraces. To form the required ridge, a ditch 0.5 m deep and 1 m wide was cut along the contour and the soil was thrown uphill (arriving at (0.5 x 1) m^2 is shown in the design of the terraces later).

During the construction the following parameters were recorded daily:

1) Number of men at work
2) Hours worked each day
3) Length cut in metres
4) Volume of soil cut (calculated)
5) Volume of soil cut per man (calculated)
6) Rate of cutting (calculated)
7) Man hours (calculated)
8) Weather - rainfall and temperature

Instruments used were: hoes, forked hoes, panga (for removing soil from the other implements)and a spade.

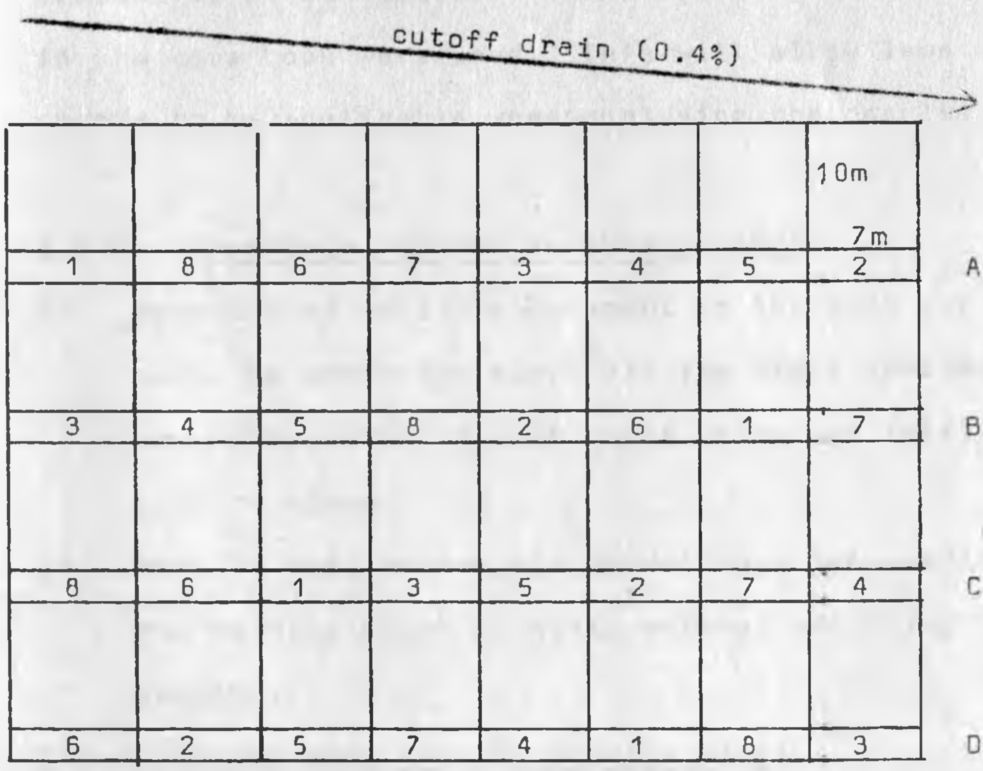
4.0. EXPERIMENT LAYOUT

4.1. Method

The randomised complete block design (RBD) was adopted in the experiment layout.

Number of the treatments - 8

Number of replications (blocks) - 4



Treatments

1) Stone (control)

2) *Panicum coloratum* var. *makarikariense*

3) Bana grass

4) *Setaria anceps* (Nandi setaria)

5) *Paspalum notatum* (Bahia grass)

6) *Brachiara brizantha*

7) *Panicum trichodadum* (Donkey grass)

8) *Tripsacum laxum* (Guatamala grass)

Blocks (replications)

A, B, C, D.

4.1.1. Randomisation

Treatments in each block were randomised using a method described by Steel and Torrie (1960) in "Principles and Procedures of Statistics". Random digits in Table AI in the same book were used. This will allow laws of chance to be applicable when analysing the results.

4.1.2. Advantages of RBD in this project

1) Variation of moisture movement in the soil due to slope is cared for since all the eight treatments are represented in each block which has fairly uniform slope.

2) Work is made easier eg. operations like weeding can be done block by block without affecting the results.

The following were assumed about a block

1) Exposure of infertile soil was uniform during the cutting along the block

2) Uniform soil fertility within the block

3) Uniformity of other characteristics of soil which affect crop yield eg. soil structure, drainage, permeability.

4.2. Planting of the treatments

During the planting of the seven grass treatments, source of planting material, means of propagation, spacing and labour were recorded (as shown in Table 2).

During the course of the experiment, visual observations were made on the following:

1) Establishment percentage

2) Height attained with time (shading effect)

3) Cover attained with time

4) Rooting system - rooting depth (at the end of the experiment)

5) Rooting system - rooting depth of maize, beans and potatoes (from the near-by plots).

4.2.1. Building stone wall

Stone wall is the control. Inclined bank was first constructed at an angle of about 70°. On the inclined bank stone was pitched as closely as possible to avoid gaps in which weed would grow. The bank was inclined so that the stone would not drop off and inclining increased the stability of the bank. Source of the stone, amount of stone and labour on stone wall were recorded. During the experiment, weed attack cover and stability provided by the stone wall were rated in comparison with other treatments.

Table 2. Establishing the treatments

Treatments	Source of planting material	Means of propagation	Labour (man-hours)
Setaria anceps	Kabete	Vegetative	8
Panicum coloratum makarikariense	Westlands	Vegetative	8
Brachiaria brizantha	Kabete	Vegetative	8
Tripsacum laxum	Kabete	Vegetative	8
Paspalum notatum	Westlands	Vegetative	8
Panicum trichocladum	Gituamba Kiambu	Vegetative	8
Bana grass	Kabete	Vegetative	8
Stone	Kabete	-	20*

*More labour was required for stone wall because of breaking the stone, collecting it and carefully pitching it to form stone wall.

5.0. RESULTS AND DISCUSSION

5.1. Design of fanya juu terrace

The design I have come out with is similar to the one which was put forward by Thomas et al (1980) except that in my design, the field observations have been put into consideration. Farmers heap soil uphill the cut ditch to form a ridge. They do not shape the ridge as shown in the design by Thomas et al (1980).

In the design I have put forward, it is necessary to cut the volume of the soil which is just enough to form a ridge of the required height. To calculate this volume, slope of the land, spacing of the terraces, infiltration and rainfall intensity of the site must be known.

5.1.1. Volume of soil to be cut per metre

From the survey, the slope of land = 14 %

The slope angle = 8°

Horizontal interval (terrace spacing) = 10 m (calculations are shown in chapter 2 - literature review)

Infiltration - Barber et al (1980) gave minimum infiltration rate at end of 1 hour treatment of 32 mm/h at Kabete on 11% bare cultivated land.

For this experiment minimum infiltration rate of 20 mm/hr at the end of 2 hours was chosen because it gives the largest volume of runoff expected in 10 yr period.

Table 3. Rainfall intensity (mm/h) for Dagoretti* and infiltration

Time (hrs)	rainfall intensity	Amount (mm)	infiltration (mm)	runoff (mm)
2	40	80	40	40

*On the assumption that there is little difference between rainfall intensity of Kabete and Dagoretti, the values for Dagoretti have been used

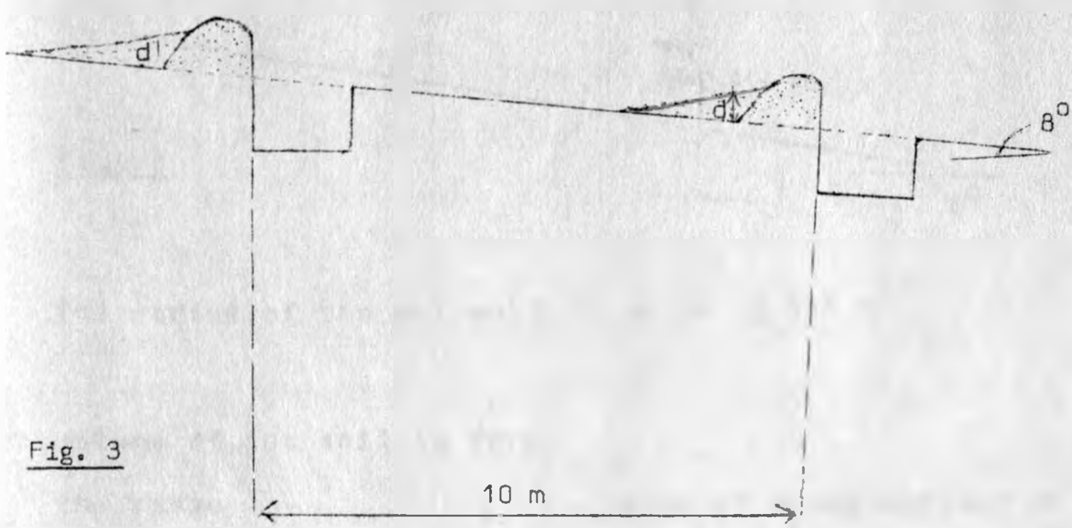


Fig. 3

Volume of runoff per 1 metre = area of cross section x 1 m

Area of cross section of the runoff = depth of runoff x spacing

$$= \left(\frac{40}{100}\right) \text{ m} \times 10 \text{ m}$$

$$= 0.4 \text{ m}^2$$

Highest storage depth (d) expected in ten years

$$= \sqrt{\frac{2 \times \text{area}}{\cot 8^{0} + 1}} \quad \text{......} \quad (6)^*$$

$$= \sqrt{\frac{2 \times 0.4}{7.1 + 1}}$$

$$= 0.314 \text{ m}$$

* This equation was developed by Thomas et al (1980) on the assumption that the upper side of the ridge meets the land slope at 45°.

Free board = 0.10 m (suggested by Thomas et al 1980)

$\therefore$ d = 0.414 m[+]

Assuming the soil cut is made into cylindrical ridge

and d = radius,

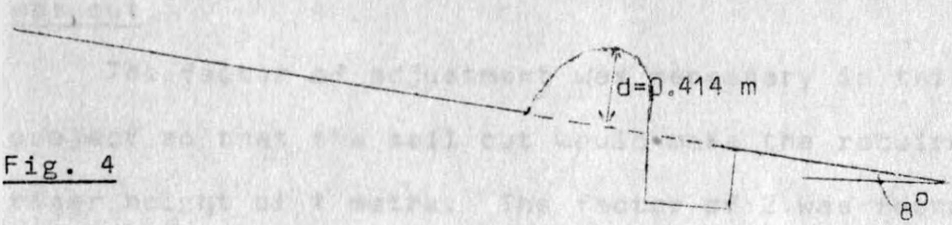


Fig. 4

The radius of the cut soil = d = 0.414 m[+]

Volume of cut soil to form

the ridge = area of cross-section of the ditch x 1 m

$$= \left[\frac{\pi r^2}{2}\right] m^2 \times 1\ m$$

Actual volume that was

cut during construction $= \left[\frac{\pi r^2}{2}\right] m^2 \times 1\ m \times$ Factor of adjustment .... (7)

$$= \left[\frac{\pi r^2}{2} \times 1 \times 2\right] m^3$$

$$= (3.14 \times 0.414^2)\ m^3$$

$$= 0.54\ m^3$$

[+]In actual construction, d must be made greater than 0.414 m to allow for settlement of the soil.

To give the required riser height of 1 metre, the ditch cut was:

Fig. 5

Factor of adjustment of volume of the soil that was cut

The factor of adjustment was necessary in this project so that the soil cut would make the required riser height of 1 metre. The factor of 2 was found suitable.

The factor of adjustment in equation (7) is necessary because:

1) It allows for settlment of the soil in the ridge without losing the required storage depth, 'd'.

2) Infiltration decreases with time of the storm and of the rain season due to saturation of the soil and filling up. This increases runoff. The additional soil cut due to factor of adjustment compensates for this.

3) In high rainfall areas, water logging may occur uphill the ridge. This can lead to seepage forces which can in turn lead to collapsing of the ridge. This can be prevented by a broad base of the ridge. This is provided by additional soil cut due to the factor of adjustment which is two in this case.

5.1.2. Land lost from crop production in this design

The arc C on the ridge can be put into crop production. Assuming it makes 45^0 to the centre of the ridge, then:

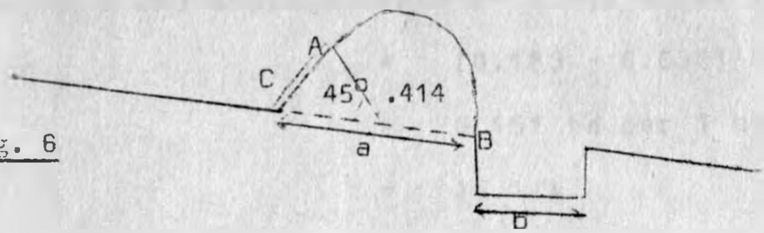


Fig. 6

The land lost from crop production per 1 metre = (a + b) m x 1 m

= (0.824 + 1) m x 1 m

= 1.824 m^2

The total land lost for 224 m terrace = $(1.824 \times 224)\ m^2$

= 0.0409 ha.

This is in a plot area of 0.2240 ha.

In 1 ha, the land lost due to terracing = $\left(\frac{0.0409}{0.2240}\right)$ ha

= 0.183 ha.

But the arc 'C' on the ridge in Fig. 6 can be put to crop production.

Area of arc 'C' can be estimated by:

$$\left\{ \tfrac{1}{2} \times \pi D \times \frac{45}{180} \times 224 \right\} m^2 \ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

$$= \left\{ \tfrac{1}{2} \times 3.14 \times 0.828 \times \frac{45}{180} \times 224 \right\} m^2$$

= 0.0072 ha

In 1 ha. total area put to crop on the ridge:

$$= \frac{0.0072}{0.2240} \text{ ha}$$

$$= 0.032 \text{ ha}$$

The net area lost in terracing (fanya juu) on 14% land

HI = 10 m and storage depth of 0.412 m per 1 ha.

$$= (0.183 - 0.032) \text{ ha}$$

$$= 0.151 \text{ ha per 1 ha}$$

$$= 15.1 \%$$

But the bottom of the excavated ditch (b) in Fig. 6 can be used for planting crops like bananas, This can reduce % area lost from crop production.

5.1.3. Area available for grass production on the ridge

The area on the ridge available for grass production is the arc AB on Fig. 6.

It can be estimated from:

$$(\tfrac{1}{2}.\ D.\frac{135}{180} \times 224)\ m^2 \text{ for } 0.2240 \text{ ha plot} \ldots\ldots\ldots\ldots \quad (9)$$

$$= (\tfrac{1}{2}.\ \pi\ .0.824 \times \tfrac{3}{4} \times 0.224)\ m^2$$

= 0.0217 ha* in 0.2240 ha plot

= 0.097 ha in 1 ha

= 9.7 %

*The actual area measured on the constructed terrace was 0.0268 ha. This is because in practice, the ridge is not cylindrical, but flattened so area for grass is more than estimated.

If this area of 0.09 ha is put under production of Bana grass, it can yield as much as 15.12 t per year (Bogdan, 1977). This would be fed to livestock.

5.1.4. Stability of the ridge

In this design, the riser angle is between 60° - 80°. This was observed to have given poor stability to the ridge. The rain of 3.12.82 of 63.8 mm led to collapse of the terrace ridge in three places. For better stability the design below is suggested.

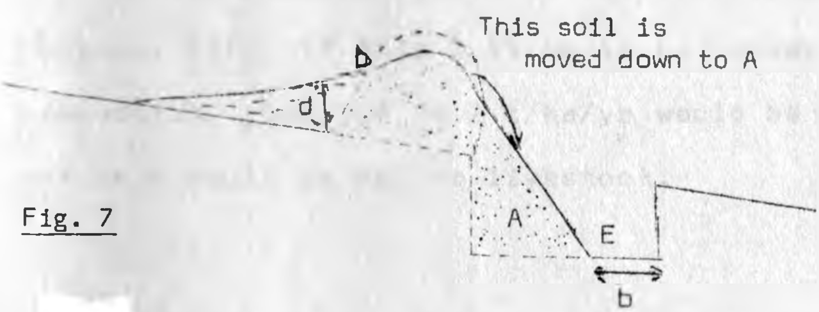


Fig. 7

In this design, the soil is thrown up and pulled down again because this requires less skill compared to cutting the slope to the correct angle at the start.

Advantages of this design include:

1) The additional soil cut due to adjustment factor (equation (7)) enables filling of portion A without losing depth 'd'. This portion (A) increases the stability of the terrace ridge.

2) If carefully done, the infertile soil exposed on the ridge can be filled in portion A. This will enable vigorous growth of the grass planted on the ridge.

3) More area is available for planting of the grass. From the constructed terraces in the project, the average length of DE was 1.5 m (see fig. 7).

The area available for growing grass in this design

$$= (1.5 \times 224)\ m^2 \text{ in } 0.2240\ ha$$

$$= 0.0336\ ha$$

$$\text{In 1 ha} = 0.15\ ha$$

In this case area for grass production has increased from 0.097 ha to 0.15 ha without affecting area for crop production. But the bottom of the ditch (b) has been reduced. So this is important if the ditch is not put under use.

At the reported yield of 168 t/ha/yr of Bana grass (Bogdan, 1977) if this 0.15 ha is put under Bana grass production, yield of 25.2 t/ha/yr would be obtained and this would be fed to livestock.

5.2. Construction of the fanya juu terraces

The total length of 255.4 m of fanya juu terrace was constructed in this project. The total number of hours worked were 35.75. The total man-hours were 152.75 and the amount of soil cut was 140.47 m^3. The experimental plot was 0.2240 ha. Assuming the land is of the same uniform slope and soil type. At the same spacing (HI = 10 m). Then the figures for 1 hectare would be as given in Table 5.

TABLE 4. Fanya juu terrace construction. Site: Kabete, Kenya. Soil type: Nitosol

Date	A No. of men	B Hours worked	C Length cut (m)	D Volume cut (m^3) per man	E Volume cut (m^3)	F Man-hours (AxB)	G Rate volume per man per hr.	H Weather Temp. Min.	Max.	Rainfall (mm)	I Comments
18.10.82	5	3¾	30.8	3.39	16.94	18.75	0.90			39.7*	It had rain prev. night. Stopped work ∵ of rain
19.10.82										5.2*	Rained whole day
20.10.82										15.3*	Public holiday
21.10.82										6.1	Rained whole day
22.10.82	5	4	29.0	3.19	15.95	20.00	0.79			-	soil wet and sticky
23.10.82	5	4	14.3	1.57	7.87	20.00	0.39			8.3	" "
24.10.82										13.3*	Sunday
25.10.82	5	4	23.5	2.59	12.93	20.00	0.64			-	soil wet and sticky
26.10.82	4	4	22.5	3.10	12.38	16.00	0.78			-	dry but not fragile
27.10.82	5	3	28.0	3.08	15.40	15.00	1.03			-	Dry & fragile
28.10.82	5	3	30.6	3.34	16.83	15.00	1.11			14.0	deeper layers soft
29.10.82	5	3	31.0	3.41	17.05	15.00	1.14			0.9	upper layer loose deeper layer soft
30.10.82	3	3	14.0	2.57	7.70	9.90	0.86			8.1	soft and loose
31.10.82										0.2	Sunday
1.11.82	5	4	31.7	3.49	17.40	20.00	0.70			30.5*	wet & sticky
TOTALS		35.75	255.4		140.47	158.75					
AVERAGES				2.97			0.85				

* Readings taken at the site of the experiment, the rest of the readings were taken at Kabete Meteorological Station

Table 5. Summary of the construction of fanya juu terrace

	AREA		
	0.2240 (ha)	1 (ha)	
1. Length of the terrace (m)	255.4	$\left[\frac{255.4}{0.2240}\right]$	= 1140.2 m = 1.140 km
2. Hours at work	35.75	$\left[\frac{35.75}{0.2240}\right]$	= 159.6
3. Work-days*	$\frac{35.75}{8}$ = 4.47	$\frac{4.47}{0.2240}$	= 19.6
4. Man-hours+	168.75	$\left[\frac{152.75}{0.2240}\right]$	= 681.1
5. Volume of soil cut (m^3)	140.47	$\left[\frac{140.47}{0.2240}\right]$	= 627.1

* Work-day is taken to be 8-hr-day
\+ Hours at work x average men = man-hours (35.75 x 4.7 = 168.75

5.2.1. Factors which affected rate of cutting the soil

The soil of the experiment plot was deep, more than 1 m. deep. It had homogenious texture with no stone and no rock out-crop. The main fact which determined the rate of cutting the soil was the hardiness and stickiness of the soil which depended on the soil moisture. Excess water in the soil made it sticky and the rate of cutting was low. This is shown by very low cutting rate on 23.10.82, when it had been raining for 4 days. The soil was observed to be sticky. The high cutting rate of 27th, 28th and 29th of the same month (Table 4) can be explained by the fact that the soil was then dry but not baked hard. This is what was observed on the examination of the soil at the plot.

From the above observations, it can be seen that terraces should be constructed at the beginning of dry season when the soil is not wet and sticky and not baked hard. This is more so for Montimollinite type of soil which is very hard with big cracks in dry season and very sticky in rainy season.

5.2.2. Labour and cost of the experimental terrace

The experimental terraces were constructed on contract. For the terrace length of 255.4 m, shs 1,500.00 was paid. The cost per 1 metre was shs 5.87. The total volume of soil cut was 140.47 m^3. So the cost per 1 m^3 was shs 10.68. From these figures the cost of terracing 1 hectare of 14% slope and HI of 10 m is shs 6,698. Wenner (1980) reported that around Nairobi (this site is in Nairobi Area), labourers were being paid shs 4.20/m^3 in 1978. At this price, a farmer would pay shs 2,633.40 to terrace 1 ha. of land the same type as the experimental plot. This is expensive for a small scale farmer. The expense may lead a farmer to neglect terracing his land unless he does the work himself with his family.

The results from this project show that a lot of labour is required for terracing. To construct terraces in 1 ha. of a similar land to that of the project

681.9 man-hours are required. This may be one of the reasons for farmers' reluctance to terracing their land.

However if the work is phased over a period of 4-5 years it may be well within the capabilities of the peasant farmer and his family for whom there are slack periods during the year when conservation can be carried out. In so far as this method of terracing can provide a permanent solution to the erosion problem the long term benefits are important.

5.3. Bank stabilisation

Seven species of grass were visually evaluated for bank stabilisation in this project. Stone was used as a control. The results were as shown in Table 6. The visual evaluation was taken on 18.1.83.

5.3.1. Discussions on the treatments

The grass species mentioned in Table 6 were chosen for this particular project because observations in the field show that they are among the most commonly used grasses for protecting and establising terraces in most areas in Kenya.

5.3.1.1. Bana grass

Vegetative means of propagation is the only method as the grass does not produce seed. The split took 2 weeks to establish. All the splits established gave 100% establishment. Several characteristics of Bana grass which make it popular for bank protection and stabilisation were observed. The grass gave a good vegetative cover. In 60 days the cover was rated 100%. The growth was observed to be vigorous. Herbage production is likely to be high. The root-system was observed to be adventitious binding soil particles together. Because the grass is a deep rooter and has high tillering rate, its persistence is likely to be high.

Because of the grass's vigorous growth, large vegetative body, and long spreading root system, Bana grass is likely to be a serious competitor for soil moisture with the crops grown on the terrace ridge. The grass's height (100 - 110 cm in 60 days) can bring about shading effect which can affect crop yield. In areas with little land this grass is good because it can provide herbage for zero grazing. It is suitable for areas with enough rainfall to support its growth.

5.3.1.2. *Panicum coloratum var. makarikariense*

Vegetative propagation was successful with 93% establishment. The suckers that dried were eaten by ants. 70% cover was obtained in 67 days. The grass showed characteristic creeping which covered and kept the soil in place. The growth was observed to be vigorous. The root system was observed to be adventitious and deep. Its persistence to drought is likely to be high. This is an important grass in protecting terrace banks in dry areas.

5.3.1.3. *Setaria anceps*

From the splits *Setaria anceps* grew very fast. In 67 days, it had attained 95% cover. 85% establishment was observed. Soil binding property of the roots is good. Because the stems are erect, close spacing is necessary. Because of its big vegetative body, herbage production is likely to be high. Because of its vigorous growth, the grass may be competitive for moisture with the crops. Otherwise it is a good grass for bank protection.

5.3.1.4. *Brachiaria brizantha*

This grass was observed to be slow growing. In 40 days it covered only 30% of the area. 90% establishment was observed. Observations on grown up *B. brizantha* at the collection plots showed 100% cover with stem creeping firmly on the ground holding the soil in place. The herbage yield is likely to be low due to small vegetative body. This grass is good in areas where zero grazing is not necessary.

5.3.1.5. *Paspalum notatum*

All the stem cuttings that were planted established. The stem were observed to be firmly creeping on the ground keeping the soil in place. It does not grow vigorously. In 67 days, it had covered 50% of the area. Its herbage production is likely to be low because of small vegetative body. It has no shading effect on the crops because it creeps. The plant was observed to be having thick stems and it seems it stores foods in the thick stems. It is therefore likely to be drought resistant. *P. notatum* completely covers the bank and holds the soil firmly. It is therefore very important for stabilising banks.

5.2.1.6. *Panicum trichocladum*

Only mature stems established. 70% establishment was recorded. The growth was vigorous. In 60 days, 85% cover was observed. The riser had been covered and protected. This grass roots at the nodes. The roots are few and not very deep. The grass's competition for moisture is likely to be low. The grass was observed to spread fast, into the crop. Because of small vegetative body, herbage yield is likely to be low. Because of the grass's fast growth and good cover, it is good for bank protection.

5.3.1.7. *Tripsacum laxum*

The take-off was observed to be slow. Establishment of 85% was observed. Observations of this grass at the collection plots, Field Station, showed that vegetative body is big. Therefore herbage production is likely to be high. Close spacing is necessary because *T. laxum* was observed to be growing in clumps. At its full growth, *T. laxum* is likely to be a high competitor for moisture with crops because of its big vegetative body. It can also have shading effect on short crops.

5.3.1.8. Stone

Stone wall was used as a control. Stone was hard to get. Estimated half of the labour for planting and placing treatment in place was spent on stone walls. For the stability of the bank, it was necessary to re-shape the bank, to create a smaller riser angle. 100% cover was provided by the stone wall. The bank was observed to be very stable. No weeds were observed between closely pitched stones in the stone wall. Where there is plenty of stone and where the climate cannot allow grass growth, stone wall provides very good alternative.

Stone walls would normally be made nearly vertical but in the trial the wall was put at an angle of to occupy approximately the same area of land as the grass and therefore enable a comparison to be made of moisture competition.

6.0. CONCLUSION

The formula by Thomas et al (1980) is useful in designing fanya juu terraces, which can safely store the largest expected runoff in specified period. With time the designed terraces are likely to reduce soil erosion by reducing slope and slope length. However for calculating the amount of soil which is to be cut to make a ridge with required height and broad base to withstand expected seepage forces in case of water logging an adjustment factor is necessary.

In constructing fanya juu terraces like other types of terraces, a lot of labour is required. This is because a large amount of soil has to be cut and moved. An average of 1.67 man-hours per 1 metre recorded in the trial seems to be the standard labour requirement in constructing fanya juu terraces on 14% land at spacing of 10 m. between terraces.

Stone wall gives better protection and stability to terrace banks than grass. The stability and protection provided by grass varies with different species. The duration of the trial was too short to evaluate the species which were established on the terrace banks.

To evaluate the grass species on the banks for: herbage production, herbage quality, competition for moisture with the crops on the terrace, persistence and resistance to water-logging , more experiments are necessary.

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APPENDIX I

PROCEDURES FOR LONG TERM EVALUATION OF THE SELECTED TREATMENTS

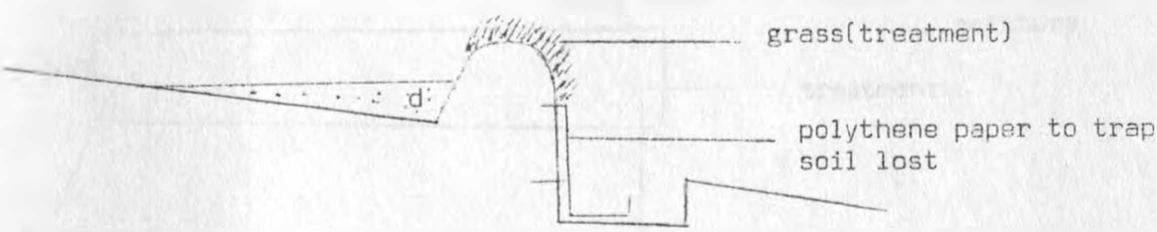
For long term, the treatments should be evaluated for: bank cover and stability, competition for moisture with crops grown on the terraces and herbage production.

I. BANK STABILITY AND COVER

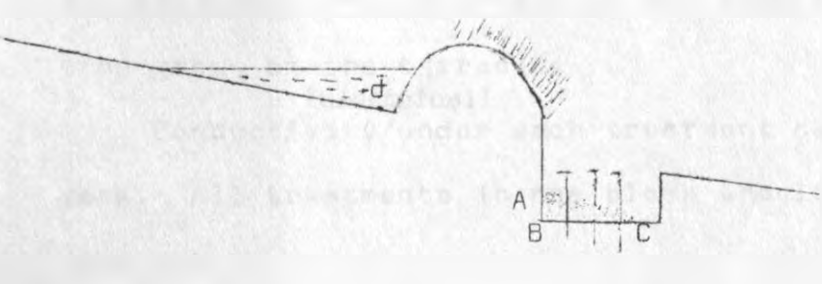
At the beginning of a crop growing season (rainy season), % cover of each treatment should be estimated as accurately as possible.

Then the soil lost from each treatment in every storm should be collected and weighed, so that the soil lost in the season from each treatment can be estimated.

Possible methods of collecting soil lost from a treatment



If polythene paper is expensive, pins can be used to estimate the soil lost from each treatment.



Cross section area of the trapped soil in square metres x 7 m will give the volume of lost soil per plot.

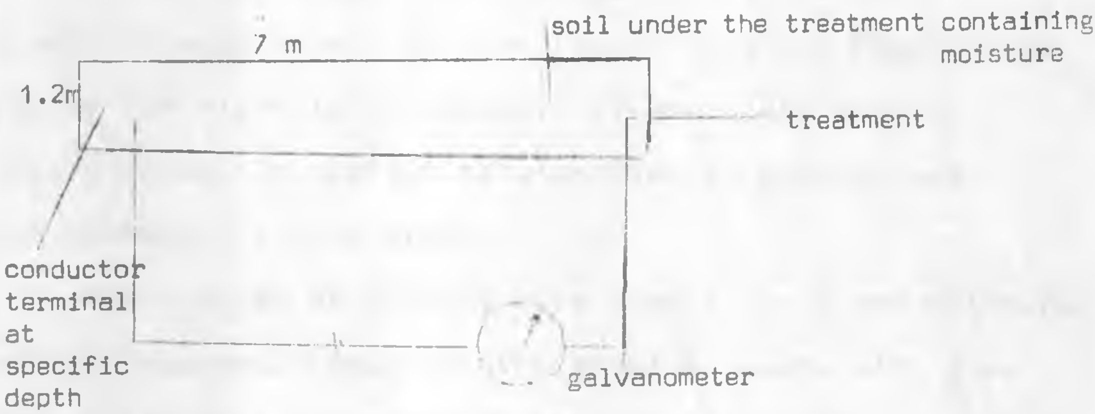
Comparison of % cover of each treatment and the soil deposited of this treatment over the growing season will give an index of the treatment's suitability for cover and bank protection.

II. <u>COMPETITION FOR MOISTURE AND OTHER MINERAL NUTRIENTS</u>

Several experiments should be carried out at the same time.

1) <u>Stress on soil moisture by each treatment including the control</u>

Moisture available in the soil under each treatment should be measured using any of the available methods from the beginning of the crop growing season to the harvest. One of the suitable methods is conducting a current in the soil under each treatment.



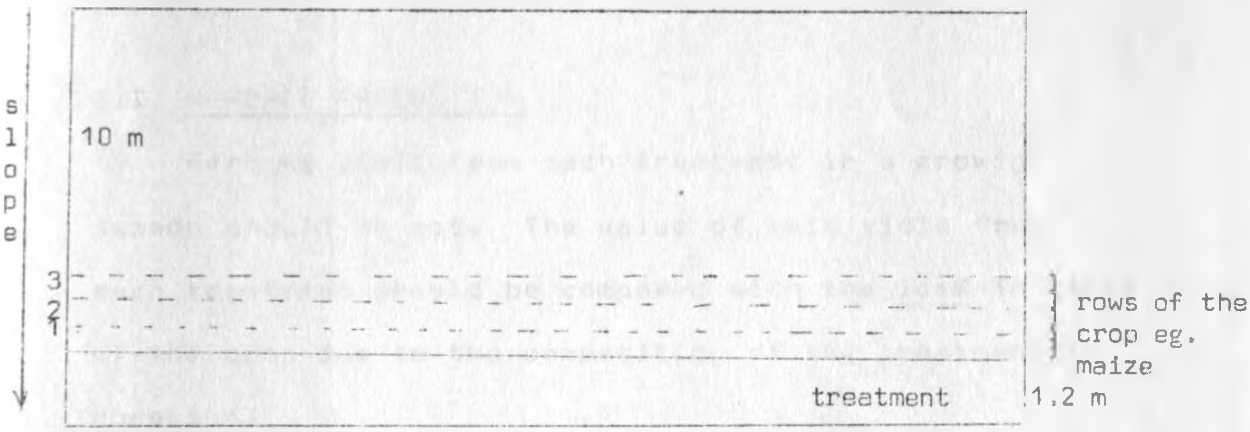
The depth of the conductor terminals in the soil under the treatment should depend on the root-system of the crop grown on the terraces.

Conductivity (electrical) under each treatment can be read every week. All treatments in one block should be read on the same day.

Difference in conductivity of each treatment when compared to that of the control will give the stress exerted by that treatment.

2) Effect on crop yield

When experiment I is being carried out, crops should be planted on the terraces in rows parallel to the treatments.



Before planting, the ditch uphill of the bank should be made level, so that runoff does not flow from one end of the block to the other. If necessary small ridges should be applied to stop flow of runoff from one treatment to the other.

Comparision of harvest from rows 1, 2, 3 and moisture stress recorded throughout the growing season will give the competition for moisture of each treatment.

3) Competition for mineral nutrients

At the beginning of a growing season, soil samples under each treatment at the same depth should be analysed for minerals. At the end of the growing season, at the same sites the sample of soil should again be analysed for minerals. The difference will give the demand for minerals by each treatment.

The difference in mineral content for each treatment compared to that of the soil under control will give an index of mineral demand of each treatment which must have an effect on growth and yield of the crop on the terraces.

III. HERBAGE PRODUCTION

Herbage yield from each treatment in a growing season should be got. The value of this yield from each treatment should be compared with the loss in yield of the crop due to the competition of the treatment in question.

In every growing season, observations should be taken on the following:

1) Labour spent on each treatment for weeding

2) Diseases and pests which may be transmitted to the crops.
3) Possibility of mulch production
4) Soil texture under each treatment at the beginning and end of the growing season

The above experiments should be carried out for at least two growing seasons.

APPENDIX II

THE PROFILE SURVEY OF THE EXPERIMENTAL PLOT BEFORE THE CONSTRUCTION OF THE FANYA JUU TERRACES

Date:	15-10-82		
Location:	Kabete, Kenya		
Type of survey:	profile survey		
Type of instrument:	quickset level		
Weather:	sunny		
Visibility:	clear		
Team:	Author	-	setting the instrument, taking readings and recording
	Worker	-	holding the staff
Assumed elevation:	100.00 m		

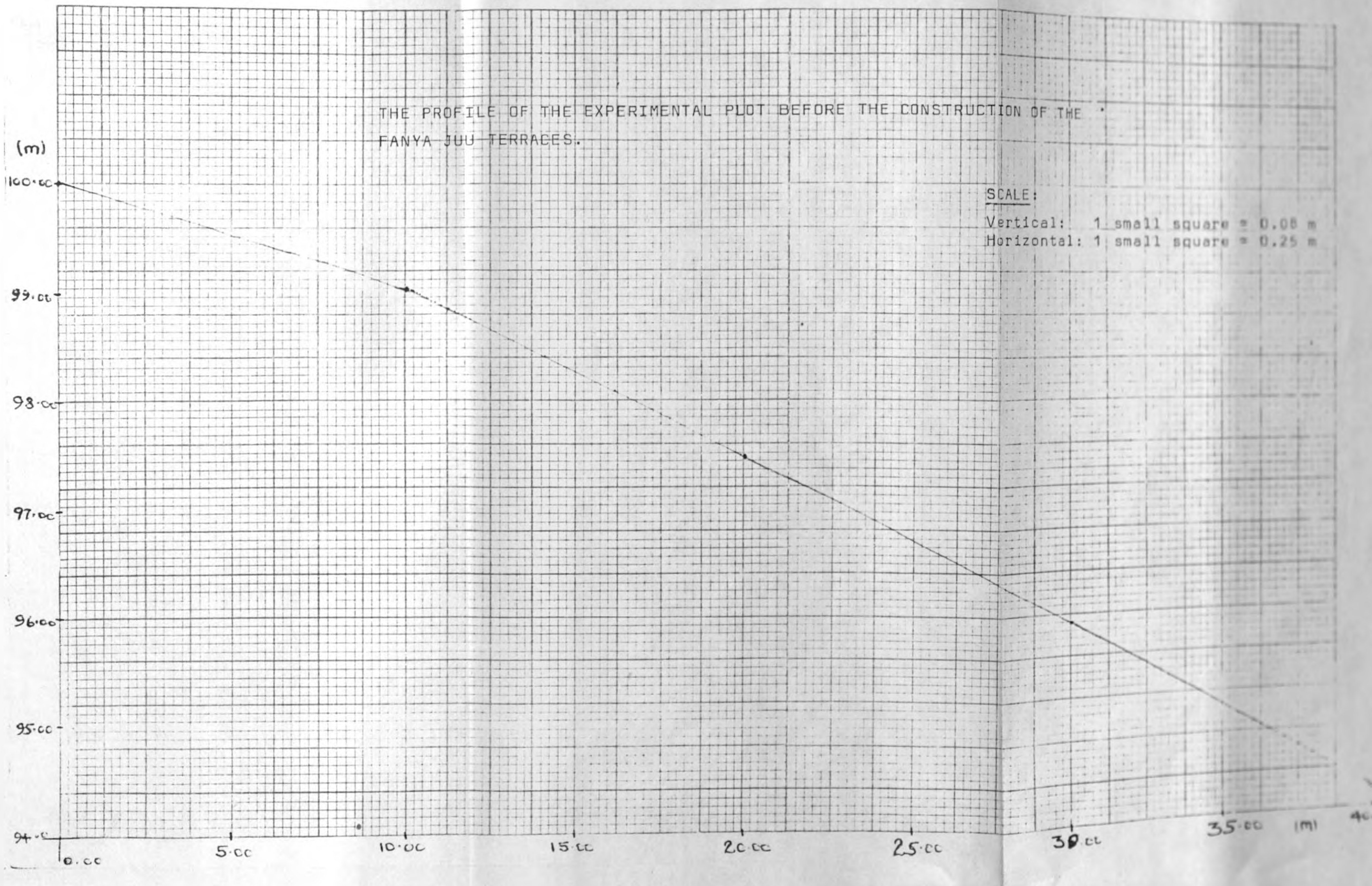
Station	Distance (m)	BS	IS	FS	HI (m)	RL (m)	Remarks
1	0	0.54			100.54	100.00	Bench mark top of plot
2	10		1.47			99.07	
3	20		3.03			97.51	
4	30	0.93		4.62		95.92	Turning point
5	40			2.63	96.85	94.22	
Total		1.47		7.25			

Check

Σ BS - Σ FS = Last RL - first RL

1.47 - 7.28 = 94.22 - 100.00

-5.78 = -5.78


THE PROFILE OF THE EXPERIMENTAL PLOT BEFORE THE CONSTRUCTION OF THE FANYA JUU TERRACES.
SCALE:
Vertical: 1 small square = 0.08 m
Horizontal: 1 small square = 0.25 m
(m)
100.00
99.00
98.00
97.00
96.00
95.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
(m)

APPENDIX III

THE PROFILE SURVEY OF THE EXPERIMENTAL PLOT 125 DAYS AFTER THE CONSTRUCTION OF FANYA JUU TERRACES

Date: 21-1-83
Location: Kabete, Kenya
Type of survey: profile survey
Type of instrument: quickset level
Weather: sunny
Visibility: clear
Team: Author - setting the instrument, taking readings and recordings
Worker - holding staff
Assumed elevation: 100.00 m

Station	Distance (m)	BS	IS	FS	HI (m)	RL (m)	Remarks
1	0.27				100.27	100.00	Bench mark top of the plot
2	6.00		0.94			99.33	
3	6.25		0.96			99.31	
4	6.50		0.98			99.29	
5	6.75		0.97			99.30	
6	7.00		0.89			99.38	
7	7.25		0.85			99.42	
8	7.50		0.80			99.47	
9	7.75		0.71			99.56	
10	8.00		0.83			99.44	
11	8.25		0.94			99.33	
12	8.50		1.15			99.12	
13	8.75		1.65			98.62	
14	9.00		1.77			98.50	
15	9.25		1.81			98.46	
16	9.50		1.82			98.45	
17	9.75		1.79			98.48	
18	10.00		1.72			98.55	
19	10.25		1.53			98.74	
20	10.50		2.08			98.19	
21	14.50		2.12			98.15	
22	14.75		2.16			98.11	
23	15.00		2.20			98.07	
24	15.25		2.21			98.06	
25	15.50		2.14			98.13	

..cont.

Station	Distance (m)	BS	IS	FS	HI (m)	RL (m)	Remarks
26	15.75		2.06			98.21	
27	16.00		2.00			98.27	
28	16.25		1.86			98.41	
29	16.50		2.04			98.23	
30	16.75		2.25			97.99	
31	17.00		2.48			97.79	
32	17.25		2.77			97.50	
33	17.50		3.07			97.20	
34	17.75		3.06			97.21	
35	18.00		3.01			97.26	
36	18.50		2.73			97.54	
37	24.50		3.47			96.80	
38	24.75		3.45			96.82	
39	25.00		3.43			96.84	
40	25.25		3.47			96.80	
41	25.50		3.34			96.93	
42	25.75		3.28			96.99	
43	26.00		3.22			97.05	
44	26.25		3.28			96.99	
45	26.50		3.37			96.90	
46	26.75		3.49			96.78	
47	27.00		3.64			96.63	
48	27.25		3.80			96.47	
49	27.50		4.00			96.27	
50	27.75		4.61			95.66	
51	28.00		4.68			95.59	
52	28.25		4.69			95.58	
53	28.50		4.67			95.60	
54	28.63		4.60			95.69	
55	28.75	1.41		4.29	97.39	95.98	Turning point
56	33.75		2.20			95.19	
57	34.00		2.20			95.19	
58	34.25		2.22			95.19	
59	34.50		2.30			95.09	
60	34.75		2.27			95.12	
61	35.00		2.27			95.12	
62	35.25		2.24			95.15	

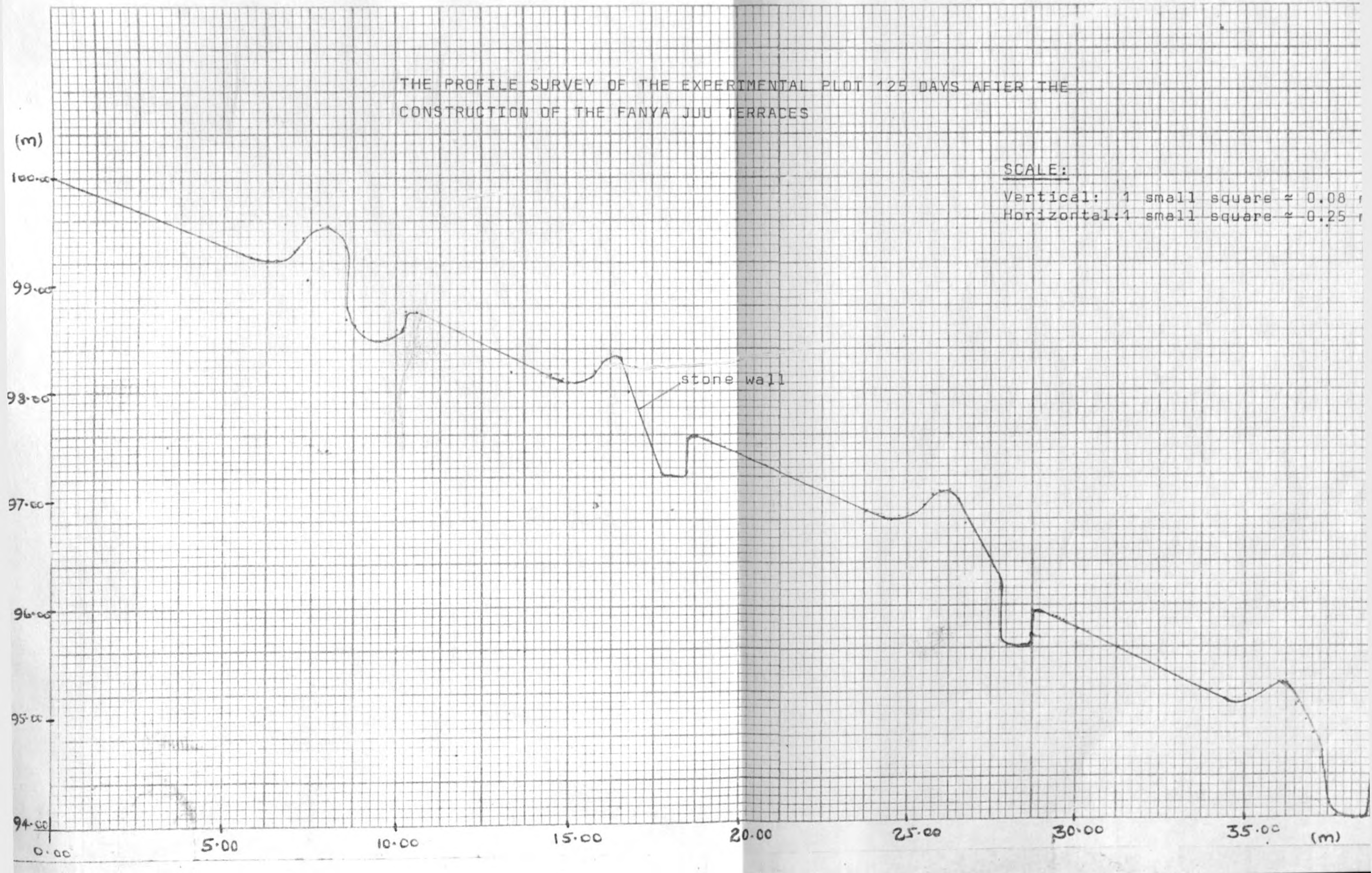
Station	Distance (m)	BS	IS	FS	HI (m)	RL (m)	Remarks
63	35.50		2.19			95.20	
64	35.75		2.14			95.25	
65	36.00		2.09			95.30	
66	36.25		2.16			95.23	
67	36.50		2.32			95.07	
68	36.75		2.45			94.94	
69	37.00		2.62			94.77	
70	37.25		2.85			94.54	
71	37.50		3.28			94.11	
72	37.75		3.36			94.03	
73	38.00		3.40			93.99	
74	38.25		3.39			94.00	
75	38.50		3.35			94.05	
76	38.75		2.99			94.40	
77	39.00			2.96		94.43	
Totals		1.68		7.25			

<u>Check</u>

$$\Sigma BS - \Sigma FS = \text{last RL} - \text{first RL}$$

$$1.68 - 7.25 = 94.43 - 100$$

$$-5.57 = -5.57$$


THE PROFILE SURVEY OF THE EXPERIMENTAL PLOT 125 DAYS AFTER THE
CONSTRUCTION OF THE FANYA JUU TERRACES
SCALE:
Vertical: 1 small square ≈ 0.08
Horizontal: 1 small square ≈ 0.25
stone wall
(m)
100.00
99.00
98.00
97.00
96.00
95.00
94.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
(m)