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RUSLE-based soil erosion assessment and erosion control evaluation in the Kabul Watershed

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ABSTRACT

The development and conservation of water and soil in the Kabul River Basin are critical for ensuring its sustainable economic, social, and environmental progress. Since the watershed drains across the international borders into the Indus River Basin, it is key for both up- and downstream countries to thoroughly plan their resource development and management. Due to relief, soil and climatic conditions, as well as the recent deforestation the Kabul River Basin has been witnessing significant soil erosion by water, indicating the need for analyzing its specifics and deploying proper control measures. This study was carried out using the combination of the Revised Universal Soil Loss Equation (RUSLE) Model and GIS techniques to investigate the gross soil loss rates and their spatial distribution inside the target basin. Thus, the annual average soil loss rate was estimated at 15.1 tons/ha/year, pointing to severe local soil erosion. As to its spatial distribution, according to the study up to 99% of mean annual soil loss rates fell within the tolerable (0-5 tons/acre/year) category. Considering the soil loss rates, local topography, and community-based participatory approaches, the authors recommend conducting a further detailed diagnostic analysis to inform and support subsequent control measures such as deforestation prevention, construction of small check dams, terracing, trenching in hilly areas, revegetation (reforestation) of open- and grasslands, and rainwater harvesting.

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1. Introduction

Soil erosion and land degradation are among the most serious environmental challenges of the 21st century worldwide, greatly impacting Afghanistan with almost 80% of the population directly relying on the natural resources of respective basins to meet their daily needs (UNEP, 2004). Soil erosion causes loss of suitable soil, reduction of agricultural production, increased turbidity of streams and waterways, silting of rivers and reservoirs, as well as affects fish and agricultural production in multiple ways.

Due to its geographic location and arid to semi-arid climate, Afghanistan is highly vulnerable to soil erosion. The long-lasting war, recent deforestation, and continual drought have resulted in extensive environmental degradation throughout the country likewise posing a serious threat to the future livelihoods of Afghanis (UNEP, 2004). On the one hand, large-scale soil erosion in the last several decades has caused silting up of the reservoirs along the Kabul River. On the other hand, it is necessary to build new reservoirs and dams to ensure sufficient water supply for household, power generation, and irrigation purposes. Thus, erosion and sedimentation assessment at the basin level is necessary to verify the scale and severity of the situation.

The assessment data collected could be likewise used by designers and water resource engineers to effectively evaluate the life expectancy of proposed dams. As of today, there are no monitoring stations along the Kabul River to measure sediment, and most of the available sedimentation data are based on the surveys executed during 1960-1980s prior to dam construction. The large Kabul River Basin includes eight sub-basins, and the Kabul Sub-Basin is the largest watershed in terms of population and area among them (FAO, 2012).

Measuring the soil loss effects also helps verifying the investment in sustainable land management and appropriate soil conservation measures benefitting land users, including economically. However, farmers still resist adopting improved erosion control measures due to poor awareness of the immediate soil loss impacts on their livelihoods, as well as insufficient competencies to build soil conservation installations (Sahar, 2013). Both farmers and policymakers need to understand the importance of accurate soil loss measurements and the status of ongoing soil preservation efforts. Overall, the study's objective was to estimate soil erosion rates and evaluate anti-erosion control measures under soil conservation plans inside the Kabul Watershed. Specifically, the study was designed to model soil erosion based on the Revised Universal Soil Loss Equation (RUSLE) and assess soil and water conservation (SWC) facilities within the framework of the national water-sector strategies.

2. Materials and methods

2.1. Study area

The Kabul Sub-Basin is one of the major watersheds inside the large Kabul River Basin (Fig. 1.). It is the source of the Kabul River and is located in the central highlands of eastern Afghanistan (33.92° to 34.84° lat. and 68.37° to 71.19° long.). The sub-basin's catchment area amounts to 12,997 km^2, and hosts four provinces, including Kabul City (FAO, 2012).

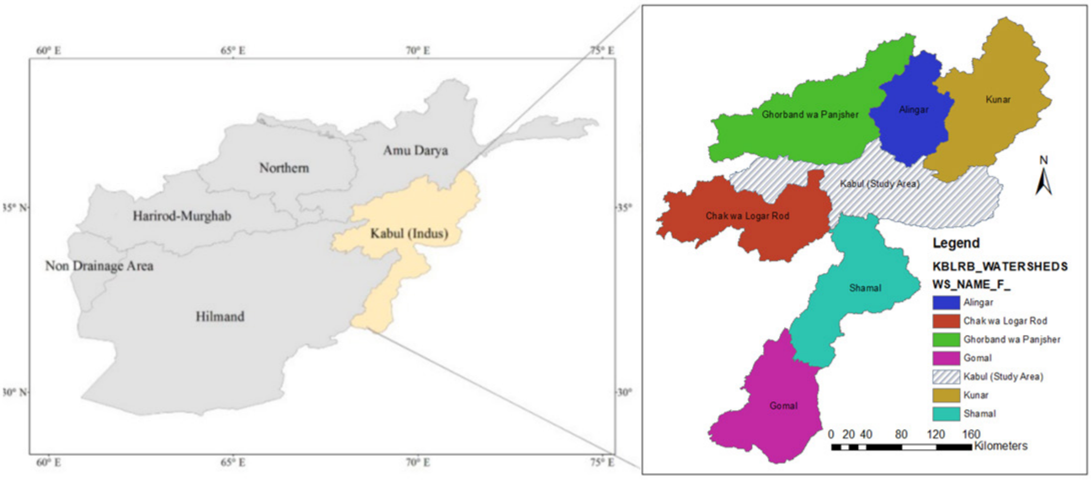

Figure 1. Kabul Watershed location and composition.

The Kabul Sub-Basin is largely dominated by rangelands (48%) and bare soils (31%). Irrigated land covers 10% of the total watershed's area, over half of which is suitable for double cropping, mostly in Nangarhar Province. Limited rainfed cultivation (0.3%) is also practiced in a few locations, e.g. near the Kotal-i-Khaikhana Pass (FAO, 2012). The local climate is arid to semi-arid. The rainfall is of monsoon type with 450 mm mean annual rainfall, 2/3 of which occur in February-April (Islamic et al., 2004).

2.2. Research methods

2.2.1. Data sources and use

The estimation of soil erosion based on the RUSLE model depends on a range of interdependent factors like rainfall erosivity, soil erodibility, slope length, slope steepness, cover management, and conservation practices. These factors can be well represented - temporally and spatially - using GIS techniques (Sahar, 2013). The adapted RUSLE model was selected due to its low data requirements and compatibility with ArcGIS 10.5. The mean annual rainfall distribution in the Kabul Sub-Basin was computed based on the 2009-2019 precipitation records (11 years) collected at 19 meteorological stations (Dakah, Pul-i-Behsood, Sultanpur, Pul-i-Qarghayi, Naghlo, Payin-i-Qargha, Qala-i-Malik, Gul Khana, Paghman, Sarobi, Darulaman, Badam Bagh, Pul-i-Surkh, Sang-i-Naweshta, Gardandiwal, Chamkani, Shokhi, Shakardara, and Nawabad). The monthly values were converted to mean annual rainfall and interpolated using the ordinary kriging method for the entire watershed. The *R*-factor was calculated as per equation (1) below recommended by Renard and Freimund for areas with $P<850$ mm (Lee, 2007).

$$R = 0.04830\, P^{1.61}, \quad (1)$$

,where *R* is the annual rainfall erosivity factor, and *P* is the mean annual rainfall (mm).

The soil erodibility factor is influenced by many soil properties and can reflect the soil resistance to erosion (S. I. Khassaf et al., 2018a). It is related to the integrated effect of rainfall, runoff, and infiltration on soil loss. The most crucial soil variables that control the *K*-factor include OM, clay content, bulk density, particle size distribution, shape, size and stability of aggregates, shear strength, porosity and permeability, and chemical composition. Yet, direct estimation of the *K*-factor is both expensive and time-consuming (Sahar, 2013). The *K*-factor values range from 0.02 to 0.69, with the low (approx. 0.05-0.15) values corresponding to high clay content soils, mainly due to their resistance to detachment (Sahar, 2013). Texture represents the principal factor affecting the *K*-values. Courser texture soils, such as sandy soils, have low (between 0.05 and 0.2) *K*-values due to low surface runoff caused by excessive infiltration, even though such soils are easily detached. Medium texture soils, for instance, silt loamy, demonstrate moderate (0.25 to 0.4) *K*-values explained by their moderate susceptibility to detachment and runoff (Manual et al., 2012). The soils with high silt content are the most erodible of all types; are easily detached, tend to crust, and produce significant runoff. The respective *K*-values usually exceed 0.4. Organic matter content reduces erodibility, decreases soil susceptibility to detachment, and boosts infiltration, in turn reducing runoff and erosion (Lee, 2007).

The soil data were provided by the Afghan Geodesy and Cartography Head Office (AGCHO). The digital soil map produced by AGCHO (published in September 2011) includes the soil texture classes for the Kabul Watershed area. The soil organic matter (SOM) datasets were obtained from the Soil Research Directorate of the national Ministry of Agriculture, Irrigation and Livestock (MAIL). The soil erodibility factor (*K*) was determined based on soil texture classes and SOM as defined by Schwab et al. (1981).

The digital elevation model (DEM) with 25m resolution was obtained from USGS (S. Khassaf & Al Rammahi, 2018). The slope length and steepness factors were calculated as per the following equations (Kouli et al., 2009):

$$L = \left(\frac{\lambda}{22.13}\right)^{m}, \qquad (2)$$

$$m = \frac{\beta}{(1+\beta)}, \qquad \beta = \frac{(\frac{sin\theta}{0.0896})}{[3(sin\theta^{0.8} + 0.56]} \qquad (3)$$

,where λ is the horizontal slope length (m), m is the variable slope length exponent, and θ is the slope angle.

The slope steepness factor (S) was calculated based on the following equations (McCool et al., 1987):

$$S = 16.8sin\theta + 0.03\ (for\ slope\ gradient\ \sigma < \ 9\%\ ) \quad (4)$$

$$S = 16.8sin\theta - 0.5\ (for\ slope\ gradient\ \sigma \geq \ 9\%\ ) \quad (5)$$

The C (Cover Management) factor shows the effect of vegetation cover on soil erosion. The FAO's 2015 Land Cover Map was used to determine the C-factor for the target watershed. Based on the map, the land cover classification inside the Kabul Watershed includes 16 classes. Thus, the C-factor was assigned to each land-use class from the literature review (FAO, 2012).

The Support Practice (P) factor ranges from 0 to 1. Due to the lack of proper support practices in place within the study area, the P-factor was assigned as 0.8 (S. Khassaf & Al Rammahi, 2018; S.I. Khassaf et al., 2018a).

2.2.2. Soil loss rate estimation

Combined with GIS, the RUSLE model manifests an effective tool for estimating soil loss based on five major factors, with each parameter as an arithmetic estimate of a specific condition affecting the severity of soil erosion in a particular location (Benavidez et al., 2018). RUSLE modeling is used to compute long-term mean soil losses from sheet and rill erosion. The model does not account for soil loss events caused by gully erosion and/or mass movements. The annual soil loss rate was calculated based on the cell-by-cell multiplication of the raster map of the six parameters as per the equation (Benavidez et al., 2018; Gis & David, 2014; Julien, 2004):

$$A = RxKxLxSxCxP \qquad (6)$$

,where A is the annual average soil loss rate (ton. acre^{-1}.year^{-1}), R is the rainfall-runoff erosivity factor (MJ.mm.ha-1.h-1.year-1) (note: since RUSLE requires input in the U.S. customary units, the values obtained based on the equations above were divided by 17.02 to obtain the properly denominated values (100ft.tons. inch.acre-1.h-1.year-1)), K is the soil erodibility factor (ton.acre.h.100ft-1.tons-1.

inch-1.acre^-1), *L* is slope length (dimensionless), *S* is the slope steepness factor (dimensionless), *C* is cover management (dimensionless), and *P* is the support practice factor (dimensionless). Fig. 2. below details the study methodology (Jung et al., 2017).

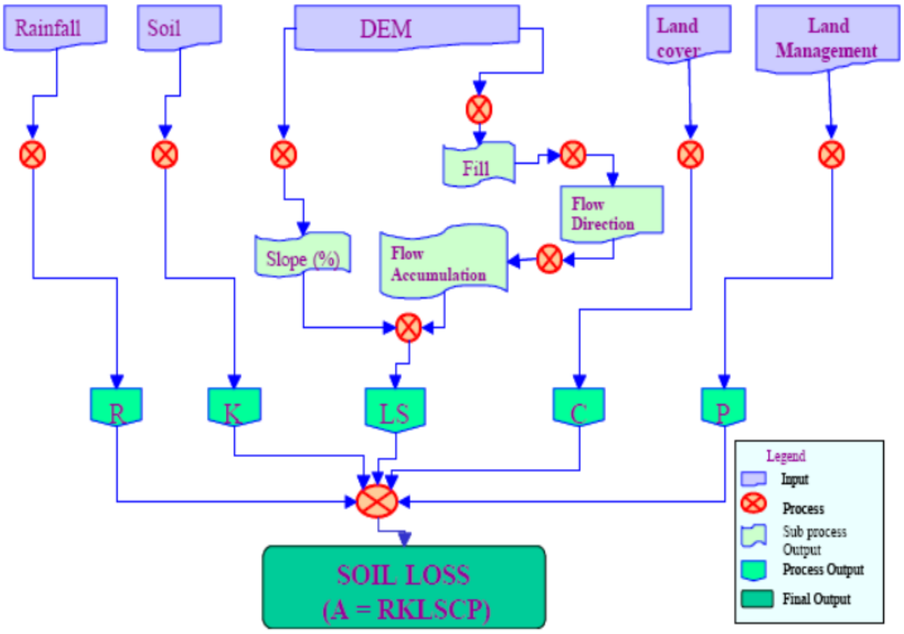

Figure 2. Research methodology conceptual framework.

3. Results

3.1. Rainfall erosivity factor (R)

In the Kabul Sub-Basin, the multi-year mean annual rainfall varies between 300 and 600 mm. The *R*-factor was determined as per Eq. 1 based on the mean rainfall data obtained from 13 stations inside the watershed area. Table I presents the rainfall-runoff erosivity factor for the rain gauge stations within the target basin.

Table I. Kabul Watershed rainfall-runoff erosivity factor (R).

#	Station	Location			Mean precip. in 2009-2019 (mm/year)	*R*-factor (MJ. Mm.ha^-1.h^-1. year^-1)	*R*-factor (100 ft.Tons. inch.acre^-1.h^-1. year^-1)	Comments
		Province	Latitude	Longitude				
1	Dakah	Nangarhar	34.230706	71.03855	251	353	21	Inside Kabul Watershed
2	Pul-i-Behsod	Nangarhar	34.442347	70.459831	217	280	16	
3	Sultanpur	Nangarhar	34.415669	70.295842	227	300	18	
4	Pul-i-Qarghayi	Laghman	34.546978	70.242489	264	382	22	
5	Naghlo	Kabul	34.637264	69.717036	276	412	24	
6	Payin-i-Qargha	Kabul	34.552539	69.035744	368	653	38	
7	Qala-i-Malik	Kabul	34.577458	68.970103	378	682	40	
8	Gul Khana	Kabul	34.506	69.202	305	484	28	
9	Paghman	Kabul	34.57500	68.98900	474	983	58	
10	Sarobi	Kabul	34.59500	69.75700	275	409	24	
11	Darulaman	Kabul	34.46000	69.12500	295	456	27	
12	Badam Bagh	Kabul	34.55000	69.11800	327	541	32	
13	Pul-i-Surkh	Wardak	34.36684	68.76965	272	401	24	
14	Sang-i-Naweshta	Kabul	34.41819	69.19113	324	532	31	
15	Gardandiwal	Wardak	34.50038	68.21266	294	455	27	Outside Kabul Watershed
16	Chamkani	Paktya	33.79588	69.81463	409	774	45	
17	Shokhi	Kapisa	34.93617	69.48439	313	503	30	
18	Shakardara	Kabul	34.68549	69.00362	465	952	56	
19	Nawabad	Kunar	34.81969	71.12032	434	853	50	

The estimated *R*-factor was used as point data in the watershed. Therefore, the *R*-factor for each data point was spatially interpolated using the ordinary kriging method in ArcGIS. Fig. 3. presents the iso-erodent map of the target basin, with the mean rainfall-runoff erosivity (*R*) factor ranging from 16.0 to 57.8 across the watershed.

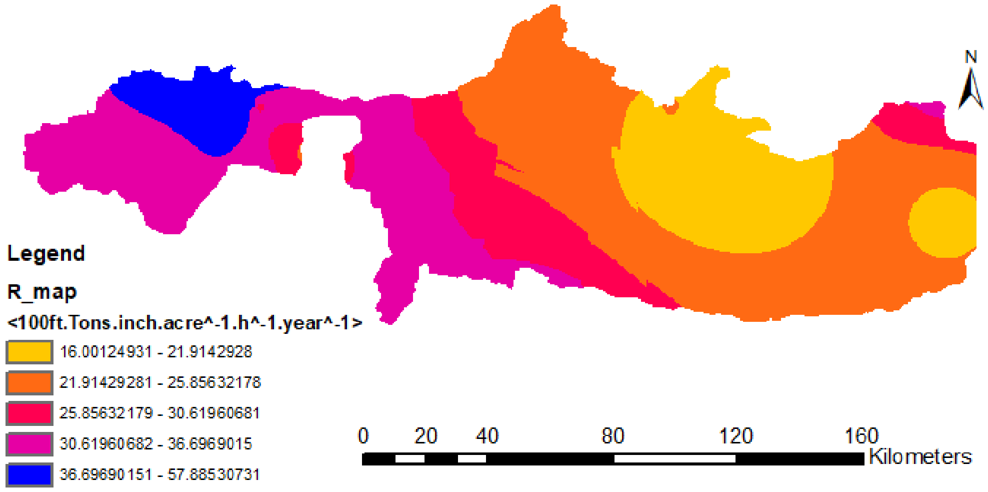

Figure 3. Study area rainfall erosivity distribution map.

3.2. *Soil erodibility factor (K)*

The Kabul Watershed soil map shape-file was obtained from the Afghan Geodesy and Cartography Head Office, demonstrating seven distinguishable soil zones each comprising several soil textures. In this study, the soil erodibility factors (*K*) for the target basin were defined based on the relationship between soil texture class and soil organic matter; due to the lack of basin-specific surveyed SOM data, it was assumed to be 0.5% (Table II below contains the corresponding *K*-values). After adding the soil map shape-file as a layer into ArcGIS, the soil map attribute table was edited, and the corresponding *K*-factors were assigned from Table II to each soil zone. Then, the shape-file was converted to grid form using the ArcGIS Conversion to Raster Tool (410m cell). Fig. 4. presents the watershed's soil erodibility (*K*) map.

Table II. Soil erodibility factor (K) of the Kabul Watershed soil zones.

#	Soil Classification	Soil texture	Mean *K*-factor (Ton. acre.h.100ft^-1. ton^-1.inch^-1. acre^-1)
1	Calcixeralfs with Xerochrepts	Silt loam with silty clay loam	0.42
2	Haplocambids with Torriorthents	Silt loam	0.48
3	Rocky land with Lithic Cryorthents	Bare rock with loamy very fine sand	0.22
4	Rocky land with Lithic Haplocambids	Rock with loamy very fine sand	0.22
5	Rocky land with Lithic Haplocryids	Rock with silt loam	0.24
6	Xerochrepts with Xerorthents	Silty clay loam with cobbly loam	0.32
7	Xerorthents with Xeropsamments	Cobbly loam with fine sand	0.22

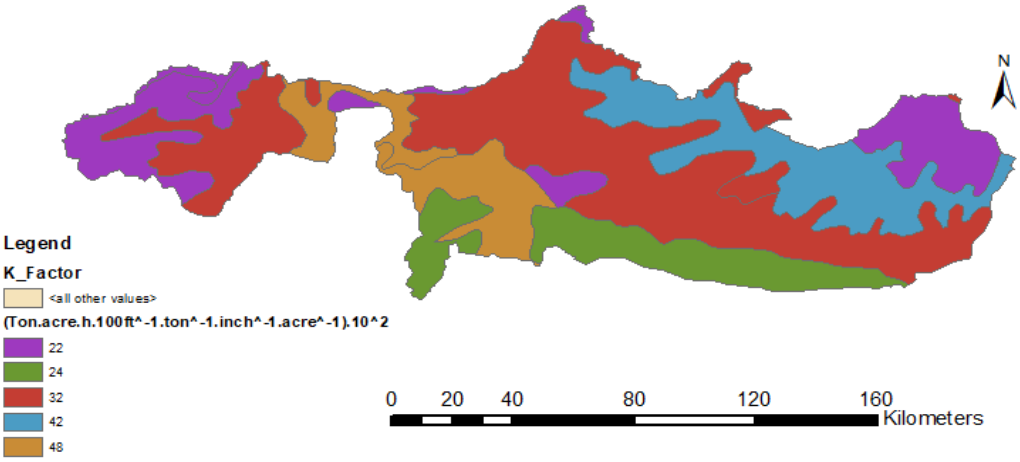

Figure 4. Soil erodibility (K) map of the Kabul Watershed.

3.3. *Slope length factor (L)*

The slope length factor indicates the impact of slope length on soil loss. Slope length is the horizontal distance from the origin of overland flow to the point where the runoff becomes concentrated. Whereas the mountainous and hilly Kabul Watershed demonstrates high *L*-values, the rest of the study area have relatively low *L*-factors (Hickey, 2000; S. Khassaf & Al Rammahi, 2018). The *L*-factor was calculated based on equations (2) and (3) using the ArcGIS Map Algebra Tool. Fig. 5. shows the *L*-factor map of the target watershed.

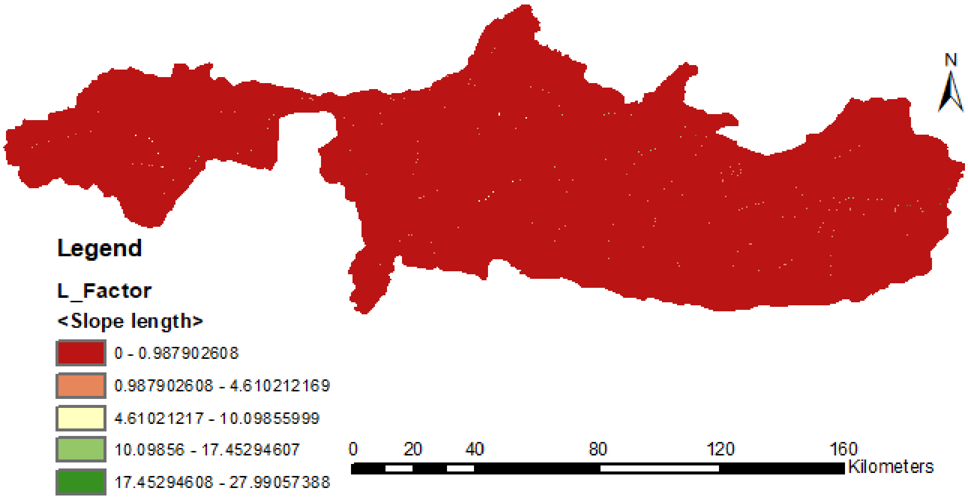

Figure 5. Slope length factor (L) map of the Kabul Watershed.

3.4. Slope steepness factor (S)

Slope steepness factor is defined as the ratio of soil loss from the field slope gradient to soil loss from 9% slope under otherwise identical conditions (Folliott et al., 2013; S. Khassaf & Al Rammahi, 2018; S. I. Khassaf et al., 2018b). As the slope steepness (S) increases, the velocity and soil erosion of surface runoff also grow. The slope steepness factor for the Kabul Watershed was calculated as per equation (5) using the ArcGIS Map Algebra Tool. Fig. 6. below presents the corresponding *S*-factor map.

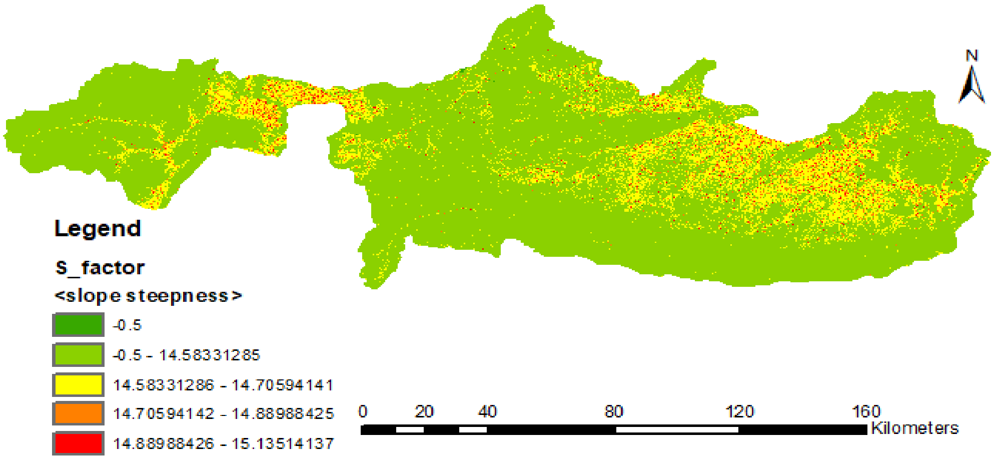

Figure 6. Slope steepness factor (S) map of the Kabul Watershed.

3.5. Crop cover and management factor (C)

The cover management factor (*C*) represents the effect of vegetation cover on soil erosion. The *C*-factor is dimensionless, with values ranging between 0 and 1. The *C*-value is 1 when an area has continuous bare fallow land with no vegetation cover, and it is below 1 in case of better vegetation cover resulting in lower soil erosion (Kuenstler, 1998). There are two methods to estimate the *C*-factor – time-variant and time-invariant. Since in the Kabul Sub-Basin about 2/3 of the annual precipitation are concentrated in the first 3 months (February-April) of the year, and over 2/3 of the basin are covered by rangelands and barren soil, the study team selected the time-invariant track. Based on the UN-FAO National Land Cover Map (2015), the Kabul Watershed has 16 corresponding classes. Thus, the crop management factor (*C*) was assigned for each land-use class from literature reviews. The *C*-values of each land-use class were processed in ArcGIS to build the *C*-factor map for the target basin (Sahar, 2013) presented in Fig. 7. below.

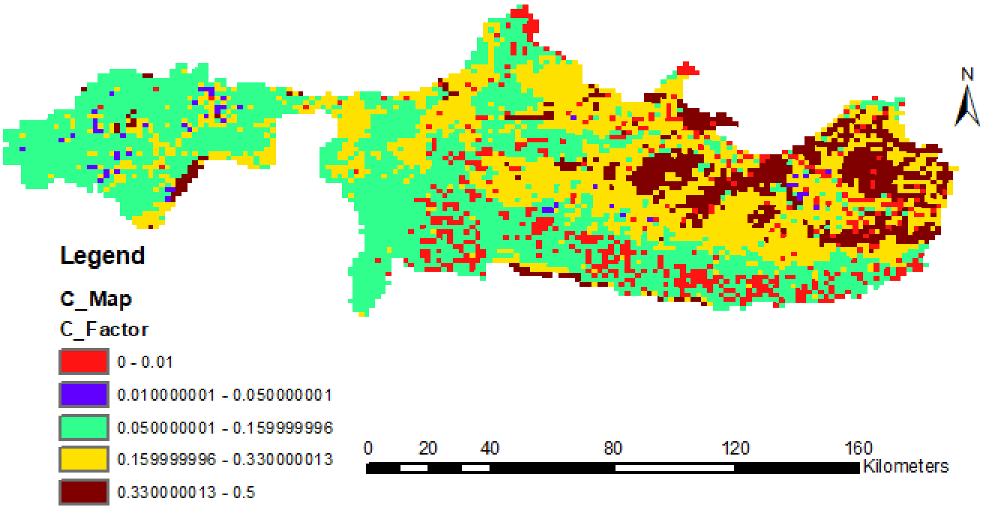

Figure 7. Crop management factor (C) map of the Kabul Watershed.

3.6. Erosion management practice factor (P)

Ranging from 0 to 1, the *P*-factor principally affects erosion by adjusting the flow pattern, steepness, or direction of surface runoff, as well as by reducing the runoff amount and rate (Folliott et al., 2013). It equals 1 when the land is directly plowed on the slope, and is below 1 when the adopted conservation practices reduce soil erosion. Terracing and contouring are common and effective support practices on the field level. As per field assessment, no proper support practices were in place within the study area, except for some small-scale recently implemented efforts. Therefore, the *P*-value for the Kabul Watershed was assigned as 0.8 (Panagos et al., 2015).

3.7. Mean annual soil loss estimation

The obtained values for all six parameters in the Kabul Watershed were as follow:

1. Rainfall-runoff erosivity factor (*R*): 16-57.8;
2. Soil erodibility factor (*K*): 0.22-0.48;
3. Slope length factor (*L*): 0-27.99;
4. Slope steepness factor (*S*): -0.5-15.13;
5. Cover management factor (*C*): 0-0.5;
6. Support practice factor (*P*): 0.8

To estimate the mean annual soil loss rate for the target basin, the above 6 parameters were multiplied using the raster calculation tool. Fig. 8. presents the corresponding mean annual soil loss rate map; the mean annual soil loss was estimated at 6.12 tons/acre/year (15.11 tons/ha/year).

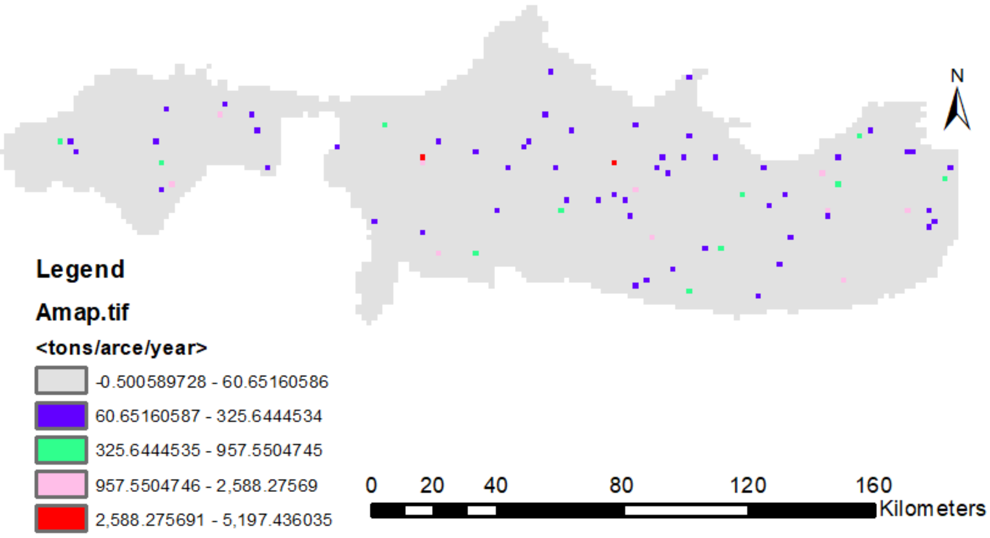

Figure 8. Mean annual soil loss rate map of the Kabul Watershed.

Most parts (98.53%) of the watershed fall within the low-severity class contributing to 1.24-149.87 tons/ha/year of the total estimated annual loss. The entire basin area was broken into five categories; the percentage for each of them is presented in Fig. 9. below.

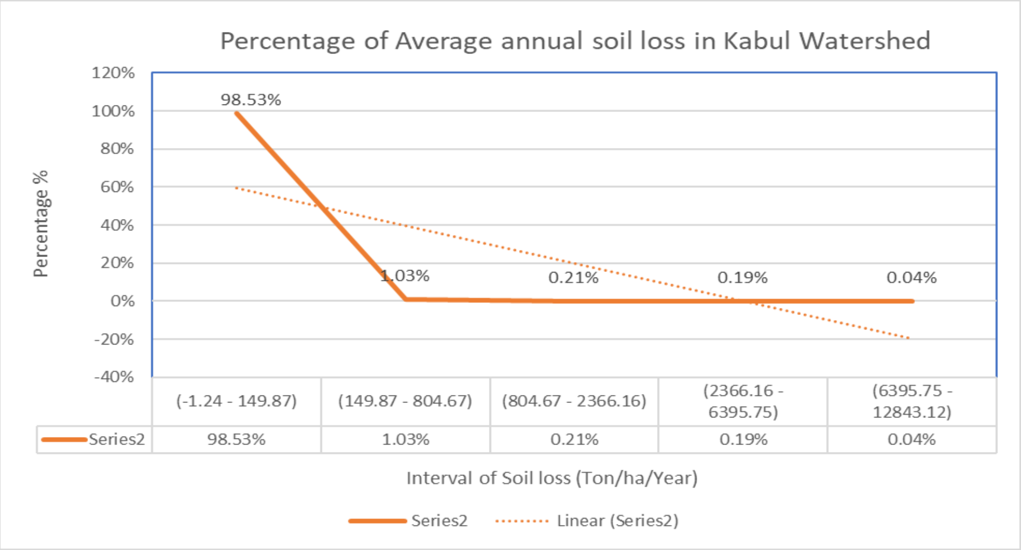

Figure 9. Percentage intervals of annual average soil loss rates in the Kabul Watershed.

Evaluation of soil conservation installations

As per the information obtained from local communities and Kabul River Sub-Basin Directorate, there are only 51 check dams across the watershed; and in some hilly zones, trenches (small ponds) are present performing below the required practices as per the corresponding annual soil loss rates. Local farmers practice contour cultivation and use dry stone terraces, which are damaged and can no longer contribute to erosion control. The number of check dams and small ponds constructed across the study area covers only its small share, again below the required conservation measures based on the technical standards. In addition, the study revealed that the existing check dams were extremely inefficient in terms of soil erosion control, as most of them were located along streams, and the distances between check dams were larger than recommended. The majority of operating check dams failed against the design technical standards.

Considering the severity of soil loss, topographic characteristics of the Kabul Watershed, and feasibility of local-level implementation, the authors recommend the following soil preservation actions (Gabriels et al., 1998; Manual et al., 2012; Molla & Sisheber, 2017):

a. Immediate stabilization of the zones featuring extremely high soil erosion (Fig. 8.);
b. Prevention of deforestation and illegal logging in forest plantations and natural woods;
c. Construction of small check dams along gullies;
d. Terracing and trenching in hilly zones;

e. Revegetation of open- and grasslands;
f. Deployment of rainwater harvesting techniques;
g. Actions to maintain operating infrastructure and forest/vegetation cover.

4. Discussion

Soil erosion poses the highest threat in the central highlands of Afghanistan, stimulating siltation of existing reservoirs along the Kabul River. In this study, spatial soil loss rates were determined using the RUSLE model. The efficiency of soil conservation facilities was evaluated based on the feasibility of their execution with the engagement of local communities. RUSLE represents an effective tool to assess the potential soil erosion in a watershed (Jung et al., 2017). As per the model, the calculated annual soil loss spatial distribution in the target basin ranged from 1.23 to 12,833.16 ton/ha/year, i.e. above the tolerance level. The findings of this research closely reflect the sedimentation data provided by Afghanistan's National Water Affairs Regulatory Authority (NWARA).

The sediment yield data obtained from NWARA was harvested from six monitoring stations inside the study area (Table III). The observed data were provided in tons/day, and were subsequently converted to tons/ha/year based on the actual area related to each station to make the data compatible with the RUSLE generated outputs.

Table III. Sediment yield data obtained from NWARA.

#	Station	Location	Latitude	Longitude	Watershed area (mi^2)	Sediment yield (tons/ day)	Sediment yield (tons/ ha/year)
		Province					
1	Dakah	Nangarhar	34.230706	71.03855	26,011.70	1,772.7	0.10
2	Pul-i-Behsod	Nangarhar	34.442347	70.459831	14,278.05	424.2	0.04
3	Naghlo	Kabul	34.637264	69.717036	10,056.41	119.4	0.02
4	Payin-i-Qargha	Kabul	34.552539	69.035744	760.62	0.16	0.00
5	Qala-i-Malik	Kabul	34.577458	68.970103	26.64	25.5	1.35
6	Pul-i-Surkh	Maidan Wardak	34.366842	68.769653	503.86	4.7	0.01

Based on Vanoni equation (1975), the relation between sediment delivery ratio and watershed area was calculated as follows (Folliott et al., 2013; Julien, 2004; Sahar, 2013):

$$S_{DR} = 0.42A^{-0.125} \tag{7}$$

,where A is watershed area (mi^2).

As per the above equation, the sediment delivery ratio was calculated for each station; and based on Julien equation (2010), the sediment delivery ratio could therefore be expressed as follow:

$$Y = S_{DR} * A_t \qquad (8)$$

,where S_{DR} is the sediment delivery ratio, Y is sediment yield, and A_t is gross erosion per unit area above a measuring point (Folliott et al., 2013; Sahar, 2013).

The sediment data obtained from NWARA stations were compared against these calculated using RUSLE (Fig. 10.), pointing to their extremely high correlation (overall, coefficient of determination (R^2) amounting to 0.91), with only one 43% increase by RUSLE, potentially due to different factors, such as varying deposition of sediment yield along the river at different stations.

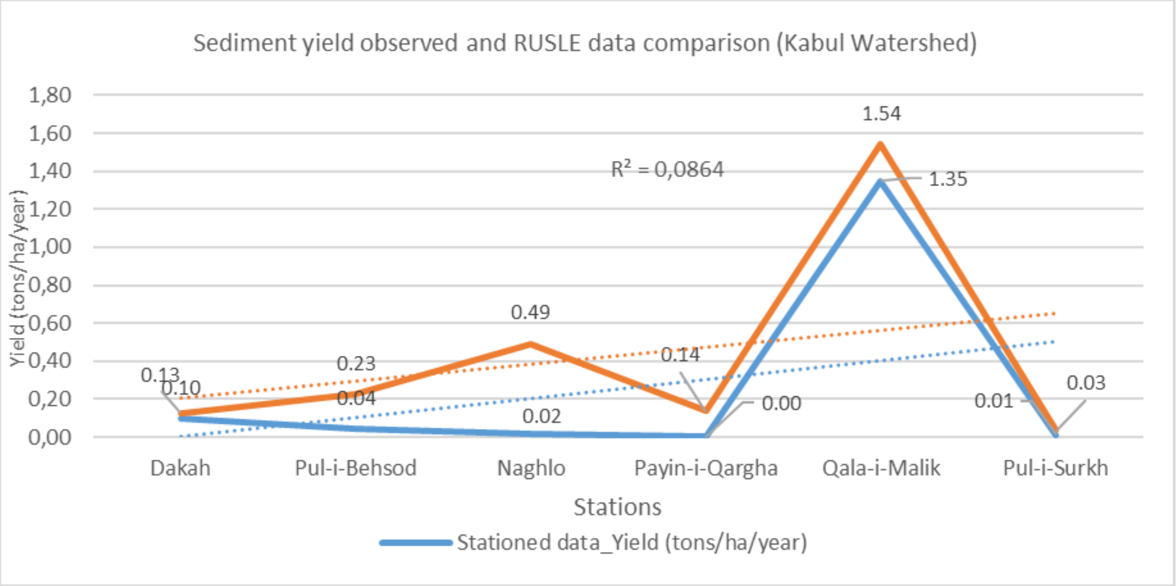

Figure 10. Comparison of observed and RUSLE sediment yield data for the Kabul Watershed.

In addition, recently NWARA had executed several small-scale targeted soil water conservation interventions, i.e. check dams and terraces, in certain hilly zones of the Kabul Watershed. Although the actions did not lead to sustainable land resource management per se, they still demonstrated high soil erosion control efficiency. In some cases, the corresponding installations were built based on the food-for-work approach, and the farmers decided on the location and other design parameters themselves. As the result, some of them were dismantled and no longer contribute to soil-water conservation, as well as require proper maintenance due to their vulnerability to livestock damage, intensive rainfall, and siltation. In general, deforestation, over-grazing, climate change, road and mining activities, and poorly designed soil-water conservation facilities are the main causes of severe soil erosion in the study area. Therefore, to stabilize land and control land degradation, soil conservation measures should be selected based on consultations with local communities and broad stakeholder participation.

5. Conclusions and recommendations

GIS-based RUSLE model represents an extremely effective technique to estimate watershed-based soil loss rate in data-scarce regions like Afghanistan. For the Kabul Sub-Basin, the model predicted the mean annual soil loss at 15.11 tons/ha, with the total loss of 123 mln tons/year across the entire study area. The study allowed revealing the sites with severe erosion (steep-slope hills, mountains, and river banks) with fragile soils prone to scouring, as well as the fact that erosion mostly occurred in the form of rills and sheets in hillside and steep mountains. Comparing the sediment yield data from gauge stations, the sediment delivery ratios were calculated and ranged from 12-19%; based on the estimates, the observed sediment yields across the target watershed fell within a similar range of predicted values.

This study showed severe soil erosion in the Kabul Watershed due to the majority of its area covered with rangelands, which can potentially curb agricultural productivity and exacerbate reservoir siltation. The national government and natural resource management authorities should focus on building soil-water conservation infrastructure across the target basin, as well as mainstreaming proper land management practices across the country to ensure sustainable nature use. To achieve these goals, the authors propose the following specific recommendations:

Establish a comprehensive hydrology and hydrometeorology data management center to enable more accurate and effective research;

Conduct comprehensive soil survey across the country to understand the current soil properties and features to render information support to farmers, land use planners, engineers and scientists;

Update the national Land Use/Land Cover Atlas based on observed and remote sensing datasets; the currently used Atlas was published by FAO in 2015 to strengthen agricultural information and statistics services in the country;

Design and build a sediment monitoring gauging network covering all main domestic rivers to expand and maintain sediment supply and transport database;

Enhance management of domestic river basins, including conduct a preliminary assessment of all river sub-basins, prioritize areas based on specific criteria, and subsequently design and implement engineering as well as agronomic projects.

The study has revealed that the Kabul Sub-Basin is largely (48%) dominated by rangelands, generally uncultivated and more vulnerable to erosion. Besides other factors, lack of adequate irrigation water and climate change manifest the key drivers of extensive rangeland zones inside the target watershed. The authors recommend converting the rangelands into irrigated farmland by introducing modern irrigation (drip, sprinkler) technologies, including imported farming technologies, to increase agricultural productivity.

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