Emirates Journal of Food and Agriculture. 2021. 33(9): 711-717
doi: 10.9755/ejfa.2021.v33.i9.2734
http://www.ejfa.me/

RESEARCH ARTICLE

A Smartphone application to compute soil erosion based on the revised universal soil loss equation (RUSLE)

Daniel Simonet[1]* and Tarig A. Ali[2]

[1]*Department of Management and Geospatial Analysis Center, American University of Sharjah, United Arab Emirates, PO Box 26666,*
[2]*Department of Civil Engineering and Geospatial Analysis Center, American University of Sharjah, PO Box 26666, Sharjah, United Arab Emirates*

ABSTRACT

Erosion negatively affects farming. It leads to a 50% decline in land productivity (Nellemann *et al*, 2009). In Africa, erosion generates significant yield reduction (Eswaran, Lal & Reich, 2001). The loss of 75 billion tons of soil per year represent a cost of US$400 billion. An acre of U.S. cropland loses 5 tons of soil per year (Briggs, 2020). Moreover, soil carried away is the source of respiratory illnesses and damages that amount to over $14 billion per year (Eswaran, Lal & Reich, 2001). Furthermore, erosion reduces soil water-holding capacity. The Revised Universal Soil Loss Equation (RUSLE) is the major tool to calculate erosion caused by rainfall erosivity; the resistance of the environment (including soil erodibility; topographical factor, plant cover, and farming techniques) and human techniques (erosion control practices in farming) (Roose, 1996). RUSLE is instrumental in keeping erosion within acceptable limits. This paper presents a new, and the first of its type, smartphone application developed to help farmers and stakeholders compute soil erosion at any location in the world using the RUSLE model. Such an application can help land users to have a more accurate perception about soil erosion and its negative impact.

Keywords: Erosion; RUSLE; Smart Phone App

INTRODUCTION

Soil erosion is a problem that affects natural resources, agricultural practices, and sedimentation throughout the world (Schwab *et al*., 1993; Ali, 1999; Bakker *et al*., 2005; Parveen and Kumar, 2012). The annual global average soil loss due to erosion is 14 tons/ha/year, approximately. Soil erosion can take place due to wind or rainfall with the latter being the most common cause. The scientific community has developed many models to estimate soil losses caused by water erosion. Some of the well-known models include the Universal Soil Loss Equation (USLE), the Modified Universal Soil Loss Equation (MUSLE), Water Erosion Prediction Project (WEPP), and the Revised Universal Soil Loss Equation (RUSLE).

RUSLE is a model developed from erosion plots and simulated rainfall experiments by the United States Department of Agriculture (USDA) to estimate annual soil loss due to erosion. The RUSLE requires five factors to predict soil losses due to erosion (Wischmeier *et al*., 1978). These factors include rainfall erosivity, soil erodibility, topographic factor, cropping management factor, and an erosion practice factor. RUSLE has gone through some modifications and revisions resulting in the Modified Universal Soil Loss Equation (MUSLE) and the Revised Universal Soil Loss Equation (RUSLE). The MUSLE model can estimate sediment yield and its factors include runoff, peak flow rate, in addition to RUSLE factors. The RUSLE has been developed based on revisions of USLE related to the identification of the input factors and it predicts soil degradation using a soil erodibility factor based on soil texture and an improved cover management factor.

The WEPP model requires four parameters including topography, climate, soil, and vegetation. The WEPP model provides estimates of not only soil erosion but also deposition and sediment delivery (Laflen *et al*., 1991; Dabral *et al*., 2008).

***Corresponding author:**
Daniel Simonet. Department of Management and Geospatial Analysis Center, American University of Sharjah, United Arab Emirates.
Email: dsimonet@aus.edu

Received: 11 February 2021; **Accepted:** 04 April 2021

RUSLE, which is the model implemented in the smartphone application developed in this study; incorporates factors such as rainfall erosivity (the R factor); the resistance of the environment, the K-factor or soil erodibility factor (i.e. the resistance to two energy sources: the impact of raindrops on the soil surface, and the shearing action of runoff) (Roose, 1996); LS (i.e., the topographical factor); C (i.e. plant cover and farming techniques) and P (i.e. erosion control practices) that may keep erosion within an acceptable limit given the climate, slope and production factors. Soil-building techniques, such as planting cover crops, contouring in farming, addition of organic matter via the incorporation of manure may help, even though these are not widely used.

This RUSLE model uses the following formula:

$$E = R \times K \times LS \times C \times P \tag{1}$$

where E equals the computed average soil loss measured in tons per acre per year. R is the rainfall-runoff erosion factor. The erosion-factor measures the erosion force of a specific rainfall event (Gobena, 2003). K is the soil erodibility factor that represents both the rate at which different soils erode and the rate of runoff. K is a combination of the percentage of silt, fine sand; sand; and the percentage of organic matter content. LS is the topographic factor, which represents the impact of slope length on erosion and is influenced by the shape, angle, and length of slope. C is a dimensionless cropping-management factor that accounts for the impact of crop management practices (Foster *et al.*, 1977), and P is a support practice factor, which accounts for the effectiveness of erosion control practices such as contouring, terracing, etc.

In this study, a smartphone application has been developed based on RUSLE to help land users calculate soil erosion at any location worldwide. Some of the land users who would appreciate this application include the farming sector, rural municipalities, property developers and construction firms, environmental groups, soil conservation organizations, soil and water conservation associations, soil science societies, etc. This application can help these land users have a more accurate perception about soil erosion and its negative impact (Teshome *et al.*, 2014; Subirós *et al.*, 2015; Assefa and Hans-Rudolf, 2015, Raento *et al.*, 2009, Vila *et al.*, 2014) and identify areas that are at a greater risk of erosion. Table 1 below provides examples of some of the uses of our new smartphone app by the land users mentioned above. Smartphone applications generally take advantage of the sensor and communication technology available in smartphones (Patel *et al.*, 2013). These apps make use of the instant access to data freely available through the internet.

Table 1: Some examples of the use of our new smartphone erosion prediction app by land users

Land user group	Examples of the uses of our smartphone app
Rural Municipalities	Environmental conservation purpose e.g. identification of areas at risk of erosion; installation of drainage systems in areas prone to erosion; prevention of desertification, etc.
Property developers and construction firms	Assessment of soil stability, identification of constructible areas (buildings, roads…)
Farming sector: farmers (570 million farms worldwide)	Long-term deterioration of land quality caused by erosion and the resulting reduction in crop yield and financial loss
Environmental Groups & NGOs:	Soil conservation, soil science purposes, etc.

MATERIAL AND METHODS

Before a smartphone application can be developed, the RUSLE model factors shown in equation 1 above need to be computed as the user interacts with the smartphone application. This section shows how these factors are being computed in our new smartphone erosion estimation application.

Erosion factors computation

Rainfall-runoff erosion factor (R)

R is computed by the Wischmeier and Smith (1978) method based on monthly and annual rainfall. Here we took advantage of this approach, which is both simple and has a wide application range and readily available data.

$$R = \sum_{i=0}^{12} 1.735 \times 10^{(1.5 \log_{10}(p i^2/p)} - 0.08188) \tag{2}$$

where,

R is the parameter for rainfall erosivity (MJ mm ha−1 h−1 year−1),

Pi represents the average monthly rainfall (mm) for each month of the year,

P represents the average annual rainfall (mm)

The average annual precipitation and monthly normal values in the US have been obtained from the World Meteorological Organization (WMO) and Food and Agriculture Organization (FAO) rain gages and are available through this popup window:

https://www.arcgis.com/home/item.html?id=e6ab69305 6a9465cbc3b26414f0ddd2c

Soil erodibility factor (K)

K represents the rate at which different soils erode. K is a combination of the percentage of silt, fine sand; sand;

and the percentage of organic matter content. Following Bazzoffi (2018), the following equation was used to compute the soil erodibility factor.

$$S = \left[\frac{2.1M^{1.14}10^{-4}(12.a) + 3.25(b-2) + (c-3)}{100}\right]0.1317 \quad (3)$$

where,

- S is the soil erodibility factor (MghahMJ−1ha−1mm−1) in Standard International (S.I.) Units
- M is the texture defined as percentage of silt multiplied by (100 – percentage of clay);
- a is the organic matter content (%); b is the soil structure code;
- c is the soil permeability class.

The organic matter content (%), a is calculated as a=1.72·orgC, where orgC is the organic carbon content in the soil layer (%) (SWAT, 2018). There are 4 soil structure codes (b): 1 = very fine granular; 2 = fine granular; 3 = med or coarse granular; 4 = blocky, platy, or massive. The selection of a soil permeability class (c) is based on permeability rates. To identify the USDA soil permeability class (c), ranging from 1 to 6, we rely on the HWSD soil map that indicates the dominant soil (heavy clay, sandy clay, loam…) for every location worldwide and use Table 2 to determine the soil permeability class (c) based on soil texture. Usually, the thinner the soil, the smaller the permeability class (Table 2)

Topographic factor (LS)

We calculate the topographic factor (LS), which represents the impact of slope length on erosion and is influenced by the shape, angle, and length of slope using the following equation (Moore and Wilson, 1992).

$$LS = (\lambda/22.13)^{m} \times (0.065+0.046S+0.0065S^{2}) \quad (4)$$

Where
λ = slope length (m)
S = slope gradient in %
m = 0.2 for S<1%.
0.3 for 1%<S<3%
0.4 for 3%<S<5%
0.5 for 5%<S<12%
0.6 for S>12%

Cropping management factor (C)

C is a dimensionless cropping-management factor that accounts for land use.

Tirkey *et al.* (2013) provide a list of C factors for different land use and cover classes. The typical values range from about 1 for bare soils; 1 to 0.9 for root crops and tuber crops; 0.01 on grasslands and cover plants and 0.001 for forests. We completed the list with data from Panagos (2015), Blanco-Canqui and Lal (2008), Wischemeier and Smith (1978), Roose (1977), Singh *et al.* (1981) and Hashim and Wong (1988) and Rao (1981) and Mir *et al.*, 2010.

Erosion practice factors (P)

Erosion Practice Factor (also known as Support Practice Factor (P) is defined as the ratio of soil loss at the location due to surface condition to soil loss with up-and-down-hill cultivation. The values used in this app are those shown

Table 2: Some. Soil Texture and Permeability Class

Soil Texture	Soil Permeability Class (c)
Heavy clay, Clay, Silty clay	6
Silty clay loam, Sandy clay	5
Sandy clay loam, Clay loam	4
Very fine sandy loam, Silt loam, Loam, Silt	3
Loamy sand, Sandy loam, Fine sandy loam	2
Sand, Gravel, Coarse sand	1

Source: Ramos David E (1997); National Soil Handbook (USDA, 1983); National Engineering Handbook (USDA, 1972)

Table 3: Erosion Practice Factor. Wischmeier and Smith (1978); Roose (1977); Tec (2011)

Erosion practice	P-factor value
Contouring: 0-1° slope	0.60*
Contouring: 2-5° slope	0.50*
Contouring: 6-7° slope	0.60*
Contouring: 8-9° slope	0.70*
Contouring: 10-11° slope	0.80*
Contouring: 12-14° slope	0.90*
Level bench terrace	0.14
Reverse-slope bench terrace	0.05
Outward-sloping bench terrace	0.35
Level retention bench terrace	0.01
Tied ridging	0.10-0.20
No support practice	1.00
Cross slope farming	0.75
Up and down slope	1.0
Strip cropping cross slope	0.37
Strip cropping contour	0.25
Grass Strip	0.50
Contour Ditches	0.50
Hillside Trench (Silt Trap)	0.60
Rain Shelter	0.10
Contour Planning	0.80
Mulching	0.20
Terraces (Continuous)	0.20
Terraces (Discontinuous)	0.40
Individual Basin	0.50
Traditional Terraces	0.60
Vertiver-Contour Hedgerow	0.60

*Use 50% of the value for contour bunds or if contour strip cropping is practiced

Table 3, which primarily cover contouring, bench terracing, and vary with the slope steepness (Chan, 1981; McCool, 1987). In the app, erosion practice factors are only applied to arable lands. With no erosion-control practice, P = 1.0 (Morgan, 1986, p. 121).

DESIGN AND DEVELOPMENT OF SMARTPHONE APPLICATION

In this section, we explain the design and development of a smartphone application, which can calculate Soil Erodibility (in both US and International Units) and soil loss due to water erosion based on RUSLE for a given land-cover, crop types, and erosion control practices. The flowchart of Fig. 1 below describes the working principle of the app, which for simplicity is presented in two sub flowcharts (A and B) as shown in Figs. 2 and 3, respectively.

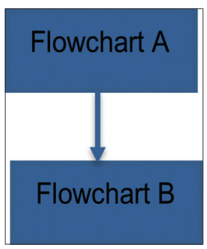

Fig 1. The general framework of the working principle of the erosion app.

RESULTS AND DISCUSSION

The following figure show screenshots of the erosion application. Fig. 4 shows the location selection screen by the user. Fig. 5 shows the screen where user selects the soil texture and the app retrieves the soil structure code and computes the K factor at this location. Fig. 6 shows the R factor estimation by the app for the selected location. Fig. 7 shows the LS factor computation based on slope length(m) and slope steepness (%) entered by the user.

Then, the user selected the type of land (Arable or Non-Arable Land) where erosion occurs. If the user selects Arable Land, then the user has to choose a type of crop for which the app screenshot is shown in Fig. 8(a). In such a case, the app retrieves the corresponding C factor (1986) as shown in Fig. 8(b).

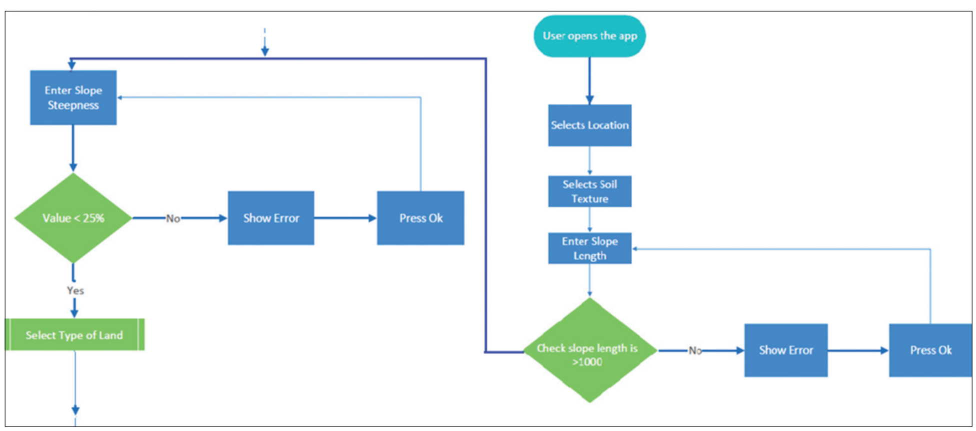

Fig 2. Flowchart A.

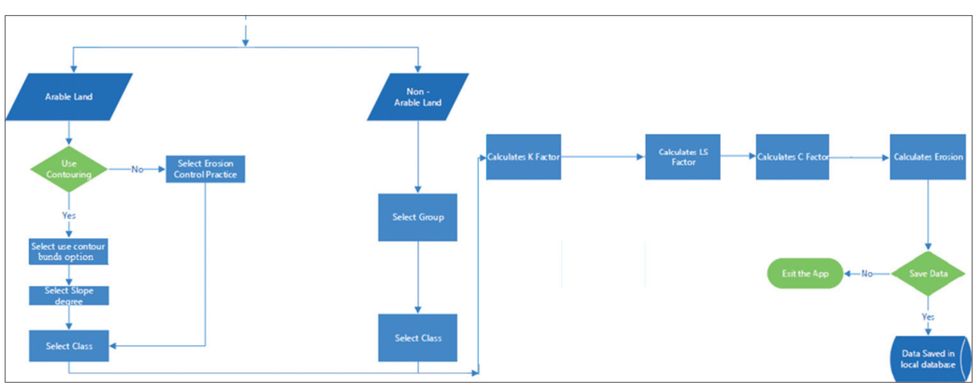

Fig 3. Flowchart B.

Fig 4. The App location Selection Screen369.

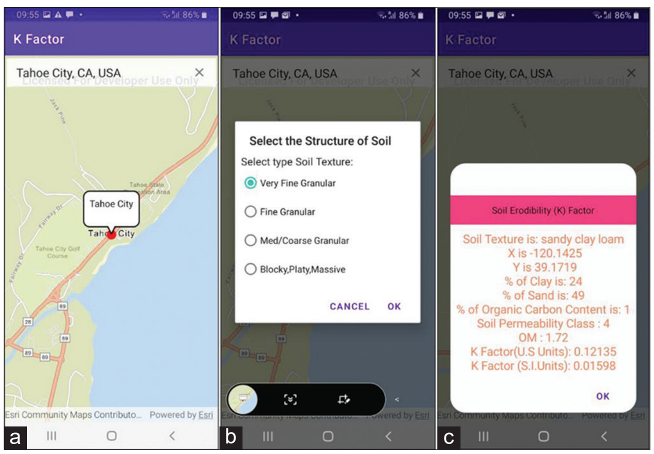

Fig 5. App screenshots showing (a) the Soil Structure selection and (b) the estimated K Factor.

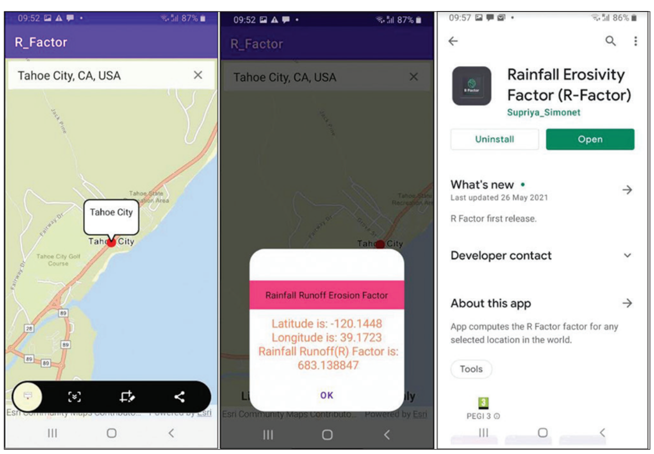

Fig 6. App screenshots showing the R factor in U.S and S.I. units for the selected location.

Then, the user needs to select an Erosion Practice from a list as shown in Fig. 9 (a). The corresponding value of the erosion practice factor will be displayed as shown in Fig. 9 (b).

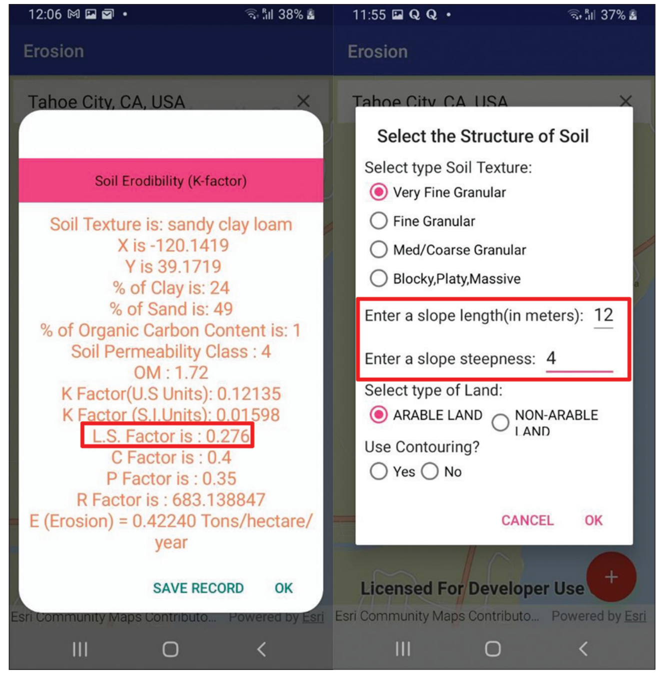

Fig 7. App screenshots showing the computed LS Factor based on Slope Length and Slope Steepeness selected by user (in %).

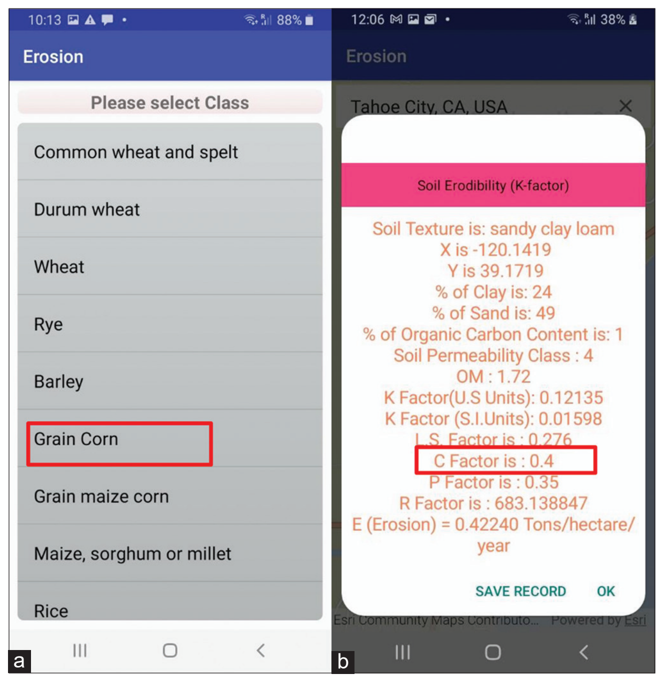

Fig 8. App screenshots showing (a) the type of crop selected by user and (b) the corresponding C factor based on Morgan (1986).

Finally, the app computes Erosion rate (tons/acre/yr) as shown in Fig. 10. We can then determine the rate of erosion (high, moderate or low) and further suggest a mitigation plan.

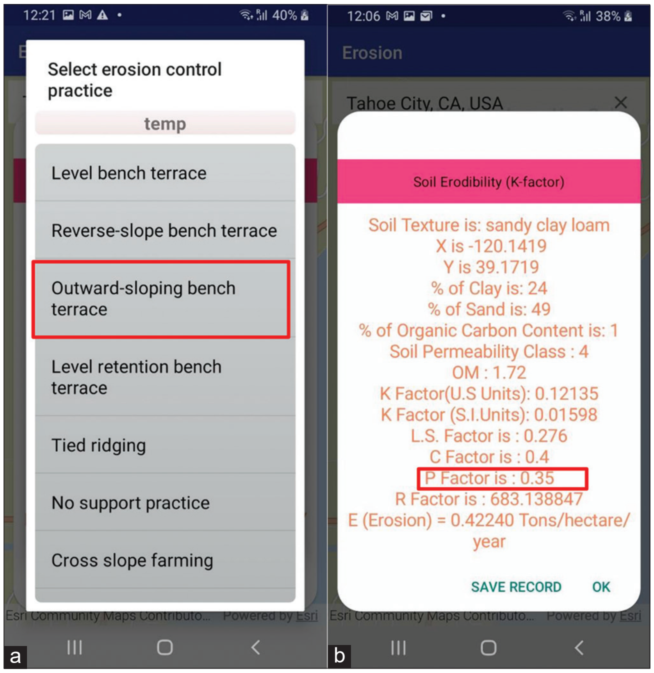

Fig 9. App screenshots showing the (a) Erosion Control Practice selection panel and (b) the corresponding P Factor.

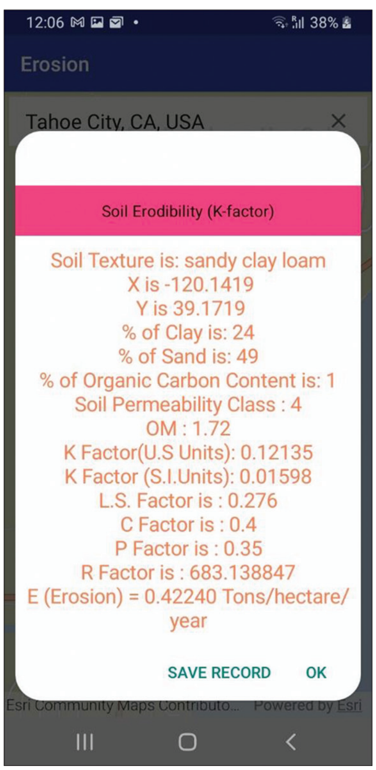

Fig 10. The computed erosion rate (in tons/acre/yr).

CONCLUSIONS

In this study, a new smartphone application has been developed to compute soil erosion at any location in the world based on RUSLE model. The main characteristics of our app include the following: (a) there is no need for soil testing, and hence it provides an inexpensive way to assess erosion risk, identify areas at risk of erosion, and further suggest alternative farming practices to reduce erosion in cropland. (b) Simplicity and ease of use as the users need to select the location, crop or vegetation type and farming practice in order to have the erosion rates computed. (c) The use of the latest soil databases and weather forecasts to provide up-to-date erosion rates. Some of the land users who would appreciate this app include the farming sector, rural municipalities, property developers and construction firms, environmental groups, soil conservation organizations, soil and water conservation associations, soil science societies, etc… This smartphone app will empower growers by enabling them to determine priority areas for erosion control and finding crops that are best suited to different erosion conditions, all of which will preserve farmers' income stability.

Author contributions

D.S.: conceptualization, methodology, App Development, validation, writing: first draft; T.A.: methodology verification, writing: review and editing. The two authors have read and agreed to the published version of the manuscript.

FUNDING

The research has received funding from the Office of Research at the American University of Sharjah (AUS) through the Geospatial Analysis Center. The authors express their gratitude to coder/developer Supriya Pravin Shah (supsabhi@gmail.com).

REFERENCES

Ali, T. 1999. GIS Modeling of Phosphorus Concentration, Soil Loss Due to Water Erosion and Coastal Terrain Change Detection in Lake Erie Coastal Areas (Master's Thesis). Ohio State University, Ohio, USA.

Arnoldus, H. 1977. Methodology used to determine the maximum potential average annual soil loss due to sheet and rill erosion in Morocco. FAO Soils Bull. 34: 39-51.

Assefa, E. and B. Hans-Rudolf. 2015. Farmers' perception of land degradation and traditional knowledge in Southern Ethiopia-resilience and stability. Land Degrad. Dev. 27: 1552-1561. Bazzoffi, P. 2018. Soil Erodibility Factor Equation. Available from: http://www.suoli.regione.marche.it/Erosioneascaladicampo.aspx. [Last accessed on 2020 Jun 4].

Blanco-Canqui, H. and R. Lal. 2008. Principles of Soil Conservation and Management. Springer Science+Business Media, Netherlands.

Briggs, R. 2020. Introduction to Soils. College of Environmental Science and Forestry. Available from: https://www.esf.edu/for/briggs/FOR345/erosion.htm. [Last accessed on 2020 Nov 20].

Chan, C. 1981. Conservation Measures in the Cultivated Slopes of

Taiwan. Food and Fertilizer Technology Center Taipei, Extension Bulletin, Taipei, p. 137.

Dabral, P. and N. Baithuri, A. Pandey. 2008. Soil erosion assessment in a hilly catchment of North Eastern India using USLE, GIS and remote sensing. Water Resour. Manag. 22: 1783-1798.

Eswaran, H., R. Lal and P. Reich. 2001. Land Degradation: An overview. Natural Resources Conservation Service Soils. Available from: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/use/?cid=nrcs142p2_054028. [Last accessed on 2020 Nov 20].

Foster, G., D. McCool, K. Renard and W. Moldenhauer. 1991. Conversion of the universal soil loss equation to SI metric units. J. Soil Water Consev. 36: 356-359.

Foster, G., L. Meyer and C. Onstad. 1977. A runoff erosivity factor and variable slope length exponents for soil loss estimates. Trans ASAE. 20: 683-0687.

Gobena, Y. 2003. Soil Erosion Assessment Using Remotely Sensed Data and Ancillary Data in the Desert of Tabernas, Southeast Spain, ITC, Netherlands.

Hashim, G. and N. Wong. 1988. Erosion from steep land under various plant cover and terrains. In: T. Tay, A. M. Mokhtaruddin and A. B. Zahari (Eds.), Steep Land Agriculture in the Humid Tropics, MARDI/Malaysian Society of Soil Science, Kuala Lumpur, pp. 424-461.

Laflen, J., L. Lane and G. Foster. 1991. WEPP-a next generation of erosion prediction technology. J. Soil Water Conserv. 46: 34-38.

McCool, D., G. Foster, C. Mutchler and L. Meyer. 1987. Revised slope steepness factor for the universal soil loss equation. Trans ASAE. 30: 1387-1396.

Mir, S., M. Gasim, S. A. Rahim and M. Toriman. 2010. Soil loss assessment in the Tasik Chini catchment, Pahang, Malaysia. Bull. Geol. Soc. Malays. 56: 1-7.

Moore, W. 1992. Length slope factor for the revised universal Soil Loss Equation: Simplified method of solution. J. Soil Water Conserv. 4: 423-428.

Moore, I. and G. Burch. 1986. Modeling erosion and deposition: Topographic effects. Trans ASABE. 29: 1624-1630.Morgan, R. 1986. Soil Erosion and Conservation. Longman, Harlow.

Nellemann, C., M. MacDevette, T. Manders, B. Eickhout, B. Svihus, A. Prins and B. Kaltenborn. 2009. The Environmental Food Crisis-the Environment's Role in Averting Future Food Crises. A UNEP Rapid Response Assessment. Available from: https://www.grida.no/publications/154. [Last accessed on 2020 Dec 10].

Panagos, P., P. Borrelli, K. Meusburger, C. Alewell, E. Lugato and L. Montanarella. 2015. Estimating the soil erosion cover-management factor at the European scale. Land Use Policy 48: 38-50.

Patel, V., M. Nowostawski, G. Thomson, N. Wilson and H. Medlin. 2013. Developing a smartphone "app" for public health research: The example of measuring observed smoking in vehicles. J. Epidemiol. Community Health. 67: 446-452.

Raento, M., A. Oulasvirta and N. Eagle. 2009. Smartphones: An emerging tool for social scientists. Soc. Method Res. 37: 426-454.Ramos, D. 1997. Walnut Production Manual. UCANR Publications, Oakland, Calif.

Rao, Y. 1981. Evaluation of cropping management factor in Universal Soil Loss equation under natural rainfall condition of Kharagpur, India. In: Proceedings of Southeast Asian Regional Symposium on Problems of Soil Erosion and Sedimentation, Asian Institute of Technology, Bangkok, pp. 241-254.

Roose, E. 1996. Land Husbandry: Components and Strategy. Vol. 70. FAO, Rome. Available from: http://www.fao.org/docrep/T1765E/t1765e0e.htm. [Last accessed on 2021 Jul 10].

Roose, E. 1977. Erosion et Ruissellement en AFRIQUE de L'Ouest: Vingt Années de Mesure en Parcelles Expérimentales Travaux et Documents. Vol. 78. ORSTOM, Paris, p. 108.

Schwab, G., D. Fangmeier, W. Elliot and R. Frevert. 1993. Soil and Water Conservation Engineering. 4th ed. John Wiley & Sons, Inc., New York.

Singh, G., R. Babu and S. Chandra. 1981. Soil Loss Prediction Research in India, Central Soil and Water Conservation Research and Training Institute, Dehradun, India.

SWAT. 2018. Theoretical documentation 2018. In: SWAT2012 Input/Output File Documentation. Ch. 22. SWAT, United States. Available from: https://www.swat.tamu.edu/documentation. [Last accessed on 2021 Jul 10].

Teh, S. 2011. Soil Erosion Modeling Using RUSLE and GIS on Cameron Highlands, Malaysia for Hydropower Development (Master's Thesis). RES, The School for Renewable Energy Science, Akureyri, Iceland.

Teshome, A, J. de Graaff, C. Ritsema and M. Kassie. 2014. Farmers' perceptions about the influence of land quality, land fragmentation and tenure systems on sustainable land management in the North Western Ethiopian highlands. Land Degard. Dev. 27: 884-898.

Tirkey, A., A. Pandey and M. Nathawat. 2013. Use of satellite data, GIS and RUSLE for estimation of average annual soil loss in Daltonganj Watershed of Jharkhand (India). J. Remote Sens. Technol. 1: 20-30.USDA. 1972. National Engineering Handbook, Section 4: Hydrology. USDA, Washington, DC.

Vila, S., R. Rodríguez-Carreras, D. Varga, A. Ribas, X. Úbeda, F. Asperó, A. Llausàs and L. Outeiro. 2015. Stakeholder perceptions of landscape changes in the Mediterranean mountains of the North-Eastern Iberian Peninsula. Land Degard. Dev. 27: 1354-1365.

Wischmeier, W. and D. Smith. 1978. Predicting rainfall erosion losses: A guide to conservation planning. In: USDA/Science and Education Administration, Agriculture Handbook No. 537. US. Goverment Printing Office, Washington, DC, p. 58.