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# Effects of various types of cover on soil detachment by rainfall

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with 4 tables and 2 figures.

Summary. One of the most important factors in predicting soil detachment is the effect of cover. But it is often reported that values which are empirically determined from plots data in one region cannot easily extended to other locations. Deriving the appropriate values for a given locality whould be facilitated by a more refined analysis of the various types of cover.

Experiments were conducted in the field on five soils of the Humid Tropics (Ivory Coast) using a sprinkling infiltrometer. The treatments included bare surface, residue mulch and mosquito gauze covers. Each plot was subjected to four 25-mm simulated rainfalls, applying either 30 or 120 mm/h rates, at various antecedent moistures. Drop size distributions were determined for free-falling and intercepted drops. Results show that the effect of the raised cover in protecting soil depends upon soil properties: a negative correlation was found between (S-G), i.e. sand fraction (0.1-2.0 mm) minus coarse fragments fraction (above 2 mm), and the relevant soil loss reducting factor (C-factor). Sugarcane residue mulch is more effective than the gauze cover. It raises infiltration capacity and thereby reduces runoff rate and runoff velocity. Mulch effect depends upon rainfall rate and soil moisture conditions.

Soil is substantially protected by gravel cover. Coarse fragments fraction is used to predict the relevant C-factor value. The regression equation is: $C = 0.697 \exp(-0.058\ G)$, with G: coarse fragments fraction, $n = 13$ and $r^2 = 0.962$. These results suggest that the covers which are included in the soil surface (gravel) or in contact with the ground (mulch) are more effective than those, such as the mosquito gauze simulating a raised canopy, which affect kinetic energy of rainfall but have no influence on the entrainment of sediment by overland flow.

Résumé . L'un des facteurs les plus importants pour prédire la détachabilité d'un sol est son couvert. Mais les données acquises empiriquement sur des parcelles expérimentales dans une région donnée ne peuvent pas, fait souvent signalé, être facilement extrapolées à d'autres. Une analyse plus poussée des différents types de couvert est alors en effet nécessaire.

Un infiltromètre à aspersion a permis de mener une étude expérimentale de terrain, sur cinq sols des Tropiques Humides (Côte d'Ivoire). Les traitements comprenaient deux types de couverts: un paillage réalisé avec des résidus de culture et une moustiquaire, ainsi qu'un témoin laissé nu. Quatre pluies de 25 mm chacune ont été simulées sur chaque parcelle, à des humidités initiales différentes. Deux intensités ont été utilisées: 30 et I20 mm/h. La distribution de la taille des gouttes a été déterminée sous moustiquaire et sous pluie non interceptée. Il ressort des résultats que l'effet d'un couvert situé au-dessus du sol dépend des caractéres texturaux de la surface: une corrélation négative a pu être établie entre le paramètre (S-G) qui représente le pourcentage de sables fins à grossiers ( 0.I-2.0 mm) diminué du taux pondéral d'éléments grossiers, et le facteur de réduction de la détachabilité (facteur C). Le paillage de bagasse est plus efficace que la moustiquaire. Il augmente l'infiltrabilité du sol et réduit ainsi l'intensité de ruissellement ainsi que sa vitesse. Son efficacité dépend de l'intensité de la pluie et des conditions d'humidité initiale.

La protection du sol est fortement assurée par un couvert constitué de gravillons. Le taux pondéral d'éléments grossiers peut être utilisé pour prévoir la valeur du facteur C correspondant à un tel couvert. L'équation de régression est: $C = 0.697\ e^{-0.058\ G}$, avec G: taux de gravillons, n = I3 et $r^2 = 0.962$. Ces résultats font apparaître que les couverts qui sont directement inclus dans la surface (éléments grossiers) ou en contact avec elle (paillage) sont plus efficaces que celles, comme la moustiquaire, ou comme probablement les couverts végétaux, qui diminuent l'énergie cinétique des pluies mais n'ont pas d'effet sur l'entrainement des sédiments par les eaux de ruissellement.

# I Introduction

One of the most significant achievements in soil erosion resarch has been the demonstration of the tremendous effect of cover on soil conservation, which resulted from the development of the Universal Soil Loss Equation (USLE) by Wischmeier and Smith (I960). In the Tropics, where high erosivities of rainfall are registered, several studies illustrate the efficiency, in terms of soil conservation, of crop cover (Hudson,I97I; Roose I977) and mulch cover (Lal I975; Valentin and Roose I98I). However, the use of the C-value (cover and management factor of the USLE) remains uncertain insofar as it combines in one numerical evaluation several sub-factors which have not been thorougly studied. It is therefore commonly conceded (Wischmeier I975) that further work is still needed to more accurately assess the effects of these sub-factors. For Rose (I983), two kinds of cover must be distinguished: that provided by a vegetation canopy, an that in contact with the ground. Surface cover intercepts the rain and reduces the velocity of running water, which plant cover generally cannot do.

Although surfaces covered with stones or gravel are very common, their influences on soil conservation have not been extensively investigated. Using rainfall simulation in the mountainous regions of Israël, Seginer, Morin and Sachori (I962) reported that no runoff and erosion was produced with 60 % stone cover. Data collected in Tunisia with rainfall simulation indicated that the percentage of coarse fragments fraction contained in the top layer accounted for 69% of the variation in erodibility values (K-factor). Therefore, Dumas (I965) propounded a simple nomograph to predict K-values from only three parameters: percentage of coarse fragments fraction, percentage of organic matter and percentage of moisture equivalent. The percentage of coarse fragments fraction however was not included as a parameter of the nomograph developed by Wischmeier, Johnson and Cross (I97I). As a matter of fact, it

is now widely accepted that the gravel cover density must be considered as integrant part of the C-factor since it acts as a surface mulch (Römkens I983) and because owing to the large variability of gravel cover density from one site to another, this parameter cannot be analysed as an intrinsic soil property. Besides, the efficiency of canopy cover in dissipating kinetic energy of rainfall was convincingly demonstrated by the wire gauze experiment quoted by Hudson (I97I:205), but the interactions between this effect and the surface texture have apparently not been investigated until recently.

The purpose of this study was to compare the effects of canopy cover, which was simulated with a mosquito gauze, and those of ground covers: sugarcane field residues and surface gravel.

# 2. Study area and soil characteristics

The study area is located near Tiéningboué, in Central Ivory Coast. The annual rainfall varies from 900 to I700 mm (the mean annual precipitation calculated for 28 years is II70 mm) depending upon whether the second dry season (July) occurs or not, according to the position of the intertropical discontinuity zone. Most often, there is only one dry season from October to May. The highest mean monthly precipitation is recorded in September (200-250 mm) but the most intense rainstorms are mainly observed in the early rainy season (60 mm during half-an-hour, with a yearly frequency), when late bush-fires expose bare soil surface (Brunet-Moret I967). Consequently erosion hazards are especially high during that period.

Vegetation cover in the study area consists of deciduous forest or dense tree savannah on the tops of the forms, low tree and grass savannah on the hillslopes and riparian forest along the rivers. As with much of Western Africa, this area is floored by the crystalline basement rocks of the pre-Cambrian which consist of coarse-grained granite. It is characterized by the presence of muscovite and small amounts of iron oxydes ($Fe_2O_3$ 4%, $FeO_2$ 2%) after Arnould (I96I). The study area ranges from 200 m to 400 m in altitude and the slope of the land surfaces averages 3 to 5 % (Poss I980). Helvic plinthic acrisols (F.A.O. legend) occupy the gently convex landscape. The texture of soils derived from shales are relatively fine, whereas soils developped from granite contain more coarse sand.

Five cultivated soils were selected on the basis of their agricultural importance and their wide range of characteristics which are representative of soils within the Central Ivory Coast. Three of them (TI,T2 and T3) are derived from granite, the others (W and M) have developed from shales. The main characteristics of their top layers are shown in Table I.

Table I

## 3. Materials and methods

At 4 sites (TI,T2,T3, and W), 3 plots of I $m^2$ were set up: A,B and C. At site M, 2 more plots were added so that 5 plots were prepared: A,B,C and E. For these I7 plots, identical slope lengths (Im) and slope angle (3%) were selected. Likewise, each plot was subjected to the same treatment which consisted of a conventional hoeing of the upper-I0 cm. The percentages of coarse fragments fraction were determined through collecting samples from the tilled layers. As reported by Dumas (I965), this method is the most convenient because it allows routine laboratory analyses of the layers. Furthermore, no pavement effect can be observed before rainfall simulation were the soils have been hoed, because the surface have been distributed and redistributed throughout the tilled zone. At each site, a mosquito gauze (I.3 mm mesh) was suspended 25 cm above the plot B, in the same way that gauze is used in that region by market-gardeners to protect seed-beds. In addition, the two extra-plots of site M (D and E) were completely covered with sugar cane bagasse ( mulch rate 4.5 tons/ha).

A sprinkling infiltrometer (Asseline and Valentin I978) was used to apply realistic simulated rainfall. This equipment is easily transportable to remote research sites and has been adapted to African conditions. It is now being used in seven African countries for soil and water conservation studies. This instrument consists of a telescoping tower, which can be rapidly and easily assembled, on which is a single nozzle (Teejet 6560) mounted. In savannah regions, a large canvas cover enclosed the experimental area to prevent wind distorsion of the spray. Water is supplied by a transportable tank which is connected to a centrifugal moto-pump. Two pressure gauges are used: one at the pump, the other one at the spray nozzle. Water pressure of 0.4 $kg/cm^2$ is selected to yield optimum experimental conditions, i.e. the most uniform spray distribution over the target area for a limited supply of water (0.6 $m^3$/hr.). The perpendicular distance from the nozzle to the impact surface area is 3.7 m. Moved by an adapted wind-screen wiper, the nozzle is oscillated across the plot. The angle of oscillation is altered by modifying the length of the driving shaft and can be rapidly regulated from the ground. Thus, rainfall intensity can be changed during a simulated storm event and reproduce a realistic hydrograph. Intensities of from 30 mm/hr. up to I40 mm/hr. can be applied. Accordingly, the uniformly sprinkled area ranges from 2.5 $m^2$ to I4 $m^2$ (8 $m^2$ when the canvas is used).

The calibration of the rainfall simulator was designed to achieve characteristics similar to natural storms. The well-known flour pellet method was used to determine drop size distributions. Drop velocities were estimated by placing the nozzle at horizontal and mesuring the average length to which the raindrops were projected. Velocities were then calculated from basic physical relationships. Finally, the kinetic energies dissipated at the soil surface were computed by a summation of the kinetic energies of the raindrops comprising the I2 drop size fractions. The results of this study indicate that the energies of the simulated rainfalls average 94% of those naturally occuring in Abidjan (Valentin I98I). This ratio ranges from 80% at 30 mm/hr. to II4% at I40 mm/hr..

Spray intensity was measured by placing a I $m^2$ pan over the plot, prior to each run, and then adjusted to the required intensity. Runoff was collected in a reservoir which was equipped with a very sensitive water-level recorder (A. OTT VIII): changes of 0.2 mm were noticeable on the runoff hydrographs. Sediment samples, manually collected in 0.3 lr. bottles, were removed from the flume at one minute intervals during the runoff periods. After every storm event, sediment trapped in the flume was weighed to produce more accurate calculations of the overall sediment concentration and soil losses relative to the runoff intensity. Water-level records were converted to discharge rates to give hydrographs and runoff volumes. These runoff hydrographs and sediment concentration values were used to calculate sediment discharge rates and total soil losses.

The test period was at the beginning of the rainy season (April-May) so that the first runs were on dry surfaces. The other three runs were performed after intervals of I7 hr., 4 hr. and 43 hr., respectively. The experimental plan was to simulate conditions that occur early in the rainy season when tilled unvegetated soils are exposed to severe storms. Each plot was subjected to the same amount of rainfall: 4 x 25 mm. But specific intensities were applied to the various plots:

- plots A (bare), B (gauze) and E (mulch) received rates of I20 mm/hr., e.g. I2.5 min-runs
- plots C (bare) and F (mulch) received rates of 30 mm/hr., e.g. 50 min-runs.

For the duration of every artificial storm, the intensity of the applied rainfall was assumed to be constant.

## 4 Results and discussion

### 4.I. The effect of interception of rainfall by mosquito gauze

Primarily, the mosquito gauze affects the drop size distribution of the simulated rainfall. Using the flour pellet method, the curves were determined for plots A (bare) and B (covered). Figure I shows that, on one hand, the largest free-falling drops (> 2.0 mm) are split up into finer droplets, and that, on the other hand, owing to the interception, some small drops aggregate into larger drops (> 4.0 mm). If the kinetic energy is computed, considering this modification of drop size distribution, but without taking into account the reduction of terminal velocity, its value is reduced from 23.7 Joules/mm/$m^2$ to I2.9 Joules/mm/$m^2$.

The second effect of this type of cover is to slacken the velocities attained by waterdrops. As an illustration, a 2.5-mm drop, starting from zero velocity, reaches a velocity of 3.0 m/s in a fall of 0.5 m, instead of 7.4 m/s in natural conditions (Laws I94I). In a fall of 0.25 m, the terminal velocity is 2.2I m/s for drops larger than 0.5 mm. This height of fall, in still air, is sufficient for smaller drops to reach the terminal velocities that correspond to their diameters.

The drop size distribution and the velocities obtained for this type of cover at I20 mm/hr. were used to compute the relevant kinetic energy of intercepted rainfall. Its value: 2.2 Joules/mm/$m^2$ indicates that the velocity reduction induces a longer decrease of kinetic energy that the single modification of drop size distribution. Since the interception does not affect the intensity component of the EI parameter of the USLE, the reduction in impact energy is equal to the predicted value of the relevant sub-factor: thus, the predicted C-gauze = 0.09. This reduction rate is comparable to the value: 0.I4, computed, after the data of Laws (I94I), for drops after

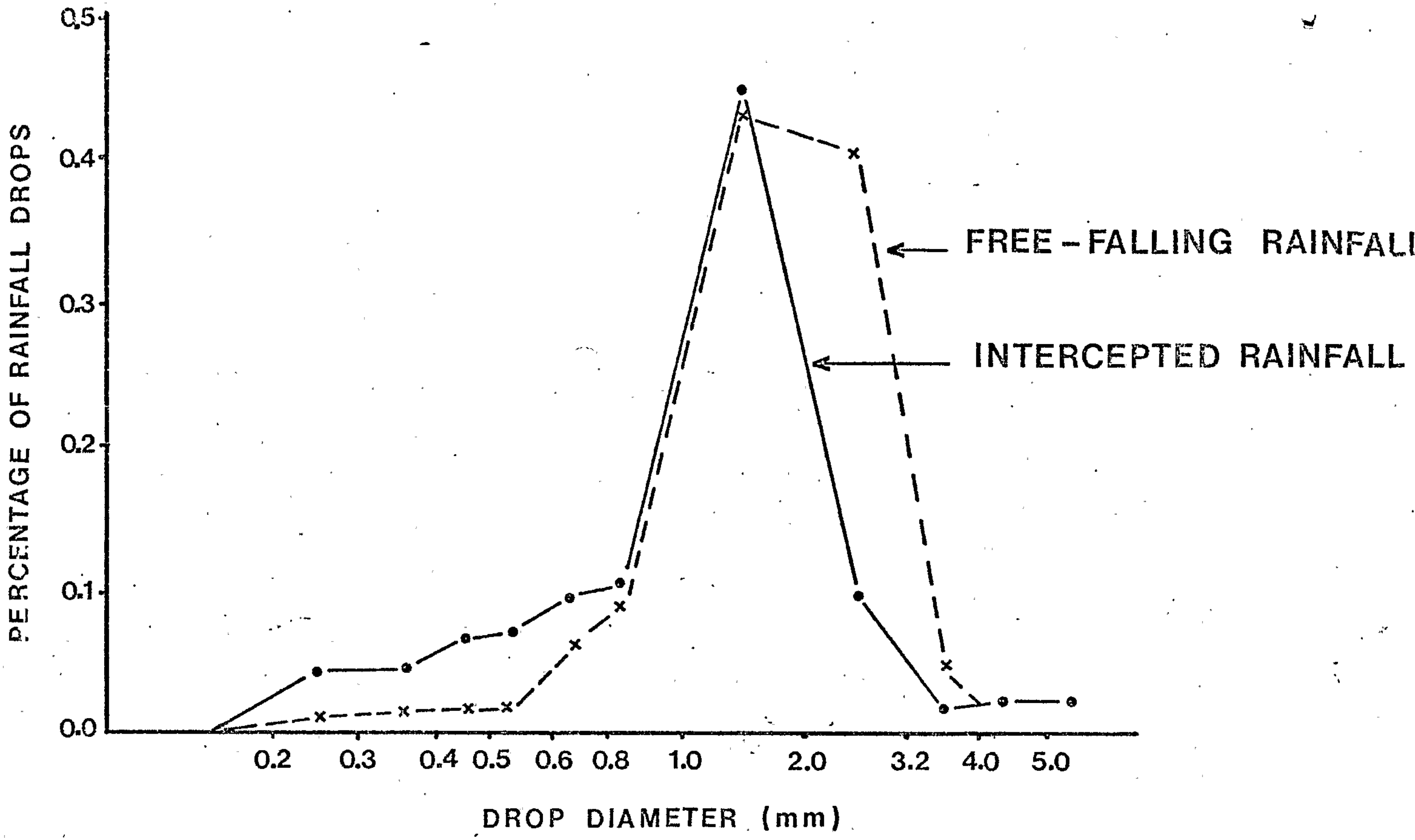

FIGURE 1. EFFECT OF INTERCEPTION OF RAINFALL BY A GAUZE ON DROP SIZE DISTRIBUTION

a fall of 0.5 m, for an intensity of I00 mm/h. The soil losses from the gauze-covered plots should therefore represent 9% of the soil losses observed for the bare plots. However, for three sites, the experimental results do not match the predicted value of the C-gauze factor (Table 2). Actually, reducing kinetic energy of rainfall has not a similar effect on all the tested soils.

Table 2

When comparing the particle size distributions of sediments of plots A to the particle size distribution of the top layers ( ratio denoted by D, in Table 2), it appears that detachment and flow transport on a short distance mainly affect the 0.I mm-2.0 mm fraction, denoted by S. Consequently, interception of rainfal by gauze is most efficient in reducing splash erosion hazards for soils with high S-content. In the opposite, for fine textured soils, the effect of the gauze is less pronounced since detachment requires smaller amounts of energy. Moreover, the influence of the gauze is less conspicuous for the soils which are already partly protected by a cover than for bare surfaces. For a more accurate prediction of the subfactor C-gauze, it is therefore necessary to include the G-factor, namely the coarse fragments fraction, in the relationship between the C-gauze values and soil characteristics. Thus, a strong negative correlation is found between the observed C-gauze values and the T-values, with T = S - G (see Table 2):

$$\text{C-gauze} = 0.795 - \text{I.359.IO}^{-2}\ T \qquad r^2 = 0.970$$

Further experiments are needed to test this relationship with a lager sample than 5. However, these results suggest that the effect of reducing kinetic energy is not independant from the textural parameters. In other words, an interaction seems to exist between the subfactor C-gauze, and others factors of the USLE, such as erodibility K-factor, and subfactor C-gravel, which corresponds to the effect of the gravel cover. As a result, subfactors C-gauze and C-gravel are not fully additive.

## 4.2. The effect of mulching

When the whole surface of a plot is covered with mulch, the soil is protected from the direct impact of raindrops. Two main consequences must then be noted:

. (i) splash erosion is essentially reduced

. (ii) sealing occurs less rapidly.

Owing to this second effect, the runoff's potential to detach and transport material is depressed. Reduction of the runoff coefficient and of the peak runoff rate, shown in Table 3, illustrates this importance effect of mulch cover.

Consequently, sugarcane residues are very effective in reducing soil losses: the C-mulch values were 0.03 and 0.05 for plots D and E respectively. The small difference observed between the results of the two plots can be ascribed to the effect of the rainfall rate: for low rates, and dry conditions, the infiltration capacity remains higher than the intensity of rainfall and hence no runoff is observed. For high rates, and for any antecedent soil moisture, intense storms promote runoff and thus detachment and transport, since the intensities, in these cases, exceed the infiltration capacity. Therefore, the C-much subfactor is interrelated with the rainfall erosion index EI of the USLE. Accordingly, deriving the appropriate C-mulch values for a given locality requires the knowledge of the relevant rainfall intensity distribution: bagasse cover will be more effective in regions where rain intensities are moderate than for locations where rainstorms are not uncommon.

TABLE 3

### 4.3. The effect of gravel cover

For a particular plot, the influence on soil detachment of the C-factor due to gravel cover (C-gravel) cannot be separately analysed from the effects of the intrinsic soil characters, i.e. of the erodibility K-factor. Thus, the expression K.C-gravel can be calculated as follows:

$$K.C\text{-gravel} = A\ R^{-I}\ L^{-I}\ S^{-I}$$

where:

A is the computed soil loss per unit area expressed in metric tons/ha/year and divided by 2.24 for obtaining american units.

R, the rainfall aggressivity index, R = P E I
where P is the rainfall amount (mm), I the maximum intensity within 30 minutes, namely the simulated rainfall rate, (mm/hr.) and E the kinetic energy corresponding to the intensity ( Joules/mm/$m^2$). R is divided by I735.6 for obtaining american units.

L, the slope-length factor, for a I-m long plot,

$$L = (45.5\ IO^{-3})^{M}$$

where M = 0.5 if the percent slope is 5 or more, 0.4 on slopes of 3.5 to 4.5 percent, 0.3 on slopes of I to 3 percent, and 0.2 on uniform gradients of less than I percent (U.S.D.A. Handbook N°537 I978)

S, the slope-steepness factor:

$$S = 65.4I\ \sin^2\theta + 4.56\ \sin\theta + 0.0065$$

where $\theta$ = Arc tang ($\alpha$/IOO)

$\alpha$ = percent slope

The K.C-gravel factor was calculated not only for the sites TI, T2 and T3, with gravel percentages of I4.2, I8.4 and 36.2, respectively, but also for ten other sites which have been studied under identical experimental conditions (rainfall simulation on I-$m^2$ plots subjected to a shallow hoeing). These data (Collinet and Valentin I979, Valentin I98I) were collected on various soils from the tropical forest zone to the Sahara desert. The effect of a large range of gravel density and other soil characteristics is thus analysed (Table 4). Only results from plots with coarse fragments fractions exceeding 5% were selected, assuming that for lower values the influence of gravel is negligible as compared with other parameters.

Table 4

A strong negative correlation was found between the expression K.C-gravel and the coarse fragments percentages G:

$$K.C\text{-gravel} = 4.2I9\ G^{-I.585} \qquad r^2 = 0.844 \qquad n = I3$$

This relation means that the coarse fragments fraction alone accounted for 84% of the variation in K.C-gravel values, and therefore in soil losses. As a result, determination of the gravel content in hoed layers allows the estimation of the combined effect of gravel and textural parameters.

Furthermore, a better approximation of the C-gravel factor would be yielded if the K values could be separately estimated. The development by Wischmeier, Johnson and Cross (I97I) of a soil erodibility nomograph made such attempts possible. Its algebraic expression is given by the equation (U.S.D.A. Handbook N°537 I978):

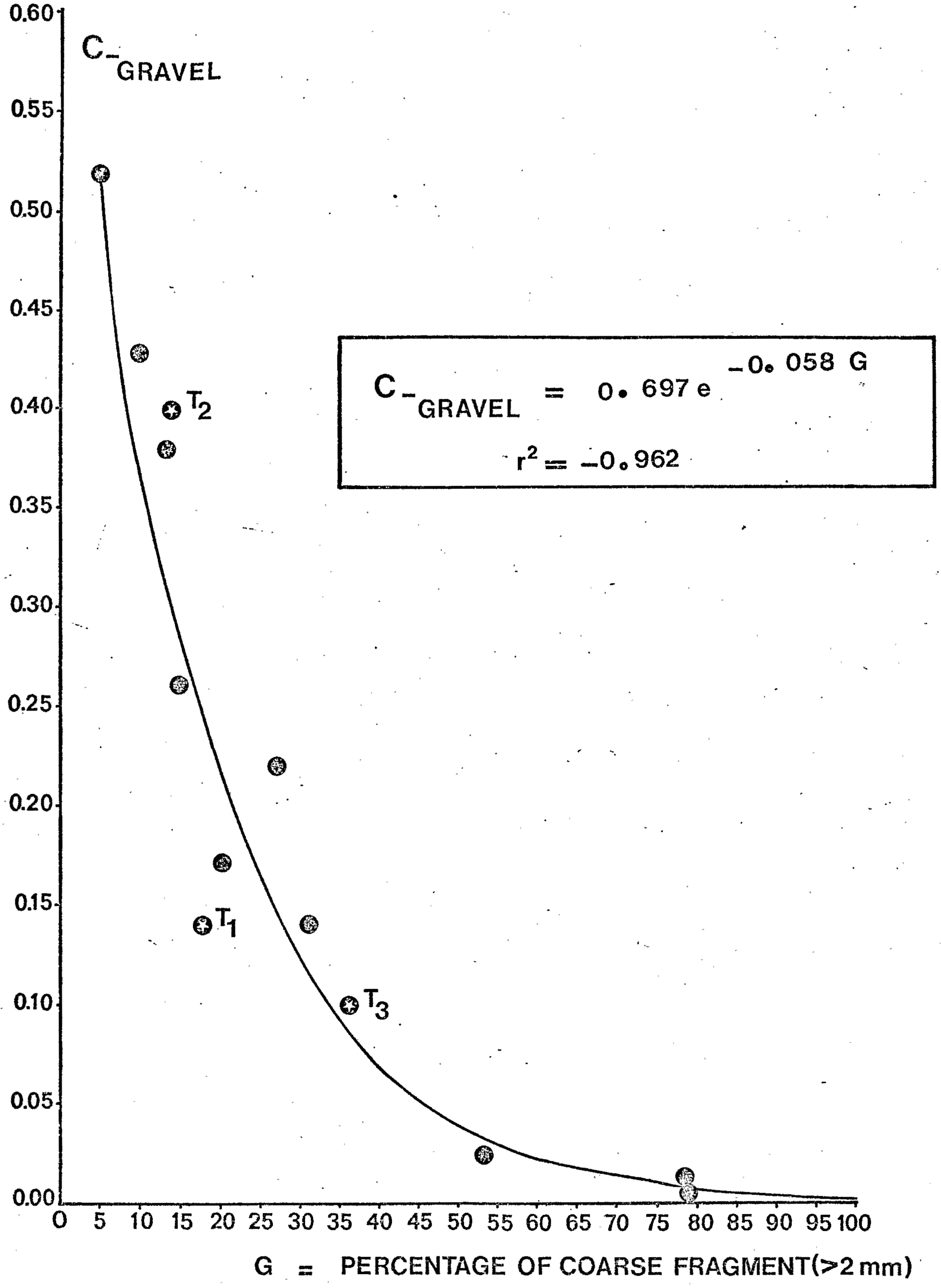

FIGURE 2. EFFECT OF COARSE FRAGMENTS ON C-FACTOR

$$I00\ Kn = 2.I\ N^{I.I4} I0^{-4}\ (I2 - a) + 3.25\ (b-2) + 2.5\ (c-3)$$

where:

Kn is the predicted value of the erodibility K-factor

N, the particle size parameter which equals percent silt (0.I00 - 0.002 mm) times I00-minus-percent clay

a, the organic matter percentage

b, the soil-structure code: I for very fine granular, 2 for fine granular, 3 for medium or coarse granular and 4 for blocky, platy or massive

c, the profile-permeability class: I for rapid, 2 for moderate to rapid, 3 for moderate, 4 for slow to moderate, 5 for slow and 6 for very slow.

Assuming that the Kn value approximate real K values, the C-gravel factor can be expressed as the following ratio:

$$\text{C-gravel} = \text{K.C-gravel}/\ Kn$$

Statistical analysis shows an enhancement in the predictive capability of G: its correlation coefficient with C-gravel raised from -0.9I9 to -0.98I:

$$\text{C-gravel} = 0.697\ \exp\ (-0.058\ G) \qquad r^2 = 0.962$$

The significance of this regression equation is twofold:

(i) it demonstrates that the G-factor, which is easily determined, alone accounted for 96% of the variation in C-gravel values, and can thus be used as a satisfying predicting factor,

(ii) it illustrates the great efficiency of coarse fragments in reducing soil losses since, for instance, an increase in G from 5% to 33% yields a decrease in the C-gravel values from 0.5 to 0.I and thus a quotient equal to 5 in dividing soil losses.

The effectiveness of coarse fragments fraction in reducing detachment can be ascribed to various effects. First, it acts as a surface mulch cover in essentially eliminating the impact of raindrops on the ground, but it seems to be more effective than an equivalent percentage of mulch cover because it obstructs more strongly runoff flow as a result of the more pronounced surface roughness. Secondly, because of their size, gravels obviously are more resistant to detachment than finer particles. Hence a strong negative correlation is found between their amounts and the potential soil losses.

## 5. Conclusion

This study allowed comparison between the effects of three types of soil cover on detachment by rainfall water:

(i) above the surface: a gauze used as a raised canopy,

(ii) on the surface: sugarcane residue mulch

(iii) in the surface: coarse fragments.

The gauze cover substantially reduces kinetic energy of rainfall and consequently is most effective on soils which are exposed to splash erosion. For that reason, the magnitude of the protecting effect of the gauze is strongly intercorrelated with soil properties. The experimental results suggest that the relevant C-gauze values can be predicted through the single parameter T = S - G (sand fraction minus gravel fraction contained in the tilled layer).

Residue mulch not only dissipated kinetic energy of rainfall, it also protects the soil from sealing and thereby raised its infiltration capacity. Accordingly volume and velocity of runoff are reduced. As a result, I00% residue cover is more effective than the equivalent percentage of raised canopy (simulated by a gauze). The experimental results indicate, moreover, that the relevant subfactor C-mulch depends upon the intensity of rainfall and soil moisture conditions.

The effect of gravel cover is emphasized by this study. Coarse fragments seem to be more effective than equivalent percentages of mulch cover because, on one hand, they more firmly obstruct runoff flow, and, on the other hand, they limit the fine earth amounts, which a mulch cover cannot do. Acceptable estimates of C-gravel values can be produced in extent of the coarse fragments fraction which is a more easily determined parameter than the gravel cover density.

For conservation purposes, appropiate cover should be adapted to soil properties, e.g. sandy soils can be satisfactorily protected by a raised canopy, whereas fine textured soils would require mulch cover or close-growing vegetation. For any soils, detachment by rainfalls is completely hindered when coarse fragments fraction equals or exceeds 50 %; top soils are then self-protected.

## References

ARNOULD (M.).I96I.- Etude géologique des migmatites et des granites précambriens du Nord-Est de la Côte d'Ivoire et de la Haute-Volta méridionale. Cadre géologique. Classification. Principaux types. Bull. N°I, Dir. Géol. et Prosp. Minière, Abidjan, I74 p.

ASSELINE (J.) and VALENTIN (C.) . I978. Construction et mise au point d'un infiltromètre à aspersion. Cah. ORSTOM, sér. Hydrol., I5 (4): 32I-350, I2 tab., I6 fig., I8 ref..

BRUNET-MORET (Y.) . I967 . Etude générale des averses exceptionnelles en Afrique Occidentale. République de Côte d'Ivoire. ORSTOM/ Comité Interafricain d'Etudes Hydrauliques, multigr., II fig., 20 p.

COLLINET (J.) and VALENTIN (C.) . I979 . Analyse des différents facteurs intervenant sur l'hydrodynamique superficielle. Nouvelles perspectives. Applications agronomiques. Cah. ORSTOM, sér. Pédol., I7 (4): 283-328, I6 tab., 26 fig., 27 ref..

DUMAS (J.) . I965 . Relation entre l'érodibilité des sols et leurs caractéristiques analytiques. Cah. ORSTOM, sér. Pédol., 3 (4): 307-333, 3 tab., 8 fig., I5 ref..

HUDSON (N.W.) . I97I . Soil Conservation. Batsford edit. London, 320 p.

LAL (R.) . I975 . Role of mulching techniques in tropical soil and water management. I.I.T.A., Ibadan, Techn. Bull., N°I, 38 p., I6 tab., 40 fig., 75 ref..

LAWS (J.O.) . I94I . Measurements of the fall-velocity of water-drops and raindrops. Trans.Amer. Geophys. Union 22: 709-72I.

POSS (R.) . I982 . Etude morpho-pédologique de la région de Katiola (Côte d'Ivoire). Carte des paysages et des unités morpho-pédologiques, Feuille de Katiola à I:200 000. ORSTOM, Paris, Notice explicative N°94, I42 p., 52 ref., 2 cartes.

RÖMKENS (M.J.M.) . I983 . The soil erodibility factor. A perspective. International Conference on Soil Erosion and Conservation. Honolulu. 3I p., 4 tab., 30 ref..

ROOSE (E.) . I977 . Erosion et ruissellement en Afrique de l'Ouest. Vingt années de mesures en petites parcelles expérimentales. ORSTOM. Paris. Trav. et Doc. N° 78, I08 p., 32 tab., 8 fig., 97 ref..

ROSE (C.W.) . I983 . Soil erosion and conservation: from processes to practices to policies. International Conference on Soil Erosion and Conservation. Honolulu. I7 p., I fig., 6 ref..

SEGINER (I.), MORIN (J.), and SACHORI (A.) . I962 . Runoff and erosion studies in mountainous terra-rossa regions in Israël, Bull.Int.Ass.Sc.Hydrol., 4: 79-82

U.S.D.A. . I978 . Predicting rainfall erosion losses. A guide to conservation planning. Agriculture Handbook N°537. 58 p., I9 tab., I0 fig., 67 ref..

VALENTIN (C.) and ROOSE (E.) . I98I . Soil and water conservation problems in pineapple plantations of South Ivory Coast. in: Soil and Conservation: Problems and Prospects. MORGAN (R.P.C.) edit.. John Wiley. New-York, 239-246, 2 tab., I fig., 9 ref..

VALENTIN (C.) . I98I . Organisations pelliculaires superficielles de quelques sols de région subdésertique (Agadez-Niger). Dynamique de formation et conséquence sur l'économie en eau. Thèse Doct. 3ème cycle. Univ. Paris VII., 229 p., 22 tab., 43 fig., 472 ref., 67 photo., 2 annexes.

WISCHMEIER (W.H.) and SMITH (D.D.) . I960 . An universal soil loss estimating equation to guide conservation farm planning. in: Proc. of the VIIth Intern. Cong. Soil Sci., Madison, I: 4I8-425, 2 fig., I tab., I2 ref..

WISCHMEIER (W.H.), JOHNSON (C.E.B.), CROSS (B.V.). I97I . A soil erodibility nomograph for farm land and construction sites. J. of Soil and Water Cons., 26 (5): I89-I92.

WISCHMEIER (W.H.) . I975 . Estimating the soil loss equation's cover and management factor for undisturbed areas. U.S. Agr. Res. Ser. Rep. ARS-S-40, 7 p., 3 tab., 3 fig..

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Table I : Main characteristics of the hoed layers

| Site | TI | T2 | T3 | W | M |
|---|---|---|---|---|---|
| Organic matter (%) | I.I | I.2 | I.4 | 2.6 | I.6 |
| Clay: 0-0.002 mm (%) | 8.7 | I2.3 | 9.7 | I5.5 | I8.6 |
| Silt and very fine sand: 0 002-0.I mm(%) | I9.7 | I9.8 | I7.2 | 42.8 | 42.9 |
| Sand: 0.I-2.0 mm (%) | 68.9 | 66.I | 70.6 | 36.5 | 34.9 |
| Coarse fragments: ❯ 2 mm (%) | I8.4 | I4.2 | 36.2 | 2.I | I.5 |

Table 2 : Measured C-gauze values, detachment rate of the sand fraction and T-parameter:

D = ratio between the percent S-fraction (0.I- 2.0 mm) contained in the sediments from plot A and the percent S-fraction contained in the hoed layer.

T = sand fraction (S) minus coarse fragments fraction (G), in the hoed layer.

| Site | TI | T2 | T3 | W | M |
|---|---|---|---|---|---|
| Measured C-gauze | 0.082 | 0.II5 | 0.35I | 0.3I4 | 0.343 |
| D (%) | I28.0 | I34.5 | II4.6 | II0.8 | II3.I |
| T (%) | 50.5 | 5I.9 | 34.4 | 34.4 | 33.4 |

Table 3 : Effect of surface mulching on runoff coe
cient and peak runoff rate at site M.
runoff coefficient = runoff volume/ rain
volume
peak runoff = maximal value of runoff ra
recorded during the four si
lated rainfalls.

| | rainfall rate (mm/h) | bare surface | mulched surface |
|---|---|---|---|
| Runoff coefficient (%) | 30.0 | 57.9 | II.4 |
| | I20.0 | 84.3 | 2I.2 |
| Peak runoff rate (mm/h) | 30.0 | 20.0 | II.0 |
| | I20.0 | I08.0 | 65.0 |

Table 4 : Range of the parameters of the soils which form the statistical sample.
s.d. = standard deviation

| | minimum | maximum | s.d. | median | mean |
|---|---|---|---|---|---|
| Clay (%) | 5.0 | 23.9 | 6.3 | I2.3 | I3.7 |
| Silt and very fine sand (%) | I7.2 | 55.9 | I4.0 | 35.9 | 35.7 |
| Organic matter (%) | 0.I | 4.6 | I.4 | I.4 | I.7 |
| Coarse fragments (%) | 5.0 | 79.0 | 24.8 | 20.3 | 30.8 |
| Percent slope | 0.7 | 23.0 | 6.I | 3.0 | 4.8 |
| Predicted K-factor (nomograph) | 0.II | 0.55 | 0.I3 | 0.27 | 0.27 |