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DETERMINATION OF THE ROUGHNESS COEFFICIENTS OF PERIWINKLE AND PALM KERNEL SHELL ON A CLAY LOAM SOIL IN AROCHUKWU, SOUTH-EASTERN NIGERIA

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ABSTRACT

Roughness coefficient is one of the parameters applied during earth constructions. Its efficiency is evident on constructions of water channels and roads if appropriately chosen. In this work, roughness coefficient of periwinkle and palm kernel shells were determined on a soil predominantly clay loam with hilly topography of slope values of 18.5- 30%. The study was also carried out on twin plots of 10.2m long, 3.5m width, and 0.3m deep laid with periwinkle and palm kernel shell surface forms each. After the overland flow had been established through simulation, hydraulic characteristics of flow such as hydraulic depths and velocities of flow were measured at six different points across each twin plot and in all the locations. These were fitted into the Darcy-Weisbach roughness coefficient model to determine the roughness coefficient values for periwinkle and palm kernel shells. Reynolds number of flow on both surfaces were equally estimated by using the measured flow velocities, hydraulic depths and the kinematics velocity data at different sections of the twin plots in all the locations. The periwinkle shell surface forms produced higher roughness coefficient of 27.134, 26.985,29.778, 47.11, 38.311 and 47.334 than that of palm kernel shell surface forms with roughness coefficient of 15.64, 23.11, 9 .310, 13.614, 19.61 and 11.90

Keywords; Roughness coefficients, periwinkle shell, palm kernel shell, hydraulic characteristics, erosion

INTRODUCTION

Erosion and its destructive effects have become one of the most serious problems in the world today. Its destructive effects are both environmental and economic. Diti (1998) enumerated the economic and environmental impacts as; dredging due to reduction of reservoir capacity, stream or channel flow and unsightly landscape respectively. As an agent of denudation, rainfall weakens, wears away, and dislodges transports and deposits the soil materials from one location to another. The ability of the rainfall to denude the soil is its energy conversion from kinetic to potential (Milos1996) . The kinetic energy of raindrops which measures the intensity of rainfall breaks the soil into friable nature (laflen et al 1991). The study of (Weltz et al1992) shows that the erosivity of the runoff which is highly dependent on its kinetic energy, determines to what quantity and extent the broken or detached soil particles can be carried to boarder locations. In a similar study, (Milos1996) showed the relationship between rainfall intensity and soil wash and explained his findings as presented in the direct relationship of the variables with soil wash model

$$SP= \quad KI^{0.8}i^{1.2} \qquad (1)$$

Where

SP= Soil wash (t ha^{-1})

I =Slope gradient in degree

i = rainfall intensity (mm/min

K =Coefficient, dependent on local conditions

All these studies accentuate share strength failures of the soil with its consequent erosion effects. Literature has shown that engineering and bioengineering mitigation measures ensure adequate safety against erosion with its concomitant effects. Athol et al (1999) described a measure of resistances to surface flow exerted by the surface forms of gravel and other micro topographic protuberances. These forms reduce erosive powers of the flow due to their high shear strengths thereby minimizing soil loss. In a related study Diti (1998) revealed the effects of vertiver grass on slope stabilization and general erosion control. Apart from the fact that the leaves absorb and neutralize the effects of energy of the raindrops by breaking those raindrops with big diameter into fine droplets which on reaching the soil make little or no impact, the roots of the vertiver grass reinforce the soil, increase the soil strength, provides support to the upslope soil mantle through buttressing and bind soil particles at the ground surface thereby reducing their susceptibility to erosion. The hydraulic resistance of flow across surfaces depends on the size, heights of the surface forms and the hydraulic depth of flow. The work of John et al 1999 shows that small hydraulic depths which is as a result of the increased roughness element or forms produced direct relationship between roughness coefficients and relates inversely with Reynolds number of flow, implying that roughness coefficient decreases with increase Reynolds number.

MATERIALS AND METHODS

The field study was conducted at six different erosion locations of Arochukwu L.G.A to determine the roughness coefficient of periwinkle and palm kernel shell. The soil samples from each location were collected to analyze for the particle size by weight. The slope angles of each location were also measured using leveling instrument. The locations, slope angles and average particles sizes of each study sites are shown in table 1. Three plots each were established on each location with each plot constructed into a twin plot of 10.2m long, 3.5m width and 0.5m deep for periwinkle and palm kernel shell. This brought the total plots to 18, each for periwinkle and palm kernel shell. Rainfall simulation was carried out on each twin plot laid with periwinkle and palm kernel shell surface forms at equal rate of 65mmh^{-1}. The water from the simulator was trickled down onto the upper end of each plot. When the overland flow was fully established, its hydraulic characteristics were determined. The flow depth and volumetric flow rate were measured with a thin scale and flow meter respectively at intervals of 6cm across each plot. The temperature of the overland flow was measured with a thermometer. The velocity of flow, V was calculated by dividing the volumetric flow rate Q by the width and depth of the plot. The roughness coefficient of the surface cover was established by the dimensionless Darcy-Weisbacch friction factor given by Anthony and Athol (1999) as

$$F = \frac{8gds}{V^2} \qquad (1)$$

Where d, s and V are depths of flow, slope lengths of the plots and flow velocities of flow respectively. The flow turbulence was assessed with the Reynolds number model,

$$Re = Vd/\mu \qquad (2)$$

as presented by Morgan (1996). While V and d remain as defined in equation 1, μ is the kinematics viscosity which was determined directly from the kinematics viscosity- water temperature relationship table after (Perry 1996) to be $0.804*10^{-3}$.

RESULTS AND DISCUSSIONS

Results presented on table1 show the geotechnical properties of various locations. In the table, the slope values of the study locations are in percentages. Also on the table are the particle sizes of the soil samples of the locations. High levels of percentage of clay were observed on locations 1, 3 and 5. In line with the work of Schwerb et al (1999) all the locations are situated on hill slopes as the slope values in all the locations fall within 10 – 30%. The hydraulic characteristics of the overland flow on the twin plots lined with periwinkle and palm kernel shells respectively are displayed on tables 2-7 for all the study locations. Variations of hydraulic depth of overland flow on the plots of periwinkle and palm kernel surface forms of all the locations were observed. The variation in depth is due to the undulating surface occasioned by surface forms. A glaring difference in depth was also observed on the hydraulic depth of overland flow on the surface forms of periwinkle and palm kernel shells with the depths of the overland flow on the palm kernel shell surfaces higher than that of the periwinkle shells. This implied that water depth was less than the heights of periwinkle surface material after overland flow had been simulated at equal rate and quantity on the twin plots.

The difference in sizes and structures of the two surface forms accounted for the variations in heights of the surface forms.

Periwinkle with its cylindrical rough surfaces produced a surface height more than the overland flow. On the contrary, the palm kernel shell formed surfaces are lower in height than the periwinkle surface forms due to its cup-like shape and its ability to slide into one another. This made the overland flow depth exceed the roughness element height of the palm kernel shell surface forms. The above mentioned structural variations of the surface forms made the hydraulic depths of the plots lined with palm kernel shell higher than that of the periwinkle shell as shown in tables 2-7 and figures 16, 17 and 18.Overland flow or hydraulic depths seem to have impacted on its overland mean velocity flow. The overland flow on the periwinkle surface forms experienced reduction in its velocity values due to low hydraulic depth occasioned by increase in height of surface materials. A reverse trend was observed on the overland flow through the palm kernel surface forms. The increase in the flow velocity was as result of the fact that the surface materials i.e. palm kernel shell, submerged under the water and the ability to retard the flow progressively decreased. These are shown at- a- glance on tables 2-7 and figures 19, 20 and 21.

Roughness coefficient and Reynolds number were significantly influenced by the hydraulic depth and the flow velocity. For hydraulic depth less than the height of periwinkle surface forms, roughness coefficient increased with retard inflow velocity and reduced Reynolds number. In the case of palm kernel shell surface form where the hydraulic depth was higher than the height of the surface forms, flow velocity increased. Consequent upon this, roughness coefficient decrease with increased Reynolds number. The relationships are shown on figs 1-6. The curves showed an inverse relationship, with the periwinkle shell curve tending toward high roughness coefficient but went into steep decline towards the Reynolds number. The palm kernel shell curves virtually assumed an exponential curve indicating low roughness coefficient value and a gradual stretch towards high Reynolds values.

Further comparisons of the Reynolds number of flow on the periwinkle and palm kernel shell surface forms and comparisons of the roughness coefficient of the overland flow on periwinkle and palm kernel surface forms were shown on figures 7-12 and 13-15 respectively. The figures13-15 show a decrease in the roughness coefficient of palm kernel surface forms and an increase in the roughness coefficient of periwinkle surface forms during the overland. A reverse relationship was observed in the case of Reynolds number of flow as shown in figures 7-12. The reason for these relationships boarders on the structures of the surface forms. Periwinkle shell, with rougher and larger surface forms than the palm kernel shell surface forms produced lower hydraulic depth, higher roughness coefficients, lower flow velocity due to high flow retardation occasioned by the surface form, and lower Reynolds number of flow than the palm kernel shell which has lower shear strength and lacks enough frictions to retard surface flows thereby making the surface vulnerable to surface wash.

CONCLUSION

The periwinkle shell with rougher and larger surface forms produced lower hydraulic depth, higher roughness coefficients, lower flow velocity and low Reynolds number of flow, hence is best suited for erosion control on a clay loam soil in Arochukwu.

Table 1: The average values of the soil samples from different locations

locations	slope(%)	particle size analysis %sand	%silt	%clay
1	18.5	16.3	38.1	45.6
2	25.7	25.1	39.6	35.3
3	20	29.9	19.8	50.2
4	25.1	38.5	32	29.5
5	23.7	19.5	37	44
6	30	30.6	44.1	25.3

Table 2: Average values of hydraulic characteristics of the overland flow on periwinkle (PS) and palm kernel (PKS) surface form of location 1

LOCATION 1

depth(mm) PS	$V(ms^{-1})$	Friction	Re	depth(mm) PKS	$V(ms^{-1})$	Friction	Re
6.3	0.11	17	1353.23	10.8	0.39	16.3875	2146.25
5.6	0.11	21.6049	447.76	8.9	0.28	19.3668	1572.5
6	0.13	31.6049	766.17	10.9	0.29	12.8	3906.25
6.8	0.16	9.0416	1677.86	9.2	0.21	17.374	2327.5
4	0.09	33.3223	451.49	11.3	0.48	9.0559	4313.75
5.1	0.19	22.7219	970.15	11.3	0.42	8.5911	4998.75

Table 3: Average values of hydraulic characteristics of the overland flow on periwinkle (PS) and palm kernel (PKS) surface form of location 2

LOCATION 2

depth(mm) PS	$V(ms^{-1})$	Friction	Re	depth(mm) PKS	$V(ms^{-1})$	Friction	Re
5.9	0.17	24.403	17.9104	10.4	0.34	28.8	26.9136
4.8	0.08	86.194	4.9751	11	0.3	60	41.6529
6.1	0.19	50.0336	15.3607	7.8	0.26	27.3684	8.955
5	0.15	30.1791	8.9552	9	0.28	30.0952	14.0417
6.5	0.19	49.5149	14.4154	8.5	0.29	26.6842	11.7956
7.2	0.21	29.5672	20.6343	10.1	0.31	25.6	22.5351

Table 4: Average values of hydraulic characteristics of the overland flow on periwinkle(PS) and palm kernel(PKS) surface form of location 3

depth(mm) PS	$V(ms^{-1})$	Re PS 3	Friction PS 3	depth(mm) PKS	$V(ms^{-1})$	Re PKS	Friction PKS 3
		LOCATION 3					
7.9	0.18	1768.66	1506.93	7.6	0.11	2415.42	1942
5.1	0.11	697.76	3888.89	12.3	0.52	6848.51	594.56
7	0.12	1606.97	1950.62	9.9	0.35	3704.1	1210.43
6.8	0.19	1044.78	3371.9	10.5	0.37	4626.87	998.96
6	0.14	1044.78	3448.98	8.8	0.23	3208.96	1846.61
4.2	0.07	365.67	6857.14	9	0.25	3210.2	1320.96

Table 5: Average values of hydraulic characteristics of the overland flow on periwinkle (PS) and palm kernel(PKS) surface form of location 4

depth(mm) PS	$V(ms^{-1})$	Re PS 4	Friction PS 4	depth(mm) PKS	$V(ms^{-1})$	Re PKS	Friction PKS 4
		LOCATION 4					
10.23	0.19	2261.19	42.8889	11.9	0.29	4292.29	10.9803
11	0.21	770.15	61.1556	7.4	0.17	4973.88	10.4166
7.8	0.17	1358.21	46.5714	9.8	0.19	2135.57	21.0659
10.1	0.18	1787.06	44.9	10.1	0.17	2315.92	19.8699
6.88	0.09	2417.54	43.0737	12.5	0.25	1564.68	27.1197
8.98	0.2	2873.13	39.9048	12.9	0.31	3886.82	15.52

Table 6: Average values of hydraulic characteristics of the overland flow on periwinkle (PS) and palm kernel (PKS) surface form of location 5

depth(mm) PS	$V(ms^{-1})$	Re PS 5	Friction PS 5	depth(mm) PKS	$V(ms^{-1})$	Re PKS	Friction PKS
		LOCATION 5					
9.3	0.25	1156.72	69.936	12.19	0.33	4951.49	11.0878
10.89	0.17	3386.19	13.1028	13.27	0.3	5003.36	8.4177
6.66	0.08	662.69	78.255	6.3	0.11	861.94	39.1537
11.39	0.28	3966.67	10.9251	10.9	0.18	2440.3	25.2988
10	0.23	2860.7	14.2155	11.32	0.21	3017.91	13.1992
9.7	0.2	1447.76	50.6556	10.11	0.24	2933.21	19.1496

Table 7: Average values of hydraulic characteristics of the overland flow on periwinkle (PS) and palm kernel (PKS) surface form of location6

depth(mm) PS	$V(ms^{-1})$	Re PS 6	Friction PS	depth(mm) PKS	$V(ms^{-1})$	Re PKS	Friction PKS
		LOCATION 6					
6.3	0.11	470.15	140	9.71	0.2	3208.96	13.2096
8.7	0.18	1082.09	69.6	11.03	0.27	3704.1	9.9896
12.3	0.2	3365.67	20.331	12	0.31	4626.87	8.4661
10.21	0.17	2158.83	28.263	13.11	0.42	6848.51	5.9456

11.01	0.22	2738.81	22.02	8.9	0.19	2415.42	19.42
9.97	0.19	1364.05	65.917	10.32	0.25	3210.2	12.1043

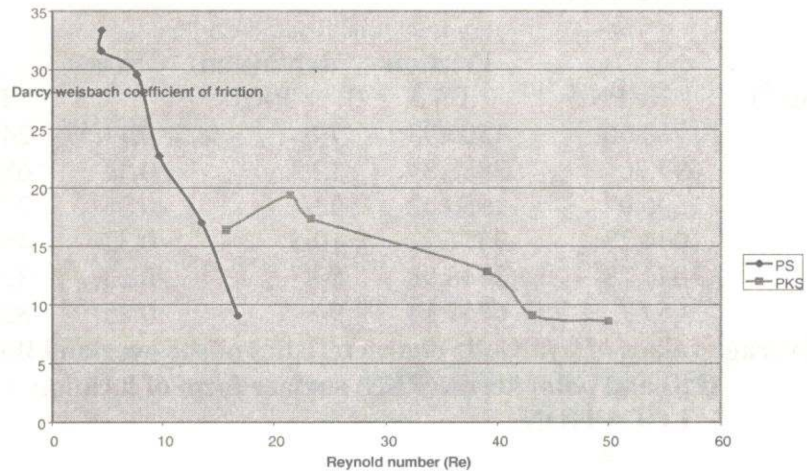

Fig 1 Darcy-weisbach coefficient of friction Vs Reynold number for the surface forms of periwinkle shell(PS)and palm kernel shell(PKS)

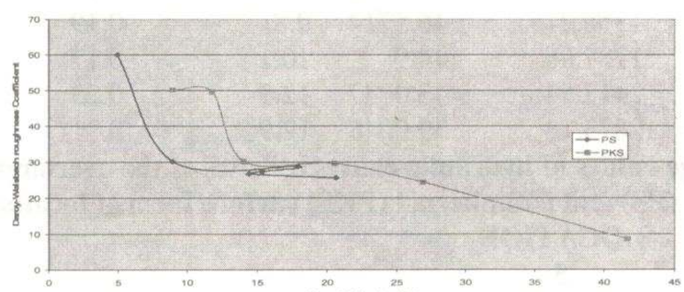

Fig 2 Darcy-Weisbach Roughness Coefficient Vs Reynold number for periwinkle shell and Palm Kernel Shell(PKS) of study location 2

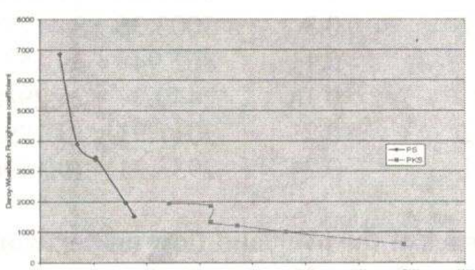

Fig 3 Darcy-Wiesbach Roughness Coefficient Vs the Reynold number for periwinkleshell and palm kernel shell surface form of location 3

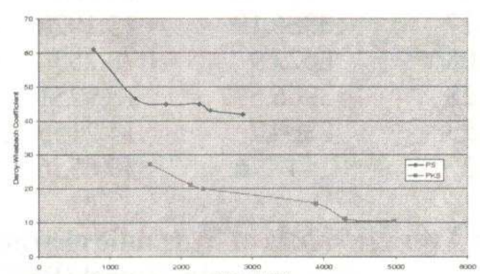

Fig 4 Darcy-Wiesbach Roughness Coefficient for Periwinkle shell and Palm Kernel shell as surface forms of location 4

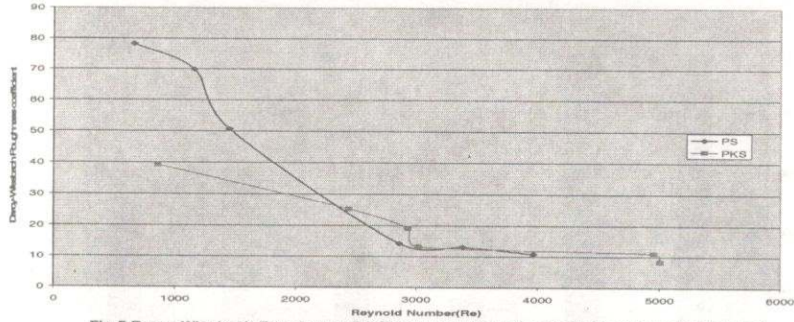

Fig 5 Darcy-Wiesbach Roughness Coefficient Vs Reynold number for periwnikle shell and Palm Kernel shell as surface forms of location 5

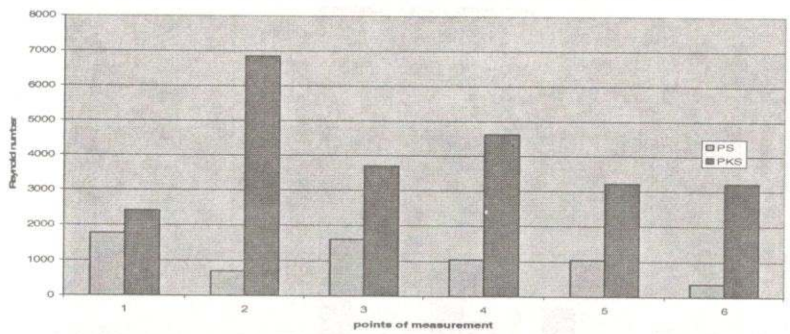

Fig 9 Variations of reynold number for overland flow on the surface forms of periwinkle and palm kernel shells in location 3

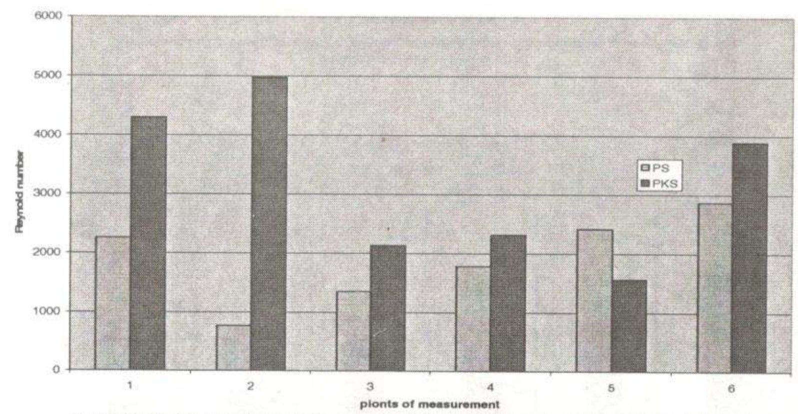

Fig 10 Variations of Reynold number for overland flow on the surface forms of periwinkle and palm kernel shells in location 4

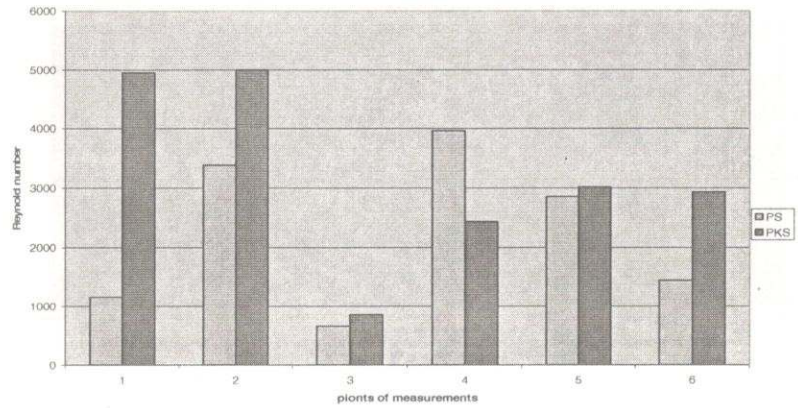

Fig 11 variations of Reynold nimber for overland flow on the surface forms ofperiwinkle and palm kernel shells in location 5

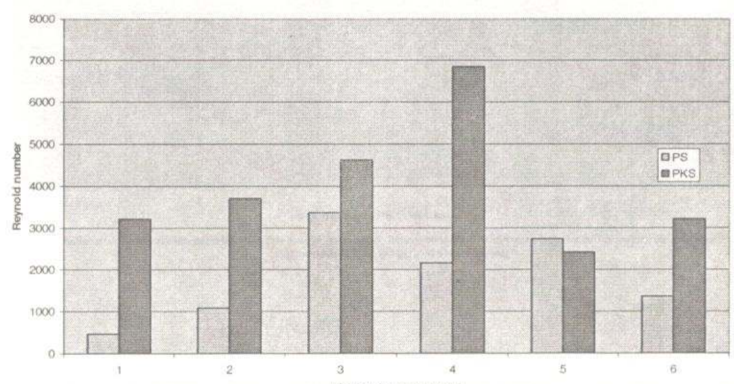

Fig 12 Variations of Reynold number for overland flow on the surface forms of periwinkle and palm kernel shells in location 6

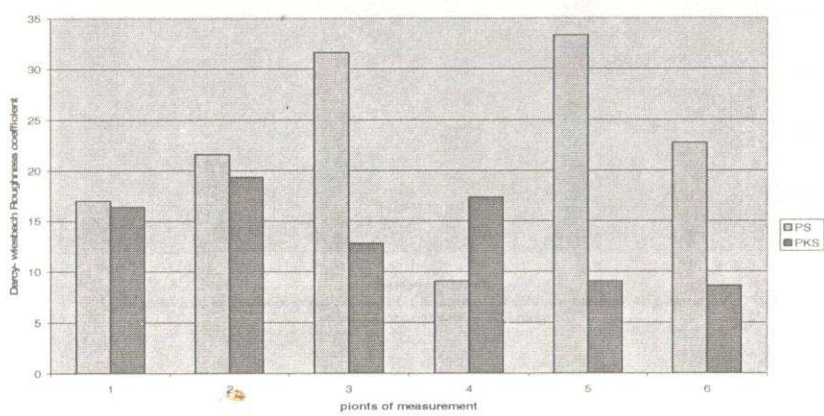

Fig 13 Variations of Darcy-wiesbach Roughness coefficient for periwinkle and palm kernel surface forms for location 1

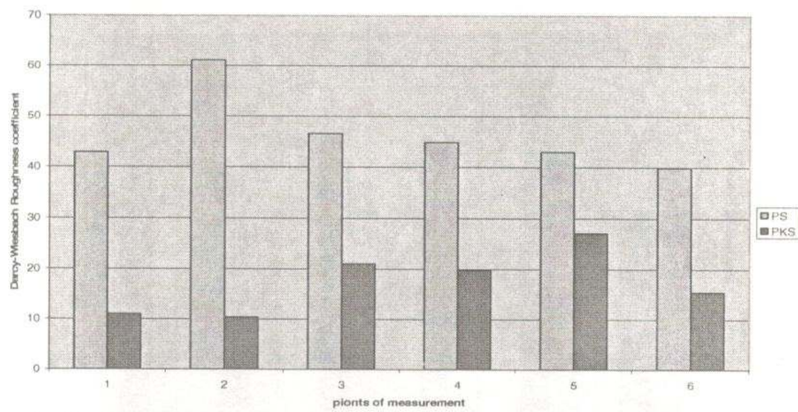

Fig 14 Variations of Darcy-Wiesbach coefficient for periwinkle and palm kernel surface forms for locations 4

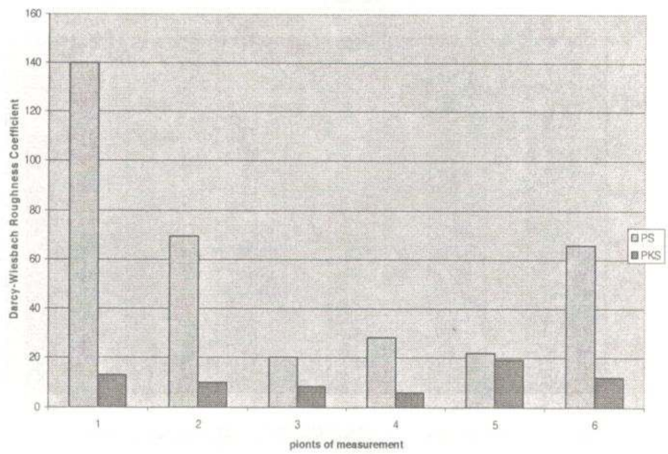

Fig 15 Variation of Darcy-Wiesbach Roughness Coefficient for periwinkle and palm kernel surface forms for location 6

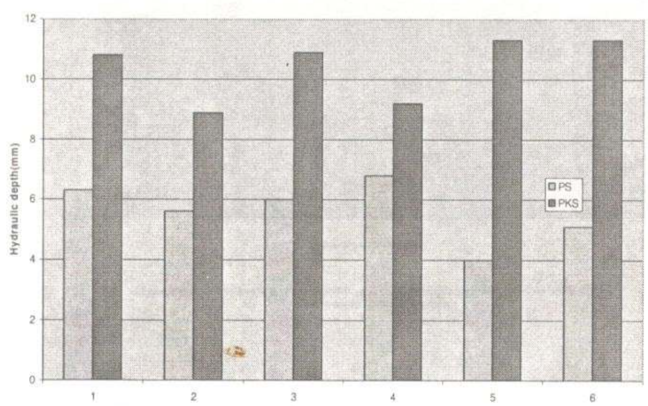

Fig 16 Variations of the hydraulic depths of surface forms of periwinkle and palm kernel of location 1

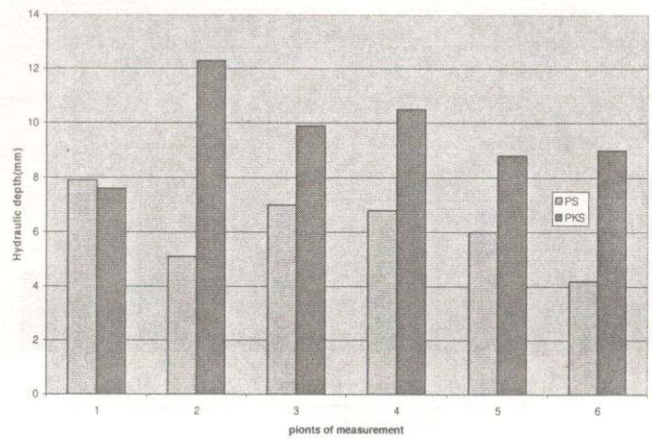

Fig 17 Variations of hydraulic depth for the surface form of periwinkle and palm kernel in location 3

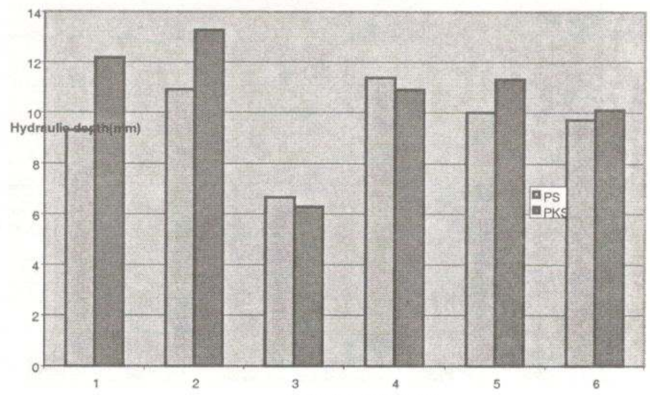

Fig 18 Variations of Hydraulic depth for surface forms of periwinkle and palm kernel in location 5

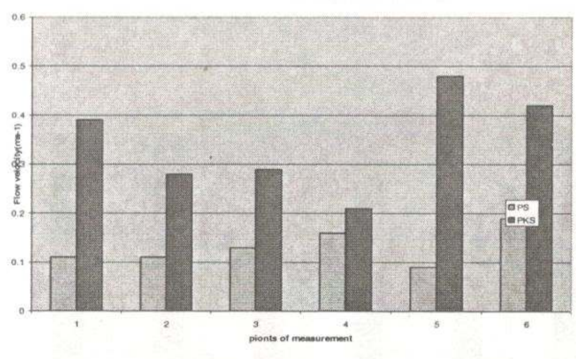

Fig 19 Variations of flow velocities of theoverland flow on the surface forms of periwinkle and palm kernel in location 1

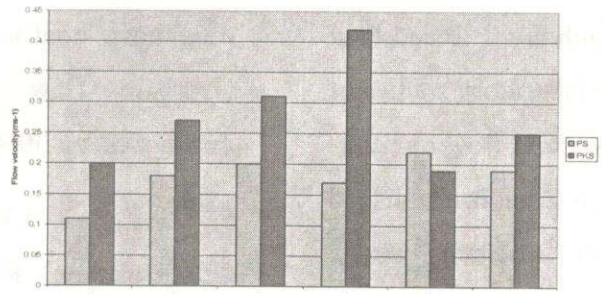

Fig 21 variations of the overland flow velocity on the surface forms of periwinkle and palm kernel in location 6

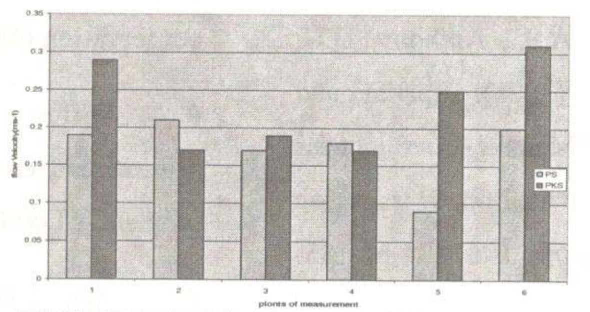

Fig 20 variations of overland flow velocities on the surface forms of periwinkle and palm kernel in location 2

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