HAITI AGROFORESTRY RESEARCH PROJECT

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AN EXPLORATIVE APPROACH FOR ASSESSING SOIL MOVEMENT ON HILLSIDES

Application for Hedgerow Performance

by

Marie-Paule Enilorac, Agronomist
Pierre Rosseau, Tropical Agronomist
Arthur Gene Hunter, Agroforester

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EXECUTIVE SUMMARY

This report describes a methodology for studying soil movement on hillsides in Haiti. Hedgerows are one of the methods used in Haiti to prevent land degradation, and the method described here can be used to assess its efficiency. Observations need to be made on the parameters influencing soil movement in order to propose the best agroforestry practice to stabilize or even increase agricultural output. The most effective spacing of these anti-erosive structures, as well as the impact of climate and human activities on soil movement, are also discussed. Most of the procedures were developed during on-farm survey research conducted by Haiti Agroforestry Research Project (HARP) researchers.

This methodology is based on the following two considerations: (1) Soil accumulation observed above the hedgerows is due to the presence of vegetal barriers and, (2) The physical arrangement of these barriers affects the amount of soil lost from a hillside field. The soil volume displaced is estimated in a strip parallel to the slope using a topographical survey and simple formulas. However, estimating soil displacement within a heterogenous zone requires a careful assessment of the procedures used. It is necessary to evaluate the methodology by comparing the figures of actual soil loss measured from runoff plots to those of the soil volumes estimated empirically. The methodology developed here consists of taking measurements on a graduated non-elastic rope tied between two stakes driven into the ground. At least three measurements must be taken at three critical times of the agricultural calender: before tillage, one or two weeks after germination, and after the harvest. More measurements are taken as needed.

Applying the methods described here provides information to the researcher regarding the place of soil departure and the areas where soil accumulates. It also provides a clearer concept of possible anti-erosive management practices.

RESIME KREYOL

Rapo sa-a décri youn fason pou étidyé mouvman té bo-koté ranp vivan en Ayiti. Ranp vivan se youn fason pou consevé té-a. Pou bay youn bon rekomandasyon sou pi bon pratik agwoforestri ki ta ka fé youn alemye nan renman agrikili, obsévasyon te fet sou tout élémen ki kapab fé té déplacé. Obsévasyon te fet sou ki kantité plas ki fet pou geyen ent batiman anti-ewosyon yo, sibyen ke éfé zact crétyen vivan é zanimo tou. Plipa métod sa yo te devlopé pendan reshech tap fet sou fem planté pa Haiti Agrofoestry Research Project (HARP).

Metod pwoposé-a bazé sou plizyé idé: (1) Nou sipozé ke té ki akimilé anwo ranp vivan-an reté poutet ranp la baré rout li, é, (2) li afekté ranjman barikad sa-yo ak kantité té ki pedi sou pant la. Estimasyon volum té ki deplasé-a fet sou youn ban paralel a pant-la ak youn rélvé topografic é kek formul semp.

Estimasyon deplasman té nan youn zon mandé youn bon jen evalyasyon dé metod kap sevi-yo. Li mandé youn comparezon ent chif té ki pedi nan ban yo é chif volum té ki te éstimé pa obsevasyon. Metod sa-a mandé ke mezi yo fet sou youn kod red maré ent de piket ki fouyé nan té-a. Fok twa mezi empotan fet: youn avan plantasyon, youn de ou twa semenn apré plant-you lévé, é youn apré rekolt-la. Plis mezi kapab fet si nesesé.

Si metod sa-yo apliké nan youn ban, li bay infomasyon sou ki koté té ap pedi é ki koté té ap akimilé. Li bay tou, youn bon idé sou ki pratik anti-éwozyon ki ta posib.

Aplicasyon métod sa yo sou youn ban complet bay infomasyon sou plas koté té kon pati é koté té reté. Li bay, tou, youn bon idé sou pratik anti-ewosyon ki posib.

AN EXPLORATIVE APPROACH FOR ASSESSING SOIL MOVEMENT ON HILLSIDES

Application for Hedgerow Performance

I. Project Description

Haiti, with a surface area of 27,750 square kilometers and over six million inhabitants, is a densely populated country with a predominately rural population. 67% of the population is actively involved in farming. Agriculture is the pivot around which the national economy revolves and represents 35% of the GNP. The total agricultural production has not increased since 1980. In 1985 it was estimated that the country failed to produce 50% of its agricultural needs. The ensuing food shortages have resulted in an increase in imports of basic food stuffs.

The growing scarcity of the primary energy source, charcoal, recurring natural disasters such as hurricanes and droughts, combine with decreasing productivity in mountain farms to imperil an already precarious food supply.

Approximately 80% of the country is at an altitude of over 200 meters above sea level. 60% of the over-all land mass is on a vertical slope exceeding 20%, and half of that is on an incline of over 40%. The abusive agricultural methods and forestry management on these hillsides are the major causes for accelerating the erosion process. Land degradation has induced a decrease in agricultural production due to soil loss and a decline in soil fertility, as well as a rapid deterioration of the soil moisture regime. In most cases, the traditional conservative techniques of subsistence farming no longer allow the Haitian peasant to make a decent living.

It is within this context that the (Agroforestry Outreach Project), AOP, has been functioning since 1981. The United States Agency for International Development, USAID, is financing the project, and PADF, (Pan American Development Foundation) and CARE

are the implementing organizations. The main goal has been to educate farmers in planting trees as a cash crop. During the first few years the emphasis was on reforestation. This part of the program was implemented in cooperation with several PVOs, (Private Voluntary Organizations). 1984 saw the introduction of hedgerow planting on mountain slopes using <u>Leucaena leucocephala</u> as the preferred species.

Hedgerows are being successfully used within the context of these projects. However, problems are still encountered in species selection and management, raising questions as to the impact of hedgerows on crop productivity, species choice, growth rate, etc. Dr. P.K. Nair, during his visit in 1988 reported that "...hedgerow planting and management has been left to the farmers, and as a result there is considerable diversity in the distances between hedgerows, pruning calendars, and other aspects of hedgerow cultivation".

To date, these techniques have been applied without the benefit of scientific research conducted in Haiti. In view of the practical advantages of agroforestry in terms of raising income and increasing agricultural output through diversification, a research component, HARP (the Haiti Agroforestry Research Project), was added in order to supply adequate technical support to these projects.

The HARP is part of AOP. Its function is to collect and disseminate information on general agroforestry practices, mixed cropping, nursery production, and the socio-economic issues. To introduce new techniques into the Haitian peasant's system, in-depth knowledge of his environment and its constraints is essential, and will be a determining factor of the success or failure of the project.

In considering this report, the reader should remain aware of the fact that agroforestry systems are complex and that hedgerows are not the only method to prevent further land degradation, or to guarantee a stable source of income to the farmer. Soil and water conservation techniques well adapted to the Haitian environment can provide a sustainable form of agriculture on hillsides. In certain cases, particularly on steep mountain slopes, hedgerows must be used in conjunction with other anti-erosive structures to prevent gullies and impede the erosion process.

II. Background and Objective

1. Objective

The purpose of this report is to describe a scientifically valid procedure to measure the impact of hedgerows on soil movement. The ideal spacing of anti-erosive agents as well as the effect of climate and human activities on erosion and soil accumulation also needs to be investigated. Observations on these last two parameters are important because they constitute the primary environmental elements influencing the efficiency of hedgerow practices.

2. Prior Studies

As part of the agroforestry research program carried out by SECID/Auburn, several farms and demonstration sites in four regions in Haiti have been used as locations for hedgerow trials. These experiments are designed to test the following grasses and fast-growing leguminous species (Creole names in parentheses):

1. Leucaena leucocephala (Lesena)
2. Leucaena diversifolia (Lesena, Ti fey)
3. Gliricidia sepium (Lila etranje, piyon)
4. Moringa oleifera (Benzoliv/ doliv)
5. Albrizzia lebek (Tcha-tcha)
6. Cassia emarginata (Bwa kabrit)
7. Cassia siamea (Kasya)
8. Delonix regia (Flambwayan)
9. Anatherum zizanoides (Vetive)
10. Panicum maximum(Zeb guine)
11. Pennisetum purpureum (Zeb elephan/napier)
12. Saccharum officinarum (Kan'n)
13. Tripsacum laxum (Zeb guatemala)
14. Zeb buffle

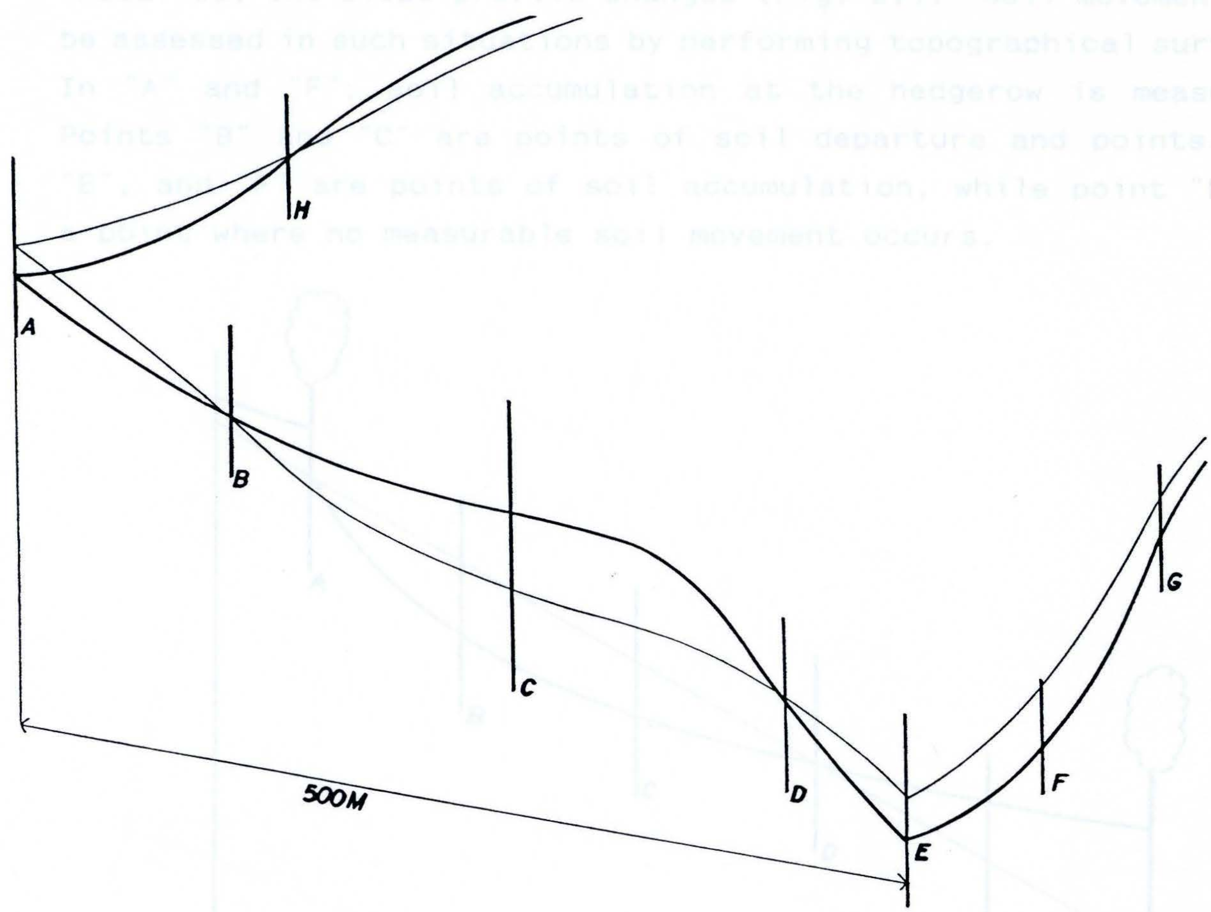
Studies have been initiated on hedgerow growth, density, biomass use and production, as well as their impact on crops, soil fertility, and soil savings.

III. Methodology

1. Procedure

Hedgerows provide a vegetal barrier which hinders the downhill movement of soil in the erosion process. The amount of soil lost from a hillside field, and thus, the efficiency of these vegetal barriers in conserving soil is affected by the physical arrangement of these barriers, both with respect to the plant density within the hedgerow and the spacing between them. Estimates are made at hedgerow sites to determine soil volume displaced in a band parallel to the slope using topographical surveys along and perpendicular to this axis.

A topographical survey will consist of measuring the heights at stake level. The stakes are driven into the ground 2 meters apart along the vertical as well as the horizontal slope. The vertical slope is defined as the slope parallel to the direction of maximum slope, while the horizontal slope is the slope perpendicular to that direction. At the time of initial measurement, a series of stakes are driven vertically into the ground, (0.50 meters deep, if possible), and their height above ground level is set at 0.30 meters for all stakes.



<u>Figure 1</u>: Soil movement on typical sloping landform.

On a typical sloping landform, figure 1, points of measurement "A", "E", "F", and "G" are in zones of soil departure, and point of measurement "C" is a point where soil has accumulated. Three points of measurement, "B", "D", "H", do not show any change and represent zones where no measurable soil movement took place. This does not mean, however, that soil did not move, but that equal amounts of soil departed and accumulated.

After anti-erosive structures such as hedgerows have been installed, the slope profile changes (Fig. 2.). Soil movement can be assessed in such situations by performing topographical surveys. In "A" and "F", soil accumulation at the hedgerow is measured. Points "B" and "C" are points of soil departure and points "A", "E", and "F" are points of soil accumulation, while point "D" is a point where no measurable soil movement occurs.

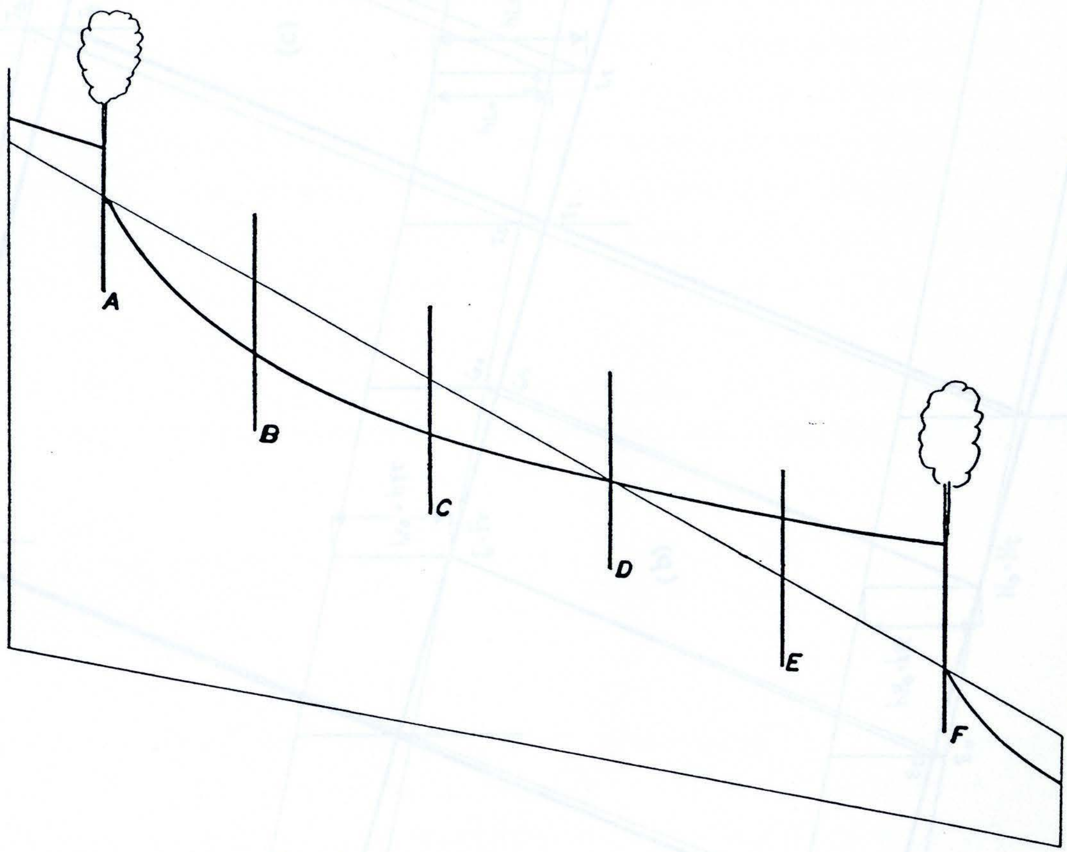


Figure 2: Soil movement between hedgerows.

The periodic topographical surveys will provide the rate and the dynamics of soil movement and allow an assessment of the efficiency of the anti-erosive structures.

Soil volume displacement is estimated using the sum of a series of volumes taken along the axes OO'(vertical), OO_1 (parallel to the slope), and OO_2 (perpendicular to the slope). Measurements are taken every 0.40 meters along the vertical slope. Figure 3 illustrates the procedure.

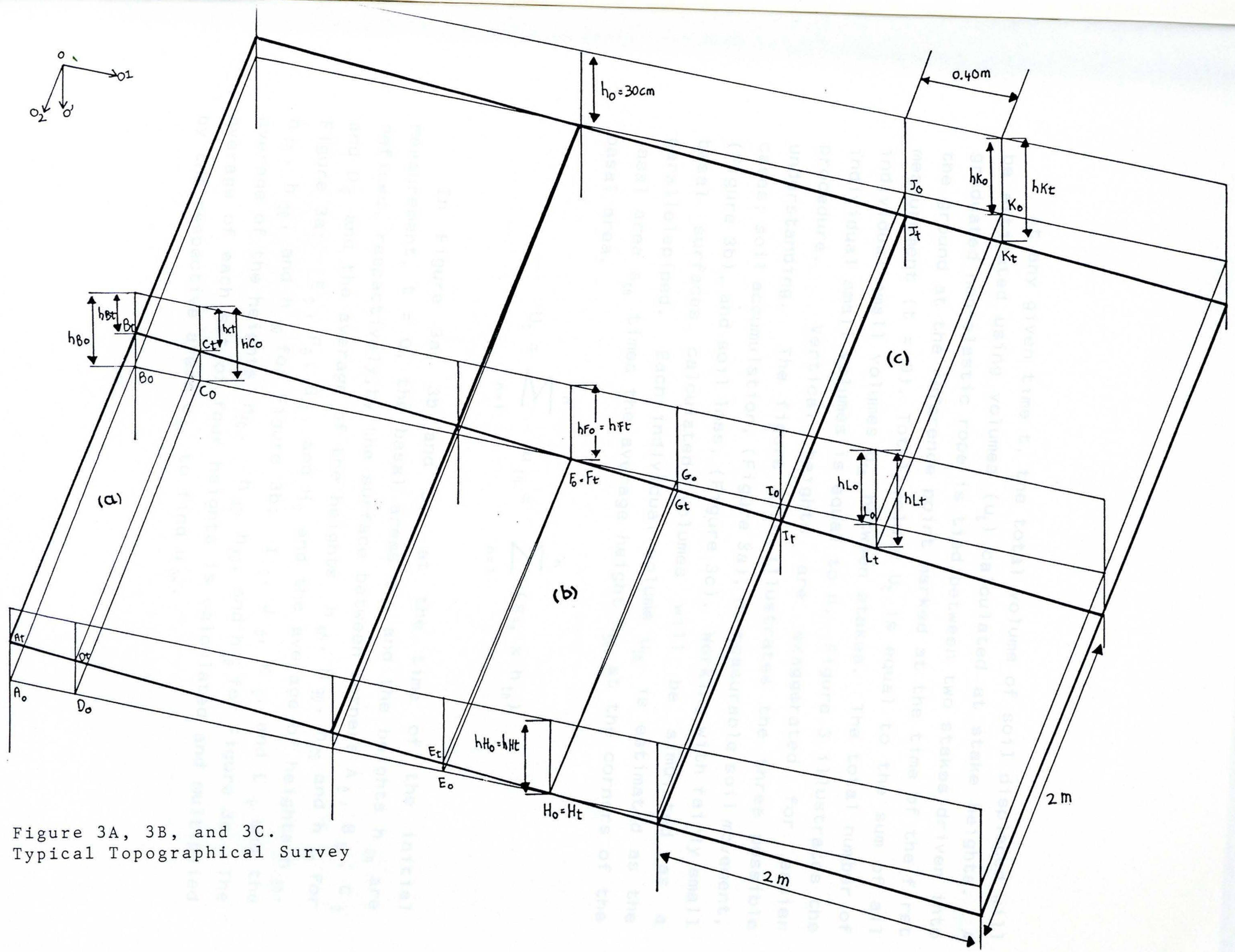


Figure 3A, 3B, and 3C.
Typical Topographical Survey

At any given time t, the total volume of soil displaced will be estimated using volumes (u_t) calculated at stake heights. A graduated non-elastic rope is tied between two stakes driven into the ground at the reference point marked at the time of the first measurement (t = 0). Total volume U_t is equal to the sum of all individual small volumes u_{tn} between stakes. The total number of individual small volumes is equal to n. Figure 3 illustrates the procedure. Vertical heights are exaggerated for easier understanding. The figure also illustrates the three possible cases; soil accumulation, (Figure 3a), no measurable soil movement, (Figure 3b), and soil loss, (Figure 3c). Working with fairly small basal surfaces calculated volumes will be simulated as a parallelepiped. Each individual volume u_{tn} is estimated as the basal area s_{tn} times the average height h_{tn} at the corners of the basal area.

$$U_t = \sum_{n=1}^{n} u_{tn} = \sum_{n=1}^{n} (s_{tn} \times h_{tn})$$

In Figure 3a, 3b and 3c, at the time of the initial measurement, t = 0, the basal areas s_{0n} and the heights h_{0n} are defined, respectively,by the surface between corners A_0, B_0, C_0 and D_0 and the average of the heights h_{A0}, h_{B0}, h_{C0} and h_{D0} for Figure 3a; E_0, F_0, G_0, and H_0 and the average of heights h_{E0}, h_{F0}, h_{G0}, and h_{H0} for Figure 3b; I_0, J_0, K_0, and L_0 and the average of the heights h_{I0}, h_{J0}, h_{K0}, and h_{I0} for Figure 3c. The average of each set of four heights is calculated and multiplied by the respective areas s_{0n} to find u_{0n}.

The total initial volume U_0 is the sum of all u_{0n}. The volume of soil displaced is set to zero;

$$V_0 = 0.$$

This first measurement will serve as a reference point, and is very important because it is the attribute to which all subsequent soil volume displacement data will be related.

At a later time (t), the new basal areas, s_{tn}, and the stake heights, h_{tn}, are defined, respectively, by the surface between the corners; A_t, B_t, C_t, and D_t and the average of heights h_{At}, h_{Bt}, h_{Ct} and h_{Dt} for Figure 3a; E_t, F_t, G_t, and H_t and the average of the heights h_{Et}, h_{Ft}, h_{Gt}, and h_{Ht} for Figure 3b; I_t, J_t, K_t, and L_t and the average of the heights h_{It}, h_{Jt}, h_{Kt}, and h_{It} for Figure 3c. The average of each set of four heights is calculated and multiplied by the respective areas s_{tn} to find u_{tn}. The total volume U_t is the sum of all u_{tn}.

After the topographical survey is completed, the volume of soil displaced between that time (t) and the initial time t = 0, will be equal to the difference between the original volume U_0 and the one measured at time t; U_t.

$$V_t = U_0 - U_t$$

A negative value, $U_t > U_0$ will indicate a soil loss, while a positive value $U_t < U_0$ will indicate soil accumulation.

The total volume can also be calculated by adding all displaced volumes V_t calculated over time.

$$V_{tot} = \sum_{t=1}^{t} (U_{(t-1)} - U_t) = \sum_{t=1}^{t} V_t$$

where t is equal to the number of times measurements are taken. The rate of soil movement can then be calculated and related to external factors such as climate and management practices that occurred during that particular time interval.

The accuracy of the result will depend on the number of measurements taken both parallel and perpendicular to the slope. The number of measurements needed for a given accuracy needs to be determined.

A graduated non-elastic rope is tied between two stakes driven into the ground at the reference point marked at the time of the first measurement (t = 0).

The distance between stakes is set at two meters apart so that the rope may be tied in a straight line without sagging. On the other hand, as few stakes as possible should be planted in order to avoid influencing soil movement. Two meters apart seems a good compromise. Iron reinforcing rods, small in diameter, thus having little effect in retaining soil, have been successfully used. When the distance between hedgerows is minimal, less than three meters apart, stakes should be placed as close to the hedgerows as possible. In this case, the impact of the stakes positioned in the hedgerow is the same as that of a young hedgerow tree.

The measurements are made at various points along the rope towards the ground i.e. at axis OO'. Data are to be recorded in sequence. To ensure accuracy, a vertical level is attached to the ruler. A sliding gauge whose function is to limit errors of parallax can also be an added device.

Soil movement will be related to rainfall as well as to other factors affecting the displacement of soil, such as animal activity, agricultural practices, etc. Certain agricultural practices have been shown to generate a downhill soil movement[1]. In Haiti, such practices include land preparation, ridging and weeding. Soil is moved down-slope, accelerating the erosive process[2]. Overgrazing by animals causes compaction which increases runoff and also leads to soil loss by sheet erosion[2]. These parameters affecting the rate of soil displacement and soil accumulation need to be recorded.

The <u>initial soil depth</u> needs to be measured at each site because it has an important impact on the potential for soil displacement. Physical parameters such as <u>texture</u>, <u>structure and permeability</u> as well as <u>organic matter</u> are important factors affecting erosion[3]. Soil analysis will provide texture and organic matter content, while structure and permeability are estimated in the field.

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[1] Revel J-C. & Rouhaud M., 1985.

[2] Enilorac M-P., 1988.

[3] cf Wischmeir.

2. Measurements

Data is recorded on Form 1. The frequency of data collection depends upon the incidence of events inducing soil movement: meteorological circumstances and human or animal activities. Mandatory data collection will occur at critical times during the cropping season, but additional ones will be taken as needed.

Rainfall may have an erosive effect depending upon its intensity and duration as well as the soil moisture at the time. A tipping bucket rain-gauge which records rainfall intensities is used to calculate rain erosivity. Rainfall erosivity is then correlated with soil movement measurement.

On runoff plots, soil loss and runoff measurements need to be taken after each rain. Runoff plots also require substantial investments of resources. The methodology developed here is not as restrictive regarding measurement schedules and can be done on a larger number of fields because it requires less resources.

Three critical measurements must be made: before tillage, one or two weeks after germination, and after the harvest. Cultural practices as well as their dates are recorded on the data sheet.

As check plots are needed, measurements will be taken in fields with and without soil conservation structures.

IV. Discussion

1. Test of the Method

The use of simple formulas to make estimates of soil displacement within a heterogenous zone necessitates careful monitoring of the procedures used. This evaluation can be made by comparing the figures on soil volume actually measured to those of the calculated soil volume.

Establishing the research process in runoff plot where soil loss is measured will facilitate the evaluation of this method of gauging soil loss. The use of plots during the first stage of research, is, therefore, very important. Interfacing among the various organizations involved in studying soil erosion in runoff plots should be carefully coordinated, and their respective roles and responsibilities defined.

At the present time only two erosion plot sites exist in Haiti where erosion is measured using runoff plots: One in Limbe (Northeast), and the other in Papaye (Central Plateau). (See Annex I).

If the correlations between the actual measurements recorded and the estimates made by the calculations are acceptable, this formula may be applied to many farms to assess the performance of hedgerows as an erosion control device.

2. <u>Application</u>

This method is time consuming but seeks to maximize the accuracy of the data collected. It needs to be carried out by well trained technicians. The area where measurements are taken may be limited to one small band across just two hedgerows.

The initial soil level is recorded at the tree root collar. Reference marks need to be placed on the stakes in the hedgerow using root collar as the initial level so that subsequent measurements are accurate.

This method may be particularly useful when resources are limited. By applying this method on a larger number of fields, more information is made available to the researcher and the extension staff; this information includes soil departure zones and soil deposit areas. A clearer understanding of anti-erosive management practices, including location and spacing of hedgerows, may be obtained.

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ANNEX I

Erosion plots - Limbe
Average annual rainfall: 1949 mm
Geological formation:
Soil depth: 30 to 50 cm
Plot area: 4 x 25 m2
Slope: 40% to 45%

The result of two years of observation are as follows:

Erosion
t/h/an
1.Crop/trees 0.97
2.Leucena hedgerow 1.24
3.Elephant grass hedgerow 1.55
4.Stone wall 1.58
5.Local wattling 2.23
6.Local ridging 5.50

The highest soil erosion figure in the above table is less than the erosion limit that can be borne by the soil.

Erosion plots - "tile factory" site in Papaye:
Average annual rainfall: 1110 mm
Geological formation:
Soil Depth: less than 20 cm
Plot area: 5 x 30 m2
Slope: 22% - 30%

Soil loss from April 1987 to March 1988:

Erosion
t/ha/an
1.Trees 8.46
2.Straw 6.18
3.Tree row 10.17
4.Contoured ditch 2.52
5.Straw row 3.93
6.Stone wall 1.94
7.Elephant grass hedgerow 3.91
8.Crops only 7.87

In two of the cases illustrated above, soil loss exceeds the soil erosion threshold.

These plots are presently being used primarily for demonstration purposes. Soil loss is measured only after it has accumulated in what is known as a "drum" (type of container). At such time as a cooperative protocol is established, a regular data collection time table should be specified.

ANNEX II

PWOJE RECHECH AGWOFORESTRI NAN PEYI AYITI
MEZI MOVMAN TE NAN EKSPERIANS AK RANP VIVAN

IDENT:

01 Depatman 02 Komin 03 Seksyon 04 Lokalite 05 Non plante-a 06 No jaden

Tout piket-yo ap numerote depi anwo jis anba jaden-a. Chak nimewo ap genyen nimewo seri piket ki nan ranp vivan-an epi yon nimewo pou chak piket. Ekri non espes pyebwa ou jwenn nan ranp vivan-an tou.

dp: distans ant chak mezi ki nan direksyon pant-la: ...
da: distans ant chak mezi ki nan direksyon pepandikule ak pant-la: ...

no. mezi	1er ranje A ant piket 1A e 2A	2eme ranje B ant Piket 1B e 2B	mezi pepandikule ant piket 1A e 1B
	ant piket 2A e 3A	ant piket 2B e 3B	ant piket 2A e 2B
	ant piket 2A e 3A	ant piket 2B e 3B	ant piket 2A e 2B

OBSEVASYON dat obsevasyon:

1. Kantite lapli total ki tombe depi denye mezi: (mm)

2. Vale gwo lapli ki tombe:

lapli(mm)	dat	tras rigol (wi/non) ou lot sign ewozyon

4. Aktivite neg:

Travay Kiliti	Pasaj	Lot ?

5. Aktivite zanimo:

Bet sou te-a	Pasaj	Fouye Twou	Lot ?

6. Kouvetu plant: a.te ni b.1/4 c.1/3 d.1/2 e.2/3 f.3/4 g.tou patou
   Ak ki-sa ? :

7.Ranp vivan:

Espes	Laje	Koupe	Ranp payi?

FORM 1

PWOJE RECHECH AGWOFORESTRI NAN PEYI AYITI
MEZI EFIKASITE RANP VIVAN NAN KONSEVASYON TE

Lokalizasyon IDENT:

01 Depatman 02 Komin 03 Seksyon 04 Lokalite 05 Non plantè-a 06 No jaden

Tout piket-yo ap numerote depi anwo jis anba jaden-a tankou pou ranp vivan -yo. Chak nimewo ap genyen nimewo ranp vivan ki plase jis apre plis nimewo piket-la.Nap separe tou dè nimero sa-yo pa yon vigil. Ekri non ranp vivan tou.

DAT(Mwa/jou/lane):

No piket	Mezi (mm)	No piket	Mezi (mm)	No piket	Mezi (mm)	No piket	Mezi (mm)	No piket	Mezi (mm)	No piket	Mezi (mm)

Obsevasyon (ak dat obsevasyon)

1. Kantite lapi total ki tonbe depi denye mezi: mm

2. Vale gwo lapi-yo ki tonbe: mm, dat - mm, dat

3. Eske tè genyen tras rigol-yo sou té ? .... - ....

4. Aktivite nèg-yo: Travay kiltiral-yo Pasaj nèg-yo sou tè Lot ?

5. Aktivite zanimo-yo: Bet ki sou tè Pasaj zanimo sou tè Fouye twou Lot ?

6. Kouvetur ak plant: a.té ni b.1/4 c.1/3 d.1/2 e.2/3 f.3/4 g.tou patou
   Ak ki-sa ? :

7.Ranp vivan: espes laj koupe ? ranp pay ?