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The effect of vegetation on the stream bank erotion of Shatt Al-Arab River, South Iraq

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Abstract

Khora, Hamdan and Abu-Flus have been selected to determine the root length density on Shatt Al-Arab River bank . The types of vegetation are murran (*Paniam repens*), bardi (*Typha domingensis*)and khwesa (*Vallisneria spiralis*) .Natural moisture content, weight density , plasticity index, shrinkage limit , grain size distribution and Maximum Shear resistance were determined . Besides the erodibility coefficient and erosion rate, the shear stress of flow on the bank toe and safety factor of the bank stability were calculated for the period between October 2007 to December 2008.

The results showed that there are noticeable variations in geotechnical properties between the sites that chosen for this study . Also, this study proved that the root length density values in the bank toe are 0.049-0319 $cm.cm^{-3}$, 0.147-0.516 $cm.cm^{-3}$ and 0.221-0.688 $cm.cm^{-3}$ for murran , bardi and khwesa plants respectively**.** The values of maximum shear resistance caused by the roots are 9.0 - 20.0 Pa , 14.0 - 29.0 Pa and 20.0 -37.0 Pa in soil vegetated by murran , bardi and khwesa plants respectably ,while this values in the unvegetated soils was 4.2 Pa , 9.0 Pa and 8.0 Pa in site 1, site 2 and site 3 respectively.The safety factor of soil reached up to 1.29 , 1.67 and 1.89 in soils that vegetated by murran , bardi and khwesa plants respectively, while these values in all of unvegetated soil were below the 1.00 unite.

The results of this study have concluded that the density and distribution of roots within a River bank play an important role in River bank erosion and stability, and the shear resistance of cohesive soils that vegetated by plants can not be a unique criterion for erodibility estimation, also the cohesion that measured by Coulomb equation in vegetated soils is not represented the true cohesion of soil, but it is apparent (true cohesion combined with additional cohesion by roots **).**

1- Introduction:

One of the main factors that affect the severity of erosion is soil erodibility. Soil erodibility refers to soil resistance against detachment and transport of particles and aggregates. Erodibility of non-cohesive soils mainly depends on their grain size and weight. Erodibility of cohesive soils, on the other hand, is affected by many factors, the most important being grain composition, shear strength, stability of aggregates, hydraulic conductivity, organic and chemical content, soil density, water content, plasticity, swelling and shrinkage characteristics and nature of clay(Chouliaras, 2005). Streambank retreat, frequently called streambank erosion, occurs by a combination of three processes; subaerial processes , mass wasting(bank failure) and fluvial entrainment . Subaerial processes are climate-related phenomena that reduce soil strength, and they are largely independent of flow. The mass wasting denote the physical collapse of all or part of the streambanks as a result of geotechnical instabilities, and fluvial entrainment is used to describe the detachment, entrainment, and removal of individual soil particles or aggregates from the streambank face by the hydraulic forces occurring during flood events, erosion occurs when the hydraulic forces in the flow exceed the resisting forces of the channel boundary. The amount of erosion is a function of the relative magnitude of these forces and the time over which they are applied (Fischenich, 2001). Fluvial entrainment is the result of shear stress on the stream bed and banks. The boundary shear stress is proportional to the velocity gradient near the channel bed or banks. The shear stress on the channel bed is typically defined by the following relationship:

$$\tau=\gamma RS$$

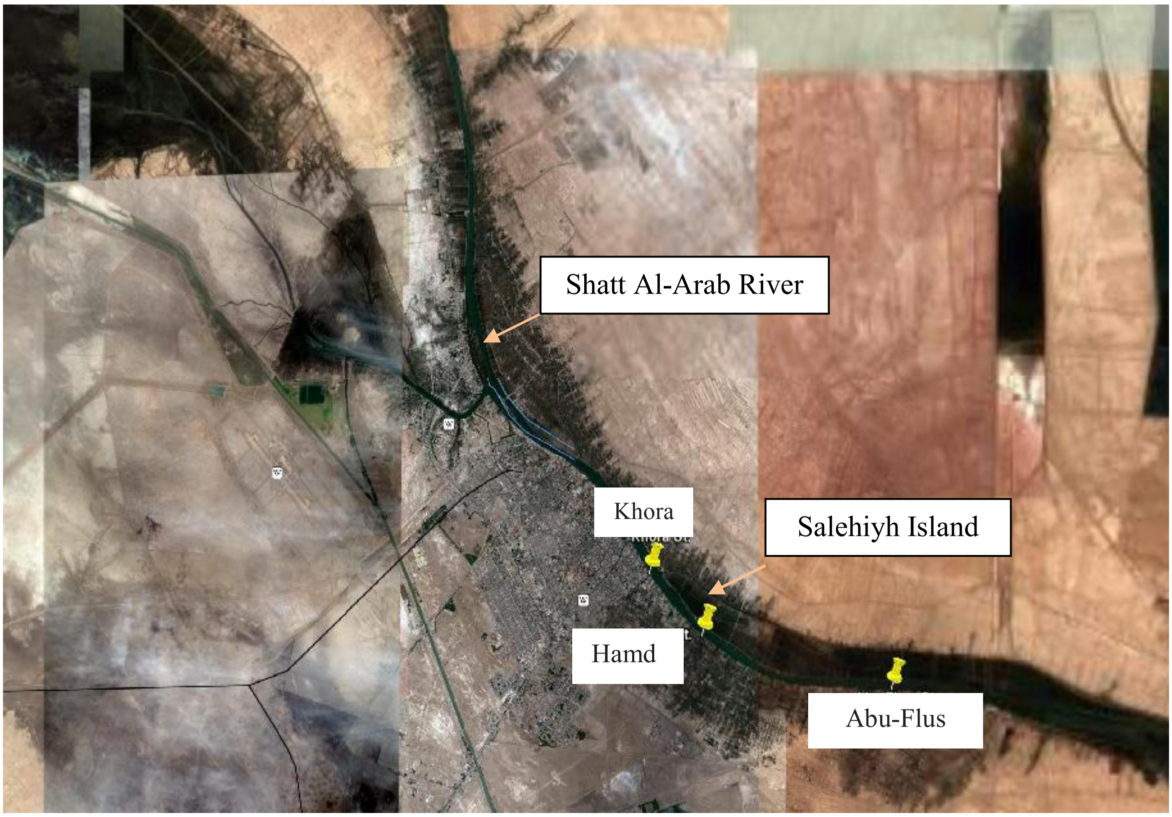
where τ is the average total fluvial shear stress on the channel bed (Pa); γ is the unit weight of water (N/m3); R is the channel hydraulic radius (m); and S is the energy slope (m/m), fluvial erosion(soil detachment) rate varies according to fluvial shear stress of the channel(Theresa, 2004). De Baets *et al.* (2006) found that the relative soil detachment rate (RSD) was greatly reduced under increasing root area ratio, increases in root area ratio had a greater impact on RSD than increases in plant cover. Pollen and Simon (2006) found that soils with high densities of grass roots decreased the volume of soil scoured during submerged jet tests. Wynn and Mostaghimi (2006) observed the susceptibility of soils to erosion is related to root density and the type of riparian vegetation that is present. Hession (2001)defined a riparian vegetation buffer as a band of vegetation adjacent to a body of water that forms the transition between aquatic and upland environments, and added that riparian vegetation type plays a key role in channel morphology. The density and distribution of roots in streambanks has significance for both the resistance of streambanks to fluvial erosion and mass failure (Wynn and Mostaghimi, 2006). Riparian vegetation density along the floodplain edges significantly affects the behavior of overall flow resistance and sediment transport rate in the compound meandering channel (Ismail and Shiono**,**2006). Roots of riparian vegetation increase streambank erosion resistance and structural stability, therefore, knowledge of root density and distribution in streambanks is useful for stream management and restoration. (Andrew and Andrew 2002 and Candice and Theresa. 2008). Found that the tree roots increased soil strength by 2-8 kPa depending on species, while grass roots contributed 6-18 kPa. Also, slope stability showed that the mechanical effects of the tree cover increased F_s (factor of safety) by 32 per cent, while the hydrological effects increased F_s by 71 per cent. Stream bank retreat typically results from erosion of the bank toe followed by collapse of the upper bank. Roots increase the strength of bank soils, making them more resistant to soil erosion and bank failures (Mamo and Bubenzer, 2001). Erosion resistance has a direct relationship with fine root density, and the better protection may provided against stream bank erosion, (Wynn et al.,2004). Wynn and Mostaghimi (2006) fonded relationship between the big roots (2-20 mm diameters), soil bulk density, and soil erodibility. Vegetation and its roots reinforce slopes, it can aid to absorb water from the ground and thus increasing matric suction and in turn increasing the apparent shear strength (Lowrance,*et al*., 2004).

While considerable effort has been directed toward developing management practices to reduce erosion from agricultural and urban lands, but the stream channel erosion has largely been ignored. Currently, designs are based on empirical methods and standardized practices which do not permit the assessment of designs for long term stability to face land use changes in the future (Hession, 2001). Little quantitative data are available on the effects of vegetation on streambank stability (Simon and Collison, 2002).

Therefore, the goal of this research is to study the effects of vegetation on shatte_ Arab River banks stability, and evaluate the susceptibility of river bank material to fluvial entrainment.

2- Materials and Methods :

Three locations sited on Shatt Al-Arabe River bank have been selected to this study. These locations are Khora, Hamdan and Abu-Flus. In each location, one site in the bank toe within area of a 10 m diameter to obtain similar soil types were selected to determine the root length density (RLD) , and each site contains only one type of plants (Figure 1). The types of vegetation which selected in Khora , Hamdan and Abu-Flus were murran (*Paniam repens*), bardi (*Typha domingensis*)and khwesa (*Vallisneria spiralis*) respectively . Five core samples (diameter = 72 mm and length = 150 mm) were taken from each site, four of them were from vegetated soil after clipped all above ground vegetation to determine RLD (Root Length Density) and shear resistance of the rooted soil, while the other from unvegetated soil to measure the shear strength of unrooted soil.



Figur-1: Map of Sampling Sites

The soil samples were transported to laboratory and stored in a refrigerator at 4°C until test. To determine root density, volume of core was calculated, and then the vegetated soil cores were washed over a mesh 35 sieve (0.5 mm diameter), the soil and roots those retained on the sieve were placed in a white plastic pan and the roots removed by hand and then total length of roots measured to determine the Root Length Density (RLD) ($cm.cm^{-3}$) which calculated was from the total length of all roots within a unit soil volume. However, RLD is a better indicator of the actual number of roots per unit soil volume (Wynn *et al.*, 2004).

For each core sample, natural moisture content, weight density , plasticity index, shrinkage limit and grain size distribution were determined according to British standard (BS) 1377: 1975. Maximum Shear resistance (critical shear stress) (τ_c) (Pa) and shearing displacment (mm) were measured by using shear box (type Wyekham Furnace Engineering limited) and (BS) 1377:1975.

The flow velocity was measured by using the current meter (type Cm2, Toho Danatan Co.), by depending on the Bowden and Sharaf AL-Din method (1960) the flow velocity rate (U) was calculated . Also, The shear stress on the bank toe is calculated by the following relationship:

$\tau_o = U \rho_w$

where τ_o is the fluvial shear stress on bed (Pa); ρ_w is the mass density of water ($k.m^{-3}$); U is velocity rate ($m.sec^{-1}$), and then the safety factor of the bank toe soil (f_s) was calculated from the following relationship :

$f_s = \tau_c / \tau_o$

τ_c=critical shear stress

Also, the erodibility coefficient (κ) ($m^3.Ns^{-1}$) and erosion rate (ε) ($m.m^{-2}$) which represented the susceptibility of rooted and unrooted soils to erosion were determined by using the following equations which used for the cohesive soil :

$\kappa = 0.1\ \tau_c^{-0.5}$.. (Hasson and Simon 2001)

$\varepsilon = \kappa\ (\tau_o - \tau_c)^a$…… (Partheniades , 1965)

Where a is an exponent often assume = 0.1

Results and Discussion :

The results showed that there are noticeable variations in geotechnical properties between the unvegetated soils fallow in all sites that chosen for this study . It has been found that the grain size distribution in all sites ranged between 3 to 5 % , 38 to 44% and 51 to 59% for the sand , silt and clay respectively , the clay is highest percent in all sites. Also, the values of natural moisture content , weight density , plasticity index and shrinkage limits ranged from 46 to 55%, 16.9 to 17.1 $KN.m^{-3}$, 27 to 38% and 19 to 25% respectively . The highest values for all of these properties were remarked in site 2 (table 1).

Table 1 : Geotechnical properties of soil for sites

Site	Grain size distribution %			Natural moisture content %	Weight Density $KN.m^{-3}$	Plasticity index %	Shrinkage limit %
	clay	silt	sand				
Site 1 (Khora)	51	44	5	46	16.9	27	19
Site 2 (Hamdan)	59	38	3	55	17.3	38	25
Site 3 (Abu-Flus)	57	40	3	51	17.1	35	22

The variance between the sites for each property is attributed to the variation in clay percent between these sites. Clay particles exhibit a negative surface charge which caused by isomorphic substitution, water molecules associate with cations that held by this charge in interlayer . This interlayer water can be removed by soil drying , removal of this interlayer water reduces the interlayer spacing between particles and consequently causes the shrinkage of soil and then increases the soil density , the degree of shrinkage and density depending on the percent and type of clay in the soil (Chouliaras, 2005). Therefore, clay percent plays a main role in these properties in soils. Also, the plasticity index of soil depends on the percent of clay , the increasing of these particles in soil increases the cation exchange capacity and consequently increases the electrical double layer. The viscosity of inner water in this layer is high comparative with outer water, this physical property of water make the soil gains more plasticity (Sworan, 1979). It can be concluded that the plasticity of soil depends on percent of clay whose electrical double layer is large. Therefore, the highest plasticity index has been recorded at sit 2 in which the clay percent is higher than others .

Also, this study, it was shown that the root length density (RLD) values in the bank toe are 0.049-0319 $cm.cm^{-3}$, 0.147-0.516 $cm.cm^{-3}$ and 0.221-0.688 $cm.cm^{-3}$ for murran, bardi and khwesa plants respectively (table 2).

Table 2 : Root length density values (RLD) of plant species

Vegetation type	RLD(cm. cm^{-3})			
	RLD1*	RLD 2*	RLD 3*	RLD4*
Murran	0.049	0.081	0.208	0.319
Bardi	0.147	0.270	0.442	0.516
Khwesa	0.221	0.368	0.516	0.688

* A deferent root length density

The khwesa plants had greater RLD than the bardi and murran plants. Also, it is found that there was a variance in the shear displacement at which the shear resistance reached at maximum (failure of soil), the displacement depends on the RLD and type of plants (figure 2). The values of maximum shear resistance (critical shear stress) caused by the roots are 9.0 - 20.0 Pa , 14.0 - 29.0 Pa and 20.0 -37.0 in soil vegetated by murran , bardi and khwesa plants Respectably(table 3) ,while this values in the unvegetated soils was 4.2 Pa , 9.0 Pa and 8.0 Pa in site 1, site 2 and site 3 respectively (Table 3) . The variation of these values for each plant depended on the Root Length Density (RLD) for the same plant. The Increasing of the critical shear stress increases soil erodibility and then erosion rate . In each vegetated site, the erodibility coefficient values are 0.022 -0.033 $m^3.Ns^{-1}$, 0.018- 0.029 $m^3.Ns^{-1}$ and 0.016 -0.022 $m^3.Ns^{-1}$ for murran , bardi and khwesa plants respectively, and the erosion rate was 0.0 - 0.102 $N.s^{-1}$, 0.0-0.135 $N.s^{-1}$ and 0.0 - 0.055 $N.s^{-1}$ for murran , bardi and khwesa plants respectively (Table 3). The safety factor of soil (f_s) (when $f_s > 1$ erosion , $f_s = 1$ critical and $f_s < 1$ no erosion) reached up to 1.29 , 1.67 and 1.89 in soils that vegetated by murran , bardi and khwesa plants respectively, while these values in all of unvegetated soil were below the 1.00 unite (figure 4), the erosion is neither occurred in all unvegetated soil and nor in some vegetated soil whose RLD is low. The statistical analysis proved that there is a linear relationship between RLD for each plant and safety factor of sediments, and the correlation coefficient between them is a positive and high significant, the values of this coefficient is 0.984** , 0.986** and 0.998** in murran ,bardi and khwesa plants, respectively (figure 5).

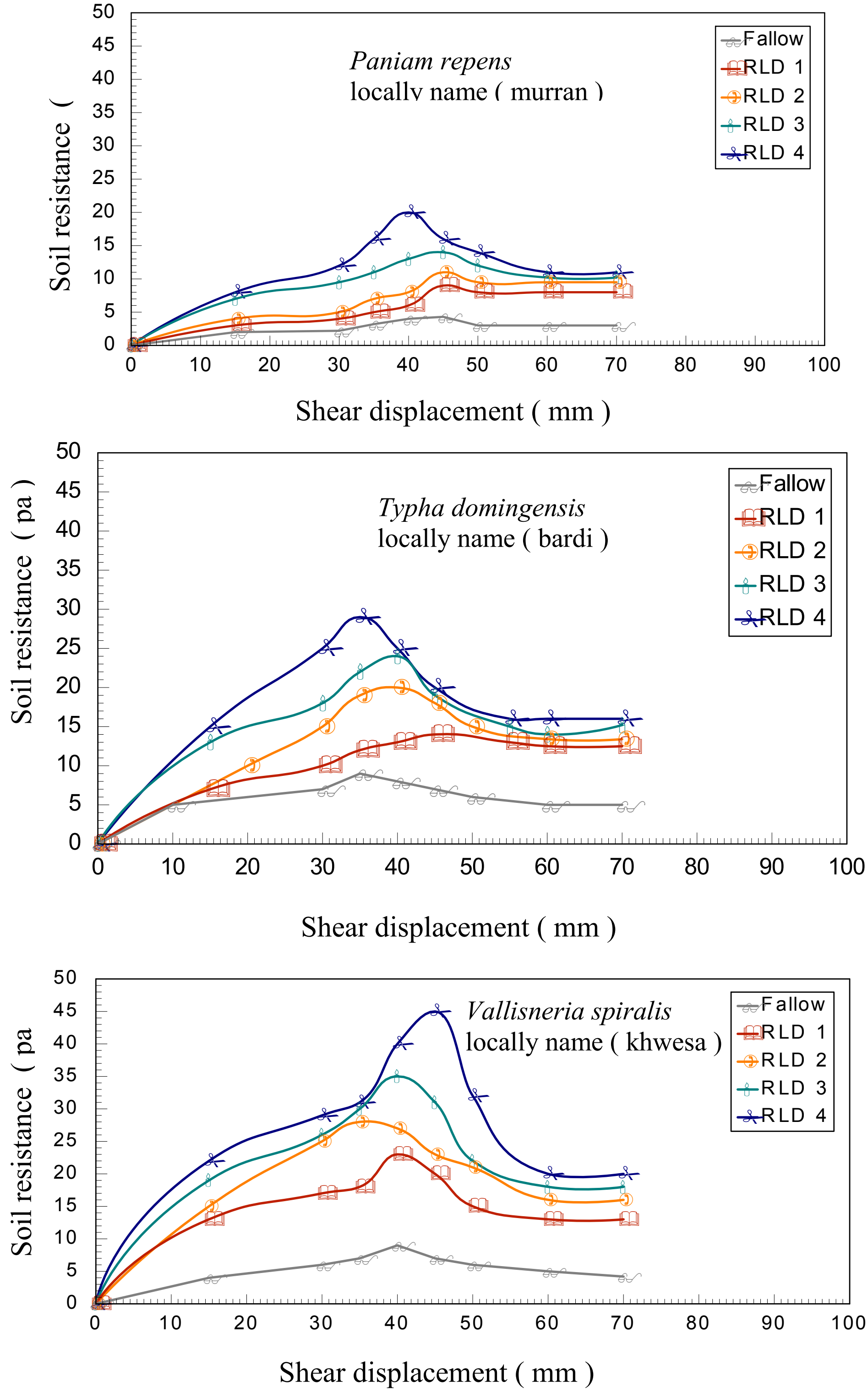


Fig. 2 : The relation between shear displacement and soil resistance for three species of vegetation

Table 3 : Maximum resistance, erodibility coefficient and erosion rate of soil for RLD of different plants

	murran (site 1) Khora			bardi (site 2) Hamdan			khwesa (site 3) Abu-Flus		
RLD	Max. resistance of soil (τ_c) N.m^{-2}	Erodibility coefficient (κ) (m^3. Ns^{-1})	Erosion Rate (ε) (m.s^{-1})	Max. resistance of soil (τ_c) N.m^{-2}	Erodibility coefficient (κ)(m^3. Ns^{-1})	Erosion Rate (ε) (m.s^{-1})	Max. resistance of soil (τ_c) N.m^{-2}	Erodibility coefficient (κ)(m^3. Ns^{-1})	Erosion Rate (ε) (m.s^{-1})
Fallow	4.2	0.387	0.386	9.0	0.039	0.336	8.0	0.035	0.507
RLD 1	9.0	0.033	0.102	14.0	0.026	0.135	20.0	0.022	0.055
RLD 2	11.0	0.030	0.033	20.0	0.022	0.0	25.0	0.200	0.0
RLD 3	14.0	0.026	0.0	24.0	0.020	0.0	30.0	0.018	0.0
RLD 4	20.0	0.022	0.0	29.0	0.018	0.0	37.0	0.016	0.0

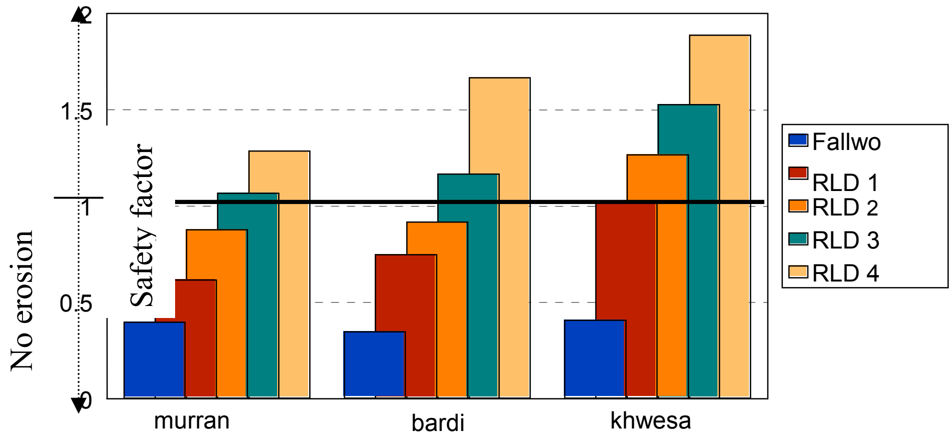


Fig. 4 : The relation of Safety factor values with RLD for the deferent plants

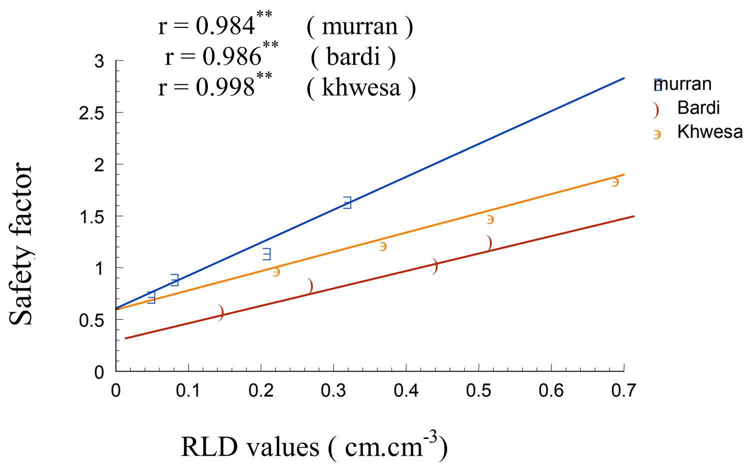


Fig. 5 : The correlation of Safety factor values with RLD for the deferent plants

Generally, the physical linking for soil particles by the roots gives the soil additional cohesion , and makes it more resistance for shearing , namely becomes less erodobility. The effect of RLD on the shearing resistance due to the reinforcement made by roots for soil particles, magnitude of this reinforcement depends on the root density. The shearing mechanisms for rooted soil occurs by two forces ; 1- force that break roots and 2- force pullout roots , this force based on the strength of the bonds between the roots and soil, these two forces combine with true strength (attractive and frictional forces between particles) and form a total strength which called apparent. When soil is more moistened, the negative pore pressures is reduced and positive pore pressures may developed, resulting in a decrease in frictional soil strength, as a consequence the apparent soil strength is reduced and the soil becomes more erodibility . But when the soil is rooted, the roots act like loaded piles, so the applied stress is transferred to them when the soil is sheared , and consequently the soil becomes more resistance and less erodibility .The safety factor for vegetated soils is more than unvegetated soils . Generally, when the applied shear stress (hydraulic shear stress) (τ_o) is less than maximum soil shearing resistance (τ_c) , the safety factor will be exceeded the one unite, this means that the soil is not eroded. therefore, the additional strength provided by roots to soil is generally considered a cohesive strength by which the soil becomes more resistance against applied hydraulic stress, and the magnitude of this additional cohesion depending on RLD (Pollen and Simon, 2005. therefore root density at the bank toe (basal area) is more critical for bank stability, when the applied hydraulic shear stress at the toe of bank exceeds the critical shear stress . (Wynn *et al*.,2004).

The results of this study have concluded that the density and distribution of roots within a River bank play an important role in River bank erosion and stability, and the shear resistance of cohesive soils that vegetated by plants can not be a unique criterion for erodibility estimations, also the cohesion that measured by Coulomb equation in vegetated soils is not represented the true cohesion of soil (attractive force between particles), but it is apparent (true cohesion combined with additional cohesion by roots). Therefore, the root density can be used as a parameter to predict soil erodibility, and the following modified equation that proposed by Theresa(2004) can be used as predicted function when there is need to calculate the stability of vegetated soil at any time :

S=c+ σN tanφ …..Coulomb equation (unvegetated soils)

S=c+Δ S+σN tanφ…..modified equation (vegetated soils)

where S is soil shearing resistance (τ_c), σN is the normal stress on the shear plane, φ is soil friction angle (degrees), and c is the cohesion. where ΔS is increased shear strength due to roots (additional cohesion).

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تأثير الغطاء الخضري على تعرية ضفاف نهر شط العرب ،جنوب العراق

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الخلاصة

اختيرت مناطق الخورة ،حمدان وابو فلوس لتقدير كثافة جذور النباتات الطبيعية المنتشرة على ضفاف شط العرب وأنواعها هي المران(*paniam repens*) ،البردي (*Tyha domingensis*) والخويصة (*Vallisneria spiralis*) .تم تقدير الصفات الهندسية والفيزيائية لترب الضفاف ومنها المحتوى الرطوبي الطبيعي ،الكثافة الوزنية ،دليل المرونة ،حدود الانكماش ،توزيع احجام دقائق التربة واقصى مقاومة قص للتربة بالاضافة الى مكافئ قابلية التربة للتعرية ومعدل التعرية والاجهاد القصي للتيار على الضفاف .وتم حساب عامل تعرية حافة الضفة وعامل الامان لضفاف النهر للفترة الزمنية من تشرين الثاني 2007 ولغاية كانون الاول 2008.

اظهرت النتائج ان هناك اختلافات واضحة في الصفات الجيوتكنيكية ما بين المواقع المدروسة ،وبينت النتائج ايضا ان قيم كثافة اطوال جذور النباتات في قدم الظفة كانت 0.049 الى 0.319 سم.سم$^{-3}$ ،0.147 الى 0.516 سم.سم$^{-3}$ و0.221 الى 0.688 سم.سم$^{-3}$ لكل من نبات المران والبردي والخويصة على التوالي. وانقيم اقصى مقاومة قص للترب قد تكون بسبب الجذور كانت 9.0 الى Pa 20.0 ،14.0 الى Pa29.0 ،20.0 الى Pa 37.0 في ضفاف الترب المغطاة بالمران والبردي والخويصة على التوالي .فيما كانت هذه القيم في ضفاف الترب غير المغطاة بالنباتات كالتالي Pa4.2 ،Pa 9.0، وPa 8.0 في مواقع الخورة وحمدان وابو فلوس على التوالي .ان عامل الامان للترب قد وصل في هذه الدراسة Pa1.29 ، Pa1.67 وPa1.89 في الترب المغطاة بالمران والبردي والخويصة على التوالي،بينما كانت هذه القيم في كل الترب غير المغطاة اقل من Pa 1.0 .

وعلى اساس هذه النتائج يمكن الاستنتاج بأن كثافة وتوزيع جذور النباتات الطبيعية الموجودة على ضفاف النهر لها دور مهم في تعرية وثباتية الضفاف وعلى مقاومة القص وتماسك التربة المغطاة بالنباتات ولكنها محدد اساسي لتقديرات قابلية التربة للتعرية .اضافة الى ان صفة التماسك المحسوبة بمعادلة كولمب للترب المغطاة لايمثل القيمة الحقيقية لتماسك التربة ولكنه قد يعتبر قيمة حقيقية للتماسك بعد اضافة التماسك الحاصل بفعل جذور النباتات الطبيعية.