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THE ROLE OF PHYSICAL ENVIRONMENT IN THE GENESIS AND AMPLIFICATION OF FLOODS IN NADOR (NORTHEAST MOROCCO)

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ABSTRACT

Northeast Morocco has experienced significant socio-economic changes that induce dramatic developments of urban areas and massive rural exodus. The urban growth processes are sometimes poorly controlled and occur on vulnerable areas.

Nador is located on the bottom of Gourougou foothills where many streams converge. Flooding is recurrent phenomenon in this site. Several exceptional rainfall events and critical flow rates were recorded in the recent decades. Thus, Nador city located on a base level plain is potentially threatened by storms falling on too close steep slopes.

The purpose of this study is identifying and mapping areas threatened by floods in Nador. The combination of different information layers dealing with land use, drainage network, slopes, lithology/geology and road network, using remote sensing and GIS tools provides vulnerability indicators and allows drawing a flood risk map. The objective is hazard causes understanding, to help early warning and to define the potential extent of flood in threatened urban areas.

Key-words: Flood risk, remote sensing / GIS, urban management, northeast Morocco.

Introduction

In the Northeast Morocco, Nador city experienced recurrent floods during the past 50 years, among them those occurred on 2008 and 2009 as extreme events (Figure 1). This study aims understanding the active processes and stream hydrological behavior, and then focuses on controlling the incurred risks.

A rather constraining natural frame

A rugged terrain with low permeability, favorable to increasingly runoff

Rising at 879 m, the Neocene stratovolcano (8 My) of Gourougou stretches about 25 km from West to East and 15 km from North to South, with steep slopes. In the south, the Beni Bou Ifrour hills are shaped in Jurassic and Cretaceous rocks (schist, quartzite, limestone-marl and marl-sandstone), while low plain of Nador is an area of recent alluvial spreading (Miocene and Quaternary), (figure 2).

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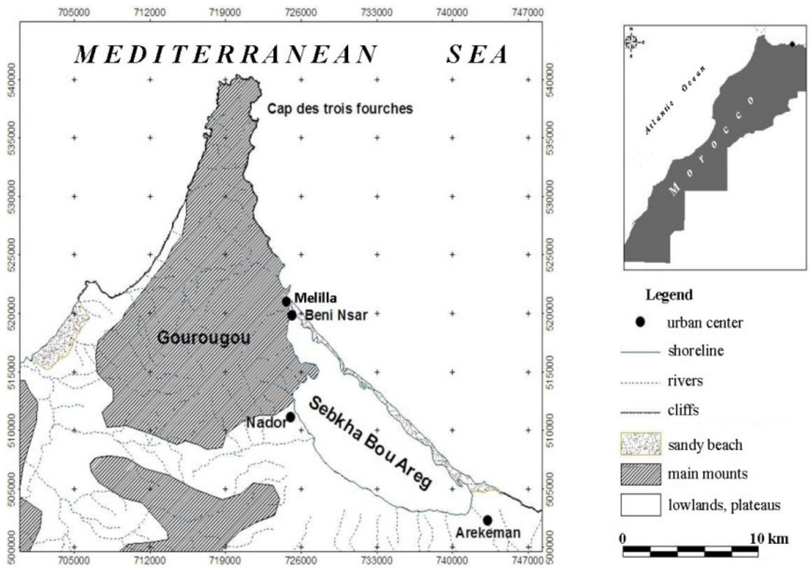

Figure 1. Location of the study area.

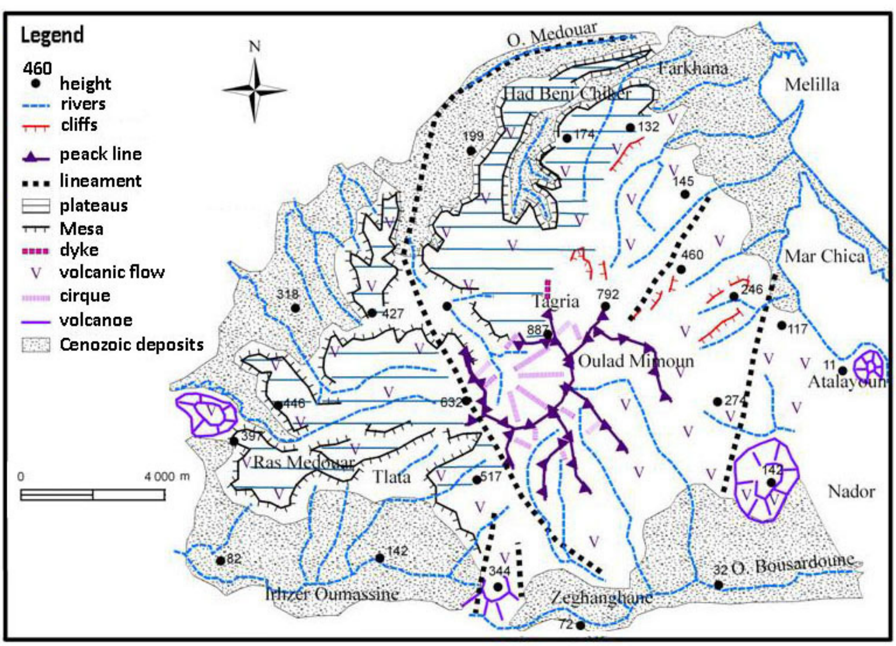

Figure 2. The main geomorphologic units of the massif of Gourougou.

A Mediterranean climate with differentiated seasons

The climate of the study area is Mediterranean, arid semi arid, with annual rainfall mean around 360 mm and 18.3 °C as annual temperature mean in Nador (August: 31.1°C; January: 6.5ºC). The 2008 storm recorded 735mm and caused great damage.

A diverse vegetation

The massifs of Gourougou and Beni Bou Ifrour are almost completely deforested. The soil restoration and reforestation works had been undertaken since colonial period (eucalyptus and Aleppo pine). Due to the lack of vegetation, this area is subject to aggressive weathering, rapid flows, hence, accentuating spasmodic runoff regime.

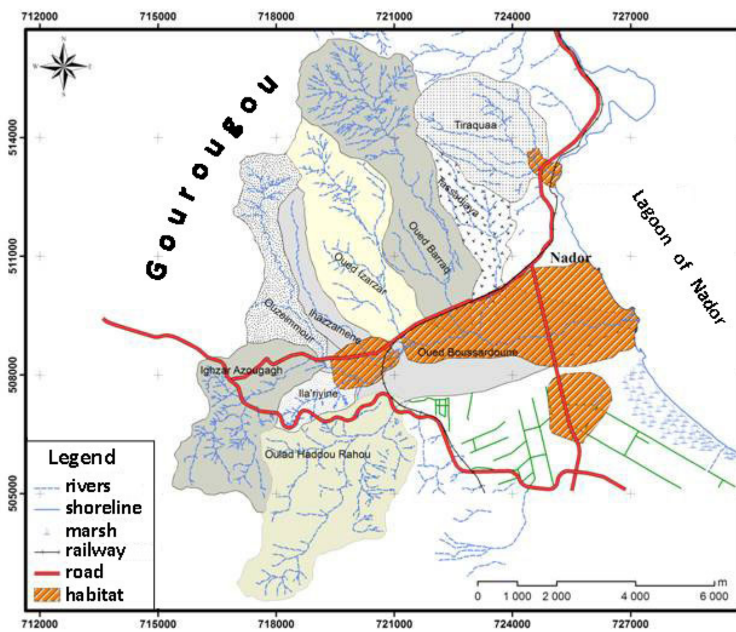

Figure 3. Watersheds.

Hydrographic feature: a disrupted flow network

The eight tributaries of Oued Bousardoune drain a watershed of area of 72.7 km2 (Figure 3). The shapes of recorded hydrographs are related to morphological characteristics, besides the nature of the downpour. Several formulas and indices allow decrypting these features (Table I).

Table I. Morphologic characteristics of major watersheds

Bassin-versant	Superficie en km²	Périmètre en km	Indice de compacité (de Gravelius)	Rectangle L (km)	équivalent l (km)	L / l
O. Tiraqaâ	7,66	11,35	1,16	3,58	2,14	1,67
I.Ouzemmour	5,48	14,62	1,76	6,53	0,84	7,78
O.Berraq	14,46	20,45	1,52	8,63	1,68	5,15
O. Tassadjaya	4,31	12,21	1,66	5,34	0,81	6,62
I. Ila'riyine	1,94	5,97	1,21	2,06	0,94	2,19
I. Azougagh	8,67	14,95	1,43	6,12	1,42	4,32
Ouled Haddou Rahhou	13,80	17,13	1,30	6,51	2,12	3,07
O. Izarzar	10,32	15,34	1,35	6,01	1,72	3,50
I. Ihazzamene	3,52	12,20	1,83	5,50	0,64	8,60
O. Bousardoune	72,70	48,42	1,60	20,92	3,47	6,02

Gravelius compactness index defines the shape of the drainage basins: in this case, it ranges from 1.16 to 1.83, reflecting a relatively elongated watershed. The main course has an index of 1.6. It forms a powered linear valley, especially on the left bank, by a succession of tributaries (Figure 3). This situation favors further flood waves growing downstream, while supported from the tributaries. Irhzer Ouled Haddou, drains the massif of Beni Bou Ifrour with a steepness of 1%, whilst steepest valleys lie in the Gourougou massif with values of 5 to 10% (O. Berraq, O. Izarzar, I. Ihazzamene).

The seasonal variability of water flows regime is well correlated to the rainfall regime, with high flows in winter and spring, while lowering in summer. The only one perennial river in the province of Nador records in May a flow range between 0.033 and 30 m 3/s at Dar Driouch and between 0.033 and 30 m 3/s at Tlet Azlef (1969-2009). The maximum instantaneous flow reached 2400 m^3/s on 24/10/2008 at 2.30, in a dry period.

Flooding of October 2008

Hydrological conditions

The year 2008-2009 began with very heavy rainfall. On 25 and 26 October 2008, heavy rain fell on the region of Nador. They reached 123 mm in Nador and caused violent and devastating flooding. (Figure 4).

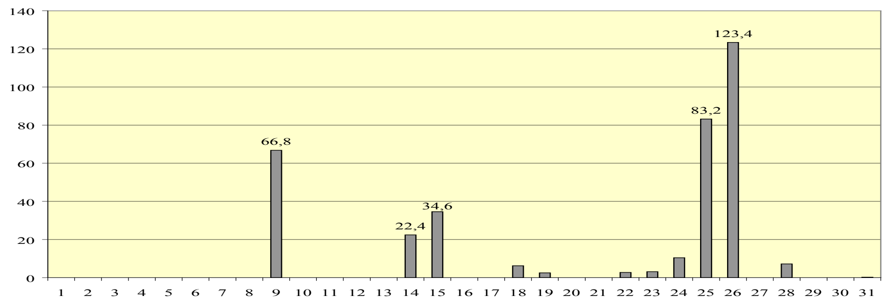

Figure 4. Rainfall in October 2008.

Impact on runoff and sediment load

Due to a great thunderstorm, one of the most deadly and devastating flood occurred on 23-24/10/2008, lasting only 8 hours, but rising barely in 3 hours. The peak value of 2400 m3/s was reached at Dar Driouch on 24/10/2008, at 00:30, mobilizing a runoff volume of 35.5 million m^3 (Figure 5).

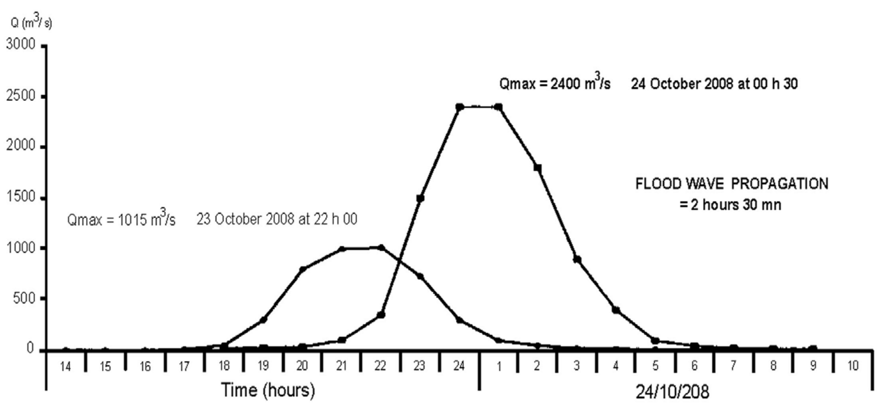

Figure 5. Oued Kert flood hydrograph.

The hydrograph sharpness highlights the monogenic simple flood with a strong tip, fairly short rise and drop with an extended depletion (Sbaï *et al.* 2010). Oued Bousardoune as well as Oued Tiraqaa cause severe flooding downstream in Nador city, constantly threatened by flow deposits and narrowing due to uncontrolled urbanization.

Socio-economic consequences and preventive measures

Floods that could have serious consequences are quite frequent in Northeast Morocco. They make roads dangerous and unusable (Photos 1, 2 and 3).

Photos 1-2-3. Examples of flood damage in Nador city (2008)

On 26th October 2008, Nador city and suburbs experienced a powerful unexpected brutal flood. According to official report, 4 people died and several buildings and roads were damaged, hundreds of victims relocated, drinking water supply cut, power network damaged, wells and irrigation channels, roads, bridges, all affected.

Preventive measures

Although an emergency plan was adopted earlier in the 1990s to protect Nador, after this disaster event, structures were needed to intercept carried sediment load.

Photos 4-5: A rainwater channel (2009) to reduce flooding; flood in Nador (2008).

Several development works have been completed or are underway: overflow protection system re-establishment within streams, trapezoidal channel structures (bays, coating stairs, falls), bridges building and restoring, riverbed cleaning, landscaping slopes.

Conclusion

Climate and impermeable litho-structural context, steep slopes, give torrential flows and brutal pulses to runoff. Harmful impacts are visible in Nador city and its surroundings. To face amplification and repetition of floods threatening Nador city located on a base level plain, strengthening civil engineering structures is needed, as preventive hydraulic measures, then sensitizing residents to this natural hazards and the danger of uncontrolled urbanization, in order to avoid damages.

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