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The Impact of Camping Activities on Soil Degradation in Kuwait

H. A. Monsef[1,*] and A. Abahussain[2]

[1]*Geology Department, Faculty of Science, Suez Canal University, Ismailia, Egypt 41522*
[2]*Desert and Arid Zones Program, College of Graduate Studies, Arabian Gulf University, Bahrain*

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ABSTRACT. Desert camping is an old tradition in Kuwait. Today's camping involves activities that negatively impact the soil due to surrounding camp sites with barriers from the top soil, off-road transport by cars, using heavy equipment such as electrical generators, camping facilities such as bathrooms with cement floors, soccer and volleyball fields. This study used remote sensing and Geographic Information System (GIS) techniques to study the role of camping activities on soil degradation in camping areas and recommend new camping sites and scenarios for environmentally safe camping. Soil erosion, soil compaction and vegetation cover decline were used as indicators for evaluating the degree of soil degradation in camping sites. Satellite images were processed, enhanced and interpreted to find out the area of camping sites. The rate of soil erosion was estimated by Revised Universal Soil Loss Equation (RUSLE). About 43% of the camping sites studied had high soil erosion rate that reached16 tons/acre/year. The other 57% of camping sites had moderate soil erosion rates of 14 tons/acre/year. Camping soil barriers increase the rate of erosion inside the camping sites. The study shows that soil and vegetation are badly affected by camping activities. Soil bulk density in camping areas surpassed that of areas not subjected to camping by an average of 12%. The vegetation coverage outside camping area was markedly higher than that inside camping. To avoid soil degradation by camping new environmentally safe sites for camping were recommended.

Keywords: soil, degradation, erosion, camping, environment, GIS, Remote sensing, Kuwait

1. Introduction

In Kuwait, severe desertification prevails due to the scarcity and irregularity of rainfall, active sand dunes, urbanization, over utilization of resources and traditional practices such as desert camping. These multiple functions are the main cause of land degradation on the vulnerable resources of Kuwait's desert ecosystem. The average annual desertification of land in Kuwait is estimated to be 285 km^2 (Al-Awadhi et al., 2005).

Spring camping is a seasonal traditional practice that takes place in most of the Gulf Cooperation Council Countries (GCC) including Kuwait. Camping takes place between November and March. Spring camping occurs during the rainy season (113 mm annually), a time when uptake of moisture by the desert soils as well as the growing season of the annuals and other perennial vegetation. The camping causes environmental damage to the desert fragile ecosystems (Shahid et al., 1999). It causes a loss of top soil through clearance of natural vegetation cover and through barriers construction around camps. Soil infiltration capacity is reduced by 50 ~ 100% because of heavy equipment and random movement of vehicles (Misak et al., 2002).Wood collection and using wild plants as a fuel for cooking and heating causes a decline of vegetation cover and desert biodiversity and reduces the ecosystem resilience (Abahussain et al., 2002).

This study measured the impacts of camping on soil and vegetation covers and recommended new camping sites and scenarios for environmentally-friendly camping.

2. Detecting Camping Sites

Barriers surrounding the camps are the most obvious remarkable feature in camping sites that can be recognized on the satellite images of moderate spatial resolution like SPOT. The changes in brightness value per unite distance in barriers area are high (high spatial frequency), although they are low (low spatial frequency) in surrounding area (Figure 1). High pass spatial convolution filter selectively strengthens the high spatial frequency objects in the image while maintaining the low-frequency components. Therefore, they were used to map the camping barriers from panchromatic band of SPOT 4 satellite images of the year 2008 (Figure 2). Because camping barriers have not a specific direction, different convolution kernels were used to detect vertical, horizontal, diagonal left and diagonal right barriers.

Sobel operator is a classic first order edge detection ope-

* Corresponding author. Tel.: +0020 1116741487; fax: +002 064316070.
E-mail address: hesham_geo@yahoo.com (H. A. Monsef).

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rator that finds contrast by a process akin with differentiation. Sobel calculates not only the magnitude of the edges, but also their direction (Folorunso et al., 2007). The operator uses a 3 × 3 template horizontally then vertically:

$$X = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} *Source\ \text{Image} \quad (1)$$

$$Y = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} *Source\ \text{Image} \quad (2)$$

Each pixel in an image is declared an edge if its Sobel values exceed some user-specified threshold. Such information may be used to create edge map, which often appear as white lines on a black background, or conversely. The resulting image uses Pythagoras to generate the magnitude of the edges:

$$\text{Soble(out)} = \sqrt{X^2 + Y^2} \quad (3)$$

Two kernels were used to enhance the diagonal left and diagonal right high frequency objects:

$$\text{Left diagonal edge} = \begin{pmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{pmatrix} *Source\ \text{Image} \quad (4)$$

$$\text{Right diagonal edge} = \begin{pmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{pmatrix} *Source\ \text{Image} \quad (5)$$

The 2008 panchromatic band of SPOT 4 satellite images of Kuwait was spatially filtered by Soble, diagonal left and diagonal right convolution filters. The filtered images were merged into one image. Camping bariers were manually traced visually out of the merged image (Figure 3) into ArcGIS shapefiles (barriers shapefiles). The camping sites surrounded by soil barriers area were delineated (Figure 4). The number of spring camps surrounded by soil barriers in 2008 was 1,278 camps surrounded by 306,818 m of soil barriers.

3. Estimating Soil Degradation in Camping Sites

3.1. Soil Erosion

Soil erosion reduces soil quality because it erodes or thins the productive topsoil. Human activities such as surrounding the camps by soil barriers increase the rate of soil erosion. It is important to estimate the rate of soil erosion in Kuwait to predict quantitatively the rate of soil erosion within the camping sites.

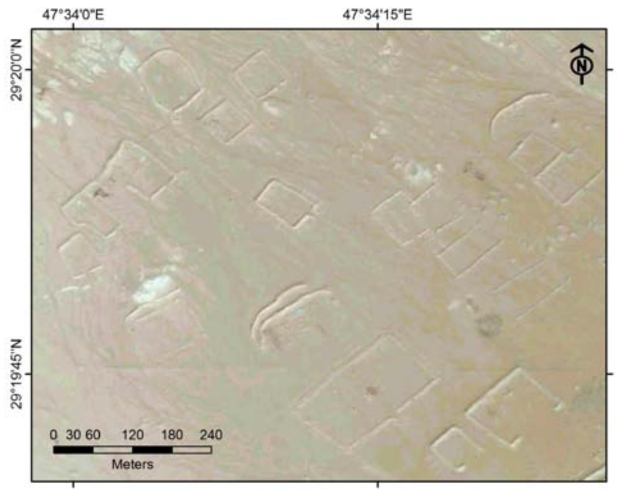

Figure 1. Examples of camping site barriers left after 2009/2010 camping season (GeoEye image, bands.1, 2 and 3, date: 8/8/2010).

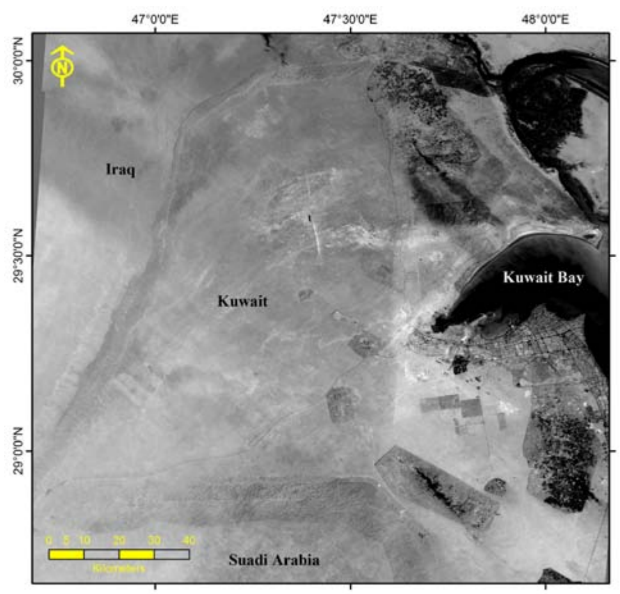

Figure 2. Panchromatic SPOT image of Kuwait (year 2008).

Smith and Whitt presented one of the first rational soil erosion equation and it is a method of estimating soil losses from fields of clay pan soils (Smith and Whitt, 1947). Since that time, a large variety of models have been developed. These models can be classified into the following categories:

- Empirical and mechanistic models: The empirical models describe a process based on empiricism. Mechanistic models like the one developed by Sklar (2004) attempt to represent the physical causes of responses to conditions. One of the most widely used empirical equations is the Revised Universal Soil Loss Equation (RUSLE) which can be used for estimating annual soil loss.

- Static and dynamic models: Static models cover assumptions about systems at rest while dynamic models include assumptions about the time-evolution. The European Soil Erosion Model (EUROSEM) is a dynamic distributed model, able to simulate sediment transport, erosion and deposition over the land surface by rill and interill processes in single storms for both individual fields and small catchments (Morgan et al., 1998).
- Deterministic and stochastic models: Deterministic models make definite predictions for quantities without any associated probability distribution. Stochastic models, on the other hand, contain some random elements or probability distributions. Except for the predicted value, stochastic models can also predict the variance.
- Spatial dimensions in models: Any model can be distinguished between one-dimensional (1D), two-dimensional (2D) and three-dimensional (3D) models.
- Qualitative and quantitative models: Qualitative models predict values on quality levels such as not risky, risky or highly risky. The input data for a qualitative model can be both qualitative and quantitative. On the other hand, a quantitative model produces a numerical output.

The main criteria in order to choose one of the above models are: objectives, data availability and cost.

Due to the deficiency of data required by precise erosion models RUSLE model has been selected in this study to estimate soil erosion. Data required by the RUSLE model are either available or can be prepared using GIS and remote sensing techniques.

The revised soil loss equation (RUSLE) can be employed in various environments including rangeland, mine sites, agricultural lands and others. It calculates soil loss by erosion as a function of 5 factors (Wischmeier and Smith, 1978):

$$A = R + K + LS + C + P \qquad (6)$$

where

A = annual soil loss (tons/acre/year)

R = erosivity of rainfall

K = erodibility of the soil

LS = slope length/steepness

C = cropping and management factors

P = erosion control practices

Because there is no special practices for soil erosion control in Kuwait, the P factor will be eliminated from equation.

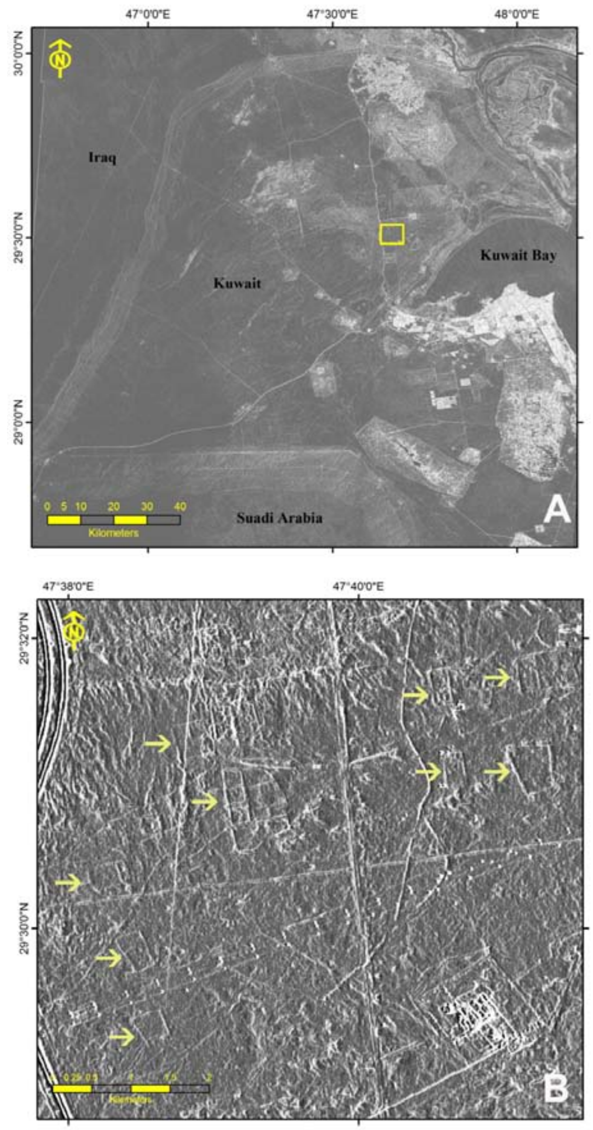

Figure 3. Output image of ERDAS filtering module (A), a magnification of the area inside yellow box (B), arrows in pointed to the camping barriers.

Erosivity of rainfall (R-Factor) is a measure of the erosive force and intensity of rain in a normal year (Goldman et al., 1986). Different indices of rainfall erosivity have been proposed for analyzing soil erosion, among them those indices based on monthly data averages, such as Fourier Index (FI) and its modification (Arnoldus, 1980). Rainfall erosivity (MFI) is more intense where there are high values of precipitation concentration and total annual precipitation:

$$MFI = \sum_{i=1}^{12} \frac{P_i^2}{P_t} \qquad (7)$$

where

P_i the monthly precipitation at month i, and

P_t the annual precipitation.

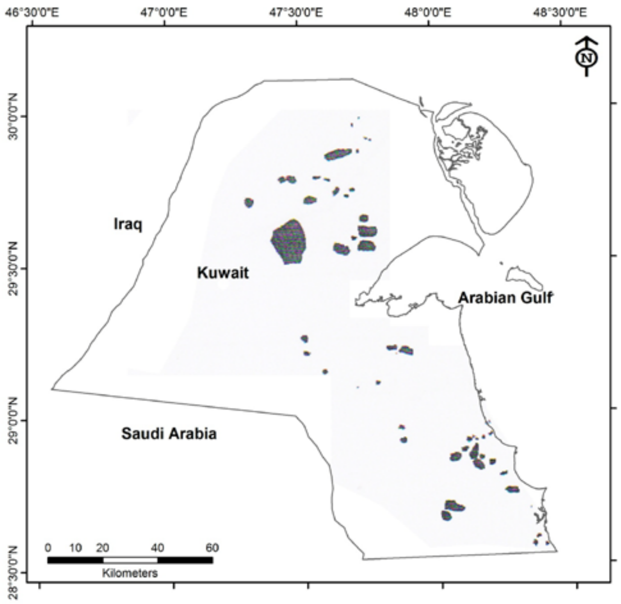

Figure 4. The camping sites surrounded by soil barriers during 2007/2008 season.

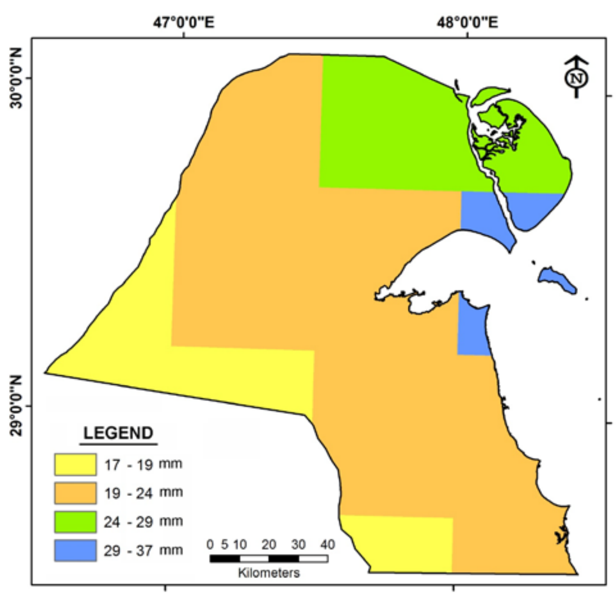

Figure 5. Average January rainfall during the period 1988–2008 in Kuwait.

In 2011, the University of East Anglia released the CRU-TS 3.1 Climate Database (http://badc.nerc.ac.uk/data/cru). This new version of database covers the global climate data of the period 1901 to 2009. CRU-TS database includes surface temperature, precipitation, and vapor pressure all interpolated globally at 0.5 degree spatial resolution on land areas. The CRU-TS 3.1 of the period 1988-2008 dataset were used to find out the average monthly precipitation and the average annual precipitation of Kuwait (Figures 5 and 6). It was then used to determine the MFI for Kuwait (Figure 7).

Soil erodibility (K-Factor) measures soil resisting to detachment and transportation. Soil erodibility is a function of the inherent soil properties, including organic matter content, particle size, permeability, bulk density and so on.

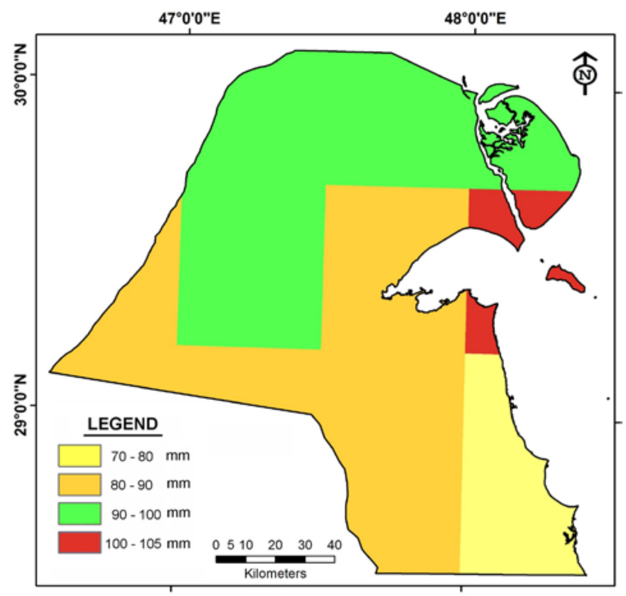

Figure 6. Average annual rainfall during the period 1988–2008 in Kuwait.

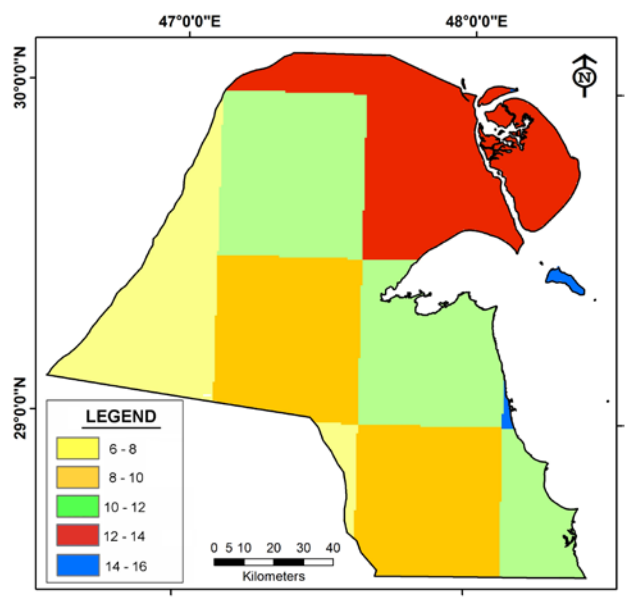

Figure 7. Modified Fournier Index (MFI) during the period 1988–2008 in Kuwait.

In 1999, a reconnaissance field survey was completed, at scale 1:100,000, for Kuwait excluding urban, agricultural and restricted areas. Based on this survey, Omar et al. (2001) identified eight soil groups characterize the soils of Kuwait (Figure 8) (Table 1). Kuwait soils are poor in organic matter and moisture content. K-factors of these soil units were calculated using Stone and Hilborn scale (Stone and Hilborn, 2000) (Table 2). K-factors of Kuwait soil units are listed in Table 1 (see Figure 9).

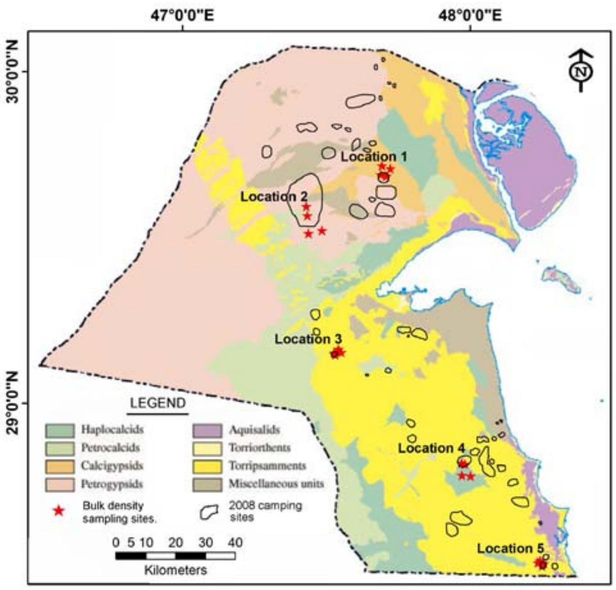

Figure 8. Soil map of Kuwait (after Omar et al., 2001) showing 2008 camping sites and location of bulk density sampling locations.

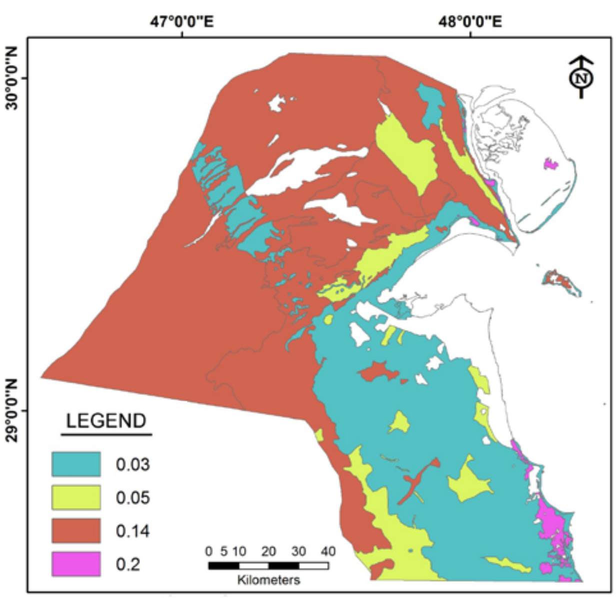

Figure 9. K-factors of Kuwait soil units.

aSlope length (L) represents the effect of slope length on erosion and the ***slope steepness (S)*** represents the effect of slope steepness on erosion. LS for Kuwait soils was determined using the methodology given by Hickey (2000). The overall method is explained in Figure 10. LS is determined using the following equation:

$$LS = (l / 72.6)^m 65.41 \sin^2 \beta + 4.56 \sin \beta + 0.065) \quad (8)$$

where

l is the cumulative downhill slope length in feet;

β is the downhill slope angle;

m is a slope contingent variable

m = 0.5 if the slope angle is greater than 2.86°;

0.4 on slopes of 1.72 to 2.86°;

0.3 on slopes of 0.57 to 1.72°;

0.2 on slopes less than 0.57° (Wischmeier and Smith, 1978).

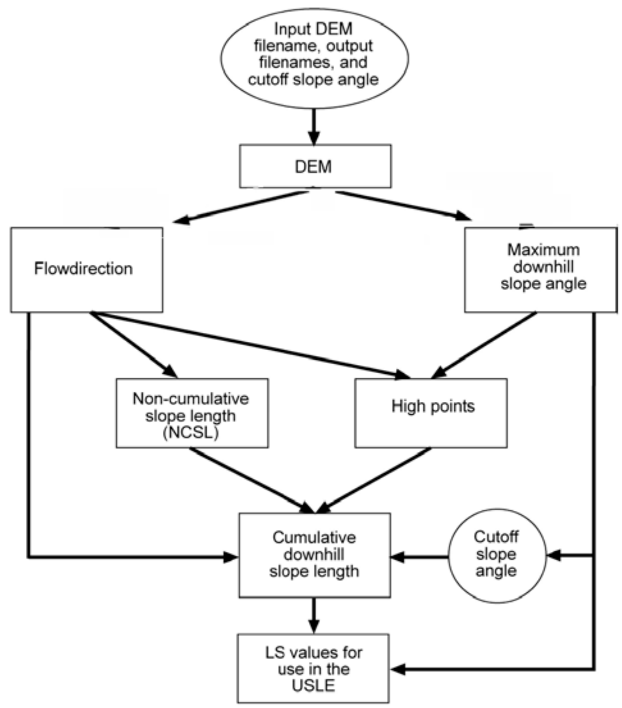

Figure 10. Flowchart illustrates the process of calculating LS (after Hickey, 2000).

Vegetation cover protects the soil by dissipating the raindrop energy before reaching soil surface. The value of C depends on vegetation type, stage of growth and cover percentage (Gitas et al., 2009).

Vegetation cover factor (C) range from 0 for well-vegetated soil to 1 for bare soil (Vicenta et al., 2007). Since Normalized Difference Vegetation Index (NDVI) values have correlation with C factor (De Jong, 1994; De Jong et al., 1999), many researchers used regression analysis to estimate C factor values for land cover classes in erosion assessment (Van der Knijff et al., 2000; Lin et al., 2002; Symeonakis and Drake, 2004; Karaburun, 2010).

Natural vegetation in Kuwait is composed of sparse low

Table 1. Description and Area of Soil Map Units in Kuwait (after Omar et al., 2001)

Map Unit	Area (%)	Description	K-Factor
Torripsamments	27	Well to somewhat excessively drained, deep or very deep sandy soils	0.03
Petrocalcids	11	Well drained or moderately drained, shallow or moderately deep, sandy to loamy soils overlying a calcic hardpan. When upper soil is truncated, it may appear at surface	0.14
Haplocalcids	8	Well drained, deep or very deep, sandy to loamy soils, which have a layer of carbonate masses and nodules	0.05
Aquisalids	7	Poorly or somewhat poorly drained, deep or very deep, sandy to clayey soils. Within the soil there is a layer of salt accumulation that usually occurs near the surface	0.20
Calcigypsids	6	Well drained, deep or very deep, sandy to loamy soils containing a layer of carbonate masses and nodules and a layer of gypsum crystals within the profile	0.14
Petrogypsids	33	Well drained, shallow or moderately deep, sandy to loamy soils overlying a gypsic hardpan. Hardpan may be exposed at surface, when upper soil is truncated	0.14
Torriorthents	1	Excessively drained to well drained, moderately deep or very deep, sandy soils. Within the soil profile there is a high content of shell fragments and some gypsum accumulations	0.03

shrubs and herbaceous perennials and annuals. Perennial shrubs form about 27.1% of Kuwait while perennial grass and sedge make up 67.9% (Omar et al., 2001).

Table 2. Stone and Hilborn Scale for K Factor Determination (after Stone and Hilborn, 2000)

Textural Class	Organic Matter Content		
	Average	Less than 2%	More than 2%
Clay	0.22	0.24	0.21
Clay Loam	0.30	0.33	0.28
Coarse Sandy Loam	0.07	—	0.07
Fine Sand	0.08	0.09	0.06
Fine Sandy Loam	0.18	0.22	0.17
Heavy Clay	0.17	0.19	0.15
Loam	0.30	0.34	0.26
Loamy Fine Sand	0.11	0.15	0.09
Loamy Sand	0.04	0.05	0.04
Loamy Very Fine Sand	0.39	0.44	0.25
Sand	0.02	0.03	0.01
Sandy Clay Loam	0.20	—	0.20
Sandy Loam	0.13	0.14	0.12
Silt Loam	0.38	0.41	0.37
Silty Clay	0.26	0.27	0.26
Silty Clay Loam	0.32	0.35	0.30
Very Fine Sand	0.43	0.46	0.37
Very Fine Sandy Loam	0.35	0.41	0.33

In this study, it is assumed there is a linear correlation between NDVI and C factor, bare soil and vegetated NDVI values were used as reference values. Sample NDVI values were collected for bare soil and vegetated land cover classes from average NDVI image (Figure 12). The C factor values for bare soil and vegetated land cover were set to 1 and 0, respectively in the regression analysis.

The regression line that describes relationship between C and NDVI values shows the correlation coefficient of regression analysis. The regression equation was found as:

$$\textit{Vegetation cover factor (C)} = 1.01 - 1.32 * \textit{NDVI} \qquad (9)$$

The equation was used to determine the vegetation cover factor (C) for Kuwait soils based on NDVI (Figure 13).

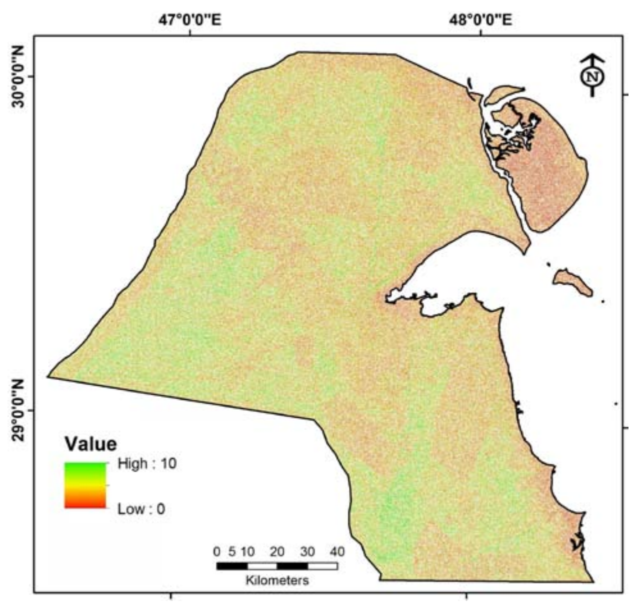

Figure 11. Slope length-Slope steepness (LS) in Kuwait.

The raster calculator of ArcGIS 10 were used to sum the erosivity of rainfall (R), erodibility of the soil (K), slope length-steepness (LS) and vegetation cover factor (C) in order to calculate annual soil loss by erosion in Kuwait, spatial analyst-zonal statistical module was used to average the annual soil loss rate (Figure 14).

43% of the camping sites had an erosion loss rate of 14 to 16 tons/acre/year. The remaining 57% camping sites were in moderate soil erosion rate zones with erosion loss rate of 12 to

14 tons/acre/year.

Field measurements showed that the soil barriers surroundding the camps have a 1-meter average height and 0.7 meter width. Therefore, each one meter of camp barrier is made up of about 0.7 cubic meter of soil or around, the average bulk density of the soil barrier was measured to be 1.6 gm/cm^3. Therefore, each one meter of soil barrier constituted about 1.12 tons of soil.

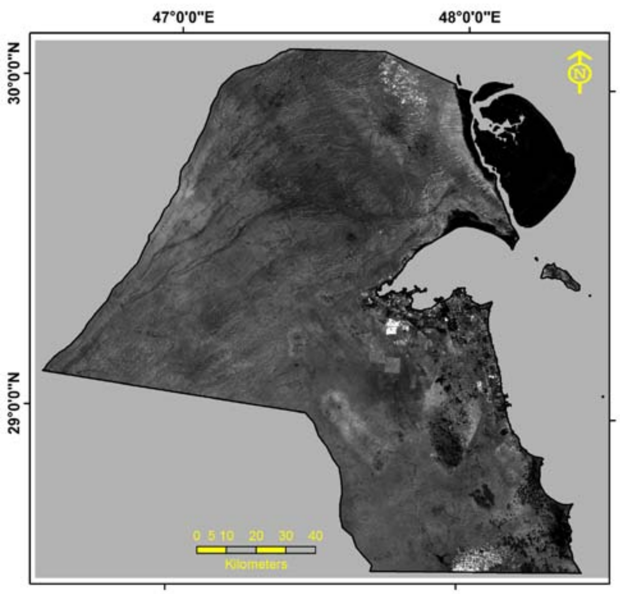

Figure 12. NDVI Landsat image of Kuwait.

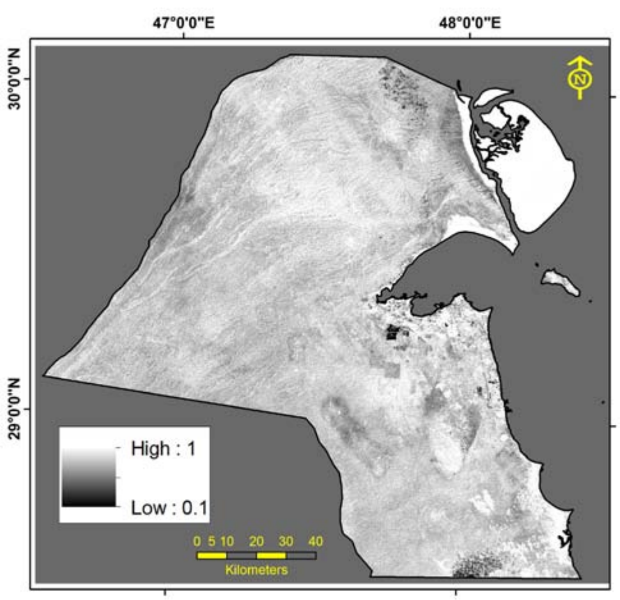

Figure 13. Vegetation cover factor (C) of Kuwait.

The number of camp grounds surrounded by soil barriers was 1,278. The lengths of the camp barriers was 306,818 m formed by using 343,636 tons of soils. These amount of soils that found in high to moderate erosion rate is more erodible than the surrounding soils because of its high slope (75^o) and because it is made of loose soils.

3.2. Soil Compaction

Bulk density is used as an indicator of soil compaction. The bulk density of soil depends mostly on the soil mineral composition and its degree of compaction. Bulk densities above thresholds signal harmed role (Table 3) (Arshad et al., 1996).

High bulk density is an indicator of low soil porosity and soil compaction. It may limit root growth, and cause poor infiltration of air and water through the soil (Holloway and Dexter 1990, Mohammed et al., 1996). Soil Compaction reduces vegetative cover available to protect soil from erosion as well as reducing the ability of soil to sequestrate carbon.

Twenty soil samples had been collected from five locations to determined soil bulk density. These locations covered by the main soil units in Kuwait: Calcigypsids, Petrogypsids, Torripsamments, Haplogypsids and Aquisalids (Figure 8). Samples had been collected from inside the camps and from outside the camps at areas away from camping activities. The bulk density of soil was determined using core samples, taken by metal cylinder with 15 cm length and 3.5 cm radius. The total volume of the sample was 577.2 cm^3. The samples were then oven dried and weighed. The bulk density was determined by dividing the mass of dry sample by the sample volume (Table 4).

The bulk density of the soil inside the camping sites increased by an average of about 12% compared with those soils not affected by camping activities. Insides the camping sites the bulk density exceed the ideal bulk densities for plant growth, it reached the limit that restrict root growth.

3.3. Vegetation Covers Change

There are 374 species of indigenous and naturalized species in Kuwait. Five major plant communities are recognized in Kuwait: Haloxylon salicornicum, Rhanterium epapposum, Cyperus congolmoratus, Zygophyllum qatarense, and Panicum turgidum (Figure 15). The communities including Stipagrostis plumosa, Moltikiopsis ciliata, Plantago boissierii, Schimpera arabica, Arnebia decumbens, Astragalus spp. and others.

Forty percent of the 2008 camping sites were in soil suitable for Stipagrostis plurnosa plants, 37% of these camps were on soil suitable for the growing of Cyperus conglomeratus, and 21% on soils suitable for Haloxylon salicomicum and 2% on soils suitable for Halophyle plants.

Stipagrostis plumose is tufted perennial grass up to 60 cm in height. It is one of the best pastures of camels and sheep. It grows after rainfall and blooms between March and May. It grows in shallow stable sands and sandy silt soils.

Cyperus conglomeratus is perennial sedge grows in deep sands. It grows up to 60 cm in height. It is renewed growth in April and continues through the summer months. It is useful

Table 3. General Relationship of Soil Bulk Density to Root Growth Based on Soil Texture (after Arshad, 1996)

Soil Texture	Ideal Bulk Densities for Plant Growth (g/cm^3)	Bulk Densities that Restrict Root Growth (g/cm^3)
Sandy	< 1.60	> 1.80
Silty	< 1.40	> 1.65
Clayey	< 1.10	> 1.47

Table 4. Soil Bulk Densities Measured Inside and Outside Camping Sites

Site	Soil Type	Soil Texture	Bulk Density (g/cm^3)		
			Inside Camping Sites	Outside Camping Sites	Change
Location 1	Calcigypsids	Sand to loamy sand	1.806	1.590	14%
Location 2	Petrogypsids	Sand to loamy sand	1.835	1.646	11%
Location 3	Torripsamments	Sand	1.616	1.570	3%
Location 4	Haplogypsids	Sand to loamy sand	1.888	1.646	15%
Location 5	Aquisalids	Sand to clayey sand	1.837	1.580	16%

grazing plant.

Haloxylon salicornicum is perennial tree. It achives a height of 60 cm. It has wooden branching from the base with olive colored leaves.

The three plants help to stabilize the soil, protecting it from erosion. The three plants grow, flower and fruit in the same time of desert camping in Kuwait, therefore camping disturb their growing and reproduction. In addition, the three plants growing best in sandy soil with high porosity, camping activity lead to soil compaction, increasing bulk density and decreasing porosity left the soil unsuitable for the growing of these three plants. Therefore, the vegetation cover within camping sites decrease with time left the soil exposed to erosion.

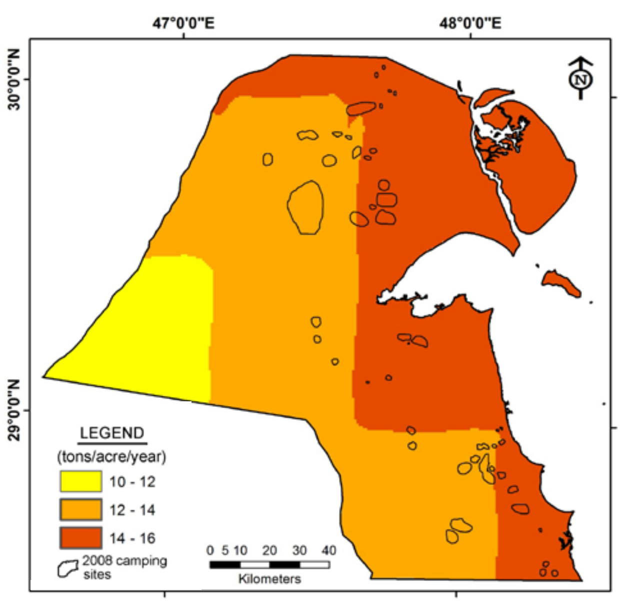

Figure 14. Annual average soil loss rates map of Kuwait.

Al-Adwani (2012) estimated the effect of camping on the vegetation coverage in Kuwait. He used line intercept method inside and outside the camping sites. Vegetation coverage had been measured inside camping sites in El Mutla, Sulaibya, Kabed and Al Julaia'a region to be 6.55, 4.45, 2.78 and 3.48% respectively. In addition, vegetation coverage was measured in area not affected by camping in Wadi El Baten, and El Zor regions to be 25.25 and 15.08% respectively. Measurements of vegetation coverage point out the negative impact of camping on vegetation coverage.

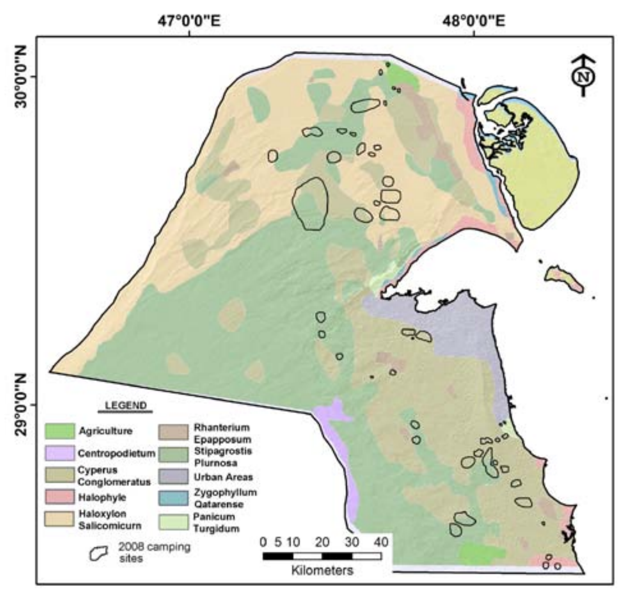

Figure 15. Vegetation cover of Kuwait (Public Authority for Agriculture and Fish Resources, 1995).

4. Mitigating Camping Soil Degradation by Selecting of New Camping Sites

The environmental decree number (210) of year 2001, section (71) stats that the camps should be away from the international boundary, governmental building, military camps or oilfield by a distance not less than 5 kilometers, and away from protected area, main roads and farms by a ditansce not less than a kilometer. ArcGIS shapefiles of the main roads, locations of permanent military camps, and protected area were got from Kuwait Institute for Scientific Research (KISR). Road and wetland shapefiles had been updated using panchromatic and multispectral SPOT images of the year 2008 respectively.

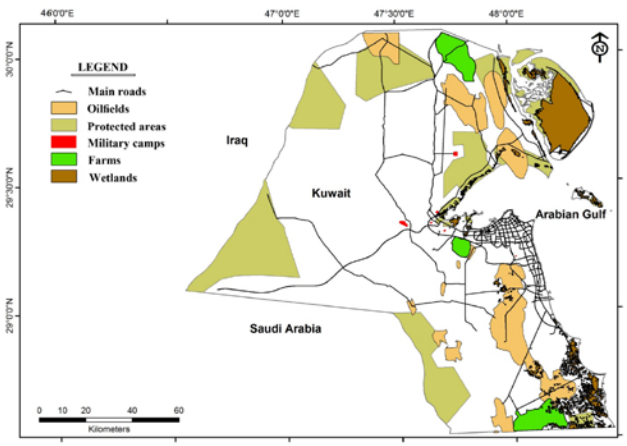

Figure 16. Main roads, oilfields, current and proposed protected areas, military camps, farms and wetlands of Kuwait.

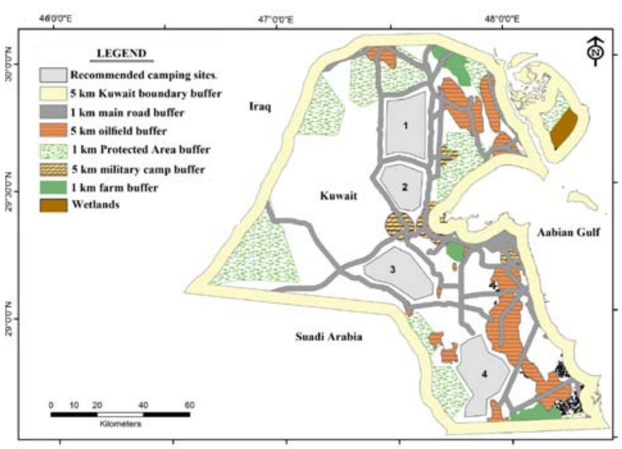

Figure 17. Colored areas represent illegal camping area according to the environmental decree number (210) of year 2001, section (71), and state of Kuwait. Grey areas represent recommended camping sites selected out of the area that meet the environmental decree.

A map of the proposed protected areas in Kuwait had been prepared by National Biodiversity Committee. This committee had been established by Environment Public Authority of Kuwait in the year 1997. A number of these areas were declared as environmental protectorates others still pending under deliberation at the council of ministers (Al-Tamimi 2012). Farms and wetlands shapefiles were mapped out of enhanced multispectral SPOT images of the year 2008. All the abovementioned maps have been digitized into ArcGIS shapefiles (Figure 16).

Using ArcGIS 10, buffers of the distances stated in abovementioned environmental decree were established around the features showing in Figure 16, and then integrated into one ArcGIS shapefile. The query engine of ArcGIS 10 had been used to select four sites that meet the environmental law of Kuwait. Selecting new camping sites take into consideration the proximity of these sites to main roads to provide an easy transportation to the sites, therefore these sits accessible to all service and rescue providers (Figure 17).

Four sites had been selected for camping in Kuwait; these sites fulfill the requirements of the environmental law of the state of Kuwait. It is recommended to use sites 1 and 3 for two consecutive seasons then left for the next two seasons and use the other two sites (2 and 4). This reciprocal scenario will give the opportunity for natural and human reform of these sites. The area of each two sites exceeds 700 square kilometers, which is enough to include all camping activities in Kuwait.

5. Conclusions

Soil erosion, soil bulk density and vegetation cover were used as indicators to study the role of spring desert camping on Kuwait soil degradation. Soil erosion washes away clay and organic matter, reduces thickness and volume of soil that provide water and nutrients to roots. The rate of soil erosion in Kuwait was estimated by Revised Universal Soil Loss Equation (RUSLE) which found that in 43% of the 2008 camping site erosion reaches up to 16 tons/acre/year. The other 57% of camping sites had moderate erosion at 14 tons/acre/year. Camping soil barriers used 343,636 tons of soils which increased the rate of erosion inside the camping sites.

High bulk density restrictions root growth, and leads to poor movement of air and water through the soil. Compaction results in shallow plant rooting and poor plant growth. Bulk density was determined using core samples taken from the soils inside and outside camping sites. It was found that bulk density increased by an average of about 12% compared with those soils not camped on. Bulk density exceeds the ideal bulk densities for plant growth and it reaches the level that restricts root growth. Increasing bulk density is one of the main reasons for decreasing vegetation coverage inside camping sites by 20%.

In order to mitigate the negative impact of camping, four sites with a total area of about 1,400 km^2 were selected as being environmentally-friendly camping sites. A reciprocal scenario is to camp only in two sites for two consecutive seasons and camping in the other two sites at the following two seasons give the chance for the ecosystem to recover.

References

Abahussain, A.A., Abdu A.S., Al-Zubari, W.K., Alaa El-Din, M., and Abdul-Raheem, M. (2002). Desertification in the Arab Region: analysis of current status and trends. *J. Arid Environ.,* 51, 521-545.

Al Adwani, F. (2012). Integrated environmental assessment of the camping activity in State of Kuwait policy analysis and future scenarios. Thesis (Master). Arabian Gulf University, Bahrain.

Al-Awadhi, J.M., Omar, S.A., and Misak, R. (2005). Land degradation indicators in Kuwait: a case study of land degradation. *Bull. Eng. Geol. Environ.,* 62, 107-115.

Al-Tamimi, H.A. (2012), Protected Areas in the State of Kuwait. Available online at: http://www.icarda.cgiar.org/aprp/PDF/PAinAp_Kuwait.pdf (last accessed 04/2012).

Arnoldus, H.M.J. (1980) An approximation of the rainfall factor in the Universal Soil Loss Equation. In: Assessment of Erosion (ed. by M. De Boodt & D. Gabriels), 127-132. Wiley, Chichester, UK.

Arshad, M.A., Lowery, B., and Grossman, B. (1996). Physical Tests for Monitoring Soil Quality. In: Doran J.W., Jones A.J. editors. Methods for assessing soil quality. Madison, WI.

De Jong, S.M. (1994). Application of Reflective Remote Sensing for Land Degradation Studies in a Mediterranean Environment. Netherlands Geographical Studies, University of Utrecht, Netherlands.

De Jong, S.M., Paracchini, M.L., Bertolo, F., Folving, S., Megier, J., and De Roo, A.P.J. (1999). Regional assessment of soil erosion using the distributed model SEMMED and remotely sensed data. *Catena,* 37(3-4), 291-308. http://dx.doi.org/10.1016/S0341-8162(99)00038-7

Folorunso, O., Vincent, O.R., and Dansu, B.M. (2007). Image edge detection: A knowledge management technique for visual scene analysis. *Info. Manage. Comput. Secur.,* 15, 23-32. http://dx.doi.org/10.1108/09685220710738741

Gitas, I.Z., Douros, K., Minakou1, C., Silleos, G.N., and Karydas, C.G. (2009). Multi-Temporal Soil Erosion Risk Assessment In N. Chalkidiki Using A Modified USLE Raster Model. *Earsel proc.,* 8, 40-52

Goldman S.J., Jackson K., and Bursztynsky T.A. (1986). Erosion and Sediment Control Handbook. McGraw-Hill Book Company, New York.

Hickey, R. (2000). Slope Angle and Slope Length Solutions for GIS. *J. Cartogr.,* 29, 1-8. http://dx.doi.org/10.1080/00690805.2000.9714334

Holloway, R.E., and Dexter, A.R. (1990). Compaction of Virgin Soil by Mechanized Agriculture in A Semiarid Environment. *Land Degrad. Dev.,* 2, 107-113. http://dx.doi.org/10.1002/ldr.3400020205

Karaburun, A. (2010) Estimation of C factor for soil erosion modeling using NDVI in Buyukcekmece watershed., *Ozean J. Appl. Sci.,* 3(1), 77-85.

Lin, C.Y., Lin, W.T., and Chou, W.C. (2002). Soil erosion prediction and sediment yield estimation: the Taiwan experience. *Soil Tillage Res.,* 68(2), 143-152. http://dx.doi.org/10.1016/S0167-1987(02)00114-9

Misak, R, Al-Awadhi, J.M., Omar, S.A., and Shahid S.A. (2002). Soil Degradation in Kabd Area, South western Kuwait City, *Land Degrad. Dev.,* 13, 403-415. http://dx.doi.org/10.1002/ldr.522

Mohammed , S.O., Farshad, A., and Farifteh, J. (1996). Evaluation of Land Degradation For Assessment of Land Vulnerability to Desert Conditions in the Sokoto Area Nigeria. *Land Degrad. Dev.,* 7, 205-214. http://dx.doi.org/10.1002/(SICI)1099-145X(199609)7:3<205::AID-LDR225>3.0.CO;2-L

Morgan, R.P.C., Quinton, J.N., Smith, R.E., Govers, G., Poesen, J.W.A., Auerswald, K., Chisci, G., Torri, D., and Styczen, M.E. (1998). The European Soil Erosion Model (EUROSEM): a dynamic approach for predicting sediment transport from fields and small catchments. Earth Surf. Process. *Landforms,* 23, 527-544. http://dx.doi.org/10.1002/(SICI)1096-9837(199806)23:6<527::AID-ESP868>3.0.CO;2-5

Omar, S.A., Misak, R., Kings, P., Shahid, A., Abo-Rizq, H., Grealish, G., and Roy, W. (2001). Mapping the vegetation of Kuwait through reconnaissance soil survey. *J. Arid Environ.,* 48, 341-355. http://dx.doi.org/10.1006/jare.2000.0740

Shahid, S.A., Omar, S.A., and Al Ghawas, S. (1999). Indicatorsof Desertification in Kuwait and their possible management. *Desertification Control Bull.,* 34, 261-266.

Sklar, L.S. (2004). A mechanistic model for river incision into bedrock by saltating bed load. *Water resour. Res.,* 40, W06301. http://dx.doi.org/10.1029/2003WR002496

Smith, D.D., and Whitt, D.M. (1947). Estimating soil losses from field areas of claypan soils. *Soil Sci. Soc. Am. Proc.,* 12, 485-490. http://dx.doi.org/10.2136/sssaj1948.036159950012000C0108x

Stone, P., and Hilborn, D. (2000). Universal Soil Loss Equation (USLE). Ontario Ministry of Agriculture; Food & Rural Affairs. Agdex#: 572/751.

Symeonakis, E., and Drake, N. (2004). Monitoring desertification and land degradation over sub-Saharan Africa. *Int. J. Remote Sens.,* 25(3), 573-592. http://dx.doi.org/10.1080/0143116031000095998

Van der Knijff, J.M., Jones, R.J.A., and Montanarella, L. (2000). Soil Erosion risk Assessment in Europe, European Commission, European Soil Bureau, (http://eusoils.jrc.ec.europa.eu/ESDB_Archive/pesera/pesera_cd/pdf/ereurnew2.pdf, last accessed, Aug. 15, 2010).

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. 2008WR007634