

MULTISCALE TERRAIN ANALYSIS FOR THE IDENTIFICATION OF EROSION SUSCEPTIBLE AREAS AN EXAMPLE OF LEBANESE TERRITORIES

Jean A. Doumit^{*}, SalwaSaidi[†]

ABSTRACT

The objective of this paper was to develop multiscale models for the identification of erosion susceptible areas, exploring the potential of different spatial resolution open source Digital Elevation Models (DEM), (MERIT, SRTM, ALOS AW3D, and ALOS PALSAR). Topography and terrain derivative parameters that have the greater impact on erosion were calculated in Geographical Information System based on geomorphometry algorithms and fuzzy logic functions proposed for the evaluation of each parameter on erosion risk in Lebanese territories.

The objective of this research was to develop based on topography parameters (slope and dissection index) and based on terrain derivatives (LS factor, profile curvature, stream power index and topography wetness index) four different models for assessing the susceptible areas of erosion on the Lebanese territories, exploring the potential of DEMs of different spatial resolutions. Topography parameters and terrain derivatives were computed from the DEM's elevation, and some fuzzy logic functions were proposed to evaluate the influence of each parameter on erosion risk.

The results showed that DEM use is relatively easy, an uncostly method to identify, in a qualitative way, the erosion susceptible areas (ESA) varies with the spatial resolution (scale) and related to the DEM way of interpolation. From this study, we can conclude that in digital erosion modeling the correlation varies with the type and resolution of the database used and influence on the shape and geometry of the Erosion Susceptible Areas.

KEYWORDS: Erosion, DEM, Profile curvature, LS factor, Stream Power Index, Topographic Wetness Index.

INTRODUCTION

Water Soil erosion has been recognized as a severe hazard because it reduces soil productivity by removing the most fertile topsoil (Shrestha, 1997; Angima et al., 2003).

With the applications of remote sensing (RS) and the Geographical Information System (GIS) technologies together they can make the study more viable as they handle complex issues and large databases for manipulation and retrieval much efficiently.

Topographic morphometric characteristics of the study area have been addressed using spatial information technology for the preparation of the erosion susceptibility maps in a GIS environment based on topography parameters and terrain derivatives.

^{*}Lebanese University, department of geography, Faculty of Literatures and Human Sciences, Fanar, Lebanon.

email: jeandoumit@gmail.com

[†]

Soil survey provides information about areas that have erosion, but do not show which areas are susceptible to erosion, applying first and second derivatives of elevation at multiscale (spatial resolution) DEM for highlighting erosion risk at different levels.

The erosion modeling of bad spatial resolution and low level of detail only shows areas with a high incidence of erosion processes, our research analyzed the multiscale level of details of erosion areas from global to local scales.

Some researches do not take into account the effect of scale by merging different spatial resolutions digital maps like soil, land use and topography for soil erosion modeling dropping that, erosion models are different in terms of their complexity, their requirements and inputs, the processes they represent and the scale of their intended use and the types of information they provide (Aksoy and Kavvas 2005; Merritt et al., 2003).

Kienzle 1994 in his paper has used terrain variables to distinguish between terrain units and estimate soil erosion potential, he determined that both slope and soil erosion estimations increase with a decrease in grid cell size.

Saulinier et al. 1997 investigated the analytical compensation between terrain derivatives and grid resolution and found that the topographic index increases with grid cell size.

Zhang and Montgomery 1994 compared grid cell sizes of elevation data and found that the grid size affects the hydrological simulations.

These studies have shown that the DEM spatial resolution affects derived terrain parameters and prove that the ability to carry out a realistic terrain analysis is limited by the chosen grid cell size and will affect erosion modeling, deposition, and water quality processes.

Spatial resolutions selected to overlay DEM with another raster should be approximately the same to output a valid analysis and modeling.

Several erosion models based on GIS analysis, of various modifications and versions of the Universal Soil Loss Equation (USLE) (Warren et al. 1989, Flacke et al. 1990, Huang and Freng 1990). The USLE was developed for an agricultural application, not for landscape-scale erosion modeling. Therefore, the application of USLE in GIS for complex terrain is rather restricted (Foster and Wischmeier 1974, Moore and Wilson 1992).

Recently developed erosion models based on the stream power theory (Moore and Wilson 1992, Mitasova and Iverson 1992, Hofierka 1992, Mitasova et al. 1996) include the influence of terrain forms and are therefore more suitable for complex topographic conditions.

In this paper, the authors assess how spatial resolution affects topography parameters and terrain derivatives for the identification of erosion susceptible areas.

Topography parameters, slope, and dissection index in other way terrain derivatives profile curvature (Kv), topographic wetness index (TWI), stream power index (SPI) and LS factor (LS).

The topography is a factor that influences the transport and accumulation of sediments, depending on the relief characteristics. Hence the effect of relief on erosion has been related to the shape and uniformity of the slope (Toy et al., 2002).

DEMs have high potential to characterize topography as an important input for different erosion models (Mitasova et al., 1996; Moore et al., 1991).

Terrain analysis is a quantitative GIS technique for terrain analysis and geomorphic processes at a variety of scales using DEMs (Wilson and Gallant 2000).

In this study terrain analysis methods are used for the extraction and analysis of topography parameters and terrain derivatives to determine factors in modeling ESA (King et al., 2005).

The importance of terrain derivative offers an opportunity to describe patterns as a function of the process (Wilson and Gallant, 2000; Moore et al., 1991) and include LS factor, profile curvature, stream power, and topographic wetness indices. The objective of this research was to explore the potential of multiscale DEM as a data source, to calculate the variables of relief that have the greater impact on erosion and to develop a model for assessing the risk of erosion,

MATERIALS AND METHODS

Lebanon is a mountainous land with an elevation interval 0 – 3080 above the sea level laying on an area of 10452 square kilometers, its physiography ranges from coastal plains in low lands, to very rugged and snow-covered high mountains. In such landscapes, the topography is an overruling erosion factor.

Figure 1 of the study area shows the elevations map of Lebanon highlighting the geomorphological structures with hydrological networks.

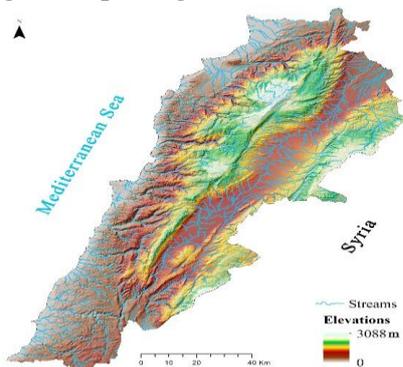


Fig.1: Elevations Map of Lebanon with stream network

Multiresolution datasets used in this study are MERIT, SRTM, AW3D and ALOS.

The MERIT DEM was developed by removing error contains in DEM such as stripe noise, speckle noise, and tree height bias from Shuttle Radar Topographic Mission (SRTM) and **ALOS World 3D** (AW3D). MERIT DEM are freely available for researches and education purpose and represents terrain elevations at a 90 m spatial resolution (Yamazaki et al. 2017).

The Shuttle Radar Topography Mission (SRTM) elevation with worldwide coverage of corrected void filled data at a resolution of 30 meters (USGS, 2006d).

ALOS Global Digital Surface Model "ALOS World 3D (AW3D)" from the Japan Aerospace Exploration Agency (JAXA) released the global digital surface model (DSM) dataset with a horizontal resolution of 30-meter mesh free of charge for scientific research and education (Takaku et al. 2016).

PALSAR is one from the Advanced Land Observing Satellite systems (ALOS),

It offers corrected DEM, with a pixel size of 12.5 m, these data are available free of charges on the Alaska Satellite Facility website (Logan et al. 2014).

The multiscale datasets used in this study expressed in spatial resolution as: MERIT (90 m), SRTM (30 m), AW3D (30 m) and ALOS (12.5 m), the same pixel size of SRTM and AW3D with 30 meters used to test the erosion susceptible area at different types of datasets.

For the calculation of topography parameters (TP), slope as first terrain derivative is calculated directly from DEMs and dissection index (DI) calculated based on Maximum relief (Rmax), minimum relief (Rmin) and relative relief (Rr).

Slope Angle (SA) Calculated from a DEM is relatively simple based on ArcMap method using the quadratic surface algorithm by (Srinivasan and Engel, 1991; ESRI, 1997). Much higher slope angle values estimate erosion risks The slope angle also corresponds to the direction of overland.

Absolute relief (AR) means the maximum height of any region, expressing the elevation above the sea level. Relative relief (RR) represents the difference in elevation between the highest and lowest points falling in a unit area (square grid). The first time a scientific and systematic study of relative relief was done by (Smith, 1935).

The highest and lowest points of a DEM were calculated in a GIS module by the maximum and minimum focal statistics on a 3 x 3 grid, the difference between the generated grids presents a better index of erosion with the stage of development (Doumit and Kiselev, 2018).

Dissection Index (DI) is the ratio between relative relief and absolute altitude, the areal differentiation of this ratio will give a good index value in the estimation of the vertical balance of erosion.

Nir (1957) calculated ‘Dissection Index’ as the ratio of relative relief and absolute relief within a specific areal unit following equation 1.

$$DI = \frac{RR}{AR} \quad (1)$$

DI gives a better understanding of the landscape its values varies from 0 complete absence of dissections to 1 a vertical cliff, DI expresses the relationship between the relief vertical distance from the erosion level and relative relief (Jha, 1996).

The Absolute Relief (AR) is a maximum elevation of a unit area (3 x 3 cells), AR is used in the delineation of the structural and erosional characteristics of an area and it is a function of tectonic processes. AR is calculated by a maximum focal statistics of a DEM.

The Relative relief (RR) represents the difference in elevation between the maximum and the minimum elevations falling in a unit area. In some study, relative relief is called relief energy as per (Doumit 2017).

The calculation of erosion susceptible areas was performed with a fuzzy equation applied on all parameters extracted from DEMS (MERIT, SRTM, AW3D and ALOS) that integrates the effect of elevation on erosion factors, by limiting the values of topographic parameters (SA and DI) from 0 to one in an ascending scale from less to more susceptible to erosion. An output of the applied fuzzy operations on topography parameters was four slope angle maps (SA_{MERIT} , SA_{SRTM} , SA_{AW3D} , and SA_{ALOS}) and four Dissection index maps (DI_{MERIT} , DI_{SRTM} , DI_{AW3D} , and DI_{ALOS}).

In this study the choose of Terrain derivatives (TD) with high influence on erosion such as LS factor, Profile curvature, Topographic Wetness Index and Stream Power Index.

LS factor represented terrain influence on erosion by which reflects the fact that erosion increases with slope angle and length. The traditional USLE method for computing the LS factor is (Wischmeier and Smith 1978).

$$LS = \left[\left(\frac{\lambda}{22.13} \right)^t (65.4 \sin^2 \beta + 4.56 \sin \beta + 0.0654) \right] \quad (2)$$

Where λ is the horizontal projection of slope length.

t is the constant dependent on the value of the slope.

β the slope angle in degree.

In this study, we applied aGIS method for calculating LS factor the same as the method used by (Dunn and Hickey, 1998; Hickey, 2000).

Hickey 2000, explained the calculation of the LS factor based on DEM and he mentioned that Slope length calculations are often the most problematic of the erosion model parameters, not the slope angle.

In his method, Hickey 2000 generates a flow direction from depression less DEM, beside the Maximum slope angle a non-cumulative slope length calculated the cumulative downhill slope length than the LS values (Hickey 2000).

Haan et al. (1994) in their research has shown that the increase of slope length produces higher overland flow velocities and correspondingly higher erosion (Haan et al., 1994).

Profile curvature or vertical curvature K_v is the terrain curvature in the vertical plane parallel to the local slope direction and defined as:

$$K_v = \frac{\theta_{xx}\theta_x^2 + 2\theta_{xy}\theta_x\theta_y + \theta_{yy}\theta_y^2}{\theta_x^2 + \theta_y^2 \sqrt{(\theta_x^2 + \theta_y^2 + 1)^3}} \quad (3)$$

where θ_x is the slope in the x-direction and θ_y is the slope in the y-direction, θ_{xx} is the second derivative of the slope in the x-direction and θ_{yy} is the second derivative of the slope in the y-direction and θ_{xy} is the second derivative of the product of the slopes in direction of x and y.

Profile curvature measures the rate of change in slope, K_v is negative on concave profiles, and positive on convex profiles, while zero on straight profiles (Shary, 1995). Geomorphologically, relative deceleration areas are known as 'concave', while relative acceleration areas are 'convex'. Profile curvature is a very significant topographic element that shows which process tends to be dominant, whether erosion or deposition. On convex terrains, erosion is more likely to prevail, as well as on concave deposition (Wilson and Gallant, 2000; Neteler and Mitasova, 2008; Kennelly, 2008; Doumit, 2017). Profile curvature is important because it reflects the change in slope angle and it controls the change of velocity of mass flowing down along the slope curve (Evans, 1980).

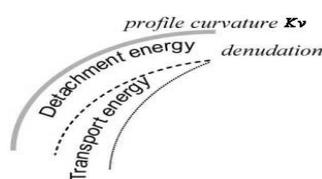


Fig.2: Effect of Profile curvature on Erosion.

The profile curvature K_v is derived from the slope gradient that expresses the ratio of gravity force down and perpendicular to the slope. Considering the part of gravitational energy expended for detachment and transport Figure 2. thus the rate of slope denudation (detachment and transport) will be related to the change of acceleration/deceleration of flows (amount of material removed or deposited) on the slope profile (Minár, et al.2013).

The topographic wetness index (TWI) is defined as the log of the ratio of the Specific Catchment Area (A_s) and the tangent of the gradient at a given location. TWI is a parameter that describes the tendency of a cell to accumulate water, it was calculated in formula 4 (Beven 2001):

$$TWI = \ln \left(\frac{A_s}{\tan \theta} \right) \quad (4)$$

where A_s is the specific catchment area and θ is the slope in degrees.

The TWI has been used to indicate the potential of saturated areas and predicts the distribution of local soil moisture (Blyth et al.2004; Guntner et al.2004). TWI is also used to predict spatially varying evapotranspiration and the liability to erosion (Xu and Li, 2003; Stieglitz et al. 2003).

Stream power index (SPI) is a secondary topographic attribute, it has been used as a measure of the erosive power of flowing water and could be used to identify places that reduce the erosive effects of concentrated surface runoff, such as grassed waterways (Moore et al., 1991).

The calculation of this parameter is done with the following Eq. 5:

$$SPI = A_s \tan \theta \quad (5)$$

SPI derived from the slope and the contributing area of flow accumulation. SPI evaluates erosive power not just in streams but across the whole landscape, it predicts contributing areas where the erosive power of overland flow will be the high (Wilson and Gallant 2000).

Pike et al. (2009) used various terrain analyses, including SPI, to model erosion potential of ephemeral gullies and then compared those results to real-world conditions. They found that about 80% of the calculated SPI values, successfully identified areas of observed gully formation (Pike et al. 2009).

The same as Topography parameters (TP) calculation of erosion susceptible areas was performed with a fuzzy equation applied on Terrain Derivatives (TD) extracted from DEMS (MERIT, SRTM, AW3D and ALOS) that integrates the effect of first and second elevation derivatives on erosion factors, by limiting their values from 0 to one in an ascending scale from less to more susceptible to erosion. an output of the applied fuzzy operations was sixteen terrain derivatives maps, from LS factor (LS_{MERIT} , LS_{SRTM} , LS_{AW3D} and LS_{ALOS}), from profile curvature (K_{VMERIT} , K_{VSRTM} , K_{VAW3D} and K_{VALOS}), from Topographic Wetness Index (TWI_{MERIT} , TWI_{SRTM} , TWI_{AW3D} and TWI_{ALOS}), from Stream Power Index (SPI_{MERIT} , SPI_{SRTM} , SPI_{AW3D} and SPI_{ALOS}).

DISCUSSIONS AND RESULTS

With the results of this study, we identified areas that are susceptible to erosion from topography parameters (TP) and terrain derivatives (TD) from multiscale DEMs.

Hamacher fuzzy function used to assess the topography sensitivity to erosion, which allows the integration of the effect of geomorphometric parameters on soil erosion. This function uses fuzzy connectives to combinethe effect of several parameters in multi-criteria decisionmaking (Canutoet al., 2003).

We used the fuzzy logic, ANDoperation for the calculation of Topography Parameters and for Terrain Derivatives grids, this method proposed by Reynolds (2001) it is implemented mathematically as a minimumfunction on the set of logical antecedents.

$$AND(x) = Min_{(x)} + \frac{(Mean_{(x)} - Min_{(x)})(Min_{(x)} + 1)}{2} \quad (6)$$

$Min_{(xi)} = i = 1, \dots, n$ the minimum value for erosion factors (topographic parameters and terrain derivatives).

$Mean_{(xi)}$ = the weighted average of xi for erosion factors (topographic parameters and terrain derivatives).

Where AND is a minimum-biased weighted average of the logical antecedents.

Topographic parameters have been calculated with an equal weight because slope and dissection index have approximately the same influence as erosion factors and gives as an output four maps of erosion susceptible areas (TP_{MERIT} , TP_{SRTM} , TP_{AW3D} , and TP_{ALOS}) figure 3.

Terrain derivatives have been weighted as high influence on erosion such as profile curvature, LS factor, and stream power, with moderate influence on erosion, comes the Topographic Wetness Index. and gives as an output four maps of erosion susceptible areas (TD_{MERIT} , TD_{SRTM} , TD_{AW3D} , and TD_{ALOS}) figure 4.

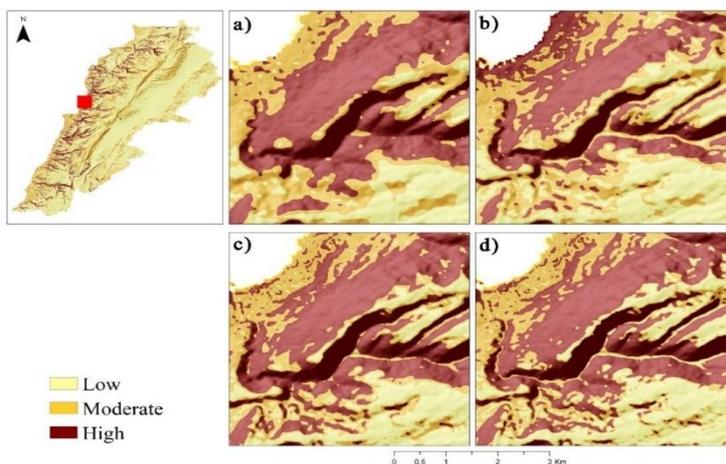


Fig.3: Erosion susceptible areas based on Topography parameters, a) TP_{MERIT} , b) TP_{SRTM} , c) TP_{AW3D} d) TP_{ALOS}

In figure 3 erosion susceptible areas scheme an assemblage of topography parameters (slope and dissection index)

Steep to very steep slopes with high dissection index explain more erosion propensity expressed in dark areas of figure 3. At 90-meters spatial resolution of TP_{MERIT} high erosion susceptibility zone covers about 9.20% of the Lebanese area.

The high erosion susceptibility zones consist of gentle to a steep slope, moderate to high dissection index, table 1 shows that high erosion susceptibility increase with the spatial resolution except at

TP_{SRTM} the area susceptible to erosion occupied 6.46 % less than TP_{AW3D} with the same spatial resolution of 30 meters and this difference is also discoverable in figure 3b and 3c.

Moderate and Low erosion susceptibility areas are decreasing with the scale when the spatial resolution is higher otherwise stable zone covers almost 90% of the study area and is associated with lower slopes and slight dissection index.

Table 1: percentage of areas susceptible to erosion according to Topographic Parameters and Terrain Derivatives.

	TP_{MERIT}	TP_{SRTM}	TP_{AW3D}	TP_{ALOS}	TD_{MERIT}	TD_{SRTM}	TD_{AW3D}	TD_{ALOS}
Low	60.88	65.65	62.60	62.71	42.49	40.85	42.46	26.85
Moderate	30.02	27.89	27.23	26.99	28.56	28.75	28.03	33.68
High	9.10	6.46	10.17	10.31	28.96	30.40	29.51	39.47

The evaluation of topography parameters at all levels of details has been found that, nearly all the relief parameters: *slope angle (SA)* and *dissection index (Di)* values are high in between ridges and channels and low in the plain areas such Bekaa and Akar valleys. Higher relief supports prompt runoff and hence it is directly related to soil erosion propensity (Phillips, et al 1999). More specifically, TP_{MERIT} occupied the higher area of ESA (39%) of the study area which lies under the high SA and Di. Figure 3a, c, and d show the quantitative degree in the cartographic generation (change in scale) expressed in a difference of ESA area of 2% between TP_{MERIT} and TP_{ALOS} .

Topography parameters indicate the structural complexity of the terrain in association with SA and DI and imply more susceptibility to erosion.

Terrain derivatives have been done based on the four multiscale DEMs. Their spatial maps, prepared in a Geographical Information System figure 4.

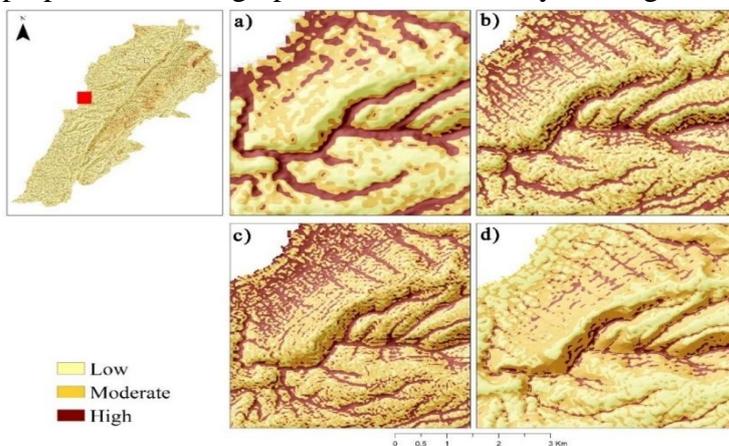


Fig.4: Erosion susceptible areas based on Terrain Derivatives, a) TD_{MERIT} , b) TD_{SRTM} , c) TD_{AW3D} d) TD_{ALOS}

The evaluation of the terrain derivatives: LS, SPI, Kv, and TWI is directly related to the structure of the landforms and lithological characteristics. Significantly high values of LS, SPI, Kv, and TWI are noticed in stream channels over the whole study area (Figure 4a, 4b, 4c, and 4d) it indicates high mountainous relief and high runoff conditions which intensify the erosion mechanisms.

The multiresolution soil erosion susceptibility maps based on terrain derivatives of Lebanon shows the relative potential areas to erosion, generated from fuzzy logic AND equation with weighted composite scores, the greater susceptibility of erosion indicated by high scores and vice versa. The dark color zones of figure 4 represent high receptiveness of erosion.

Figure 4a of TD_{MERIT} shows high values of ESA in channels and deep valleys and low values on the top of ridges

These results are due to higher TWI values that represent depressions in the landscape, where water is likely to concentrate through runoff (Martínez and Correa, 2016).

Moreover, SPI high values indicating the erosive power in the water flow correspond to lower and concave shapes of the terrain, and, therefore, presents values of membership degree close to 1

TD_{SRTM} and TD_{AW3D} of figure 4b and 4c are very similar in values and in shape which proves that Terrain Derivatives are only influenced by the spatial resolution not the type of DEM. At large scales figure, 4d of TD_{ALOS} shows ESA on cracks and high terrain amplitude zones

The percentage of areas in table 1 of TD is increasing for high and moderate values with the scale from small to large.

Kv values less than zero presented a low incidence of erosion risk and corresponded to concave terrain in the vertical direction to the slope, while the convex terrain had a higher incidence. Kv values influences on flow acceleration, erosion and deposition rate; a convex curvature accelerates flow and erosion process, while a concave one has a big influence on the sedimentation process (Wilson and Gallant, 2000; Neteler and Mitasova, 2008; Kennelly, 2008).

Zhang and Montgomery 1994 investigated the effects of different DEM resolutions on the TWI and found that higher resolutions lead to lower TWI values (Zhang and Montgomery 1994). We found that also all other terrain derivative parameters (LS, SPI, and Kv) are under the influence of spatial resolution and their values increase with the increase of the scale.

The maps of figures 3 and 4 based on topography parameters and terrain derivatives demonstrate the qualitative classification of the areas susceptible to erosion.

The result of visual and quantitative analysis of multiscale TP and TD shows a similarity in all dataset with some difference due to the variation in spatial resolution.

A GIS combination algorithm combines the generated maps of topography and terrain derivative erosion susceptible areas into four final Erosion Susceptible Areas map (ESA_{MERIT} , ESA_{SRTM} , ESA_{AW3D} , and ESA_{ALOS}).

The algorithm takes multiple input raster and assigns a new value for each unique combination of input values in the output raster in a way to give the highest values to the area of high erosion and the lowest value to the areas of low erosion.

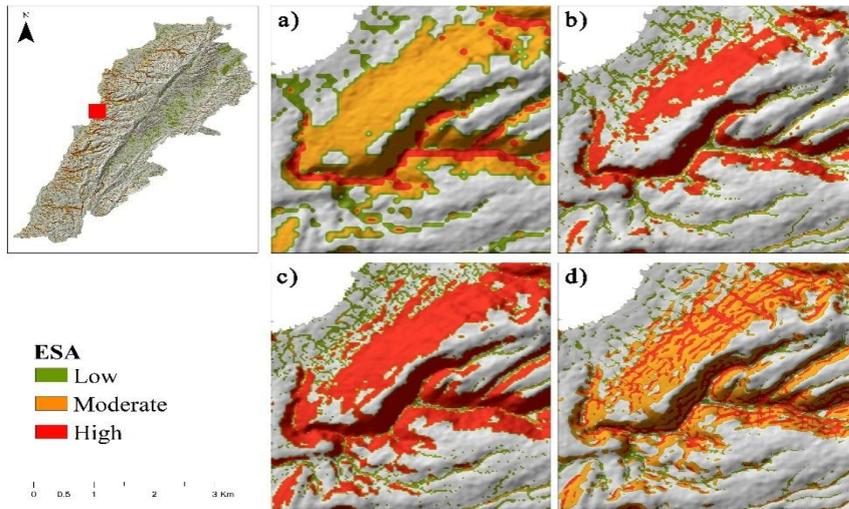


Fig.5: Erosion Susceptible Areas maps, a) ESA_{MERIT} , b) ESA_{SRTM} , c) ESA_{AW3D} d) ESA_{ALOS}

The resulted ESA maps illustrated in figure 5a shows a very high degree of ESA in channels and moderate ESA in convex breaks (areas between ridges and channels).

In ESA_{SRTM} and ESA_{AW3D} of 30 meters resolution the high degree of ESA found in convex breaks and the low degree of ESA in the plain areas in another way in figure 5d of high-resolution ESA_{ALOS} convex breaks have moderate and high degree of ESA, the evolution of ESA with the scale passed by two phases, 1) spatial changes of high ESA from channels to convex breaks between ESA_{MERIT} and ESA_{AW3D} . 2) shape changes by the decrease of the high ESA surfaces between ESA_{AW3D} to ESA_{ALOS} .

Table 2: percentage of areas susceptible to erosion.

	ESA_{MERIT}	ESA_{SRTM}	ESA_{AW3D}	ESA_{ALOS}
Low	79.88	82.99	80.03	83.24
Moderate	11.75	12.05	11.20	9.63
High	8.37	4.96	8.77	7.13

The quantitative analysis of ESA percentage of areas in table 2 proves in numbers the evolution of the generalization from 8.37 % of high ESA degree to 7.13%, the decrease in area percentage of high ESA degree ESA_{MERIT} to ESA_{ALOS} gives an increase in low ESA area percentage.

To test the similarity between the multiscale erosion susceptible areas maps a correlation analysis done figure 6

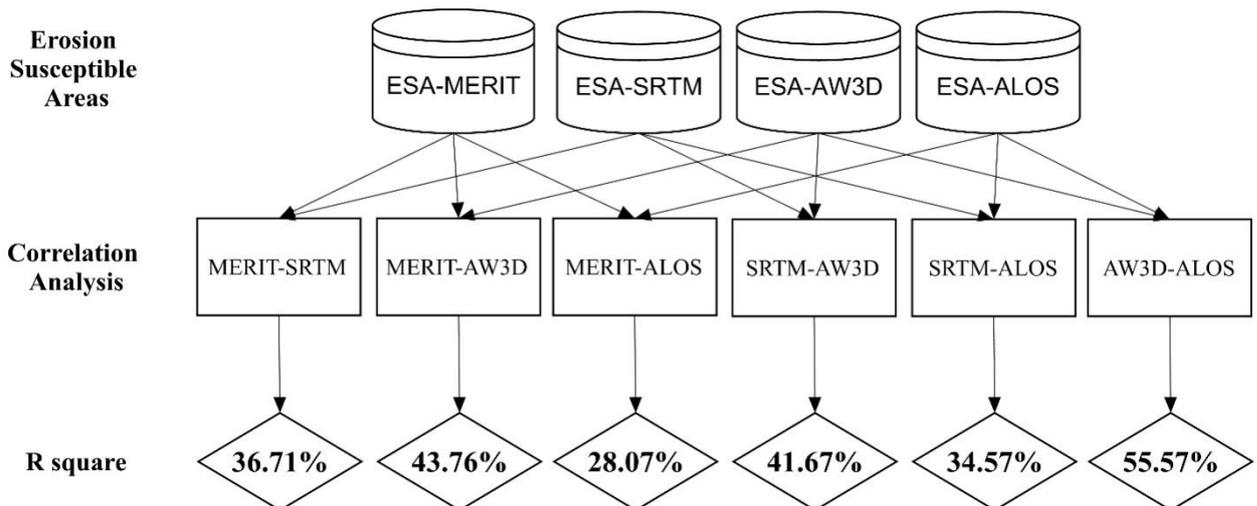


Fig.6: Correlation analysis schema between different scale ESA maps.

The correlation analysis schema begins from the four multiscale erosion susceptible maps generated from digital elevation models than compared between each for the calculation of R^2 .

A very low percentage of similarity between ESA_{MERIT} and ESA_{ALOS} due to the difference in scale, the spatial resolution of ESA_{ALOS} is seven times smaller than ESA_{MERIT} .

R^2 values of ESA_{SRTM} and ESA_{AW3D} with similar scale is 41.67% not a high degree of similarity, hence the Erosion Susceptible Areas not only depend from scales but it defers with the type of data source (the way of DEM generation).

ESA_{AW3D} and ESA_{ALOS} took a higher degree of similarity of 55.57% to prove in the above visual and quantitative analysis in figure 5 and table 2.

The modeling of erosion susceptible areas predicts the highest erosion in strongly convergent areas indicating the creation of channels.

These results were due to the higher resolution of the ALOS DEM (12.5 m) and the better representation of the Earth's surface lead to very high accuracy in defining the Erosion Susceptible Areas.

CONCLUSION

The multiscale level of details of ESA required the application of a very precise quantitative model. Open source high spatial resolution DEMs improves information on erosion and the level of detail of the information by using multi-spatial resolution, the calculation of geomorphometric parameters facilitate the understanding of the factors affecting erosion. The use of fuzzy logic provides a more realistic approach to the erosive phenomenon based on DEMs that have considerable uncertainty.

The present paper delineates the erosion susceptible areas of the Lebanese territory using geospatial method taking into consideration Topography and Terrain Derivative. The study revealed that almost (7%) of the study area is potentially erosive, the use of fuzzy-logic in geosciences, more precisely ESA has several advantages that improve the use of conventional logic. In this study we mentioned that digital modeling has many factors

influencing data uncertainty in complex erosion processes, the fuzzy approach has a great potential for modeling

Low and high-resolution DEMs.

In small scales, Micro features to increase and slow the runoff, and therefore erosion. Thus, with the increasing of DEM resolution and accuracy, erosion estimation will be better and the landscape will be more accurately described.

Finally, we can conclude that erosion modeling depending on data source type and scale by influencing the shape and geometry of the Erosion Susceptible areas.

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