Natural Mulch or Chemical Conditioner for Reducing Soil Erosion in Humid Tropical Areas[1]

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E.J. ROOSE[2]

ABSTRACT

According to results of research done by ORSTOM and French Institutes of Applied Research Overseas, Wischmeier's Universal Soil Loss Equation seems to be applicable to African soils poor in swelling clays. In Ivory Coast 17 years of experimentation with runoff plots has demonstrated that ferrallitic soils are resistant to erosion (K = 0.10), but rainfall is particularly severe (R = 500 to 1,400). Therefore, it is important to cover the soil during critical rainy periods. Natural mulching reduces erosion to the same level as under rain forest vegetation (rainfall = 2,100 mm; runoff = 0.5%; erosion = 0.1 metric tons/ha). An artificial mulch (Curasol at 60 g $liter^{-1}$ m^{-2}) tested during 3 years on three sets of duplicate plots reduced annual erosion from 40 to 75% of check plots, and runoff from 25 to 55%. This technique is too expensive for poor extensive agriculture, but it may be useful in protecting industrial and urban areas during construction and while vegetation is being established.

INTRODUCTION

The equation predicting soil losses,[3] published by Wischmeier and Smith (1960, 1965) is very useful in the USA where soils are not very rich in swelling clays. The results of studies carried out by the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) and the French Institutes of Applied Research (Roose, 1967, 1973) have shown that this equation is also applicable to the ferrallitic and ferruginous soils of humid and dry tropical belts of West Africa and Madagascar, providing that one calculates the equation coefficients from a sufficient number of annual replications.

[1]Contribution by the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Center of Adiopodoume, Soil Science Laboratory, P. O. Box 20, Abidjan, Ivory Coast, West Africa.

[2]Master of Research in Soil Science, ORSTOM.

[3]The Universal Soil Loss Equation is $A = RKLSCP$, where A = average annual soil loss in tons (US) per acre per year, R = rainfall factor, K = soil erodibility factor, L = length of slope factor, S = percent slope factor, C = cropping-management factor, and P = erosion control practice factor.

The only weak point is the topographic factor (SL) for which only one relationship has been developed regardless of soil type.

With the application of this equation, we have shown (Roose, 1973) that in Ivory Coast (i) the index of rainfall energy-intensity (R) is very high and increases from 500 to 1,400 in terms of the amount of annual precipitation (1,100 to 2,400 mm annual average from more than 20 years of data); (ii) the influence of vegetative cover is great (C = 0.9 under food crops to 0.001 under forest); (iii) the ferrallitic soils are quite resistant to erosion (K = 0.10 for Tertiary sands, 0.15 for granite, and 0.18 for schist); and (iv) cultural practices are of relatively minor importance and the mechanical erosion control techniques (terraces, etc.) are more expensive and less effective (P = 0.7 to 0.3) than a good cover crop (C = 0.1 to 0.01).

In tropical areas with relatively thin population (2 to 80 inhabitants per km^2), it is necessary to intensify the agriculture (by deep tillage, adequate fertilization, denser and earlier sowing, spraying for weeds, insects, and diseases, etc.) on the better soils and the flatter slopes rather than to use expensive erosion control management which may be short term and of little or no economic return. Because of the high energy of the rains and the natural resistance of the ferrallitic soils, the solution to the erosion problem in this area is keeping cover on the soil during critical periods. This is a more effective method than using mechanical means to increase the infiltration rate which is already very high (10 to 120 cm/hour). But natural conditions are such that most food crops (cassava [*Manihot esculenta*], yam [*Dioscorea* sp.], maize [*Zea mays*], and peanut [*Arachis hypogaea*]) and some industrial crops (banana [*Musa* sp.], pineapple [*Ananas comosus*], etc.) are not able to sufficiently cover the soil before the critical rainy period. The objective of this study was to determine the effectiveness of complementing the living green cover by a natural (straw or branches) or artificial mulch (Curasol) as an adjunct to a cropping system for controlling erosion.

PROCEDURE

The experiments took place at the ORSTOM center at Adiopodoume (5° 20′ N; 4° 8′ W; 30 m altitude) 20 km from Abidjan in South Ivory Coast (West Africa). The climate is subequatorial with two rainy seasons (Figure 1) characterized by average temperatures varying slightly (±3C) around the annual average (26.2C) and an average annual precipitation of 2,100 mm, of which one-half falls in 2 consecutive months. One can expect a rainstorm of more than 200 mm every 4 years and of more than 150 mm each year. The highest intensity rarely exceeds 150 mm/hour during 15 minutes, 80 to 100 mm/hour during 30 minutes, 60 mm/hour during 1 hour, and 30 mm/hour during 3 hours. The natural vegetation is a rain forest. The profile is that of a ferrallitic soil highly desaturated, high in coarse sands, homogeneous, and very permeable.

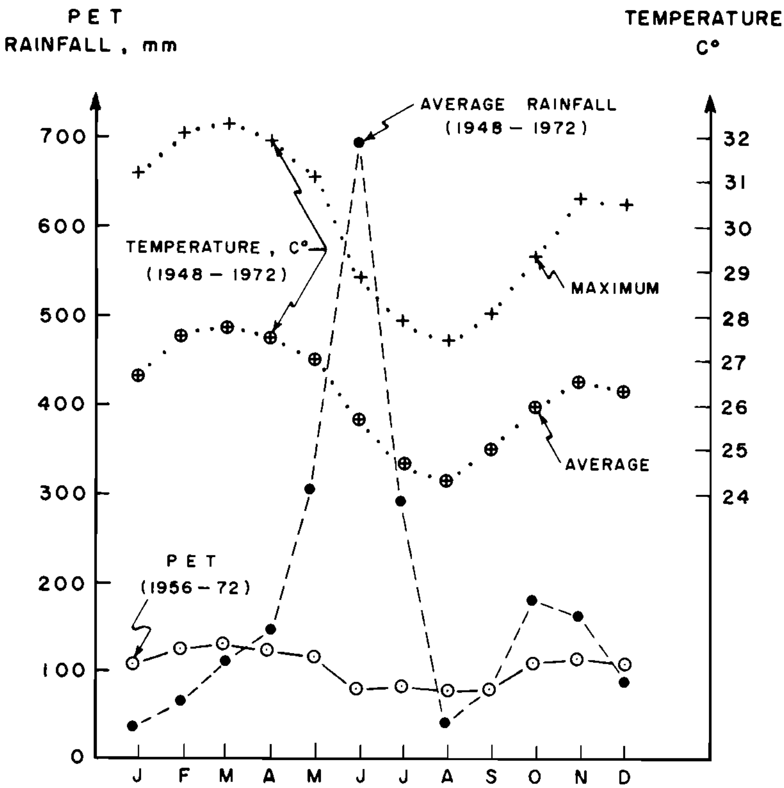

Figure 1. Monthly average rainfall, temperature, and evapotranspiration at Adiopodoume, Ivory Coast.

The experiments were carried out on small runoff plots 15 m long with a total surface area of 90 m^2. At the base of the plots, protected from outside runoff by sheet metal pushed into the soil, a concrete channel conducts eroded material into two tanks connected by a seven-slot divisor. Channels and tanks are protected by a roof. A standard rain gauge and recorder give the amount and instantaneous intensities of the rainfall. The plots are plowed and leveled each year before the crop is planted.

RESULTS

Annual erosion and runoff from two plots are given in Table 1. The first plot was planted to banana (a light cover crop) with straw mulch, and the other was maintained under a secondary rainforest vegetation. The mulch was of Guatemala grass (20 metric tons/ha) (*Tripsacum laxum*).

In spite of large amounts of very intense rainfall (R = 978 to 1,293), the erosion and runoff registered during 2 consecutive years are negligible and are similar under a litter of a few centimeters of straw as under a thick forest

Table 1. Erosion and runoff under a straw mulch (slope 7%) and under secondary rain forest vegetation (slope 23%). At Adiopodoume, South Ivory Coast.

Year	Rainfall		Erosion		Runoff	
	Amount	Rainfall index, *R*	Mulch	Rain forest	Mulch	Rain forest
	mm		$kg\ ha^{-1}\ hour^{-1}$		%	
1960	1,897	978	5	13	0.47	0.58
1961	2,289	1,293	11	15	0.53	0.34

of 30 m height. Both the mulch and the forest absorb the kinetic energy of the raindrop as well as that of the runoff water. Eroded material consists of only very small particles in suspension.

Mulch is, therefore, a very effective method of conserving water and soil, and it is feasible and desirable to use in traditional agriculture where it is easily available. However, in specialized agriculture it is not always easy to obtain natural mulch material. Therefore, it seemed desirable to test an artificial mulch available commercially. This is polyvinyl acetate sold under the name of Curasol[4] by the Hoechst firm.

At Adiopodoume just after tillage (and planting), one application of 60 g Curasol diluted to 1 liter of water per m^2 of soil was made. After 2 or 3 hours of sunshine, Curasol formed a flexible film 1 or 2 mm thick which protected the soil against raindrop kinetic energy. We have tested this treatment during 3 years on three pairs of plots treated and not treated with Curasol. Main plots were (i) a slope of 7% planted to *Panicum maximum* on 40-cm centers, (ii) a slope of 7% on bare soil, and (iii) a slope of 23% on bare soil.

In Table 2 we can see that Curasol has considerably reduced soil losses (reduction of 40 to 75%) and to a lesser degree water losses (reduction of 25 to 55%). The protective effect diminishes after 3 months of heavy rainfall (1,200 mm), but it is still effective after 1 year. The Curasol treatment did not have a significant effect on forage yield (*Panicum maximum*), but it was particularly effective in protecting the soil under the grass canopy.

It was not evident, at first, how the polymer acted to decrease runoff. Field observations show that the application on well-aerated soil (recent tillage) forms a flexible film which increases runoff slightly over the check during some rainstorms. After that, the porosity of untreated soil decreases more rapidly than that protected by Curasol. This is because Curasol is not an impermeable and continuous film, but coats the soil surface aggregates and makes them more resistant to destruction by raindrop impact.

Curasol does not eliminate erosion. The film is not continuous and the water looks for a weak spot. Raindrop impact results in holes in which runoff water enters. This undermines the film and enlarges the eroded area. If a

[4]The recommended application of Curasol is 40 to 120 g $liter^{-1}\ m^{-2}$; price delivered in Abidjan in 1973 was 340 CFA/kg, i.e. $800/ha for an average application of 60 g $liter^{-1}\ m^{-2}$.

Table 2. Effects of a plastic mulch (Curasol at 60 g liter^{-1} m^{-2}) on runoff and erosion observed on runoff plots at Adiopodoume (Ivory Coast).

Adiopodoume 1970–1973	Rainfall		Erosion						Runoff					
			Panicum, S = 7%		Bare fallow, S = 7%		Bare fallow, S = 23%		Panicum S = 7%		Bare fallow, S = 7%		Bare fallow, S = 23%	
	Height (mm)	R(USA)	Check, metric tons/ha	Curasol, % of check	Check, metric tons/ha	Curasol, % of check	Check, metric tons/ha	Curasol, % of check	Check, mm	Curasol, % of check	Check, mm	Curasol, % of check	Check, mm	Curasol, % of check
Ploughing, 4 May 1970							1970							
May to July 1970	882.0	848.3	88.62	25	132.32	48	451.71	25	356.20	37	420.95	66	320.29	36
Aug. to Dec. 1970	386.0	139.2	0.54	33	8.86	61	47.57	36	11.38	27	108.00	24	81.74	56
Jan. to Mar. 1971	121.0	69.7	0.01	100	8.80	67	32.79	40	0.54	87	46.33	47	20.75	35
Amount, 1970	1389.0	1057.2	89.17	25	149.98	50	532.07	27	368.12	37	575.28	56	422.78	40
% of total									26.5		41.4		30.4	
Ploughing, 15 April 1971							1971							
April to July 1971	1216.5	775.6	3.92	32	121.28	54	514.12	58	188.45	77	401.85	106	212.56	132
Aug. to Dec. 1971	354.0	119.3	0.18	0	7.85	68	55.10	70	1.12	7	87.50	96	40.36	213
Jan. to Mar. 1972	245.5	128.0	0.01	0	10.08	62	48.51	64	0.21	62	72.95	104	33.21	179
Amount, 1971	1816.0	1022.9	4.11	30	139.21	55	617.73	59	189.78	77	562.30	105	286.13	149
% of total									10.5		31.0		15.8	
Ploughing, 31 Mar. 1972							1972							
April to July 1972	1044.8	580.3	1.20	10	99.39	51	245.51	53	106.13	16	431.71	69	295.54	46
Aug. to Dec. 1972	344.0	109.6	0	0	9.90	39	20.97	66	0.06	12	121.45	50	48.69	74
Jan. to Mar. 1973	172.7	128.7	0	0	4.30*	55	6.38*	213	0	0	39.45	90*	18.26*	144
Amount, 1972	1561.5	818.6	1.20	10	113.59	50	272.86	57	106.19	16	592.61	66	362.49	55
% of total									6.8		36.3		23.2	
Average	1589	961	31.5	25	134.3	52	474.2	47	13.9	45	36.3	75	22.5	74

* The plot without Curasol was tilled with a hoe to a 5-cm depth. This was enough to minimize erosion for 1 month following tillage.

canopy protects the flexible film, it resists destruction much longer. The Curasol film does not prevent sand particles being transported into an active rill. It also does not support the weight of heavy machinery (tractors, etc.). Erosion takes place very quickly on abraded areas and where the film has been broken by tractor traffic.

DISCUSSION

Many researchers have tested the efficiency of soil conditioners to stop water or wind erosion (Armbrust & Dickerson, 1971; Chepil, 1955; DeBoodt, 1970; Lyles et al., 1969; Moldenhauer & Gabriels, 1972). Some of them have tried to increase the stability of soil aggregates and have tested this in the laboratory under artificial rainfall (Blavia, Moldenhauer & Law, 1971; Gabriels, Moldenhauer & Kirkham, 1973). Others have carried out field experiments on small plots using a wind tunnel (Chepil et al., 1963; Lyles et al., 1969) or artificial rainfall (Mannering & Meyer, 1963; Meyer & Mannering, 1963; Meyer, Johnson & Foster, 1972). Encouraging results for the improvement of the structural stability of rainfall infiltration (Kijne, 1967; Pelishek, Osborn & Letey, 1962) and of stabilization of sands have been obtained with several polymers and emulsions (flocculating agents, wetting agents, bitumen emulsions) as polyvinyl alcohol (PVA at 8 g/m^2), polyacrylamide (PAM at 8 g/m^2), potassium silicate (16 g/m^2) and Bitucoat (500 ml/m^2).

One of the goals of the experiments carried out in Ivory Coast was to study Curasol behavior during the entire year under very heavy rainfall, alone and in conjunction with a grass (*Panicum maximum*). Although the treatment with Curasol reduced erosion considerably, it did not decrease it below the 12 metric tons/ha soil loss we consider allowable on that kind of soil. The cost (200,000 CFA/ha, i.e., approximately \$800/ha in the USA for one application of 60 g $liter^{-1}$ m^{-2}) and the great quantity of water necessary to spread it, are major inconveniences for its use even in intensive agriculture. However, Curasol may have a role in erosion control on roadbanks, irrigation canals, and urban and industrial scalped surfaces, if mixed with certain herbaceous seeds and the fertilizer necessary for their development.

A number of workers conclude that the use of natural mulch (Adams, 1966; Lassoudiere & Godefroy, 1971; Roose, 1967) or polyethylene film (Charpentier, Godefroy & Menillet, 1970; Py & Barbier, 1966; Py, 1968) gives excellent results in establishing a cover crop. A higher relative humidity in the soil, better rainfall infiltration, and higher resistance of soil to erosion are obtained with several kinds of cover—straw, branches, wood chips, broken stones. It seems that for the same weight, the material which covers the highest percentage of the soil surface protects it best against erosion. However, if the slope is steep and too long, the light particles of mulch are carried off by runoff water and rills are formed (Meyer et al., 1972).

In Ivory Coast 200 to 250 man-days of work are required to harvest and spread 40 to 80 metric tons/ha of branches on a field at an average cost of

\$250/ha. If a field of Guatemala grass (*Tripsacum laxum*) is available, the cost falls to an average of \$150/ha to obtain a satisfactory mulch (written communication, Mr. Godefroy, August 1973). Experiments on road banks (Mannering & Meyer, 1963; Meyer & Mannering, 1963) show, however, that we can reduce a straw mulch to < 10 metric tons/ha and still obtain sufficient protection against erosion.

CONCLUSIONS

In the humid tropics where rainfall is very intense, it is imperative to cover the soil during the rainy season. Intensive cropping of the most fertile soils (which involves a good canopy cover) is more effective in stopping erosion than expensive terracing from which the economic return and the longevity have not been proved. During the critical first 2 months of vegetation establishment, the use of a mulch will greatly improve soil protection.

In urban and industrial areas, the use of a soil conditioner may help in the establishment of a protective sod on banks, drains, and scalped surfaces. On high value crops such as horticultural crops, organic mulch is frequently substituted by a thin polyethylene film or a soil conditioner. On lower value crops where vegetative residues are available, mulching and leaving these residues on the surface appears to be much more economical than artificial mulches and to have beneficial effects on temperature, soil nutrients, and moisture utilization.

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