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Monitoring and Evaluating Environmental Erosion in the North Western Coast of Egypt and Tunisia

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Monitoring and Evaluating Environmental Erosion in the North Western Coast of Egypt and Tunisia

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Contents

Abstract

Soil erosion in Egypt and Tunisia is one of the major hazards not only for agricultural production, but also for the environmental challenges related to watershed protection and biodiversity conservation. These regions, already limited in arable land, are susceptible to severe erosion due to wind and rain particularly when poor agricultural methods are used or preventive measures are not taken. This paper was based on data collected from Ali (1998) and El-Flah (2003) for evaluating soil erosion due to rainfall events in agricultural areas of North Western Coast Zone of Egypt and some data from Tunisia. Statistical relationships were used to evaluate the water erosion, and then it can be possible to estimate the effectiveness of various soil management techniques in preventing soil erosion.

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This paper was written at the International Institute of Applied Systems Analysis, Laxenburg, Austria, where the author participated in the Young Summer Scientists Program 2004. Islam M.M.Khater is working as associated researcher at the Desert Research Center, Cairo, Egypt.

Monitoring and Evaluating Environmental Erosion in the North Western Coast of Egypt and Tunisia

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1 Introduction

As revealed at the 3rd United Nations "Conference of the Parties to the Convention to Combat Desertification" in November 1999 in Brazil, exploitive land management practices result in the desertification of ten million hectares of land every year. This is equivalent to an almost unbelievable 200,000 m^2 per minute as mentioned by Kopp and Bell (2003). In addition to desertification, the quality of soil and its fertility are increasingly deteriorating as a result of intensive cultivation. Soil deserves protection in the same way as air and water and is vital to the survival of mankind, a fact that is becoming increasingly recognized by industry and politicians. Legislation to this effect is being developed worldwide.

The accelerating extension of rainfed agriculture onto the North Coast of Africa and the paucity of input and techniques for sustainable agriculture production are leading to soil degradation far above acceptable levels. In parallel, the farming community that is facing demographic pressure and depletion of suitable agricultural land area has developed a traditional strategy for soil and water conservation through a wise and integrated use of the land. The characterization of soil erosion ought to include aspects related with inherent characteristics of natural conditions, functionality and soil use, and its management. The soil functionality reflects its current natural dynamic and its potential fertility. The soil response is related to the interactions of its components via physical, chemical, and biological properties in order to maintain biodiversity, the preservation of the natural resources, and human health.

Soil and water conservation techniques are being used more and more for agricultural activities, particularly in arid developing countries. This occurs more on lands with growing physical limitations and in regions with severe social and economic problems. Soil and water conservation in these arid areas is a priority. This is not only for reasons having to do with agricultural production, but also due to the environmental challenges caused by such use, particularly with countries who impact water supply sources and biodiversity.

The North Western Coastal Zone of Egypt has land that could potentially supply substantial agricultural products to Egypt; however, this area is suffering from soil water erosion due to high rainfall in certain periods of the year. The runoff is associated with other negative impacts such as water erosion, water loss, pollution of water reservoirs, and the washing out and depletion of soil nutrients.

The aim of this work is to determine statistical relations between the soil loss and runoff for different soil management techniques. These relations should be updated and improved with additional monitoring and data collection in the north western coast of Egypt and Tunisia as representative to North Africa. These regression equations will make it easier for decision-makers to see the relation of a complicated situation as regarding the water, soil and topography with the levels of erosion and production.

2 Background

Eswaran et al. (2001) reported that land degradation would remain an important global issue for the 21st century because of its adverse impact on agronomic productivity, the environment, and its effect on food security and the quality of life. Productivity impacts of land degradation are due to a decline in land quality on-site where degradation (e.g., erosion) occurs and off site where sediments are deposited. Some economists argue that the on-site impact of soil erosion and other degradative processes are not severe enough to warrant implementing any action plan at a national or an international level. The productivity of some lands has declined by 50% due to soil erosion and desertification. Yield reduction in Africa due to past soil erosion may range from 2 to 40%, with a mean loss of 8.2% for the continent. Desertification is occurring on 33% of the global land surface and affects more than one billion people, half of whom live in Africa. They added that the economic impact of land degradation is extremely severe in densely populated South Asia, and sub-Saharan Africa. Dregne (1990) mentioned that the productivity of some lands in Africa has declined by 50% as a result of soil erosion and desertification. Oldeman (1994) showed that the global extent of water erosion (by all processes and all ecoregions) is about 1.1 billion ha, while Dregne and Chou (1994) showed that degraded area in Africa amounts to 1.05 billion ha or 73% of the total 1.43 billion ha of the total land area in African arid regions.

Tripathi and Singh (1993) distinguished soil erosion into two phases, the detachment of individual particles from the soil mass and the transport by erosive agents such as running water or wind. When sufficient energy is no longer available to transport the particles, the third phase, deposition occurs. As a result of the third phase, large floodplains and coastal-plains are formed due to wearing off. Soil erosion can be mitigated by various planting and conservation techniques. Water erosion studies by Hudson (1981), Frederick et al. (1980), Morgan (1995) and Biswas and Mulkherjee (1995) indicated that under humid condition the amount of annual soil loss from land covered with grasses or trees is only a fraction of a ton per hectare. But from bare or previously cultivated field, it amounts up to 200 and sometimes up to 450 ton/ha for a single winter season. With respect to the changes in soil texture, Schwab et al. (1993) stated that soil erosion process also changes the environment in the remaining soil surface. The coarser grains are left near their origin while the finer ones transported some distances. If soil texture is not significantly changed by erosion, depletion of organic matter and organic-rich soil aggregates by erosion may result in a higher bulk density in the remaining soil surface. Consequently, total soil porosity decreases, especially the number of macro pores. Nutrient depletion as a form of land degradation has a severe economic impact at the global scale, especially in sub-Saharan Africa. Stoorvogel et al. (1993) estimated nutrient balances for 38 countries in sub-Saharan Africa. Annual depletion rates of soil fertility were estimated at 22 kg N, 3 kg P, and 15 kg K/ha. On the other hand Lal (1995) estimated that yield reduction in Africa due to past soil erosion may range from 2 to 40%, with a mean loss of 8.2% for the continent. If accelerated erosion continues unabated, yield reductions by 2020 may be 16.5%. Annual reduction in total production for 1989 due to accelerated erosion was 8.2 million tons for cereals, 9.2 million tons for roots and tubers, and 0.6 million tons for pulses.

El-Flah (2003) clarified the Physiographic features of the North Western Coastal Zone of Egypt (the area along the southern Mediterranean sea shore from Alexandria to the Libyan border). This area covers an area of approximately 1.6 x 10^6 ha and displays different geomorphological and pedological features where arid and semi-arid climates prevail. FAO (1997) estimated the area of Tunisia by 85,162 km^2, with annual rainfall in the northern area, maximum 735 and minimum 60 mm/year. The agricultural production concentrated in the north and along central coast, while the South is mostly semiarid or desert.

Wassif et al. (1995) reported that soil erosion is usually correlated with the depth and intensity of precipitation during rain storms. FAO (2003) showed that in Tunisia erosion causes the loss of the arable layer of soils, its intensity depends on the topography of the superficial layer, the nature and density of the vegetation cover and the nature of precipitations. The annual loss of soil related to water erosion is about 49 millions m^3, that is 10,000 ha of useful agricultural soils. In addition Mtimet and Hachicha (1996) mentioned that water erosion is located mainly in the watersheds of Wadis of Mejerda, Mellègue, Tessa, Nebhana, Zeroud and El- Fekka, as well as in the mountains of Gafsa and Matmata (Tunisia). The total area affected by water erosion is estimated at 3,321,630 ha, that is, 20% of the whole surface area of the country.

According to the soil and water conservation techniques, Debeny et al. (1993) reported that no-till was found to decrease soil erosion from instant rain-storms to between 11 and 45% of the conventionally tilled, on-cultivated treatments, in addition Edwards et al. (1994) mentioned that residue left on the soil surface and various conservation tillage practices help in runoff, soil loss, and subsequent nutrient loss.

The effect of the proper conservation management was investigated by Jones et al. (1994) who used three-year rotations, winter wheat, sorghum, and fallow, on six 4 to 12 ha graded terraced watershed fields in a dry land. There were three pairs of watersheds in the rotation each with no-tillage and stubble mulch treatments on the same watersheds each year. The results indicated the following:

1) Storm runoff measured from no-tillage treatment averaged 56% greater than runoff from stubble mulch treatment on slowly permeable soil.
2) Infiltration rates declined more rapidly with no-tillage than with stubble mulch treatment.
3) Total infiltration was greater for stubble mulch treatment because tillage destroyed the surface crust and decreased bulk density, increased surface roughness and depressed storage capacity.

Khater (2003) reported that different types of soil are more prone to erosion; a number of different factors may be distinguished:

1) Soil moisture content: only dry soils undergo erosion.
2) Soil texture: fine particles are more vulnerable to erosion than coarse ones.
3) Cementing materials: an absence of cementing materials (such as organic matter)

makes soil more prone to erosion.

4) Disaggregating particles: fine plowing or the addition of disaggregating materials like calcium carbonate makes soil more prone to erosion.
5) Condition of topsoil: smooth surfaces are more prone to erosion than rough surfaces.

The soil and water conservation management affects the relation between soil productivity and erosion. Paez (1994) reported that erosion risk or potential erosion is understood to mean the maximum loss of soil possible in the absence of a cover crop and conservation practices, that is to say, only taking into consideration the interaction of the physical factors of the land: soil, climate and topography. On the other hand Fernando (2002) classified the erosion risk in terms of the values of the Erosion Risk Index (ERI), showing general requirements for soil conservation, the ERI values were ≤0.10, 0.11-0.30, 0.31-0.60, >0.61 for low, moderate, high and very high, respectively. There are various methodologies for land classification, evaluation, and planning in arid environments. The majority of these methods are oriented toward evaluating the agricultural production potential and limitation for "marginal" lands: the productive capacity of soil (potential) and erosion risk (limitation).

Kiome (1992) identified that sophisticated models such as EPIC require databases that are not readily available in many developing countries. Simple models like those simulating the effect of soil erosion on soil water storage capacity cannot always give accurate predictions of the effect of soil erosion on soil-crop productivity because they do not take into account the physical and chemical properties of soils important for crop growth and affected by soil erosion. In his survey, Abou Yuossef (2004) classified the North Coast lands of Sinai (Egypt) according to the relative values of soil erosion risk index show that 36% have the low erosion risk index, 29.34% are within the range of the moderate erosion risk index, and 34.66% have the high erosion risk index. The value of this index (ERI) shows different land classes as well as soil conservation priorities, conservation requirements, and proposed land uses. The agricultural classification of lands showed that 62.68% of lands are reserve (R) (the 4th priority conservation treatment). These lands at present have soil at a moderate and low productivity, with a slight risk of erosion, while 34.66% of the soils are within critical lands (C) (the 2nd priority conservation treatment). These lands at present have a moderate to low soil productivity, but are in a condition of a strong risk of erosion. Moreover, 2.66% of the soils are sub-critical lands (S) (the 3rd priority conservation treatment). These are lands that at present have soil with a high to very high productivity, and with only a slight risk of erosion. This was a systematic way to selection of soil conservation practices for North Sinai, including the following soil conservation categories: (I) Practices to improve soil productivity and soil erosion resistance, as well as to reduce rainfall erosivity impacts; and (II) Practices to reduce runoff impacts.

3 Materials and Methods

The study areas vary in their geological and geomorphological characteristics. Figure (1) shows risk of human-induced desertification in North Africa. Figures (2) and (3) show the NOAA Satellite Image for Egypt and Tunisia.

The Universal Soil Loss Equation (USLE) reported by Robert (2000) was used to estimate the soil loss from the representative areas. The Erosion Risk Index (ERI) was used to identify the range of danger to erosion and compared to productivity, which was measured at each of the sites. The data were analyzed to show statistical relationships between runoff and soil loss for each management technique, and also between the Erosion Risk Index (ERI) and Productivity Index (PI).

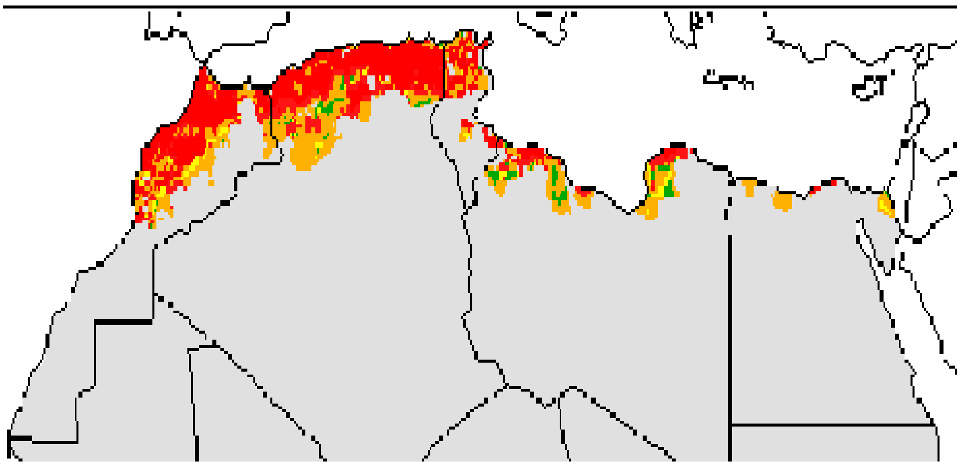

Fig. (1): Risk of human-induced desertification in North Africa UNEP (1993).

Fig. (2): Egypt. NOAA Satellite Image FAO (2004).

Fig. (3): Tunisia. NOAA Satellite Image FAO (2004).

3.1 Relationship between rainfall intensity and runoff

3.1.1 Case study I

The annual short rainfall varies from one year to another and from location to another, which leads to a non-regular runoff. Data from Ali (1998) were determined at Wadi El Ramla for 1993-1994, 1994-1995 and 1995-1996 (North Western Coast Zone of Egypt). The total rainfall depths were 45.2, 176.2 and 75.4 mm with 8, 11, and 15 rainy days. Eleven storms occurred only in the second winter season. Six storms were effective as they caused runoff and consequently soil loss.

The statistical relationship between rainfall intensity and runoff was analyzed. Fig. (4) shows linear relationship for case study (I) (r^2 = 0.5554).

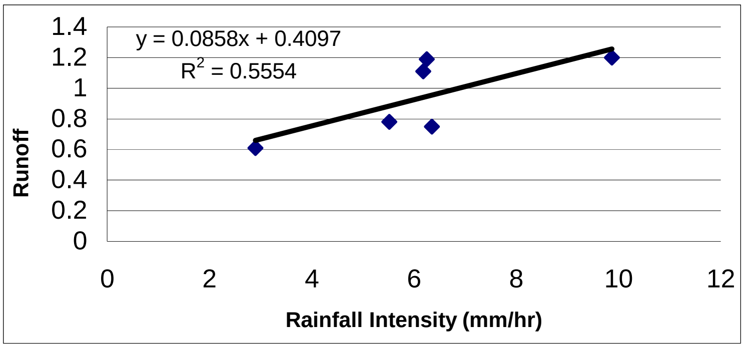

Fig. (4): Relationship between rainfall intensity and runoff (Case study I)

3.1.2 Case study II

El Falah study was carried out at El-Qasr area for 1997-1998, 1998-1999, 1999-2000 (North Western Coastal Zone of Egypt). The total rainfall depths were 115.2, 102 and 100.6 mm with 30, 27 and 24 rainy days. Eleven storms were effective during the three seasons as they caused runoff and consequently soil loss.

The statistical relationship between rainfall intensity and runoff was analyzed. Fig (5) shows linear relationship (r^2 =0.4104). Although the Wadi El Ramla region had greater rainfall intensity, the El-Qasr region has much greater runoff. The difference in runoff values between the two studies depends on the difference in soil properties such as erodibility. The site in the El-Qasr region has severe slopes which increase the kinetic energy of the water in this region.

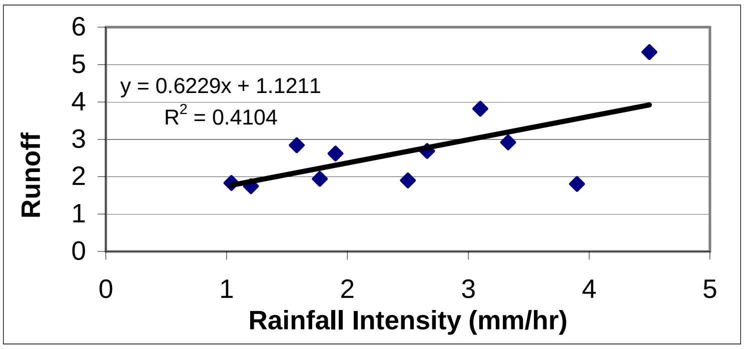

Fig. (5): Relationship between rainfall intensity and runoff (Case study II)

3.2 Relationship between runoff and soil loss under different soil management

Data from six storms were analyzed to determine the statistical relationship between soil loss and runoff under different soil management techniques: bare soil, planting without mulch, planting on mulch 0.5 ton/unit area, and planting on mulch 1 ton/ unit area. Table (1) shows soil loss values in tons/ha under different soil management systems. These relations were discussed as follows.

Table (1): Soil loss values ton/ha under different soil management systems.

Soil Management	Max. value	Mean value
Bare soil	5.1	0.85
Soil planting without mulch	2.8	0.47
Soil planting with 0.5ton/unit area	1.2	0.2
Soil planting with 1ton/unit area	0.8	0.13

3.2.1 Relationship between runoff and soil loss under bare soil

Fig. (6) shows a linear statistical relation (R^2=0.4079). It was clear that with increasing runoff the soil loss will also increase since runoff carries suspended sediments with it especially in case with no vegetative cover.

The greatest soil losses were obtained under this kind of soil management since there was no other resistance to the action of the rainfall Table (1). For bare soil, the maximum value was 5.1 ton/ha, while the mean value was 0.85 ton/ha

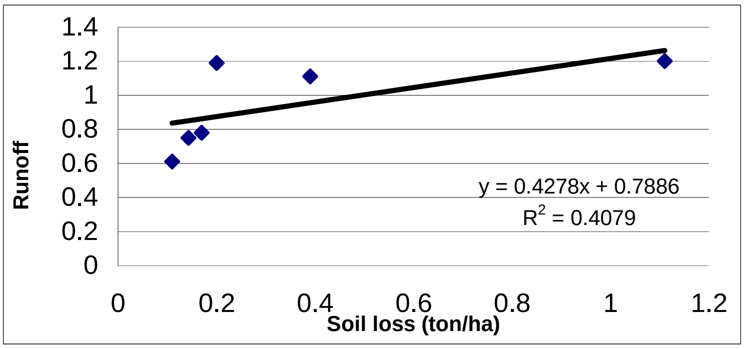

Fig. (6): Relationship between runoff and soil loss under bare soil

3.2.2 Relationship between runoff and soil loss under planting without mulch soil

Planting, even without additional mulch, is better than bare soil because the plants provide more soil stability. From Table (1) the maximum soil loss was only 2.8 ton/ha compared to 0.85 ton/ha under bare soil management, while the mean value was 0.47 compared to 5.1 ton/ha under bare soil management. Fig. (7) shows a linear statistical relation with (R^2=0.6991). A further increase in the runoff leads to the increase of soil loss due to the turbidity of the water into the soil but in less than soil loss as compared with the bare soil type of management.

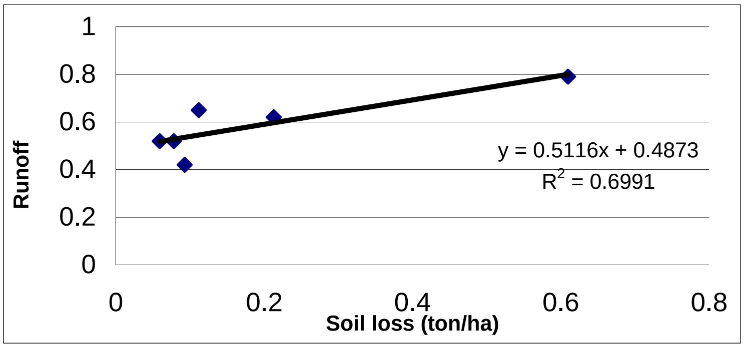

Fig. (7): Relationship between the runoff and soil loss under planting without mulch soil

3.2.3 Relationship between the runoff and soil loss under planting with mulch (0.5 ton/ unit area)

Concerning the application of 0.5 ton mulch/unit area, the obtained results for the soil loss is less than the bare soil and planting without mulch systems respectively because of the protection to the soil surface given by the plants which decrease the action of water flow into the soil. The maximum value of soil loss was 1.2 ton/ha, while the mean value was 0.2 ton/ha (Table 1). Fig. (8) shows the linear statistical relation (R^2=0.8151). Generally, this soil management technique is much better for protecting the soil, which leads to less soil loss.

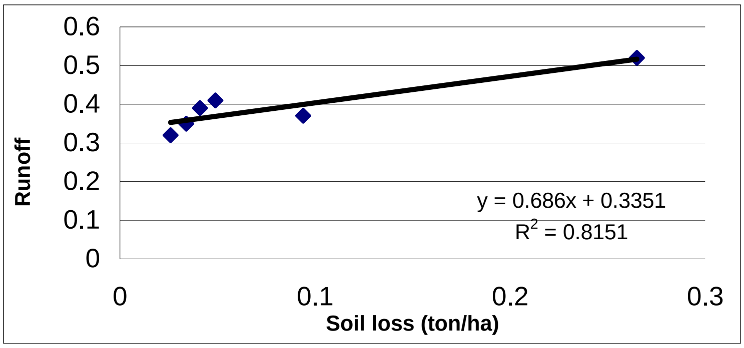

Fig. (8): Relationship between the runoff and soil loss under planting with mulch (0.5 ton/ ha)

3.2.4 Relationship between the runoff and soil loss under planting with mulch (1.0 ton/ unit area)

This kind of soil management is the best of the four soil management systems tested in this study for conserving the soil from the action of the water runoff since the mulch and plants decrease the force of water on the soil. The maximum soil loss was 0.8 ton/ha and the mean value was 0.13 ton/ha for all six storms (Table 1). The logarithmic statistical relation (R^2=0.893) between runoff and soil loss is shown in Fig. (9) under this kind of soil management.

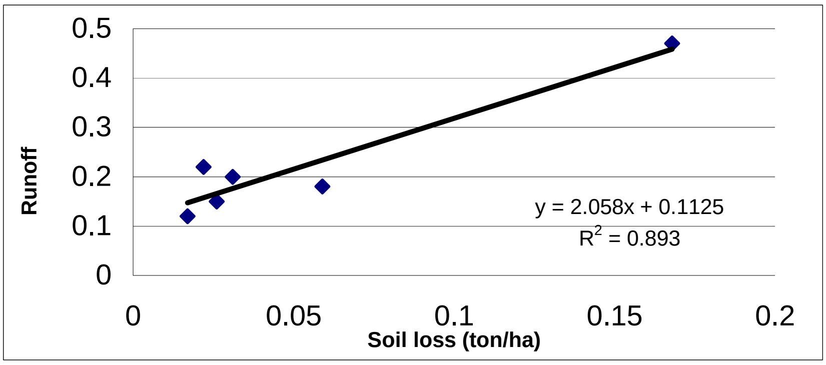

Fig. (9): Relationship between the runoff and soil loss under planting with mulch (1.0 ton/ ha)

4 Universal Soil Loss Equation (USLE)

The Universal Soil Loss Equation (USLE) remains the most powerful and usable practical tool for estimating soil erosion. The model is as follows. Robert (2000) reported that USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems, but is also applicable to non-agricultural conditions such as construction sites. The USLE can be used to compare soil losses from a particular field with a specific crop and management system to "tolerable soil loss" rates. Alternative management and crop systems may also be evaluated to determine the adequacy of conservation measures in farm planning.

Five factors are used to calculate the soil loss for a given site. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to varying weather conditions. Therefore, the values obtained from the USLE more accurately represent long-term averages.

The USLE is as follows:

$$\mathbf{E=R\ K\ L\ S\ C\ P}$$

Here:

E= represents the potential long-term average annual soil loss in tons per hectare per year. This amount is compared to the "tolerable soil loss" limits by ton/ha.

R=Rainfall erosivity factor which represents the rainfall and runoff factor by geographic location and defined as mean annual EI_{30} . If E is in J/m^2 and I_{30} is in mm/hr and R $=EI_{30}/1000$,then R is in metric units.

K=Soil erodibility factor, defined as the mean annual soil loss per a unit of R for a standard condition of bare soil, continuous fallow with an arbitrarily selected slope length and steepness. K is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Texture is the principal factor affecting K, but structure, organic matter and permeability also contribute, K can be calculated for a unit of metric R. Wherever possible, K should be based on measured values. If its value is obtained from the literature, it should be remembered that the estimate is subject to error. K has the same units as E. Thus if is in ton/ha, for one unit of metric R the multiplication by the metric R-value gives E in ton/ha.

The other factors in USLE are:

L= Slope length factor (a dimensionless coefficient).

S=Slope steepness factor represents a ratio of soil loss under given conditions to that at a site with the "standard" slope steepness. The steeper and longer the slope, the higher is the risk for erosion (a dimensionless coefficient).

C=Crop management factor (a dimensionless coefficient) defined as the ratio of the soil loss under a given crop to that from bare soil. It is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss. The C factor is a ratio comparing the soil loss from land under a specific crop and management system to the corresponding loss from continuously fallow and tilled land. The C Factor can be determined by selecting the crop type and tillage method

P= control factor (a dimensionless coefficient). P reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. The P factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. With no erosion-control practice P=1.0.

The most commonly used supporting cropland practices are cross slope cultivation, contour farming and strip cropping. Tables of these values are available for different control practice Robert (2000).

To estimate soil losses using the USLE model parameters are required for every rainfall event and each treatment. The obtained results are given in (Table 2). The estimated values for rainfall erosivity factor (R) with combined slope length factor were 0.66 and 0.52 for Wadi El Ramla and El Qasr respectively. The crop management factor (C) was given the values of 1 for bare soil. Comparing the predicted soil loss by USLE between the two sites varies due to the variation in erosivity factor and the variations in (K) and (LS) factors.

Table (2) also reveals that all predicted and measured soil loss were lower than soil loss for Tunisia, which is due to high rainfall in Tunisia which reach to over 600 mm/year. Soil loss was calculated for 4 regions using USLE, two in Egypt and two in Tunisia. For example in the site (wadi Ramla) R=67.55, K=0.13, LS=0.66 for bare soil, the calculated soil loss for this treatment was 5.79 whereas the measured soil loss = 5.05 ton/ha. The second site (Wadi Splashka) at El Qasr area represent C1 = planting parallel to the slope without organic matter, C2 = Planting perpendicular a cross the slope without organic matter and C3 = planting perpendicular across the slope with organic matter.

Table (2) shows 4 different sites with the estimated, calculated and measured soil loss (ton/ ha).

Site	Estimated USLE						Calculated soil loss				Measured soil loss			
	R	K	LS	C1	C2	C3	Bare	C1	C2	C3	Bare	C1	C2	C3
Wadi Ramla (Egypt)	67.55	0.13	0.66	0.55	0.25	0.15	5.8	3.18	1.4	0.83	5.1	2.8	1.2	0.8
Wadi Splashka (Egypt)	17.6	0.25	0.52	0.88	0.71	0.59	2.3	2.01	1.6	1.3	2.8	2.4	1.9	1.5
Menzah (Tunisia)	198.57	0.38	0.44	0.32	0.58	0.58	33.6	10.91	6.37	3.71	17.05	10.58	8.28	5.72
Near Bizerte (Tunisia)	146.65	0.29	0.56	0.4	0.68	0.58	23.8	9.6	6.53	3.81	17.05	10.88	8.62	6.49

5 Erosion Risk Index (ERI)

Erosion risk or potential erosion is understood as the maximum potential loss of soil in the absence of a cover crop and conservation practices, that is only due to the interaction of the physical factors of the land: soil, climate and topography.

The erosion risk index (ERI) is a function of physical characteristics of the land that encourage water erosion and is estimated using the following model (Fernando, 2002):

$$ERI = \alpha \ \beta \ \eta$$

Here:

α evaluates the soil runoff potential beginning with granulometry and a soil structure degree.

β evaluates the relative rainfall aggressiveness Morgan (1995).

η evaluates the impact of the topography on erosion risk, η is determined by the terrain slope and is expressed as a percentage.

ERI values can be classified into different levels of erosion risk as shown in table (3). The ERI data in this study were determined previously by Abou Yuossef (2004).

Table (3): Classification of erosion risk in terms of the values of the Erosion Risk Index (ERI) Fernando (2002)

ERI	*Erosion Risk*
$\leq$ 0.10	Low
0.11 – 0.30	Moderate
0.31 – 0.60	High
$\geq$ 0.61	Very high

5.1 Relationship between the erosion risk index (ERI) and Productivity Indices (PI)

Erosion Risk Index (ERI) and Productivity Index (PI) are related because soil erosion affects many soil characteristics, which are related to crop growth and yield. Continued soil erosion in area like North Saini resulted in reduced rooting depth and soil water storage capacity, crusting, soil compaction, change in root zone and deterioration of soil biological properties. Fig. (10) shows an Exponential statistical relation (R^2=0.9273) between ERI and PI, in which the Productivity Index decreases with increasing Erosion Risk Index. Therefore, soil conservation practices should be selected that lower erosion risk index (ERI).

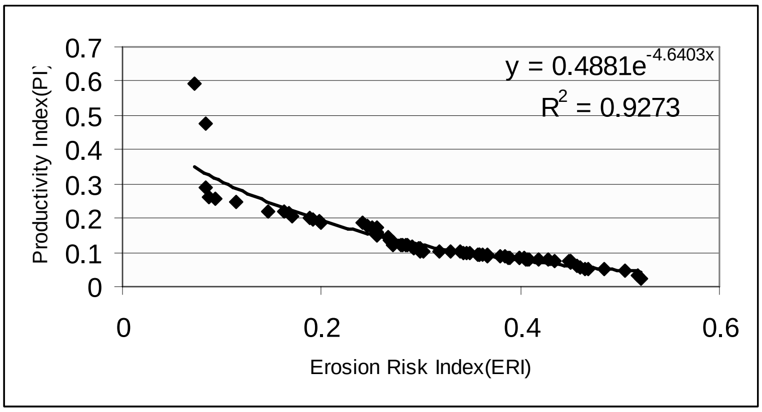

Fig. (10): Relationship between the erosion risk index (ERI) and Productivity Indices (PI)

6 Concluding remarks

This research addressed the problem of water erosion in North Africa. Both Egypt and Tunisia were used as case studies for the Northern African region in order to determine the relation between 1) runoff and soil loss under different management techniques and 2) Erosion Risk Index and Productivity Index. In addition a comparison was made between the measured soil loss and soil loss estimated by Universal Soil Loss Equation (USLE) for four study sites. We found in general the USLE underestimates soil loss but nonetheless we recognize the ubiquitous use of USLE as an easy to use tool.

This study also presents data supporting the selection of certain soil and water conservation techniques for sustainable agriculture on North African soils, primarily the use of planting cover crops and mulching. Those techniques reduce runoff and subsequently lower the Erosion Risk Index (ERI).

We found that the Productivity Index (PI) decreases with increasing Erosion Risk Index therefore a lower ERI generally results in greater productivity. The relation between ERI and PI was $\mathbf{Y = 0.4881\ e^{-4.6403\ x}}$ where Y is Productivity Index (PI) and x is Erosion Risk Index (ERI). This can be used by the existing decision support system for water erosion control to estimate productivity for a given ERI in North African countries.

The real situation is much more complicated and the approach for dealing with the problem discussed would benefit from additional research and data from all North African countries.

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