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Landslide susceptibility modelling using GIS and statical méthod in the Oued Larbaa basin (Eastern Rif, Morocco)

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Abstract

Landslides are an important hazard in the Oued Larbaa catchment area. 54 slope movements were identified in a 267 km^2 test site, corresponding to 3.3% of the total area. The landslides that have occurred in recent decades and six predisposing factors were mapped for applying Informative value method to assess landslides susceptibility. The results show That close to 30% of the catchment area has a high to very high susceptibility to mass movements, 25% presents medium susceptibility and 45% a low to very low threat. The obtained results are critically compared and validated through the construction of The success rates curves and the computation of the corresponding Area Under Curves.

1. Introduction

Landslides are natural hazard that affect marly slopes in the oued Larbaa basin located in the Oriental Rif, Morocco. Landslides have generated important economic, social and ecological effects, by destruction parts of useful agricultural areas, and by damaging houses, roads, tunnels, careers and other basic infrastructures.

The reduction of socio-economic losses due to landslide activity needs effective methodology for analysis, quantification and prevention of this of hazard. The uncertainty which presses on the available data on the necessary parameters for this hazard has led us to use an approach where the risk analysis is accomplished through the implementation of a comprehensive mitigation landslide risk program

The first task of this program is the definition of landslide susceptible areas based on the study of relationships between spatial distribution of past landslides and the cartographic set of landslide predisposing factors. Therefore, the major aim of this work is to create a landslide susceptibility map for the study area.

2. Study area

The oued Larbaa basin, located northwards the Taza city (Fig. 1), has an area of 267 km^2 and the elevation ranges between 450 m and 1300 m. Morphology is characterized by rounded hills cutting marly formations of Pre Rif units. Land use is dominated by cereal cultures and a few sparse tree plantations. Natural vegetation shows a very high level of degradation and usually appears as shrub tufts.

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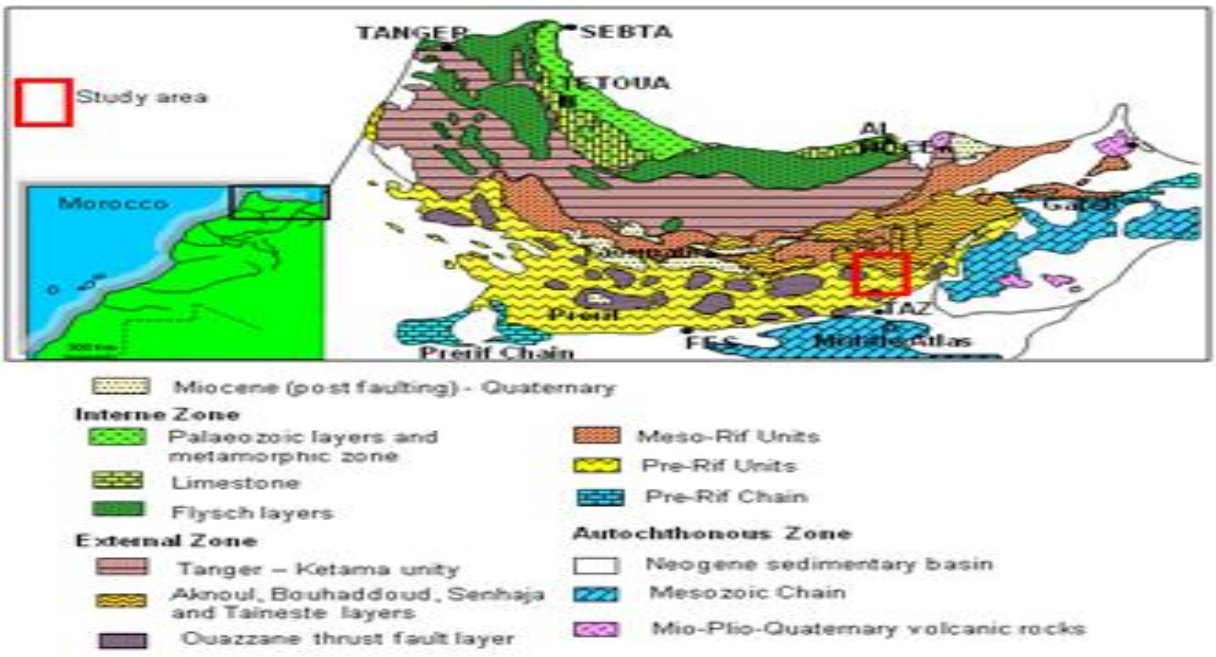

Figure 1: Location of the Study area and the Rif structural settlement

3. Methodology

The susceptibility assessment was carried out for each type of landslide (rotational slides and translational slides) under the assumption that future landslides will occur under the same environmental patterns that generated landslides in the past (Hansen 1984).

The inventory of instability events has been made for the study area and it includes 56 slope movements (22 rotational slides and 26 shallow translational slides). Landslides were represented as polygons indicating separately landslides depletion and accumulation zones (Fig. 2). The landslide map was included into a GIS database which also includes a set of thematic layers assumed to be landslide predisposing factors: slope angle, aspect and curvature, inverse wetness index, lithology and land use (Fig. 3).

Assessment of susceptibility has been made separately for each type of landslide (rotational and translational).

The method chosen to evaluate the landslide susceptibility in the study area is a statistical method called method of Informative Values (VI) and its principle is as follows:

Once the slides of the study area located, physical characteristics of hillslopes affected by landslides are studied and mapped. These characteristics are the variables that serve as thematic maps for assessing the susceptibility (slope angle, aspect and curvature, inverse wetness index, lithology and land use). Each variable is divided into different classes (Fig.3).

The information value is assigned to each class. This value is an indicator to quantify the landslide susceptibility of the class. It is calculated as follows:

$$VI_{\text{classe i}} = \ln\left(\frac{Si/Ni}{S/N}\right)$$

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Si = area of class i which slides, **Ni** = class i area
S = total area which slides, **N** = total area of the study zone

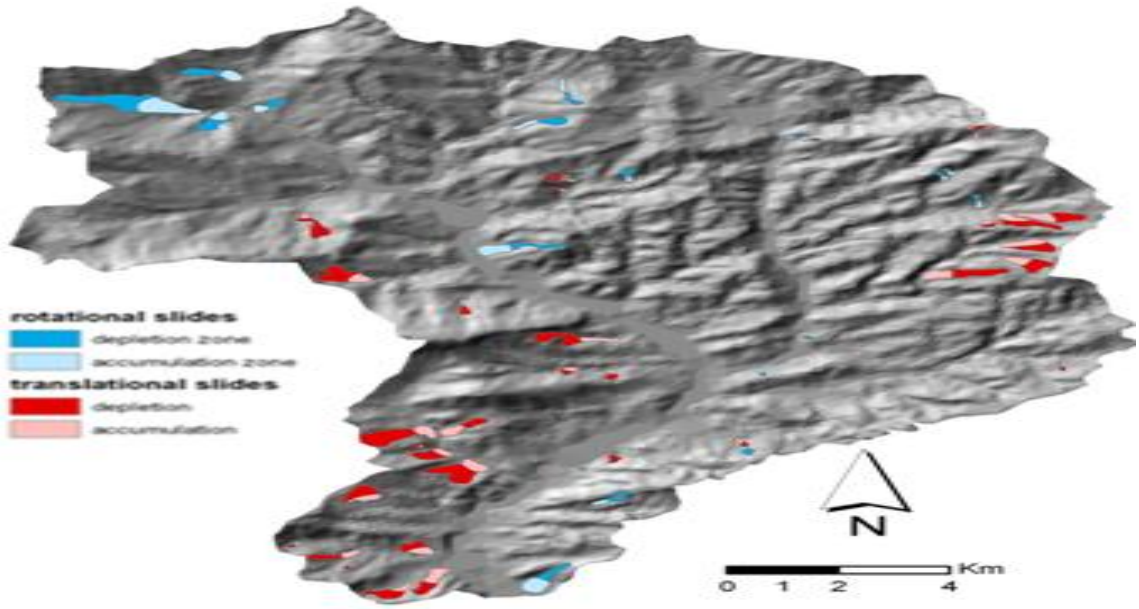

Figure 2: Rotational and translational landslides in oued Larbaa basin

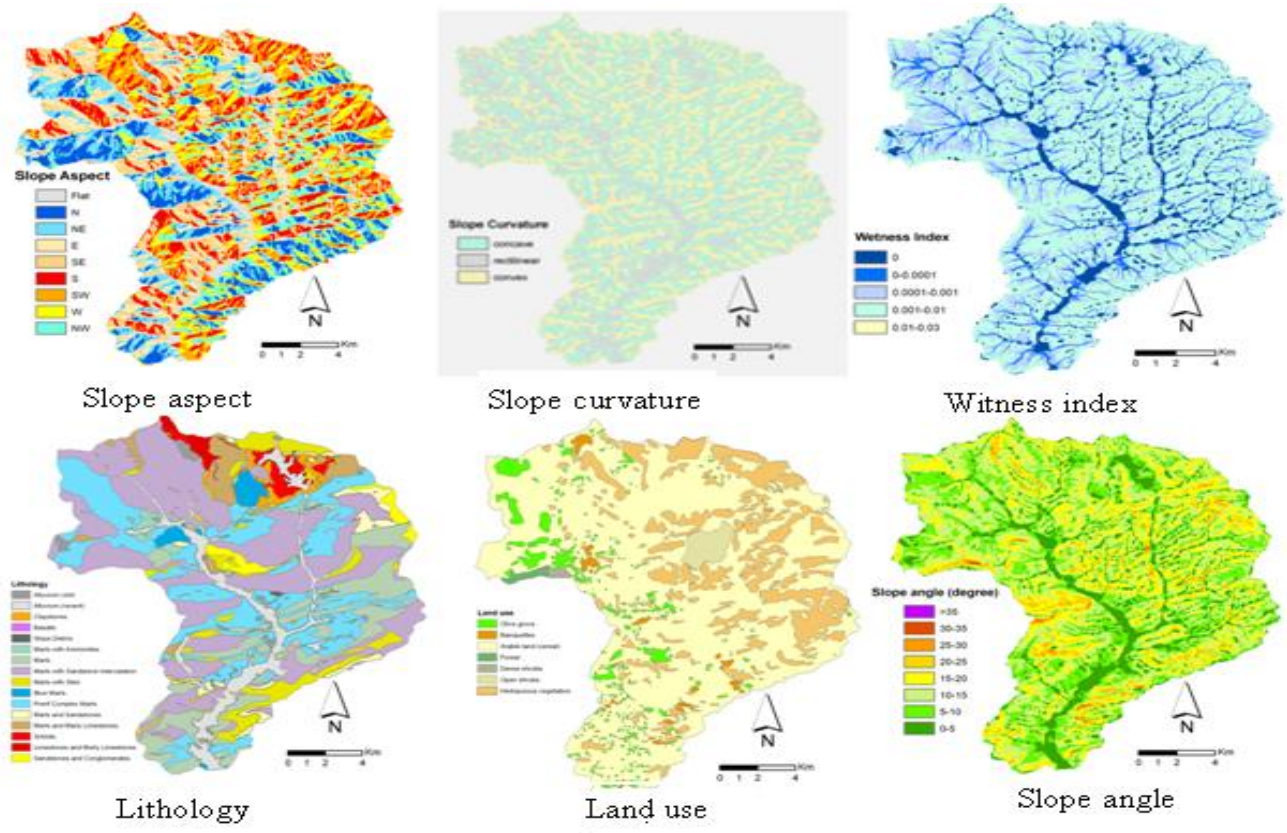

Figure 3: Maps of predisposing factors

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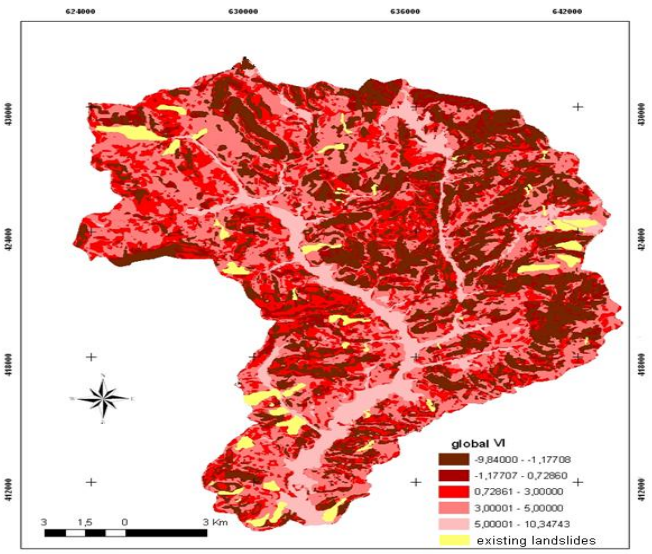
The susceptibility map is then obtained by the overlay of the six predisposing factor maps and by calculating the sum of informative value of each predisposing factor. In raster representation, each pixel of each theme has a Informative Value. The susceptibility map is then obtained by the sum of VI of each theme present in each pixel. The result map informative values are also grouped into classes

4. Results and Discussions

Only the area of the landslide depletion zone was considered to build the susceptibility models. The results for the slope angle are summarized in Table 1. The sum of informative values of all the predisposing factors gives an indication about the objective and quantifies the relative importance of each variable in the distribution of landslide.

The results show that close to 30% of the catchment area has a high to very high susceptibility to mass movements, 25% presents medium susceptibility and 45% a low to very low threat (Fig. 4).



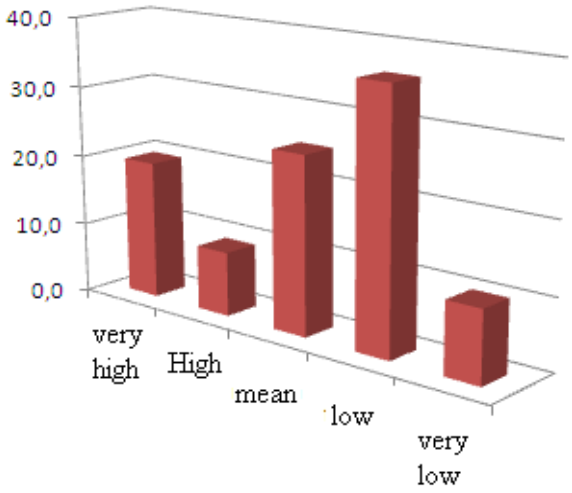


Figure 4 : Landslide susceptibility assessment

variable	class	Class area (m^2)	Lanslide area (depletion zone m^2)			VI total landslide	VI Rotational landslide	VI Translational landslide
			Total lanslide	Rotational landslide	Translational landslide			
Slope angle degree	0 – 5	38990000	205200	94000	111200	-1,35529	-2,13598	-1,96795
	5 – 10	61773600	2348800	722000	1626400	**0,62220**	**-0,55742**	**0,25467**
	10 – 15	91988800	2054000	586000	1468000	0,08990	-1,16432	-0,24598
	15 - 20	53651600	751200	246400	5048000	-0,37681	-1,49153	1,52825
	20 – 25	17358600	83600	37600	46000	-1,44402	-2,24306	-2,04142
	25 – 30	2819600	4000	4000	0	-2,66627	-2,66627	
	30 – 35	291600	0	0	0			
	>35	8400	0	0	0			

Table 1. Informative values for Slope angle

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The robustness of this model is evaluated through the determination of success rates curves (YIN and YAN, 1988). The success rate is an indication of the fiability of the model using slides that were used to construct the susceptibility model and the computation of the corresponding Area Under Curve (AUC) (Fig.5) to assess the accuracy of model created. The obtained results show that degree of model is higher for susceptibility models developed with individual types of landslides (e.g. rotational slides, AUC = 0.813; translational slides, AUC = 0.835), when compared with the model corresponding to the total landsli set (AUC = 0.799).

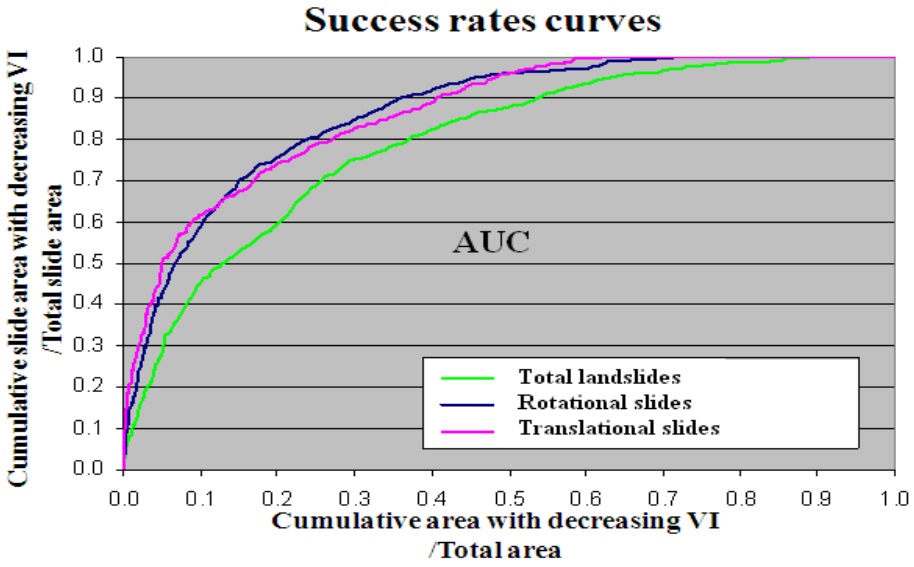

Figure 5: Performance evaluation

Susceptibility modèle	Area Under Curves (AUC)
Rotational slides	0,835
Translational slides	0,813
Total slides	0,799

Conclusion

Informative value for each pixel of the catchment area based on six predisposing factors and landslides that have occurred in recent decades hierarchy the study area in terms of The landslide assessment of susceptibility.

The modelled landslides for susceptibility assessment (rotational slides and translational slides) show different spatial relationships with the set of considered landslide conditioning factors.

The degree of the model fit was assessed through the success rates curves and computing the corresponding area under curves which show that degree of model fit is higher for susceptibility models developed with individual types of landslides when compared with the model corresponding to the total landslides.

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