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ESTIMATION OF SOIL ERODIBILITY FACTOR IN RUSLE EQUATION FOR EUPHRATES RIVER WATERSHED USING GIS

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ABSTRACT: Universal Soil Loss Equation (USLE) and Revised Universal Soil Loss Equation (RUSLE) are the models to compute the soil erosion loss, to estimate the accurate value of soil erosion that must be predicted several factors of its model. The land cover surface of topsoil is the important effect on the estimation of soil erosion loss. In this paper, the Euphrates watershed river of Iraq country will be adopted. This watershed includes seven provinces Najaf, Karbala, Al-Qadisiyyah, Dhi Qar, Al Muthanna, Babylon and Basrah of Iraq. The objective of present study was estimated the erodibility factor K for the watershed area. The K factor map was derived from the database of the UN-FAO (Food and Agriculture Organization of the United Nations 2007). This map of erodibility factor was prepared by ArcMap 10.2 software. It was estimated that K factor values of this watershed of study area range from 0.02276 to 0.00928. The K factor is depended on the percentage of topsoil content as sand, silt, clay and organic carbon. The large value of K factor for the topsoil type is Jc symbol (39% sand, 40% silt and 21% clay), while the soil erodibility factor is low for Qa-topsoil kind (92% sand, 3% silt, 4% clay and 1% organic carbon) because the silt of topsoil content is low compared with different other kinds. The big area of topsoil watershed type is Yk-type (63% sand, 18% silt, and 19% clay), it has been occupied about 47.2% of the whole watershed area.

Keywords: Erosion, RUSLE, Soil erodibility, Euphrates River

1. INTRODUCTION

The abstraction of the topsoil surface material by wind or water is called soil erosion [10]. The principal agent of erosion is water where the procedure includes detachment, transportation and deposition of individual particles (sediment) by raindrop influence impact and flowing water [5], [19], [8]. One of the main problems in agriculture and natural resources management is erosion. The erosion is reduced the soil efficiency, pollutes the streams and fills the reservoirs [3]. The construction of roads, highways, dam, and regulator works on streams and rivers, mining, urbanization and other of human activities have usually accelerated the process of erosion, transport, and sedimentation [9]. To estimate the soil erosion loss and its spatial distribution are the main factors for successful values of erosion assessment. The effective reduction of soil erosion loss under different geographical conditions can be possible to develop and implement policies [2]. The prediction soil erosion model and its factors have calculated the accuracy of soil loss estimation. There are many models to estimate the soil loss and identify areas where conservation methods will have the greatest effect on reducing soil loss for soil erosion calculations [1]. The Universal Soil Loss Equation (USLE) models are empirical models for soil loss erosion [4]. It was considered to predict longtime average soil losses erosion in runoff from specific field areas in specified cropping and management systems. The USLE [18] guesses the average annual soil loss erosion from:

$$A=R.K.LS.C.P \qquad (1)$$

Where, A is the values of predicted rate soil erosion loss per year, R is the Rainfall-Runoff erosivity factor, LS is the slope length and steepness (topographic) factor, C is cover management factor (vegetation cover), K is the soil erodibility factor and P is the support practice factor [18]. Revised Universal Soil Loss Equation (RUSLE) was developed by integrating several new techniques and additional data that develop the accuracy of factors of USLE model [12], [13], [21]. The RUSLE was extended to contain forest, rangelands and disturbed areas compared to USLE. It is widely used as an analytical model for estimating soil erosion potential and effects of changed management practices for over forty years [13].

The K factor is calculated the soil resistance to the erosion powers of rainfall and runoff energy [7]. The rate of soil loss per rainfall erosion index unit for identifying soil as measured on a unit plot is called the experimental soil erodibility factor K, which is defined as being 72.6 ft (22.1 m) long, with a width sixteen feet (1.83 m), with the slope 9%, and in a perpetually clean-tilled fallow condition with tillage achieved up and downslope [18].

Estimation the soil erodibility K factor is depended on the soil properties such as the distribution of the particles size, the content of organic matter, the structure of soil and the soil permeability [20]. Figure 1 is used to calculate the soil erodibility factor depended on the percentages of silts, very fine sand (0.002-0.1 mm), sand (0.1-0.2 mm), organic materials, structural of soil and permeability.

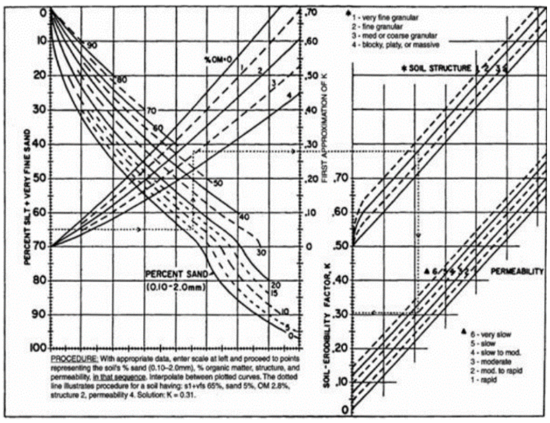

Fig. 1 Soil erodibility nomograph [18]

The soil erodibility K factor is calculated at the range from 0.02 to 0.69. The high clay soil has low K values ranging from 0.05 to 0.15 while the coarse texture sand soil also low factor K ranging from 0.05 to 0.2, this deferent values due to the resistance to detachment [6]. Furthermore, the main important factor of soil erodibility is the silt percentage content from whole topsoil content because the silt is easily detached and tend to crust and produce high rates of runoff. So the soil has been high silt content are the most erodible of all soil. Organic carbon content has a computable effect on soil erosion. It decreases erodibility factor, reduces susceptibility to soil erosion, while increases infiltration rates of water through soil layers. Due to high infiltration rater of water decreasing the runoff and erosion.

The present research is depended on the multi-equations to estimate the erodibility factor [15], [17], [11] as shown below:

$$K_{usle} = f_{csand} \times f_{cl-si} \times f_{orgc} \times f_{hisand} \quad (2)$$

$$K_{Rusle} = K \text{ factor} = K_{usle} \times 0.1317 \quad (3)$$

Where:

K_{usle} : USLE model soil erodibility factor

$$f_{csand} = \left[0.2 + 0.3 \times exp\left(-0.256 \times m_s \times \left(1 - \frac{m_{silt}}{100}\right)\right)\right] \quad (4)$$

$$f_{cl-si} = \left(\frac{m_{silt}}{m_c + m_{silt}}\right)^{0.3} \quad (5)$$

$$f_{orgc} = \left(1 - \frac{0.25 \times orgC}{orgC + exp[3.75 - 2.95 \times orgC]}\right) \quad (6)$$

$$f_{hisand} = \left(1 - \frac{0.7 \times \left(1 - \frac{m_S}{100}\right)}{\left(1 - \frac{m_S}{100}\right) + exp\left[-5.51 + 22.9 \times \left(1 - \frac{m_S}{100}\right)\right]}\right) \quad (7)$$

m_s: the percentage of sand fraction content (0.5-2 mm particle diameter) [%]

m_{silt} : the percentage of silt fration content (0.002-0.05 mm particale diameter) [%]

m_c : the percentage of clay fration content (<0.002 mm particale diameter) [%]

orgC: the percentage of organic carbon fraction content) [%]

The all fractions of soil sand, clay, silt and organic carbon were represented to the topsoil cover of the watershed because it is affected directly by the raindrop energy.

2- Study Area

The watershed of the presented study was contained the seven provinces of Iraq which included Najaf, Karbala, Al-Qadisiyyah, Dhi Qar, Al Muthanna, Babylon, and Basrah. The area of the watershed is 131722 km^2 for these provinces about 30% from the entire area of Iraq as shown in the Fig. (2). The Euphrates river passes through eight provinces, it is the longest and one of the most historically main rivers of Western Asia. Originating from eastern Turkey, the Euphrates flows through Syria and Iraq to join with the Tigris in the Shatt al-Arab.

Using the UN-FAO (Food and Agriculture Organization of the United Nations 2007) data to derived the topsoil type of Euphrates river watershed. The ArcMap 10.2 software was used to input the data of topsoil percentage for the presented watershed of the keys symbols as the Fig. (3).

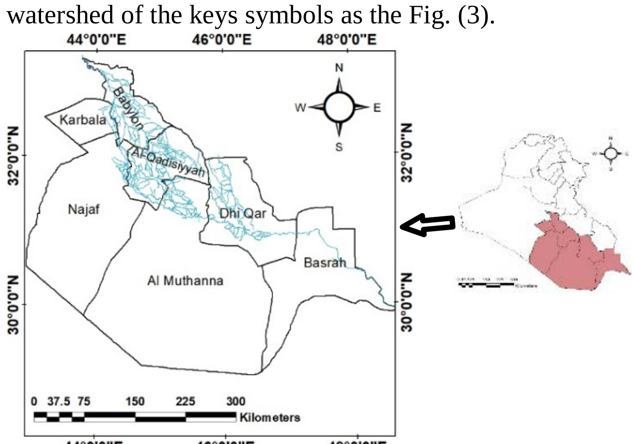

Fig. 2 Study area of watershed location map

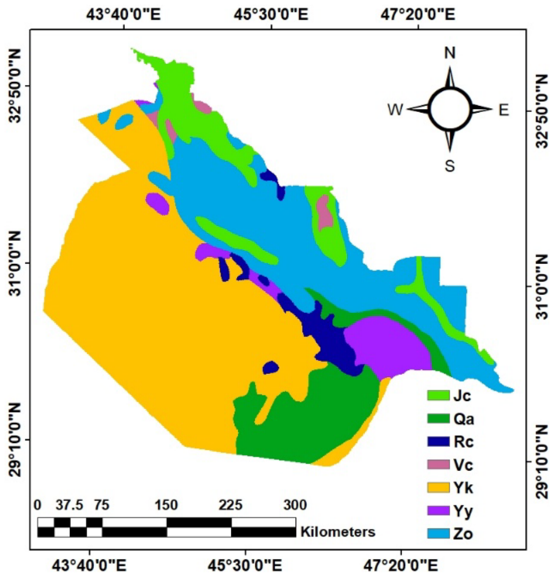

Fig. 3 Types of topsoil for the watershed

The symbols of map legend are explained the different type of watershed topsoil and its distribution of whole Euphrates watershed as shown the Table (1) [16]:

Table 1 The percentage of the type of topsoil [16]

Soil unit symbol	Sand % topsoil m_s	Silt % topsoil m_{silt}	Clay % topsoil m_c	Organic Carbon % topsoil $orgC$
Jc	39.35	39.54	20.46	0.65
Yk	63.38	17.78	18.58	0.26
Yy	48.96	10.68	40.23	0.13
Zo	43	24.43	32.17	0.4
Vc	22.2	24.3	52.81	0.69
Rc	63.25	18.9	17.09	0.76
Qa	92.34	3.27	3.52	0.87

2. The Results and Discussion

The soil erodibility factor K of the Euphrates watershed is defined by application the pervious equations 2, 3, 4, 5, 6 and 7. These equations mainly depended on the UN-FAO data of the topsoil percentage material of land cover surface as Table (2). The map of K factor distribution can be derived using the ArcMap 10.2 software (30*30 m) cells size as Fig. (4). These number of cells for each different type of topsoil and soil erodibility factor can be computed as a histogram of the Fig. (5). The area of each topsoil categories can be obtained via multiply the cell size by the number of cells for specify categories as shown in the Table (3).

Table 2 The value of soil erodibility factor

Soil unit symbol	K factor
Jc	0.02276
Yk	0.02088
Yy	0.01646
Zo	0.02032
Vc	0.01847
Rc	0.02062
Qa	0.00928

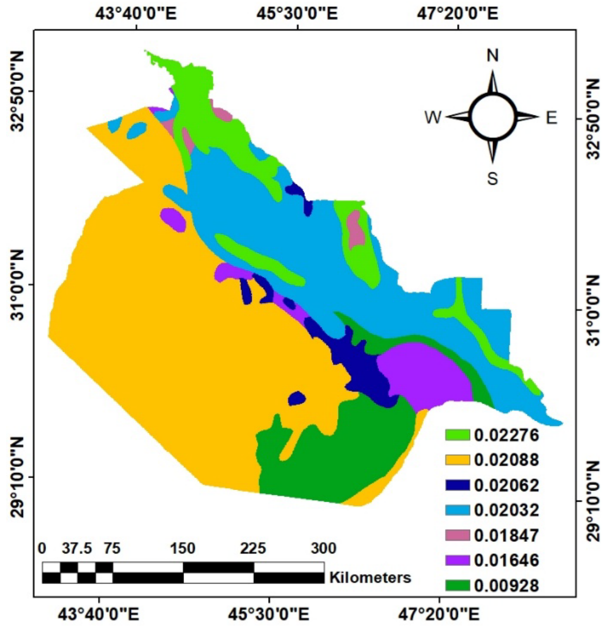

Fig. 4 K factor values of the Euphrates basin

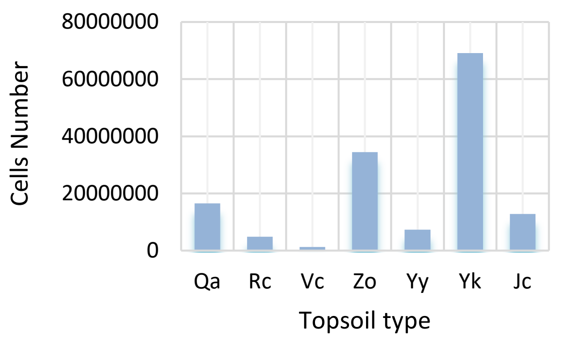

Fig. 5 Cells number for each topsoil data

Table 3 The area of topsoil of watershed

Symbol soil	Area km^2	Area %
Jc	11534.1678	8.76
Yk	62191.3374	47.22
Yy	6548.3613	4.97
Zo	31046.1156	23.57
Vc	1136.0061	0.86
Rc	4416.9615	3.35
Qa	14849.1396	11.27
Total	131722	100

The topsoil types and the K factor can be computed for each of seven provinces of Iraq as shown in the Figures below while the area (square kilometers) of topsoil for each map of provinces can be estimated as Table (4).

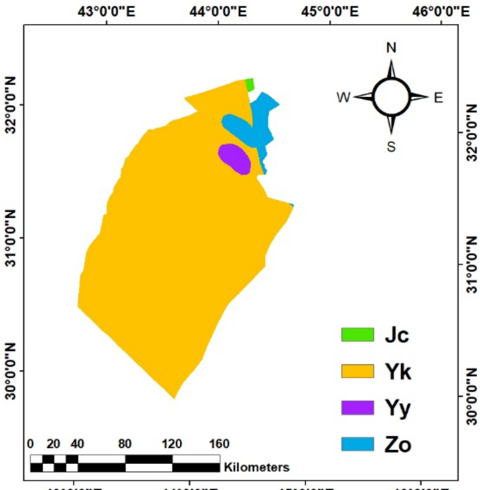

Fig. 5 The topsoil types of Najaf province

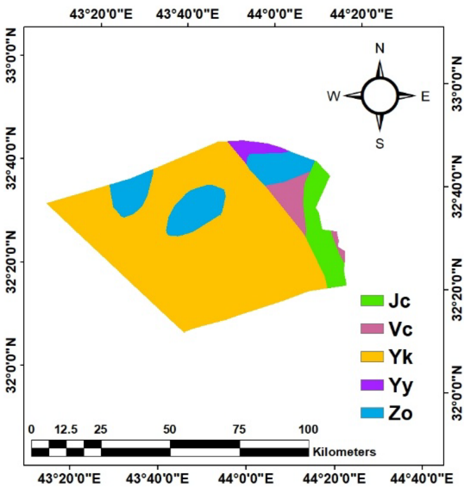

Fig. 6 The topsoil types of Karbala province

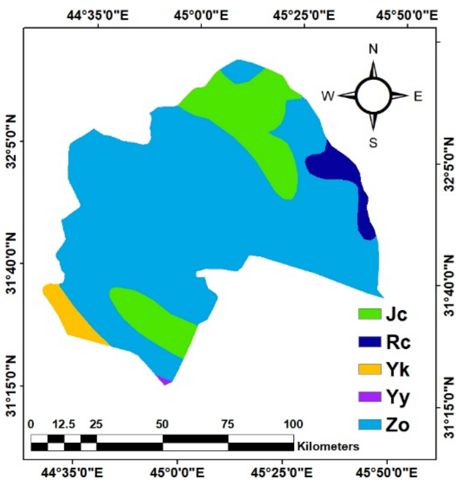

Fig. 7 The topsoil types of Al-Qadisiyyah province

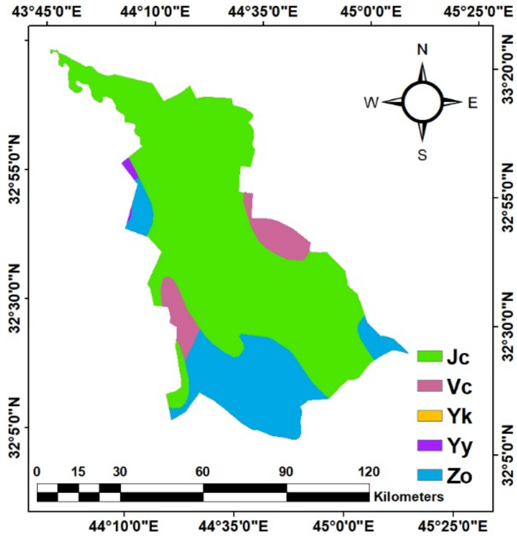

Fig. 8 The topsoil types of Babylon province

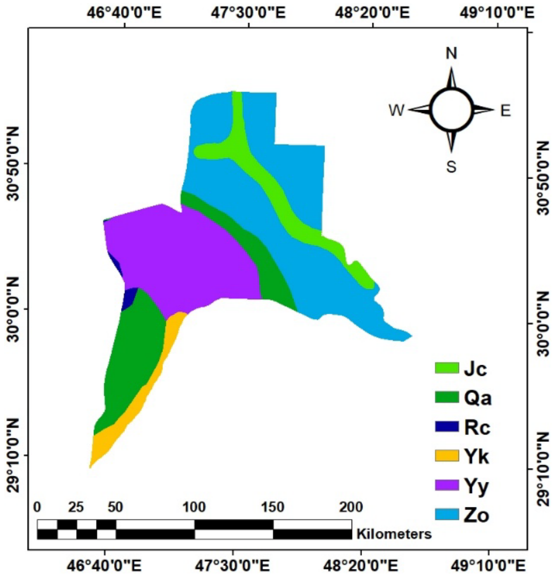

Fig. 9 The topsoil types of Basrah province

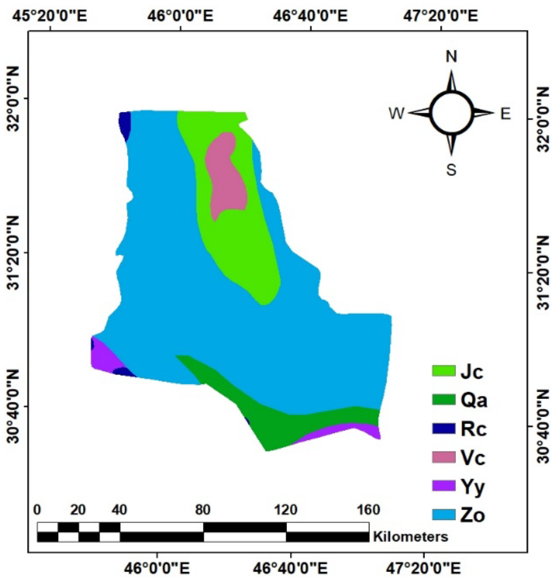

Fig. 10 The topsoil types of Dhi Qar province

Table 4 Area (square kilometers) of topsoil for every seven provinces of Iraq

Province Symobl	Najaf	Karbala	Al-Qadisiyyah	Babylon	Dhi Qar	Basrah	Al Muthanna
Jc	67.2093	318.9267	1464.3612	4953.999	2114.245	1675.47	940.0077
Yk	25906.93	3375.732	196.5141	0.3375	0	795.433	31916.3958
Yy	478.008	79.1568	8.4969	24.1794	308.6433	4787.18	862.6968
Zo	1222.799	623.1006	6825.3462	1425.475	9854.957	7441.69	3652.6644
Vc	0	170.5464	0	419.3235	546.1362	0	0
Rc	0	0	279.6354	0	107.4654	129.136	3900.7251
Qa	0	0	0	0	1027.081	3134.6	10687.4586

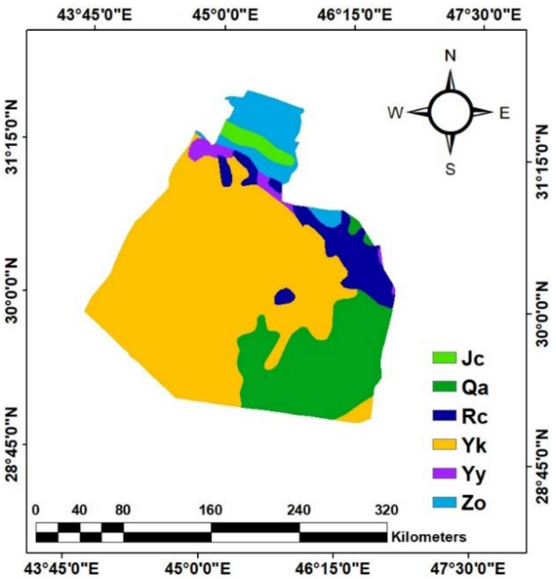

Fig. 11 The topsoil types of Al Muthanna province

5. CONCLUSION

The soil erodibility factor (K) is one of the important factors to find the soil erosion loss of USLE model and RUSLE model. The K factor of the presented study is ranged from 0.02276 to 0.00928, the high value for the maximum content of silt while the low value for the minimum content of silt. So the K factor mainly depends on the silt content of topsoil, the large value of K factor for the topsoil type is Jc symbol (39% sand, 40% silt and 21% clay), while the soil erodibility factor is low for Qa-topsoil kind (92% sand, 3% silt, 4% clay and 1% organic carbon) because the silt of topsoil content is low compared with different other kinds. The big area of topsoil watershed type is Yk-type (63% sand, 18% silt, and 19% clay), it has been occupied about 47.2% of the whole watershed area. The topsoil types of sand, silt, and clay are the most covered of the surface for seven provinces of Iraq.

6. ACKNOWLEDGEMENTS

The data of the topsoil of Euphrates watershed were the UN-FAO website at the year 2007. This website is designed as a source of soil data and knowledge on the different components and parts of soils.

7. REFERENCES

[1] Angima, S.D., Stott, D.E., O'Neill, M.K., Ong, C.K. and Weesies, G.A. (2003). "Soil erosion prediction using RUSLE for central Kenyan highland conditions." Agriculture, Ecosystems and Environment 97, 295–308.

[2] Colombo, S., Hanley, N. and Calatrava, J. (2005) "Designing a policy for reducing the off-farm effect of soil erosion using choice experiments." Journal of Agricultural Economics, 56, 81–95.

[3] Fangmeier, D.D. Elliot, W. J. Workman, S. R. Huffman, R. L. Schwab, G. O. (2006). Soil erosion by water. Soil and Water Conservation Engineering, 5th ed. Thomson Delmar Learning, New York. 134-158.

[4] Fistikoglu, O. and Harmancioglu, N.B. (2002). "Integration of GIS with USLE in Assessment of Soil Erosion." Water Resources Management 16, 447–467.

[5] Foster, G. R. and Meyer, L. D. (1977). Soil erosion and sedimentation by water- an overview. Procs. National Symposium on Soil Erosion and Sedimentation by Water, Am. Soc. Of. Agr. Eng., St. Joseph, Michigan, 1-13.

[6] Goldman S.J, Jackson K, Bursztynsky T.A (1986) 'Erosion and sediment control handbook.' McGraw-Hill Book Company, New York.

[7] Haan, C.T., Barfield, B.J., and Hayes, J.C. (1994). Design Hydrology and Sedimentology for Small Catchments, Academic Press, San Diego, California.

[8] Julien, P. Y. (2002). "River Mechanics." Cambridge University Press, New York, pp. 31-78.

[9] Julien, P.Y. (2010). Erosion and Sedimentation. 2nd ed. Cambridge University Press, Cambridge.

[10] Kirkby, M. J, and Morgan. R.P.C. (1980).Soil erosion. Chichester, New York. Brisbane, Toronto, John Wiley & Sons Publications.

[11] Neitsch S.L., Arnold J.G., Kiniry J.R., Williams J.R. (2000) “Erosion Soil and Water”. Assessment Tool Theoretical Documentation Texas Agricultural Experiment Station. pp. 625.

[12] Renard K.G. and Freimund, J.R. (1994). “Using monthly precipitation data to estimate the R factor in the revised USLE.” J Hydrol 157, 287–306.

[13] Renard, K.G., Foster, G.R., Weesies, G.A. and McCool, D.K. (1997). “Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE).” Agric. Handb., US Department of Agriculture, Washington, DC, vol.703.

[14] Renard, K.G., Foster, G.R., Weesies, G.A. and McCool, D.K. (1997). “Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE).” Agric. Handb., US Department of Agriculture, Washington, DC, vol.703.

[15] Sharpley, A. N. & Williams, J. R. Epic “Erosion/Productivity Impact Calculator: 1. Model Documentation” (1990). U.S. Department of Agriculture Technical Bulletin, v. 1768, p. 235 pp.

[16] UN-FAO (2007). This website is designed as a source of soil data and knowledge on the different components and parts of soils, http://www.fao.org/soils-portal/en/ .

[17] Williams J.R. Chapter 25: The EPIC model. In V.P. Singh (ed.) (1995) Computer models of watershed hydrology. Water Resources Publications. p. 909-1000.

[18] Wischmeier, W. H., and D.D. Smith. (1978). “Predicting rainfall-erosion losses - a guide to conservation planning.” AH-537. U.S. Dept. Agr., Washington, D.C.

[19] Wischmeier, W. H., and Smith, D.D., (1978). Predicting Rainfall Erosion Losses- A Guide to Conservation Planning. U.S. Department of Agriculture Handbook No.537.

[20] Wischmeier, W.H., Johnson, C.B., and Cross, B.V. (1971). A soil erodibility nomograph for farmland and construction sites. J. Soil and Water Conserv. 26:189-193.

[21] Yoder D. and Lown, J. (1995). “The Future of RUSLE: inside the new revised universal soil loss equation.” Soil Water Conservation 50(5), 484–489.

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