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Landslide Cartography at the Region of Nabeul-Hammamet Based on Geographic Information System and Geomatic

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Abstract

Landslides are one of the most significant natural damaging disasters in hilly environment [1]. The location of our study area is to the north of Tunisia, home to several manifestations of land instabilities, we bring to study this area of interest by GIS and geomatic approach to reduce social economic losses due to landslides. The performance of a cartographic data base for the landslide study in the Cap-Bon region was realized through studying geologic 1/50,000 and topographic 1/25,000 maps, aster optic Remote Sensing, land observation, and climatologic seismic data. These data will be digitalized, georeferenced, vectorized, spatially analyzed, classified and geotreated in order to produce a landslides card. The findings have shown that fields with smooth and friable lithology which are located at rather important seismic zones (more than 4 at Richter's scale) have some stability. However, the most endangered zones are in the North-West around Oued El Kbir and El Ain. Realizing this work helps to determine the most hazardous zones so that policy makers have an effective field intervention.

Keywords

Cartography, GIS, Geomatic, Landslide, Nabeul-Hammamet

1. Introduction

The Cap Bon region has an interesting economical importance for Tunisia. It contains about 30% of the touristic resorts of Tunisia and is having an important urban development. For these reasons, this work is focusing on cartography of instability hazards of land for the region lying between the town Beni Khiar and Hammamet. Landslides are a common hazard, especially during the rainy season [2] [3]. For these reasons, a data collection study about land instability has been conducted. By analyzing and integrating it, a "SIG" allowed us to realize a land instability map which could be used as a helping tool for decision makers for better urban and environmental management.

2. The Study Method

The cartography of land instability areas in the regions of Nabeul and Hammamet compels us to analyze the process of realizing this map step by step (**Figure 1**).

2.1. Geographic Level

Nabeul-Hammamet region is located in the North-East of Tunisia between the meridiens 641.963 and 667.000 and the parallels 4.028.304 and 4.054.072. It lies on the south west of the Cap Bon peninsula (**Figure 2**).

2.2. Definition of Land Instability

Land instability means wrench, displacement on a slope and along an identifiable rupture of a surface of ground and rockets under the effect of gravity [4]. It depends mainly or the type of land morphology, the geologic structure, climate conditions, the seismicity, the hydrographic system, underground hydraulic pressure and anthropic activities [5]. These phenomena differ according to their extent, to their movement speed, to the land lithology and to the geometry of their braking surfaces.

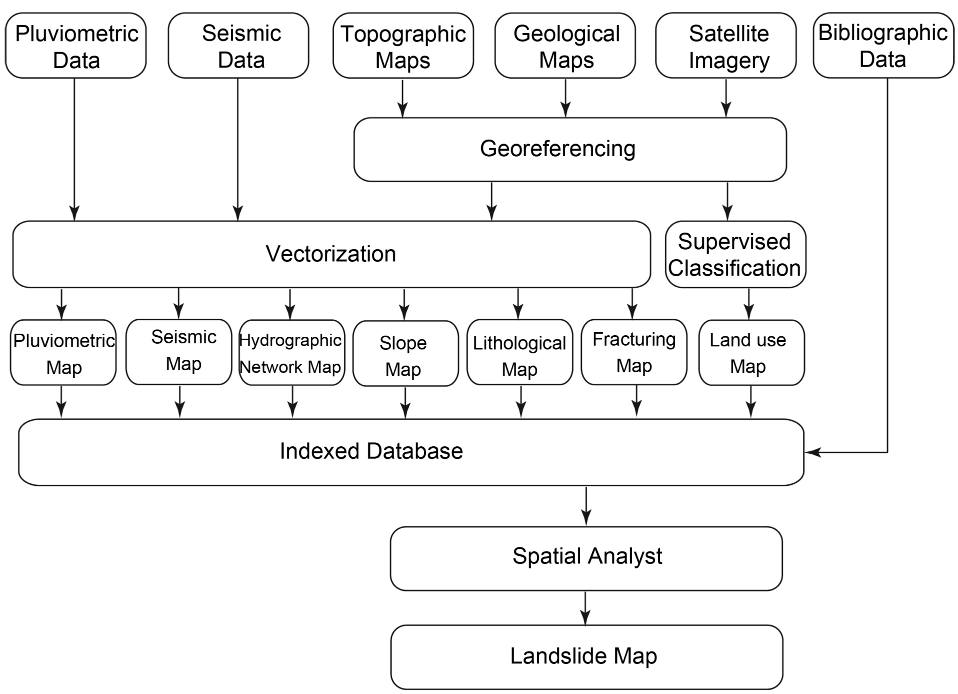

Figure 1. Methodology adopted for the implementation of the hazard map.

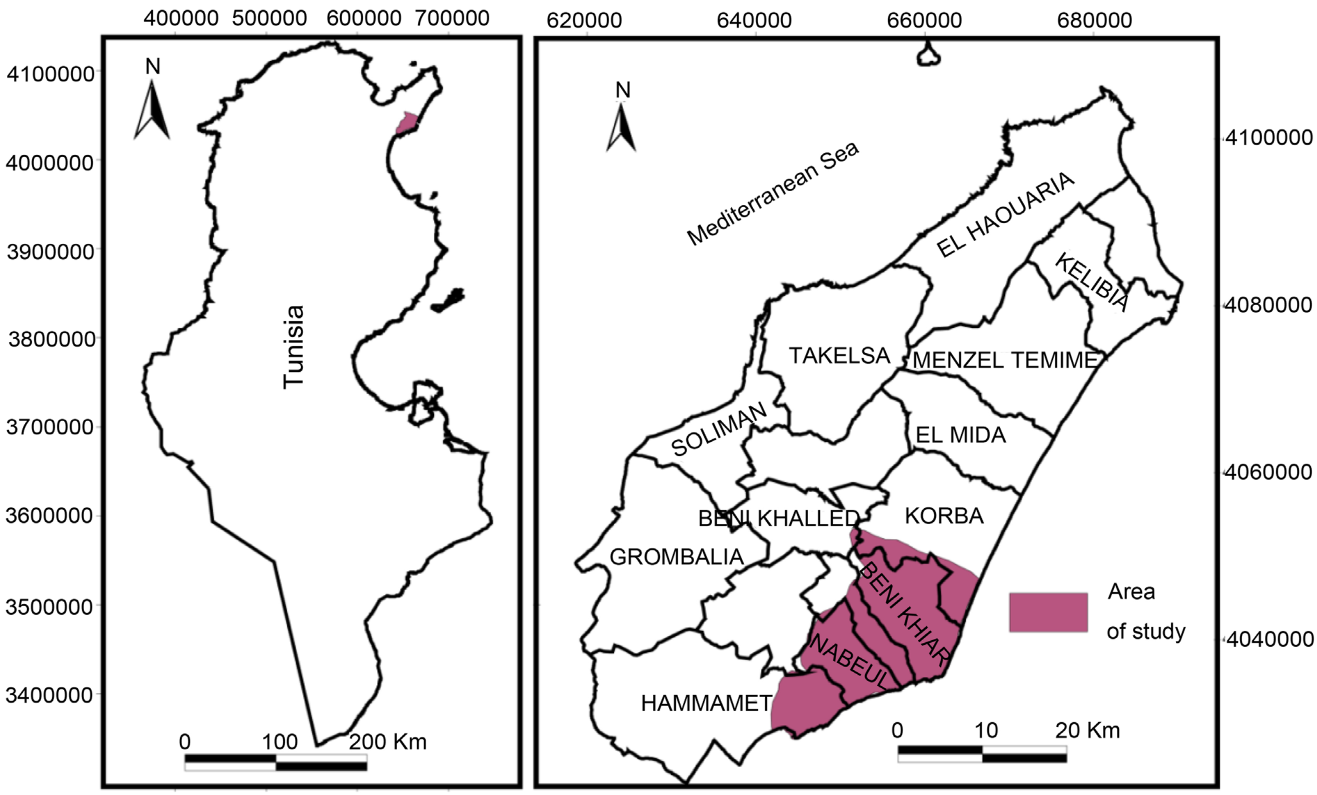

Figure 2. Geographical setting.

2.3. Identifying the Cartographic Data Base for Land Instability

Geographic Information System (GIS) modelling of landslide phenomena has taken precedence in recent time. Geospatial technologies like the use of GIS, and Remote Sensing are useful in the hazard assessment, risk identification, and disaster management for landslides [6]. For it while performing this study we have used image processing software (Envi 4.7) and SIG (Arcviews 3.1) so that to set a geographic data base (GDB) which allows us to a better understanding to the risks of land instability in the region of Nabeul-Hammamet. Realizing the GDB needed a collection of multidisciplinary data, its numerisation, and georeferencement and vectorisation so that produce the necessary themes for the targeted maps.

2.3.1. Lithologic Maps

Our lithologic map was realized according to a vectorization of two geologic cards at 1/50,000 of Nabeul and Hammamet. With regard to the works of [7]-[10], the studied land is composed mainly of sand, clay and sandstone (**Figure 3**).

-The Somaa formation, it is composed yellow or red sands intercalated with conglomeratic levels.

-The Beni khiar formation, presents a progressive passage of continental sandstones to oolitic limestone.

-The Oued El Bir formation is composed of sandstones, sand and azoic clays.

-The pottery clay is plastic with a grey color and bleu patina.

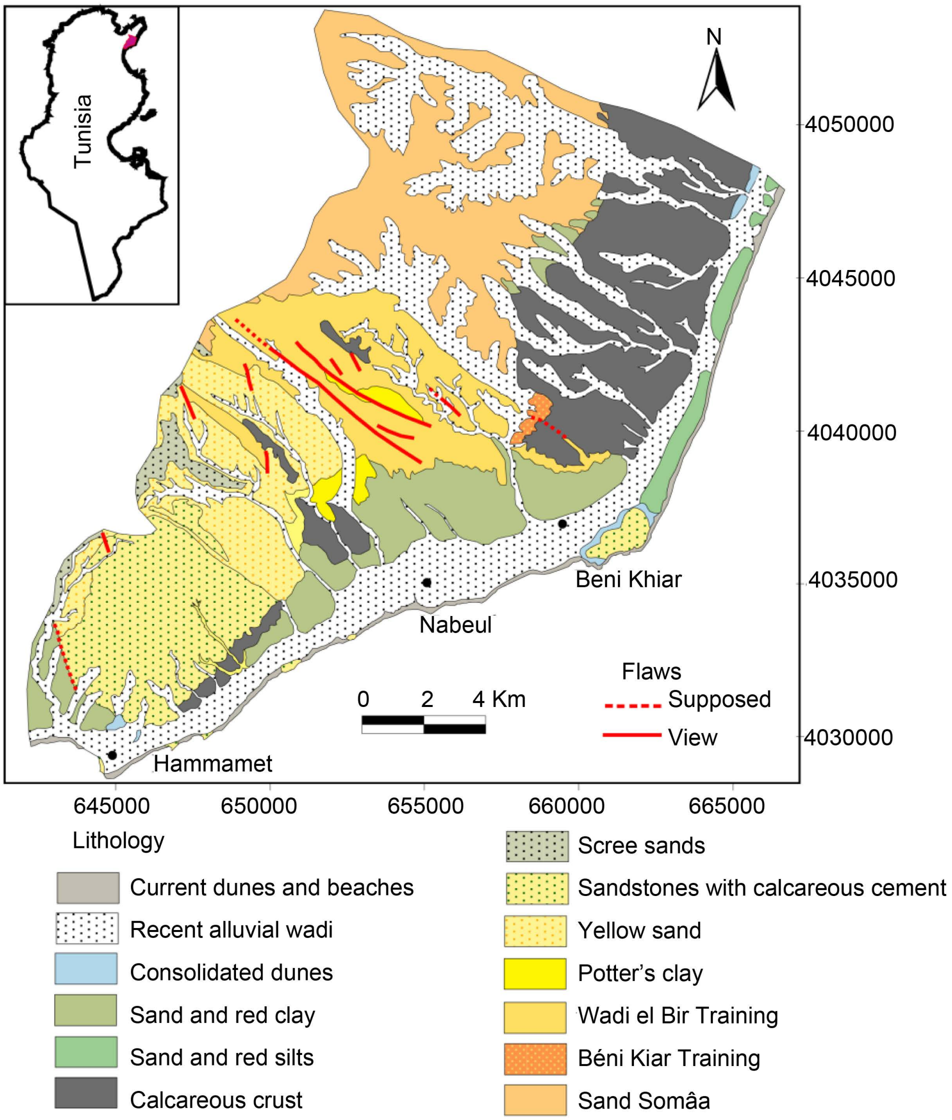

Figure 3. Map of lithology and fracturing.

-The yellow sand of Nabeul is characterized by a varying granulometry with some conglomeratic levels.

-The sand and sandstones of Hammamet are yellow fin sand, sometimes containing clay.

-The Sicilian, its levels are composed generally by conglomerates poorly consolidated and dark grey sand.

-The Tyrrhenian outcrops a cord formed by sandstone and limestone and sandstone at the base dune large oblique stratifications at the top.

The lithologic nature and the consolidation state of each formation allowed us to predict the mechanical behavior of each formation.

This is checked out by the work of [11] that had proved the direct relation with the friction angle φ and the horizontal displacement of materials:

$$\sigma h = Ka \cdot \sigma v$$

σh: horizontal stress.

σv: vertical stress.

Ka: thrust coefficient of land.

$$Ka = \tan^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right)$$

Applying this equation allowed us to classify the lithologic unites into 3 classes depending on their aptitude to the instability. To facilitate implementing this classification in the data base, some proportional indexes at each instability have been affected to the surface lithology (**Table 1**).

Table 1. Classification of evidence of hazards lithological.

Land state	Stable	moderately stable	unstable
Hazard index	1	2	3
Lithology	Sandstone and limestone	Consolidated dune	Dune, Alluvium, Sand and Clay

2.3.2. Fracture Map

It includes the estimated and identified breaks at the level of our section. These breaks are generally oriented N120 to N170 (**Figure 3**). According to [12], 1981 who affirm that break disposition is the most important criteria in our thematic, we have chosen to attribute:

-Index 1: to the estimated faults that affected sand and clayful lands or those which are not reactivated for a long time.

-Index 3: for the faults that represent a dip less to that designed breaks and also for the conjugated faults.

2.3.3. Slopes Map

The obtained slopes map is a derived map through a digital elevation model (DEM) product following the extraction and processing of contour to 25 m not included on topographic maps at the scale 1/25,000 in the Fevilles of Hammamet and Nabeul NE, NW, SE and SW.

It shows that the study area is a peneplain except the Nabeul-Hammamet monoclinal where the slopes can exceed the value of 30% (**Figure 4**). The works of [13] [14] have showed that stability of slopes is maintained thanks to a balance between the propulsive forces and the resistance forces.

$$F = \frac{\text{maximum resistant forces}}{\text{Driving forces}} = \frac{\tan\varphi}{\tan\alpha}$$

φ: friction angle, α: slope.

Applying this equation, which is in relation with the slope, allowed us to classify the topography into three classes depending on their contribution to instability (**Table 2**).

2.3.4. Hydrographic Map

The same previous topographic maps were used as a data base during the vectorization

Table 2. Classification of topographic indices hazards.

Slope %	Land state	Instability index
≤15	stable	1
between 15 and 30	moderately stable	2
>30	unstable	3

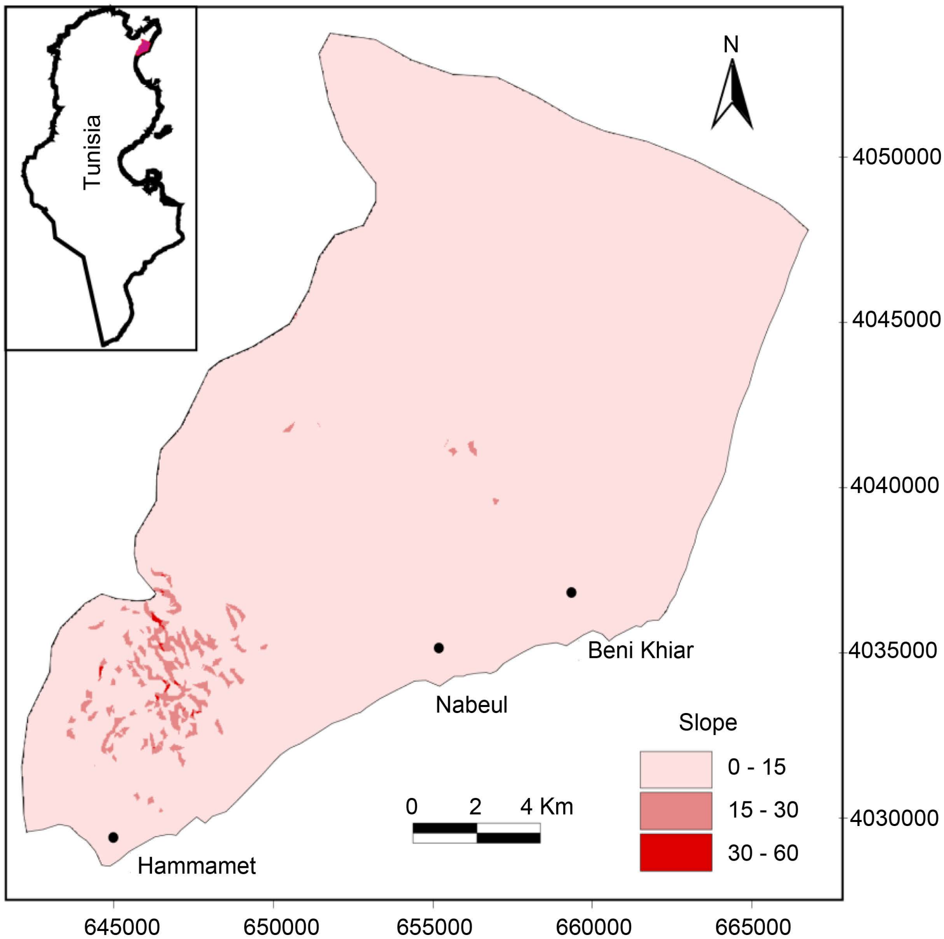

Figure 4. Slope of map.

of the hydrographic network illustrated in the study area (Figure 5). The result has shown that the majority of the networks are in the form of trills which prove the preserve of permeable and friable land where water could dig and mobilize the particules easily [15]. In consideration with Strahler Classification to the whole network, land observation has proved that land instability is proportional is proportional to the order of the drain.

This is confirmed by the progressive increase of the solid charge in the drains from upstream to downstream. Hence the choice of indices is for different drains classes (Table 3).

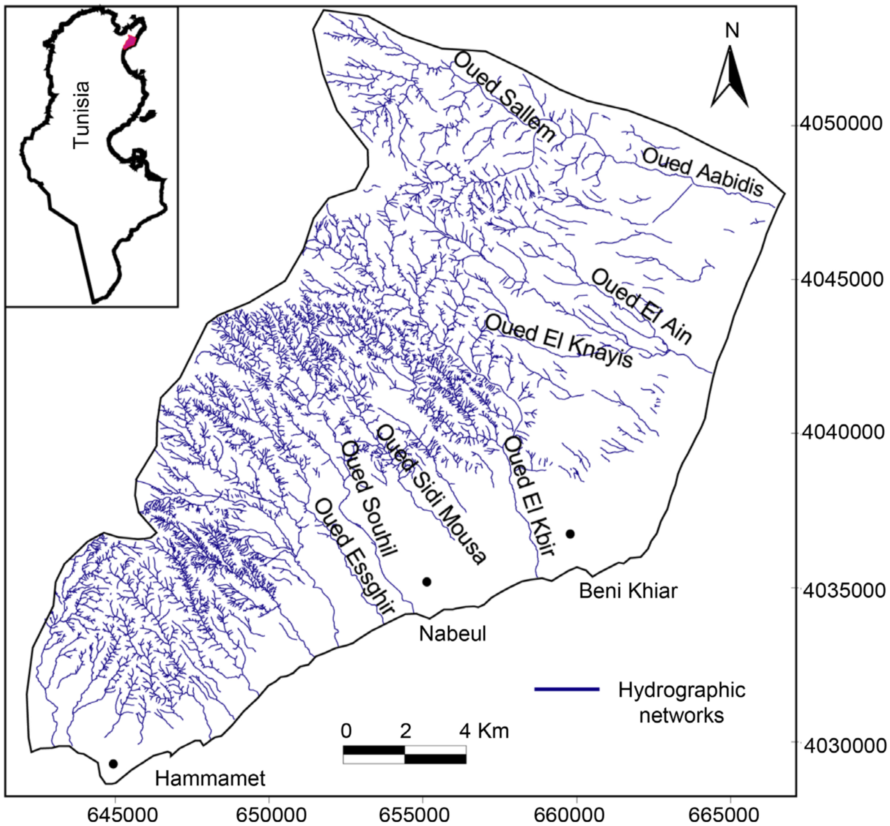

Figure 5. Hydrographic map.

Table 3. Classification of evidence of hydrographic hazards.

Order of drain	Land state	Instability index
1, 2 and 3	Stable	1
4 and 5	moderately stable	2
>5	unstable	3

2.3.5. Seismic Map

The seismic map (**Figure 6**) of the average change in the intensity of earthquakes that affected the southern part of Cap Bon for the last thirty years which were registered by many geophones situated in Nabeul-Hammamet, Dar Chabaan, Bou Argoub and Grombalia. These data issued by National Meteorology Institute represented in the raster mode prove that the Nabeul-Hammamet region is seismically stable. In fact the maximum magnitude recorded was at the scale of 4.1.

The following **Table 4** illustrates the adopted classification for the seismic factors.

2.3.6. Rainfall Map

The rainfall map (**Figure 7**) shows the special distribution of the interannual average rainfall for the last decade. The data base used in realizing this map is the monthly precipitations measured in the meteorological stations: Nabeul, Oued Souhil, Hammamet, Khangt El Hagag and Bou argoub.

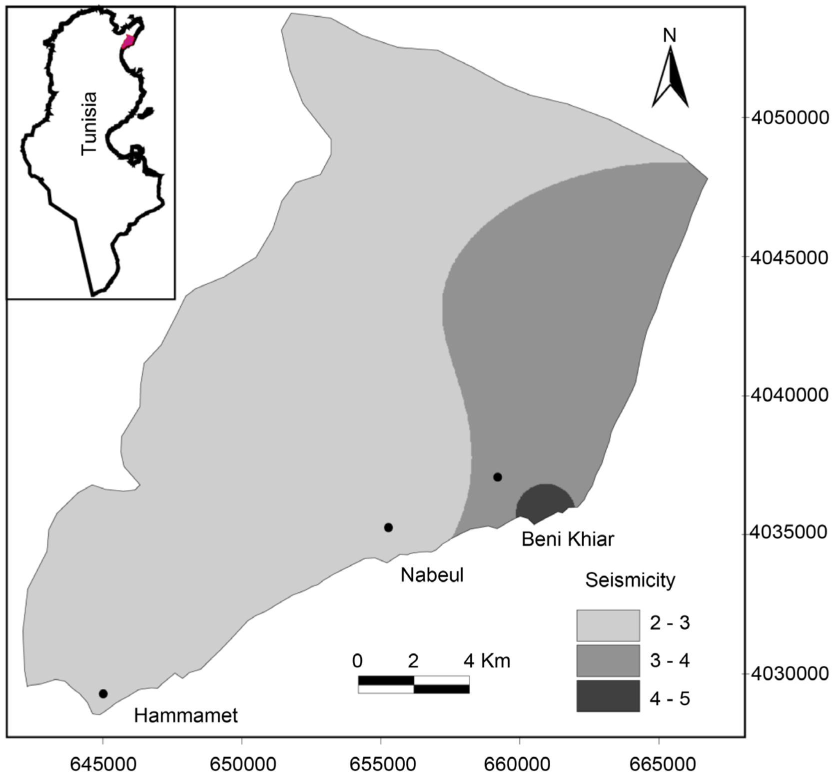

Figure 6. Seismic map.

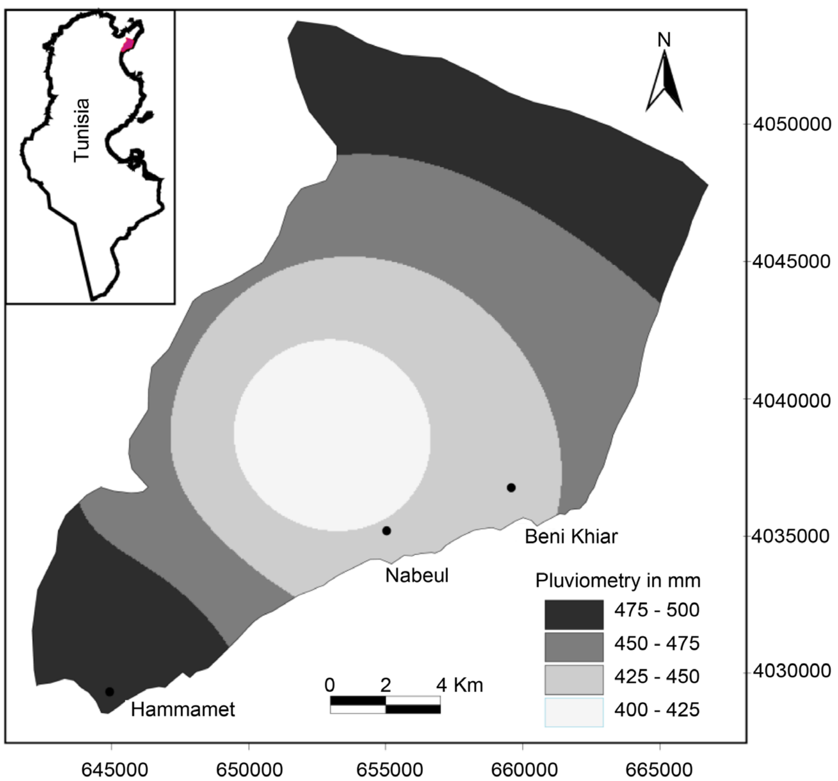

Figure 7. Rainfall map.

Table 4. Classification clues seismic hazards.

Seismic magnitude	Land state	Instability index
<3	stable	1
>3 and <5	moderately stable	2

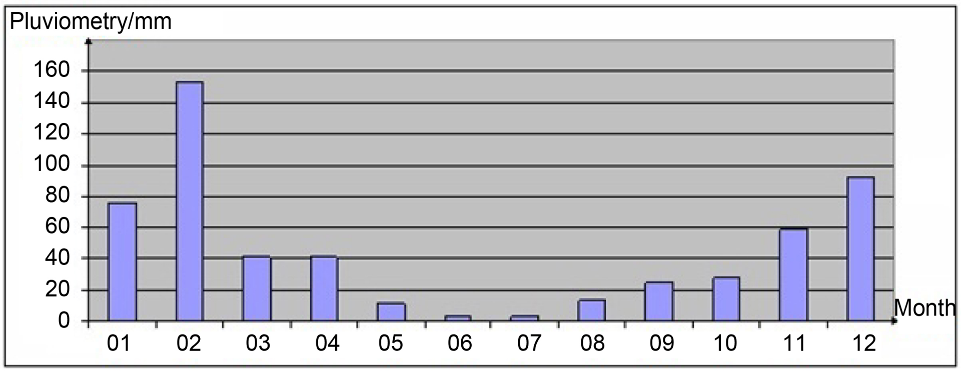

Figure 8. Average monthly precipitation the past decade.

Belonging to the Mediterranean climate which is characterized by its precipitations of low frequency and high intensity (Figure 8), it allowed us to attribute the instability index 2 to the whole area.

2.3.7. Soil Exploitation Map

The land use map was created following the supervised classification of satellite Aster high resolution image acquired April 16, 2002, which essentially shows five classes of land cover (Figure 9). It is essentially exploited by agricultural land that covers more than 65%, the urban sites (Nabeul, Hammamet, Dar Chaabane and Beni Khiar), the forest of Jebel Nabeul-Hammamet, Jebel Ksous and waste Lands.

Every type of exploitation contributes to the land instability in a special way. This is illustrated through the following Table 5.

2.4. Spatial Analyst

2.4.1. Applying Tampon Areas to the Break Theme

[16] has proved that the impact of fracturation sector on the land instability is generally localized at the level of a nearly 100 m thick corridor. This offered us a basis for creating "tampon" areas which are at the level of 50 m and an instability index to the present breaks in our data base.

2.4.2. Applying Tampon Areas to the Hydrographic Factor

In the case of hydrographic network this operation is a bit more complicated because we have attributed a specific distance for each chosen index:

- 25 meters for the index 1 drains
- 50 meters for the index 2 drains
- 75 meters for the index 3 drains

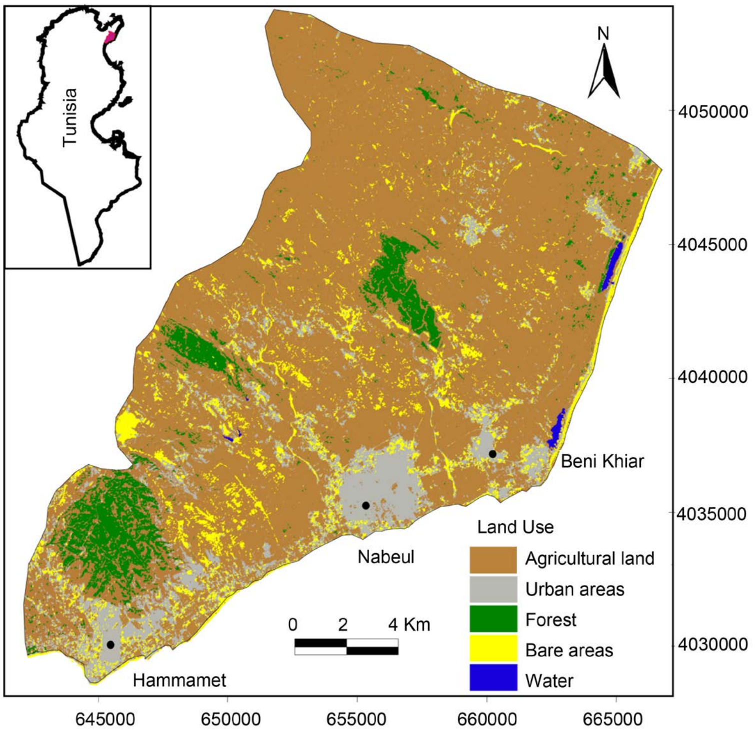

Figure 9. Land use map.

Table 5. Soil types classification according to its contribution to land instability.

Soil exploitation	Land state	Instability index
Urban sites and water plan	stable	1
Agricultural lands and forests	moderately stable	2
Bare areas	unstable	3

This choice was taken through land observation of the most sensitive areas to land instability around oued Essghir, El Kbir and Abid.

2.4.3. Themes Union

This operation associates the entities of an introductory these with the polygons of a recovering theme to produce a closing theme containing the attributes and the general view of the two themes.

As a result of our choice, we elaborated the synthesis map by working in vector mode by converting maps of the slopes, the soil exploitation, rainfall, seismicity and the tampon areas in vector files.

The first union operation was realized through lithologic and break themes, the result was afterwards combined with the slope theme.

Analogue operations were performed by integrating theme after theme the instability indexes. These were covered through:

- Rainfall,
- seismicity,
- drain classes,

- Soil exploitation.

After each association operation we have paid tribute to the data base to multiply the indexes of instability for the introductory theme by the recovering theme (Table 6).

Table 6. Multiplication of the proportional indexes to the lithologic theme and to the break theme.

Lithology index X Faults index	1	2	3
1	1	2	3
3	3	6	9

The above box shows the use of new indexes produced through multiplying the above indexes in box 8 by the instability indexes linked to the slope factor (Table 7).

Table 7. Second multiplication of instability indexes.

Index Litho + Faults X Slope index	1	2	3	6	9
1	1	2	3	6	9
2	2	4	6	12	18
3	3	6	9	18	27

The final result of these special analysis operations and data combination is illustrated through the instability map of Nabeul-Hammamet (Figure 10).

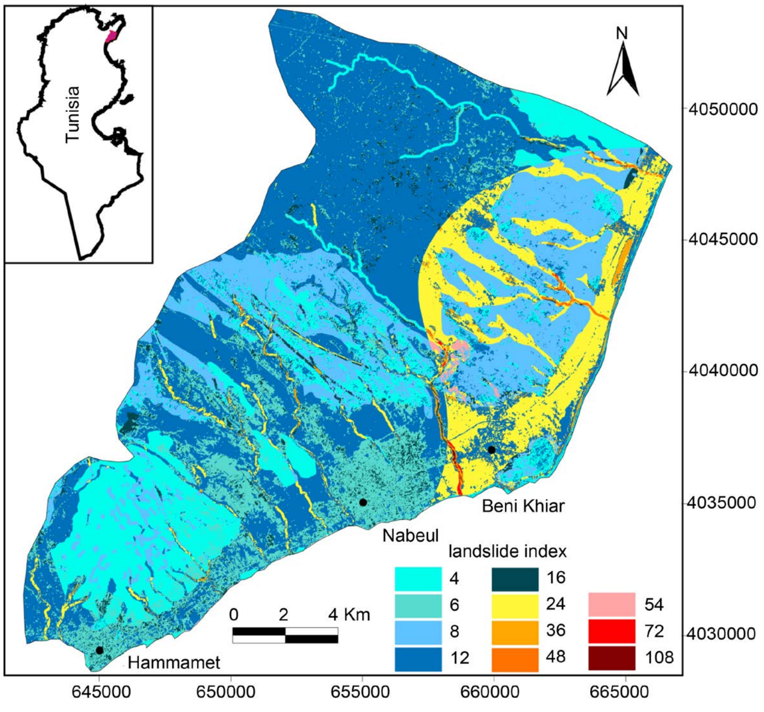

Figure 10. Map of field instability hazard.

2.5. Interpreting the Cartographic Maps

The realized land instability map contains 11 indexes representing the state of the land instability. The lowest indexes 4, 6, 12 and 16 cover 87.08% of the total surface of the study area. This indicates that the studied area is generally stable despite the abundance of crumbly lands. The impact of topographic, tectonic, seismic and hydrographic factors have generated very important indexes 24, 36 and 48 which proved the increase of surfaces instability. These indexes are mainly in the North-East of the studied area at the level of the seismic aureole of the index 2 or on the tampon areas where rivers and breaks are present.

The most important indexes which represent the most concerned areas by land instability are only 0.3% of the total surface, but they cover 103 hectares. These indexes are localized on the bank of the wadi El Kbir and El Ain. They cross loose lands which are influenced by seismic factors aureole of the index 2.

The highest values on the map (**Figure 10**) are manifested on land in different forms:

- Rational landslides that caused the fracture and detachment (**Photo 1**) and ever the fall (**Photo 2**) of some defensive walls.
- Some fractures and collapses due to the karst of limestone crusts on the bank of Wadi El Kbir (**Photo 3**).

Photo 1. Fracturing and detachment of the wall located on the edge El Wadi Ain.

Photo 2. Fall of a portion of the wall at the bridge El Kebir wadi.

Photo 3. Fracturing and collapse of limestone crusts.

2.6. Conclusions

Through this study, a hazard instability land map has been realized. This geo-cartographic multisource document is designed to attract the attention of planners to the potential or real risks of some lands in relation with nature and the specificity of each area.

Producing up-to-date and accurate landslide susceptibility maps can ensure safety to people and property at risk and avoid extensive economic loss (Kavzoglu *et al*., 2013).

The SIG techniques have facilitated the use and management of the data base for this work. The realized map has shown that in addition to the lithologic and topographic factors, land instability might be conditioned by hydrographic and seismic factors.

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