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Sediment Transport Index (STI) modeling using the GIS at Small Agricultural Catchment

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Abstract: *Sediments transported by rivers are the major sources of materials for protecting deltas from the natural processes of subsidence.Several deterministic sediment transport models have been developed that use conservation of mass and momentum principles to model sediment transport.Hydrological indices provide excellent input to geographic information systems for the successful mapping oferosion-prone areas. In this research, a digital elevation model was processed and analyzed to obtain the necessary hydrological indices necessary for erosion modeling.The indices (such as the sediment transport index, compound topography index, and stream power index).The chosen index in this study is the STI which can provide vital information onsustainability and the potential of sediment transport in the stream network of a given watershed.The application of this index within the catchment of Tiguert, which is the chosen study area, showed that the downstream part of the catchment has high values of the index, which is significant for a high dynamic of transportation.*

Keywords: *sediment transport index – hydrological indices –Tiguert catchment.*

1. Introduction

The sediment transport phenomenon is a problem of interest in the environmental field. Besides the typical application in the morphology of a river, the sphere of action of the sedimentation process is wide and it has a deep impact on its environment. Due to the flow of the river some particles are swept along the current. This material is taken mainly from the riversides and also from the bottom, being deposited downstream when the flow becomes weaker, either again on the riversides or in its mouth(Garres-díaz, Fernández-nieto, and Narbona-reina 2022).

Sediments transported by rivers are the major sources of materials for protecting deltas from the natural processes of subsidence. However, sediment loads worldwide have been significantly reduced by climate change and anthropogenic activities; (Hackney, C; Darby, S; Parsons 2020); (Kim et al. 2022)(Binh et al. 2022). Modeling is an important method of soil erosion parameters estimation, and the selection of aprediction model may largely affect the results (Zhao and Hu 2019);(Zhang et al. 2018).

During the past two decades, several deterministic sediment transport models have been developed that use conservation of mass and momentum principles to model sediment transport. Deterministic models produce the exact results for a particular set of inputs which usually require a large simulation time compared to stochastic approaches. These models do not consider the randomness of the data and generate the same result for a given input parameter set, whereas the stochastic approaches present data and predict outcomes that account for a certain level of unpredictability or randomness, which could generate different outputs for a given set of input variables (Kalin and Hantush 2014);(Baharvand, Ahmari, and Taghvaei 2022)

Small catchments, such as a natural geographic unit, have relatively independent material transmission processes. Given this advantage, small catchments are ideal study areas for quantifying sediment transport in the research of earth surface processes (Lane 2019);(Bonaccio et al. 2018);(Xiong, Tang, and Yang 2021)(Dai et al. 2022).

Hydrological indices provide excellent input to geographic information systems for the successful mapping oferosion-prone areas. In this research, a digital elevation model was processed and analyzed to obtain the necessary hydrological indices necessary for erosion modeling. The indices (such as sediment transport index, compound topography index, and stream power index)(Ahmad and Dar 2019).

The sediment transport index (STI)characterizes the processes and of erosion and disposition and, can provide vital information on the potential of sediment transport in the stream network of a given catchment .

This research aims to study and calculate the sediment transport index in order to determine the areas with high processes of transport at the catchment.

2. Study Area

The Tiguert catchment, a small catchment located at the downstream part of the Ouaoumana catchment, belongs to the Oum Er-rabiaa basin. Extend over 10.3 km^2. Characterized by a semi-arid climate, the rainfall ranges between 450 and 500 mm, marked by irregularity in space and time, which creates flash flood events. This accumulation and aggressive flow of water removeschunks of land, which causes soil erosion. In terms of lithology, the catchment is indicated by spreading of limestone and red clay, and it is also considered an agricultural area.

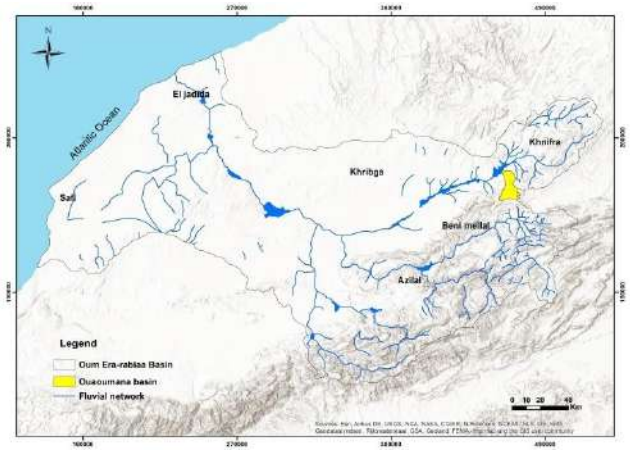


Fig 1: The localization ou Ouaoumana basin within the Oum Er-rbia.

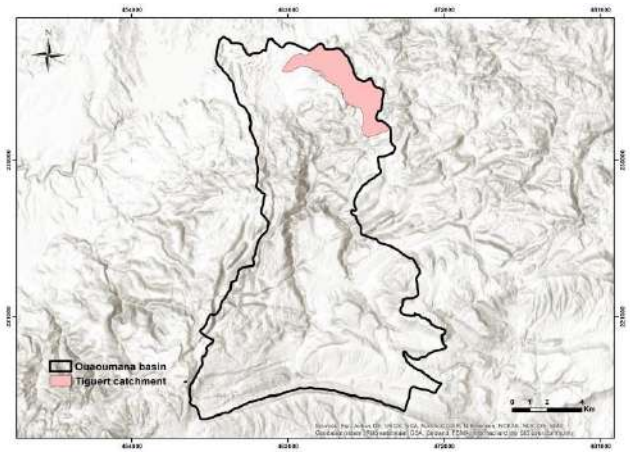


Fig 2: The Ouaoumana basin.

Fig 3: The Tigeurt catchment.

3.Material and Methods

hydrologic indices were examined for their use in detecting areas affected by flood and erosion from heavy rainfall and inundation (Moore, Orth, and Nowak 1993)(A. Bannari, A. Ghadeer, A. El-Battay 2017).Therefore, the selected index in this study is the sediment transport index which is considered as energetics-based model predictions were compared to the tracer experiment results. This model combines transport. Components induced by wave-asymmetry and mean flow ; it is used most widely in morphological model approaches and is considered one of the best theoretical models for timedependent, cross-shore sediment transport .(Voulgarist et al., n.d.).The STI can provide vital information on the potential of sediment transport in the stream network of a given watershed(Huisman and By, n.d.)(Rahmati et al. 2019).the index combines upslope contributing areaA_S, under the assumption that contributing area in directly related to discharge and slop (B). The index is calculated as :

$$STI = (m + 1) \times (A_S / 22.13)^m \times \sin(B / 0.0896)^n$$

Where

$A_s$is the specific catchment area (i.e. the upslope contributing area per unit contour length) estimated using one of the available flow accumulation algorithms in the Hydrology toolbox.

B is the local slope gradient in degrees; the contributing area exponent,

m, is usually set to 0.4 and the slope exponent, n, is usually set to 1.4. Notice that As must not be log-transformed prior to being used; As is commonly log-

transformed to enhance visualization of the data. The slope image can be created from the base digital elevation model (DEM) using the slope tool. The input images must have the same grid dimensions.

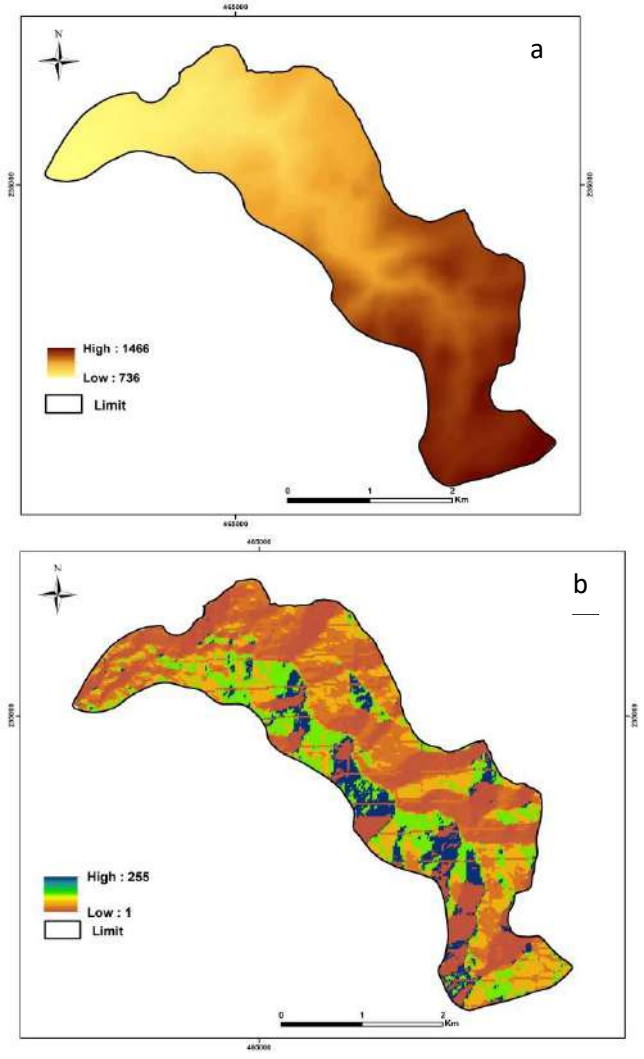
Required inputs

Digital elevation model (DEM)
Flow direction
Flop accumulation
Slop map

4. Results and Discussion

The Sediment transport index (STI) is considered as one of the hydrological indices, described by Moore and Burch (1986).

The STI can provide vital information onsustainability the potential of sediment transport in the stream network of a given watershed. It considers the effect of topography on erosion and is, as such, used for characterizing erosion and deposition processes, and as a flood conditioning factor that defines the movements of waterborne sediments due to the water movement.



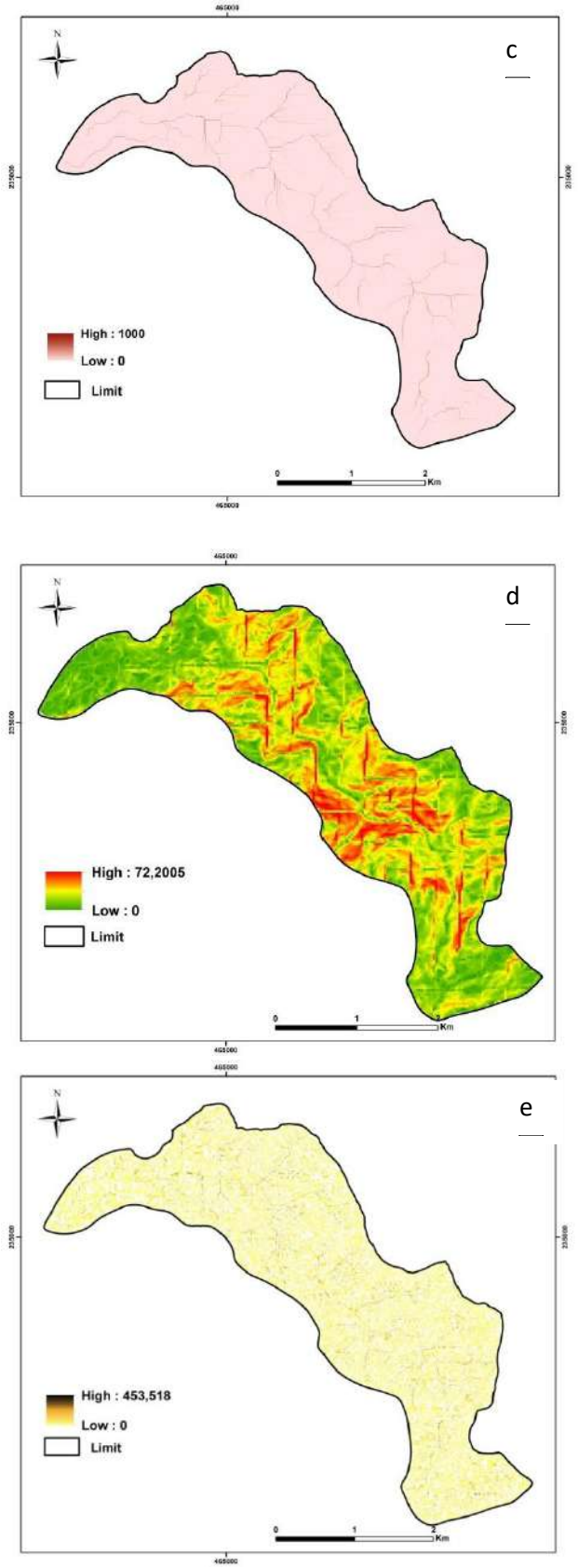


Fig 4 :Maps showing the main steps and factors considered sediment transport factor. (a) Digital elevation model, (b) Flow direction, (c) Flow accumulation, (d) Slop, (e) Sediment transport index.

Topography represented by a DEM can be used to model flood impact on land erosion and degradation and sediment accumulation because water tends to flow and accumulate in response to gradients in gravitational potential energy (Murphy, and Loughlin 2009).The elevations at the catchment as shown in the Fig 4(a), are considered very high at the upstream part reaching the peak 1499 m, decreasing towards the downstream part of the catchment .This remarkable change in elevations within the different parts of the catchment, it gives an idea about the significant influence of basin elevation and morphology on river sediment fluxes.

The slope gradient map was extracted from conditioned DEM using 3D Analyst tool in ArcGIS environment (Fig. 4 (d)(Ahmad and Dar 2019).Based on DEM, the slope angle map was produced by ArcGIS 10.3 and its values produced by the map (Fig 4 d), the high slops concentrated especially at the middle part of the catchment.

The highest values of the sediment transport index correlate to steepslopes and the downstream part of the catchment, associated with a significant degree of significant soil erosion and degradation.(Ahmad and Dar 2019).Whilethe lowest STI values reflect the slow mobility and, consequently, the accumulation of the sediment, matches the zones with dense vegetation cover at the upstream part of the catchment. This index is well correlated with landscape erosion assessments because it explicitly demonstrates the sediment flow convergence and divergence from the top of the mountains to the areas prone to inundation and sediment accumulation(A. Bannari, A. Ghadeer, A. El-Battay 2017).Several factors controls the sediments transportation within the catchment; the gravity , slops, rainfall concentration .

5. Conclusions

The use of geographical information systems in catchment hydrological and erosion modelling offers considerable potential.The hydrological indices derived from a DEM provide a suitable input to a GIS for delineation of erosion potential zones. Hydrological indices were given potential weight for the successful demarcation of erosion-prone areas in the Tiguert catchment.

After the elaboration of sediment transport index map, the values show a remarkable decrease from the upstream towards the downstream part that knows a high dynamic of transportation.

Conflicts of Interest:

The authors inform that there is no conflict of interest.

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