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Assessing the Threat of Erosion to Nature-Based Interventions for Stormwater Management and Flood Control in the Greater Accra Metropolitan Area, Ghana

Joel Kofi Asiedu[1]

[1] Landscape Architecture and Regional Open Space, Technische Universität München, Emil-Ramann Str 6. D-85354 Weihenstephan-Freising, Germany, e-mail: klartlands@yahoo.com

ABSTRACT

Perennial flooding has become a major feature in urban areas in developing economies generating research interest towards finding alternative approaches to stormwater management which could complement the existing systems and help address the challenge of flooding. One of such alternative approaches is nature-based stormwater management and flood control, the implementation of which could be affected by soil erosion. This paper, as part of a wider research, was developed to determine the extent of the threat of soil erosion to stormwater management in an urban area on the example of Greater Accra Metropolitan Area, Accra Ghana as the focus of the research. Landsat 8 images (2014) were used in the research to prepare the Landcover maps. Daily rainfall data from 6 raingauge stations from 1972 to 2014 were utilized to prepare the rainfall erosivity factor maps, whereas DEM was used to prepare the slope and slope length (SL) factor maps. The land cover map with an overall accuracy of 73.6 and Kappa 0.7122 was combined with literature sources to prepare the vegetative cover factor map, and conservation practice factor map. A soil series map, prepared and updated with literature sources and data from the Harmonized World Soil Database on physical parameters, was used to calculate the soil erodibility factor (K factor) for each soil series. These were integrated into RUSLE model as 30 m raster maps to generate a soil loss map at tons/ha/yr. The results produced rainfall erosivity index values based on the modified Fournier index ranging between 0.058 and 23.197 which is classified as low. Low soil erodibility factor (K) ranging between 2.9×10^{-5} and 8.5×10^{-2} t ha/MJ mm indicated low susceptibility to erosion, SL factor value showing areas of low to almost flat relief with a few isolated areas of moderate slope length were generated. A soil loss of 69,5918 tons/ha/yr classified the soils as having high potential soil loss. The results showed a very low soil loss threat of 0–5.1853 tons/Ha/yr for more than 90% of the study area. Targeted intervention for source areas with high potential soil loss will contain any threat of erosion and sediment yield to the implementation of an infiltration-based stormwater management and flood control system.

Keywords: RUSLE model, soil loss, clogging, infiltration, stormwater management

INTRODUCTION

The Greater Accra Metropolitan Area (GAMA), the most densely populated urban area in Ghana, like most urban areas in Sub-Saharan Africa, experiences perennial floods which constitute an annual event [ILGS/IWMI, 2012; Karley, 2009; Kayizzi-Mugerwa, 2017; B.K Nyarko, 2002]. The risk of flooding defined as the probability of a flood happening and its impact [Gyekye, 2011, p. 201] causes fear each time the clouds gather, resulting in loss of life and property, destruction of public infrastructure, it also creates perfect conditions for outbreaks of diseases, has adverse socio-economic impact, including slow down of transportation and economic activity and is considered one of the major factors affecting Africa's urban development [Atuguba, 2006, p. 10; Bhattacharya-Mis, 2011, p. 2; Gyekye, 2011, p. 204; 2013, p. 65; ILGS/IWMI, 2012, pp. 2,4; Tengan, 2016, p. 498]. Several approaches have been proposed to address the flooding challenge [Tengan, 2016, p. 498], including identifying and mapping flood risk zones [Nyarko, 2000, p.

1040], identification of flood prone areas for effective flood management [Twumasi, 2002, p. 2875], public education on flooding, community involvement in infrastructural and land-use planning and enforcement of bye-laws on building permits [ILGS/IWMI, 2012, pp. 80–81; Karley, 2009, p. 40], develop a holistic approach to the flooding problem [Karley, 2009, p. 39]. However, one approach which holds great promise and has become popular in both the developed and developing countries, is the nature-based approach to the stormwater management and flood control, which is known under several names, including Low impact development (LID), Green infrastructure (GI), sustainable urban design systems (SUDS), best management practice (BPM), decentralized rainwater/stormwater management (DRWM), integrated urban resource water management (IURWM), water sensitive urban design (WSUD) [Hoyer, 2011, pp. 15–16]. In this paper, I have chosen to describe it as nature-based stormwater management. The underlying principle behind this approach is the source control of storm water runoff which combines storage and infiltration based technologies with evapo-transpiration to control flooding [Chouli, 2007, p. 62; Hoyer, 2011, p. 14; Lim, 2016, pp. 843–844]. However, a successful implementation of such an approach could be seriously affected by siltation which is directly related to the erosion potential of soils.

Soil erosion is of much concern, as urbanization – with its attendant pressure – has lead to the removal of vegetational cover which protects the soil from the direct impact of rainfall and wind. Thus, soils free of the protective vegetative cover become susceptible to soil erosion [PWUD, 2006, p. 56]. Rainfall induced erosion is a major contributing factor to soil loss and movement [Okorafor, 2017]. It is affected by the dispersive or erosive action of rain, which is a function of rainfall characteristics in terms of volume, duration and intensity (rainfall erosivity) and the physical properties and management of the soil (soil erodibility) [Costea, 2012, p. 313; Oduro-Afriyie, 1996]. Where soil is eroded by the action of rainfall, rainfall runoff dislodge and transport individual particles from a soil aggregate which are eventually deposited to form new soil or fill lakes and reservoirs by siltation [Okorafor, 2017; Rahaman, 2015, p. 207]. Thus, soil loss due to erosion and sedimentation or siltation are closely related [Kamaludin, 2013, p. 4569] requiring a quantitative assessment to determine the magnitude and extent for effective management strategies to be introduced [Rahaman, 2015, p. 207].

Surface clogging due to sedimentation has been linked to poor performance and even failure of most nature-based storm water management systems which depend on detention, retention or some form of infiltration [Industries, 1993, p. 13; Urbonas, 2000]. Le Coustumer explained that sediment deposition is the principal cause of clogging and occurs when runoff carrying eroded soil in the form of fine soil particles fill pore spaces of filter media to cause an infiltration-based retention system to fail [Le Coustumer et al., 2008, p. 20]. Most infiltration-based stormwater management systems have failed as a direct result of this phenomenon [PWUD, 2014, pp. 8–7]. Although various management practices may be introduced to reduce erosion, control siltation and surface clogging, these may be infective, usually expensive and inconvenient [Palmer, 2014, p. 69].

Erosion potential of soils in the focus study area is described as usceptible to severe erosion [Oppong-Anane, 2006, p. 6] with adverse effect on soil physical properties including infiltration rate [Obalum, 2012, p. 2]. An earlier work by the Soil Research Institute of Ghana estimated that at least 23% of the country is at risk of very severe erosion from sheet and gully erosion, and 29.55% is at risk of slight to moderate sheet erosion [Baatuuwie, 2011, p. 103]. Given this background, this part of the research aims to assess the overall erosion potential of the focus study area and to determine to what extent erosion could be a challenge to the implementation of an infiltration-based stormwater management system. Combining the data from the local sources and literature, the level of soil erosion in the study area was determined through the RUSLE soil loss model, which has been widely used to predict soil loss due to sheet and rill erosion [Kamaludin, 2013, p. 4569; Silva da, 2010, p. 8].

MATERIALS AND METHODS

The study adopted part of the Greater Accra Metropolitan Area (GAMA), a densely populated urban area in Accra-Ghana as the focus of the research. The focus area covers 5 administrative districts within GAMA and lies within Long. 5.804253 and 5.492637 dd West and Lat. 0.527292 and -0.082525 dd North, covering a total land mass of 900 km^2. The climate is described as Coastal Savannah with two rainy seasons of unequal intensity, averaging 730–800 mm per annum. The soils in the area have developed on thoroughly weathered parent material with alluvial soils and eroded shallow soils [Oppong-Anane, 2006, p. 4].

Daily rainfall data covering the years 1972 to 2015 from 6 rain gauge stations with coordinates and elevation were obtained from the Ghana Meteorological Services Department (Fig. 1). These data were used to create a rainfall erosivity map for the rainfall erosivity factor. A detailed soil map for the study area at the soil series level was prepared by combining different maps and using literature to assign physicochemical attributes to the soils including silt, clay, fine sand, sand, and organic matter content, which were used to create a soil erodibility factor (K). The P factor, conservation practice was built in a similar manner. A vegetative cover factor (C) was created using Landsat8 images downloaded from the USGS web site. A 30 m resolution DEM map for the entire country was obtained and clipped to the study site and used to determine the Slope and Slope length factor (SL).

The RUSLE model was used to estimate the rate of soil loss per annum using the formula based on [Kusimi, 2015; Owusu, 2012; Shamshad, 2008];

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

where: A – is rate of soil loss (t/ha/yr)
R – is rainfall runoff erosivity factor (MJ mm ha /h/yr)
K – is soil erodibiility factor (t h MJ^{-1} mm^{-1})
LS – slope length and steepness factor (%)
C – vegetation cover factor (dimensionless)
P – conservation practice factor (–)

Rainfall erosivity factor (R): Rainfall erosivity is the erosive force of rainfall [Essel, 2016] and is defined as the aggressiveness of rainfall to induce erosion of soils [Sholagberu, 2016]. This factor is of paramount importance in its effect on soil erosion due to the ability of rain to dissolve, loosen, or wear away soil by the force of raindrops or runoff [Essel, 2016; Okorafor, 2017; Sholagberu, 2016]. It is thus used to quantify the effect of raindrop and induced runoff on bare soil [Efthimiou, 2014]. It was calculated using the daily rainfall values summarized as monthly and

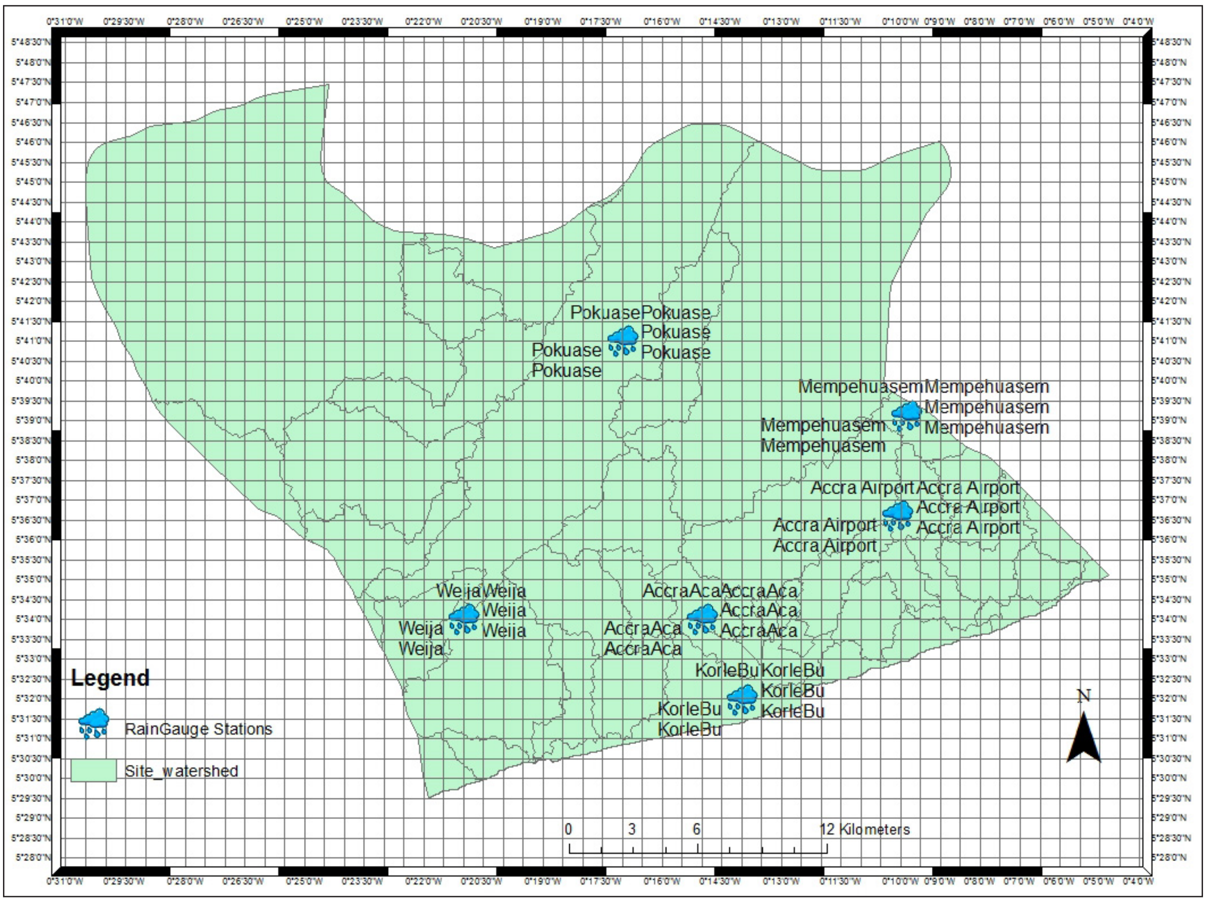

Fig. 1. Spatial distribution of rain gauges within study site

annual rainfall based on similar approaches used or reported by [Efthimiou, 2014; Okorafor, 2017; Rahaman, 2015; Sholagberu, 2016; Ufoegbune, 2011]. A rainfall erosivity index was calculated from the summaries using the modified Fournier index [Essel, 2016] and the resulting values were used to prepare a map. The preparation of the map involved the following:

- summarizing the daily rainfall data from each raingauge station as monthly and annual rainfall levels,
- calculating an index of rainfall erosivity using the modified Fournier index (MFI) by means of the formula;

$$MFI = \sum_{i=1}^{12} \frac{Pi^2}{P} \tag{2}$$

where: Pi is the monthly rainfall amount for the ith month (mm) and P is the annual rainfall mount (mm) [Essel, 2016].

- loading the rainfall summaries as an Excel.cv file in Arcmap and using the interpolation tool “Kriging” to prepare a map based on the rainfall erosivity index values [Kamaludin, 2013, p. 4571].

The resulting map (rainfall erosivity index map) was clipped to the site and exported into a .gdb as a 30 m raster file (Fig 2).

Soil erodibility factor (K): This factor is used as a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. A high value means the soil is more prone to erosion [Kusimi, 2015] and will probably have high suspended sediment load [Efthimiou, 2014]. Its value varies from 70/100 for the fragile soil which are highly susceptible to erosion to 1/100 for the most stable soil which are least susceptible [Tallis, 2011]. A detailed soil map at the soil series level was prepared for the study area. The literature sources, combined with data from the Harmonized World Soil Database (HWSD), were used to build a physicochemical data base for each of the soil series showing silt, fine sand, clay and organic matter content (%) (Table 1). This, in turn, was used to calculate the K value for each of the soil types (Table 1) by means of the formula adopted from Tallis *et al.*, [Tallis, 2011, p. 241];

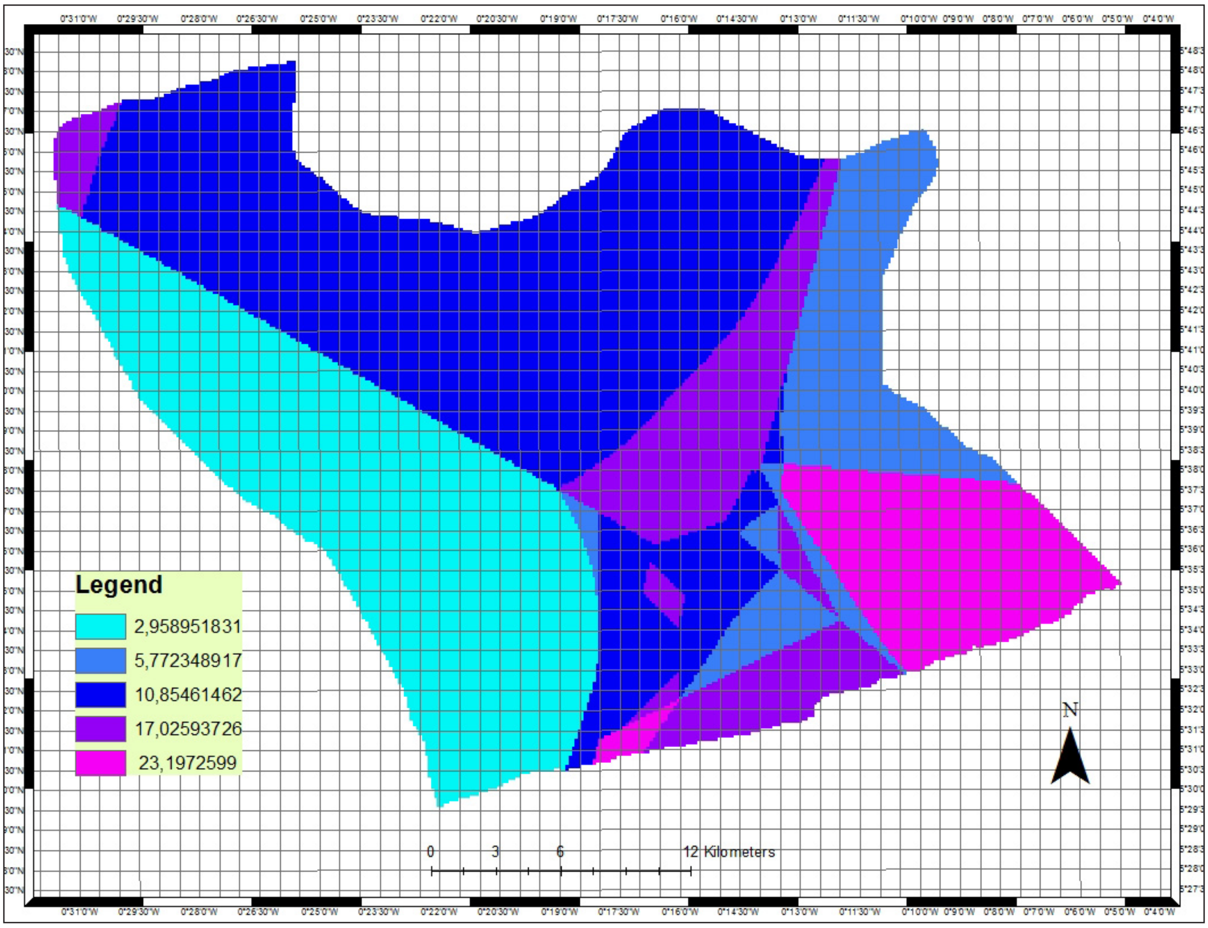

Fig. 2. Rainfall runoff erosivity factor (R factor) map

$$K = 27.66 \times m^{1.14} \times$$
$$\times 〚10〛 \text{^}(-8) \times ((12 - a) + \quad (3)$$
$$+(0{,}0043\ (b-2)) + (0{,}0033(c-3)$$

where: K – is soil erodibility factor (t ha/MJ mm);
m = (%silt + % very fine sand) × (100 – %clay);
a – % organic matter;
b – structure code: very structured or particulate (1), fairly structured (2), slightly structured (3), and solid (4),
c – profile permeability code: rapid (1), moderate to rapid (2), moderate (3), moderate to slow (4), slow (5), and very slow (6).

The calculated K values were used to populate the attribute table of the soil map to prepare the K factor map using the K values as the value field. The resulting K factor raster map at 30 m resolution was prepared in ArcGIS using the K as the value field (Fig. 3).

Slope length and steepness factor (SL factor): This factor reflects the effect of topography on erosion [Kamaludin, 2013]. High values indicate high values of runoff volume and velocity [Efthimiou, 2014]. Slope length (L) is measured in meters while the angle of slope or slope steepness (S) is measured in percentage. This factor was derived and adapted for use in ArcGIS using the equation based on [Lahlaoi, 2015];

$$LS = \left(FA \times \frac{CS}{22.13}\right)^m \times$$
$$\times (0.065 + 0.045 \times S + (0.0065 \times S^2)) \quad (4)$$

This was applied in Arcmap 10.1 using Map Algebra to obtain the SL. Where LS is – slope length and steepness factor; FA – flow accumulation; CS – cell size; m – a constant dependent on the value of the slope gradient (given as 5%); S – angle of slope [Lahlaoi, 2015, p. 132].

As far as derivation of individual parameters in the formulae is concerned, FA and S were derived from a DEM with 30 m cell size using Arcmap Spatial Analyst tool. The result is a map showing steepness and slope length (Fig. 4).

Vegetative cover factor (C factor): This represents a reduction factor to soil erosion vulnerability due to the shielding effect of vegetation which absorbs, dissipate energy from rain drops and runoff and increases infiltration [Efthimiou, 2014; Lahlaoi, 2015]. The C factor is closely associated with land use types [Kamaludin, 2013; Lahlaoi, 2015]. For this research, the land cover maps where prepared from 2014 Landsat8 images. The ArcGIS 10.1 classification tool (maximum likelihood or interactive supervised classification tools) was used to develop and catego-

Table 1. Soil series with corresponding calculated K factor values for the major soils of the study site

Soil type	Silt(%)	Fine sand	Clay (%)	M value	OM% (a)	Structure (b)	Permb (c)	K factor
Oyarifa Mamfe	13.3	34.9	8.5	4,410.3	2.13	2	3	0.038982
Korle-Adentan	3.4	66.2	30.4	4,844.16	7.74	2	4	0.018739
Nyigbenya	17.7	98	0	115.7	1.14	2	2	0.000676
Alajo	8.4	79.1	12.5	7,656.25	4.99	2	5	0.05197
Sakumo	54	35	11	7,921	2.064	2	5	0.07655
Danfa-Dome	42	35	24	5852	2.167	2	5	0.053648
Fete	42	35	23	5,929	2,167	2	1	0.05438
Bediesi	25	32	12	5.0164	0.91	–	3.5	0.0507
Adawso-Bawjiase	14	1	30	1050	2.31	2	3.5	0.007454
Ayensu-Chichiwere	16	74	10	8100	1.204	2	1	0.085216
Nyanao-Opimo	16	74	10	8100	1.204	2	3	0.085268
Keta	54	35	11	7921	2.064	2	3	0.0765
Simpa-Agawtaw	13.5	27.3	7	3794.4	0.58	2	2.5	0.03799
Oyibi-Muni	46.4	3.2	50.4	2460.16	5.10	2	5	0.01402
Songaw	54	35	11	7921	2.064	2	5	0.000029
Chuim-Gbegbe	54	35	11	7921	2.064	2	3.5	0.000029
Sango	54	35	11	7921	2.064	2	5	0.000029
Chemu	54	35	11	7921	2.064	2	5	0.000029

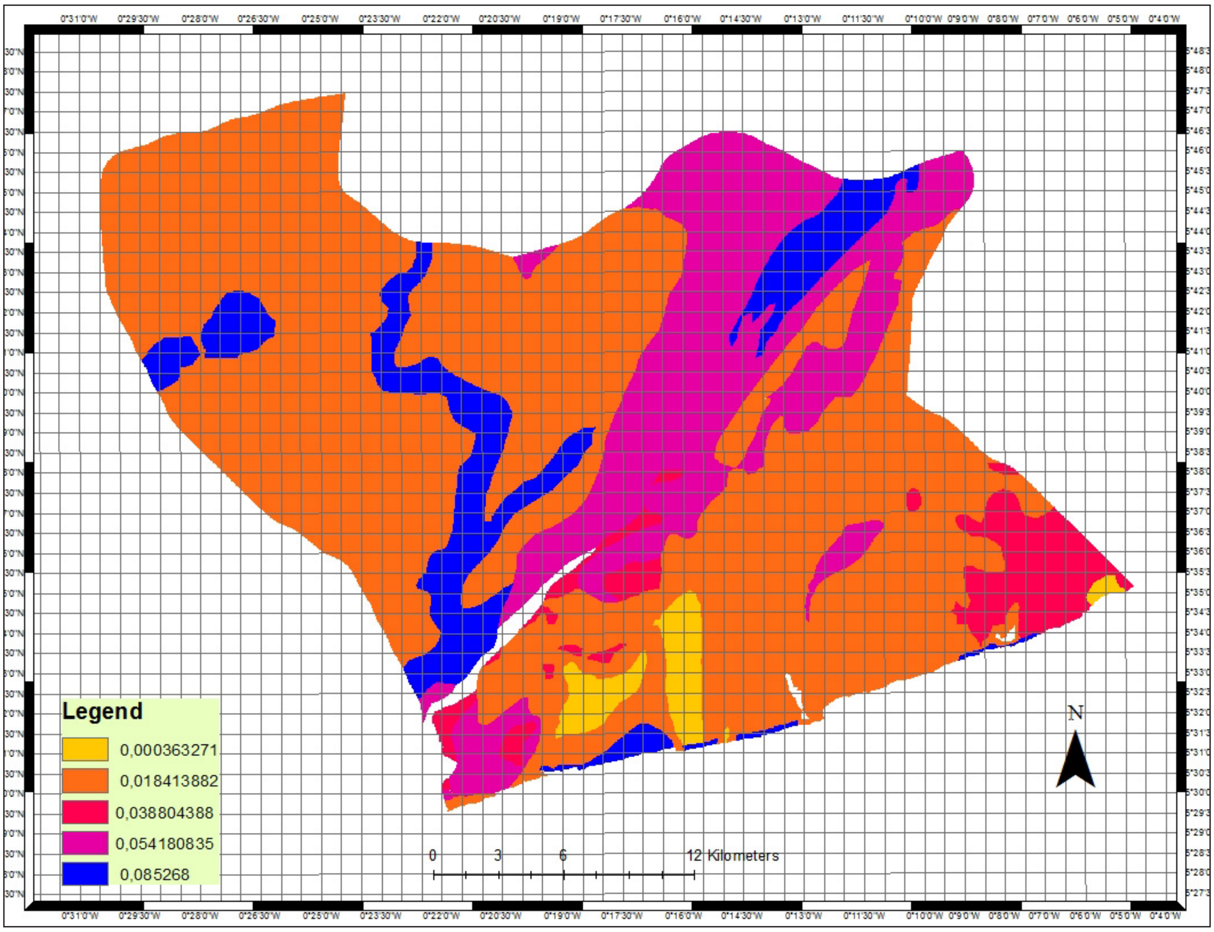

Fig. 3. Soil erodibility factor map (K factor)

rize 14 different classes, including forest, urban forest, riverine vegetation, tree mosaic, tree groves, grass mosaic, water features, salt pond and quarry, dense urban, semi/less dense urban, bare soil surface, paved and unpaved roads. The land cover map had an overall accuracy of 73.6 and Kappa 0.7122. These classes were identified in the map and stored as a raster data. C factor values corresponding to the various classes were identified from literature (Table 2) and used to prepare a raster map (Fig. 5).

Conservation practice factor or support practices factor (P factor): P values were similarly derived from literature sources and applied to the respective cover types in the Landcover map. P values were derived from literature sources and applied to the polygonized classified image for 2014.

Using the Spatial Analyst tool, raster calculator, the maps which were in raster format at 30 m resolution were used to run the RUSLE model (Fig. 7). The resulting map was a soil loss map

Sediment yield – was calculated based on the following equation from [Kamaludin, 2013];

$$SY = SDR \ x \ SE \tag{5}$$

where: SY – sediment yield; SDR – sediment yield delivery ratio
SE – annual potential soil loss (A) ton ha^{-1} yr^{-1}

$$SDR = 0.151A^{-0.11} \tag{6}$$

where: A is area in km^2. A = 893,553 km^2

Applying Eq (6), SRD = 0.2415. From the soil loss model SE = 69.5918 thus, using Eq (5), SY = 0.2415 × 69.59177971 = 16.8064 (T/ha/yr). Thus sediment yield (SY) is 16.8064 (T/ha/yr).

RESULTS AND DISCUSSION

The interpretation of the results from the model is conducted according to [Lynch, 1971, p. 61] who posited that when working with data simplified using models, average conditions

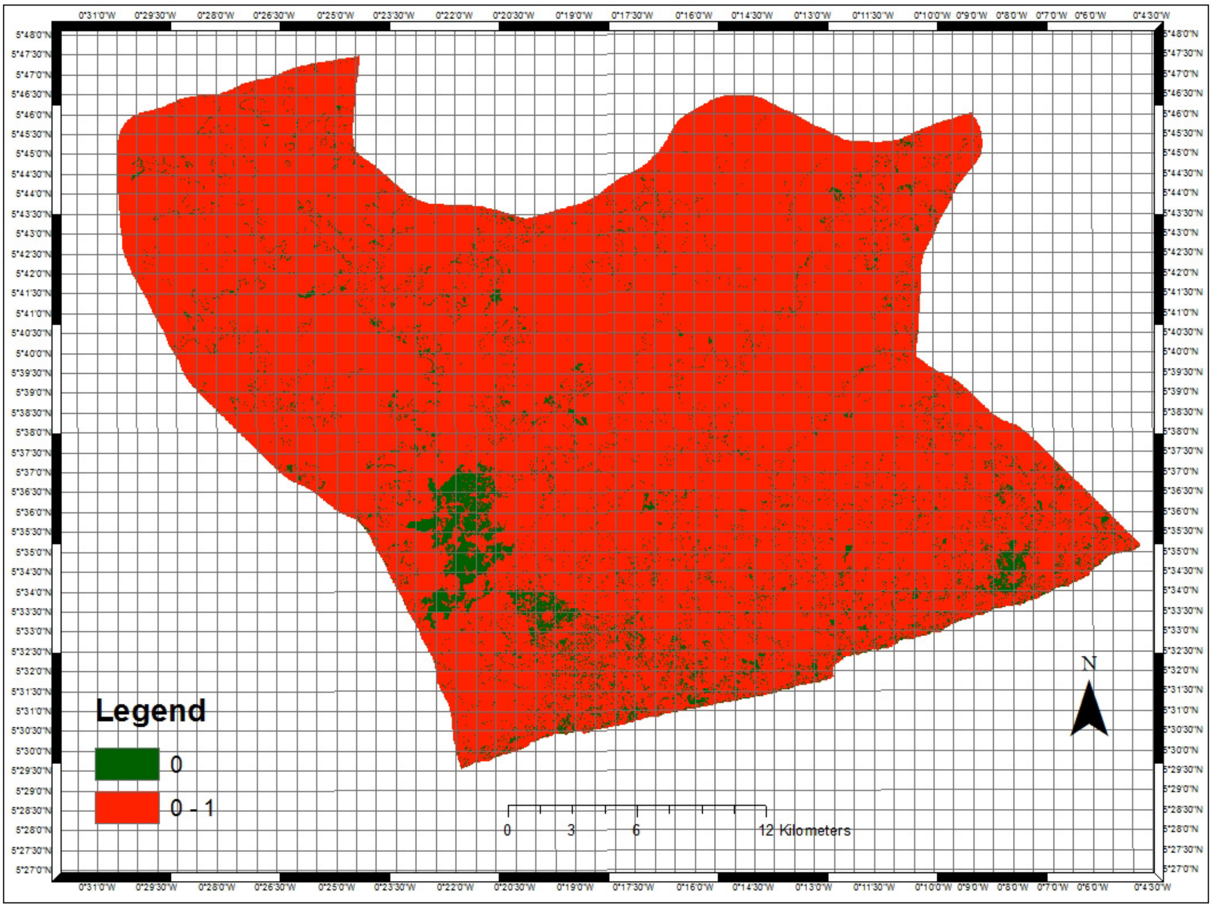

Fig. 4. Slope length and steepness factor map (SL factor)

Table 2. Land cover types and their descriptions, C factor and P factor values. Sources: [B.A.S.M.A.A., 2003; Erencin, 2000; Jain, 2000; Jin, 2010; Kamaludin, 2013, p. 4577; Kusimi, 2015; McCloy, 2006; Panagos, 2015; Prasannakumar, 2012]

Landcover classes	Description	C factor	P factor
1. Dense urban	Highly developed areas with 80–100 coverage and < 20% vegetation	0.8	0.01
2. Less dense urban	Mix developed and vegetated areas with 30–80% un-vegetated cover and 20–70% vegetation	0.9	1
3. Urban forest	Designated forest areas made of 25–100 non-natural woody vegetation	0.05	0.7
4. Tree groves	Cemeteries. government facilities. universities campus. undeveloped private land with extensive tree coverage	0.05	0.1
5. Marshlands	Periodically saturated. salty and waterlogged areas including Ramseur site	0.001	0.01
6. Saltpond	Salt mining area	0	0.01
7. Water	Still and moving water like lake. river. ponds	0	0
8. Bare soil	Exposed soils free of any form of cover. bare areas within developments. sand winning and gravel pits	1	1
9. Road paved	Bituminize. concrete. asphalt roads	0.7	0.01
10. Road unpaved	Unpaved roads	1	1
11. Riverine	Vegetation along rivers	0.21	0.5
12. Forest	25–100% tree dominated disturbed secondary forest areas located in difficult and inaccessible areas	0.003	0.1
13. Farmlands	Mixed farms. fallow areas. grass with sparse trees. cultivated land with 75–100% herbaceous cover	0.5	0.4
14. Tree mosaic	Tree dominated mixed shrubs	0.003	0.1

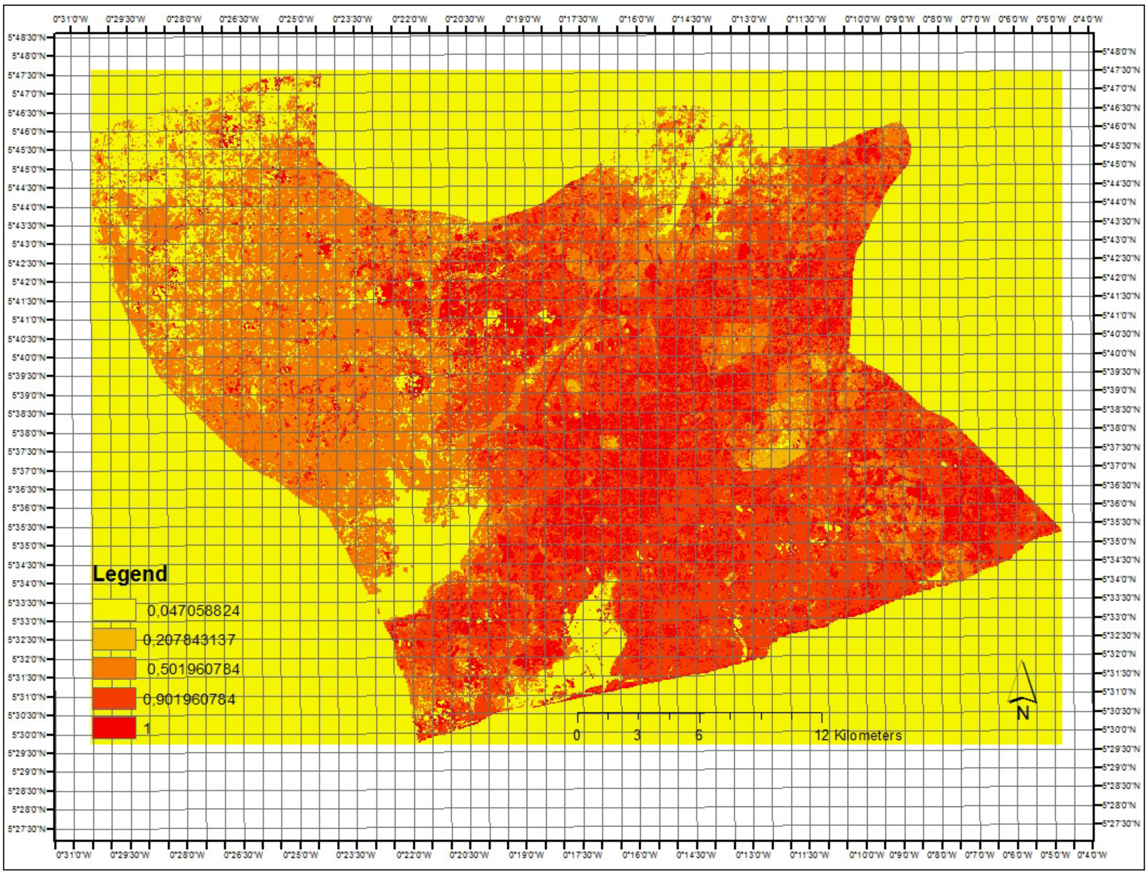

Fig. 5. Vegetative cover factor (C factor) map

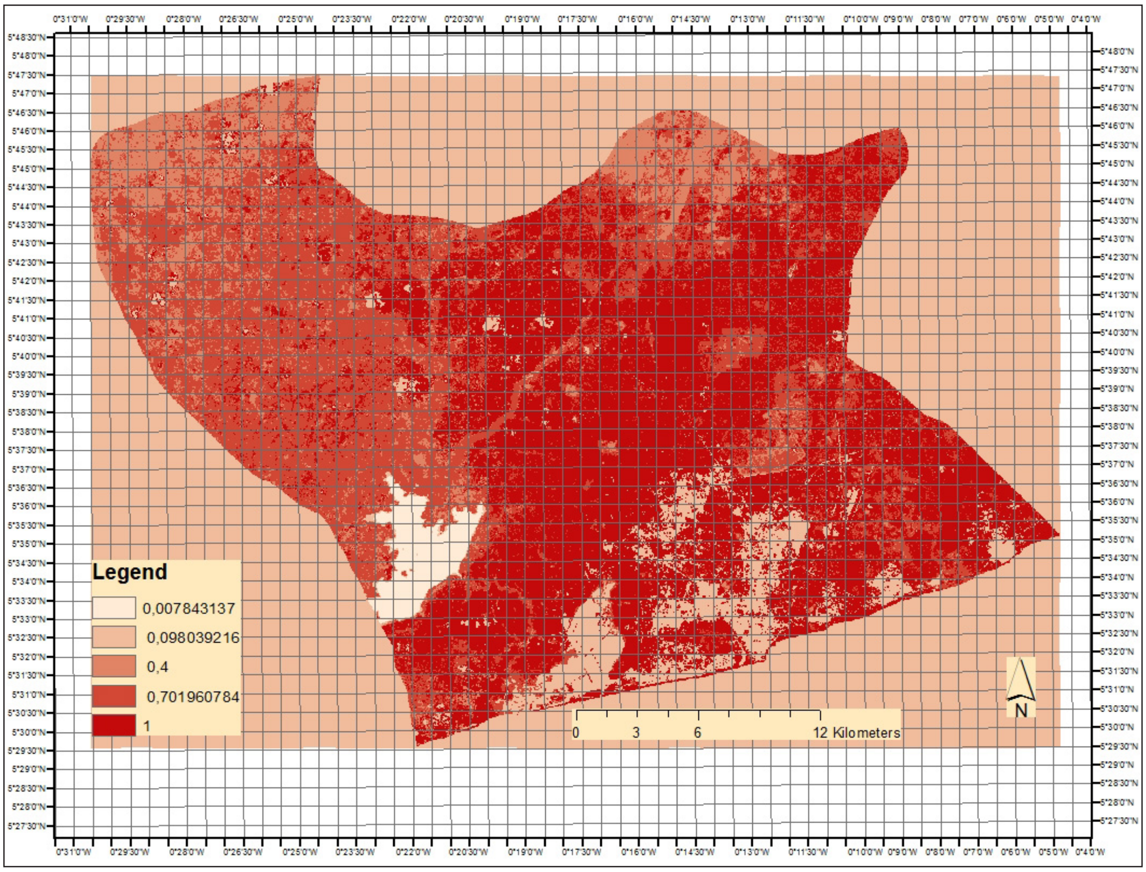

Fig. 6. Conservation practice factor map (P factor)

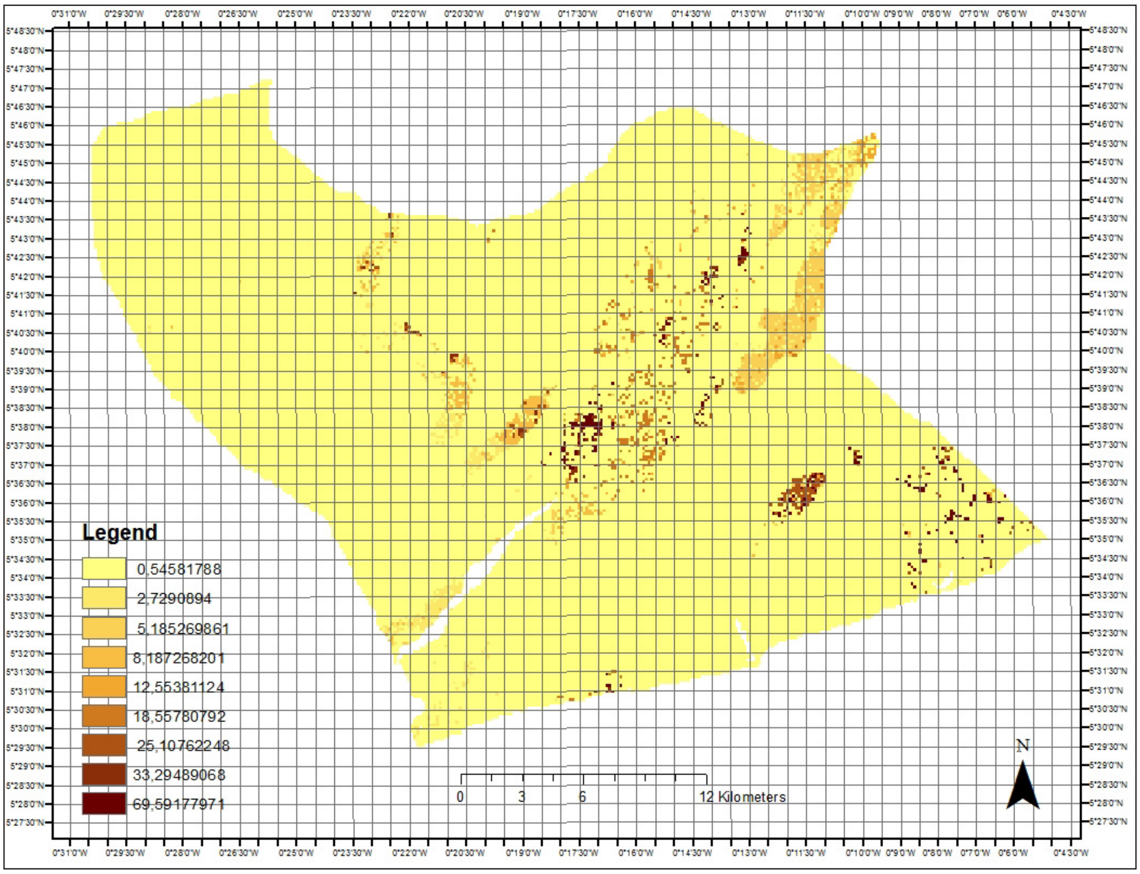

Fig. 7. Soil loss map based on RUSLE model

or values will not suffice, rather the extremes, thus the maxi values were used in interpreting the results. The rainfall erosivity index values obtained based on the modified Fournier index (MFI) ranged between 0.058–23.197. This showed a low rainfall erosivity according to [Essel, 2016] who had done similar work in part of the study area and classified the annual rainfall erosivity values less than 60 mm as very low, 60–90 as low, 90–120 as moderate, and 120–160 as high. In that work, the highest range, i.e. greater than 160 mm, was classed as very high. [Ufoegbune, 2011] in a work in Nigeria similarly considered the values less than 50 to be slight, 50–500 moderate and greater than 1000 to be very high rainfall erosivity. The low rainfall erosivity index values are in line with the generally low slope degree for most of the study area [Rahaman, 2015, p. 210]. The results also showed a strong correlation (0.8999) which was statistically significant at 1% between the monthly rainfall and rainfall erosivity index with an adjusted R sq of 0.8098. This is slightly stronger than what was reported by [Essel, 2016] who also found a strong correlation at 0.7. It is worth noting, however, that an earlier work by [Oduro-Afriyie, 1996] using the Fournier index approach for the entire country classified the Coastal Savanna Ecological zone within which the study is located under severe to extremely severe erosion risk zone [Essel, 2016, p. 4], whose work covered a relatively small part of the study area, also drew similar conclusions when they classified erosivity as high. This difference between what has been reported by Oduro-Afriyie and Essel et al. may be attributed to the scale and length of data period. Oduro-Afriyie worked at a far larger scale and thus may not have captured variations within the coastal savanna ecological zone. On the other hand, Essel *et al.* used a shorter data period of 10 years (2003–2012) compared with 44 years (1972–2015) used for this research, a fact which could affect the accuracy of the results as more than 20 years of rainfall data is recommended for a rainfall erosivity evaluation [Lee, 2015, p. 2; Yin, 2015, p. 4113]. Soil erodibility factor (K) for the various identified soil types ranged between 2.9×10^{-5} and 8.5×10^{-2} (t ha/MJ mm) which leans soils of the study site towards the most stable according to [Tallis, 2011, p. 241] and thus less susceptible to erosion with probably low suspended sediment load content [Efthimiou, 2014]. Tallis (2011) reported a value of 1/100 for most stable soils.

The result of the slope length factor (SL) was a raster map showing areas of low to almost flat SL values and few isolated areas with moderate SL values (Fig. 2). The low lying nature of the area and its implications have been noted by a number of researchers [Baffour, 2012, p. 205; Gyekye, 2011; 2013, p. 75; Tengan, 2016, p. 501], making erosion and its attendant sediment generation less of a threat.

RUSLE model – soil loss

The maximum soil loss of 69.592 ton/ha/yr recorded by the model is considered high according to the FAO soil loss classification scheme (1967) cited by Kusimi and Silva *et al.* [Kusimi, 2015; Silva da, 2010] which provided four classes of basin soil loss as follows, very low < 10; moderate 10–50; high 50–120 and very high > 120 [Lahlaoi, 2015] working in Morocco (North Africa), classified soil loss of between 20–30 ton/ha/yr as high and although a range of 7–20 is moderate, such losses can still be considered as important [Lahlaoi, 2015, p. 136]. On a regional basis, the estimated soil loss is high compared with soil loss of about 50 tons/ha/yr quoted by [Obalum, 2012, p. 2]. Kamaludin [2013] used a similar approach and reported soil loss values ranging between 0.0 and 95.5 ton/ha. The observed result is not inconsistent with the low rainfall erodibility, low soil erodibility, low slope degree and the relative high clay content of more than 30% [Obeng, 2000] of majority of soils of the study area. For more than 90% of the study area with low relief conditions, the soil loss ranges between 0 and 5.185 t/ha/yr (Fig. 6), which is considered very low according to [Kusimi, 2015; Lahlaoi, 2015; Silva da, 2010].

The sediment delivery ratio (SDR) of 0.2415 is considered low according to [Kamaludin, 2013, p. 4579] who, using the same approach but working under different conditions, had 99.4% classified as very low; 0.5% as low; 0.06 as moderate and 0.04 as high. The estimated sediment yield of 16,8064 (T/ha/yr) is higher than the range of 0 and 13.79 t/ha/yr reported by [Kamaludin, 2013, p. 4579] but lower and within range of 0 to 193 t/ha/yr reported by [Kusimi, 2015, p. 51] who worked on soil erosion in the middle belt region of Ghana.

Implication for a nature based flood management

The life of infiltration-based stormwater management facilities like bioretention, detention basin, or rain gardens, bioswales depends on the extent of clogging by sediments. Infiltration-based stormwater management facilities become progressively degraded by erosion and sedimentation, two closely related processes; making it critical to maintain soils within the catchment of the facility to prevent sedimentation [Industries, 1993, pp. 13,14; Stephens, 2002, pp. 3–6, 6–22]. As a major threat, sediments deposition from erosive events are the principal cause of clogging which complicate the successful installation and management [Gogate, 2012, p. 38; Le Coustumer, 2008, p. 20]. Various publications including [Liu, 2014, p. 1077; Lucas, 2010, p. 487; PWUD, 2014, pp. 8–7, 8–17; Shafique, 2016, p. 230] have also noted that surface clogging caused by fine silts and sediments generated from erosion have a reducing effect on surface infiltration rates which affects the performance of infiltration-based stormwater management facilities. In addition, clogging under tropical conditions results in prolonging shallow surface ponding which may provide breeding grounds for mosquitoes [PWUD, 2014, pp. 8–27]. Where potential erosion is high, there will be a high possibility of system failure or the need for frequent maintenance [PWUD, 2000, pp. 8–61]. Additionally, problems with stagnant water and aesthetics may increase the cost and reduce the attractiveness of the system [Le Coustumer, 2008, p. 7].

CONCLUSION

The results from the RUSLE model predicted a high soil loss compared to similar works in other environments. The introduction of effective control strategies and interventions to reduced erosion and sediment yield within site and in the catchment of the infiltration-based interventions will be the challenge. On the basis of the prediction from the model, it is encouraging to know that the challenge of erosion and sedimentation may not be a limiting factor to the introduction of infiltration-based stormwater management facilities to the study area, as the observed high soil loss is mostly over less than 10% of the study area. The RUSLE model did not only estimate soil loss but also showed spatial distribution. This will allow targeted intervention at the source areas. Thus, the identified areas with high erosion and sediment yield will be critical to the success of any infiltration-based stormwater management and flood control system. However, it was necessary to evaluate the erosive potential of the entire study area as a guide to necessary remedial interventions to guarantee the successful performance of infiltration-based stormwater management facilities.

Further work in this direction could use high accuracy land cover classification maps (compared to the 73.5% used for the study) to determine how much would that change the dynamics in the soil loss model.

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