

Modeling Floods Risk Using Gis in Agadir Morocco

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ABSTRACT : The aim of this work is the identification and mapping of areas at risk of flooding in Agadir city in southern Morocco. This work is based on the integration into a geographic information system (GIS), data interpreted from satellite images, products derived from a digital terrain model (DTM) and hydrological and geological data. The main factors considered in this study are: flow direction; slope; the relief; permeability and land use. The spatial analysis realized in a GIS, has allowed the development of the map of the risk of flood in the city of Agadir. The flood risk assessment shows that the Agadir area between the mountain and the Atlantic sea presents a high risk of flooding. The obtained risk map has four classes ranging from low to very high risk of flooding.

KEYWORDS: Souss, floods, Agadir, GIS, stakes, hazard, risk, DEM, geology, hydrology

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I. INTRODUCTION

Floods caused by meteorological phenomena are considered among the most devastating natural disasters. They have a negative impact on activities and human settlements. In addition to the loss of life they cause, the floods are causing significant economic damage of several million dollars, disrupting the social fabric and undermining the sustainable development of affected communities. This situation is all the more worrying because global climate change will increase, with the risks of some types of severe weather and climate phenomena including floods. Floods must be given special attention because they pose great risks to humans, their property and their environment. Recently, there has been an awareness of the importance of prediction and protecting against the risk of floods. Several studies have been conducted to better understand the factors and parameters responsible for triggering this devastating and destructive natural phenomenon. The geographical position of the study area (Agadir city) between the High Atlas Mountain and the Atlantic Ocean, its shape, its highly variable rainfall, its waterways, and its impervious soils, make the city of Agadir an area exposed to frequent and severe floods. Remote sensing and GIS are particularly powerful tools for the study of natural risks [1]. Earth observation data is a powerful tool for monitoring flood phenomena [2] because it allows the affected areas to be identified, but can also help to put in place risk prevention plans [3-7]. Several studies have used radar and optical satellite images to assess flood risk [8-13]. The objective of this work is to establish a flood risk prediction map using the 2007 Lee equation by the integration of five main causative factors in a geographic information system (GIS).

II. CHARACTERISTICS OF THE STUDY AREA

1. Geographic location:

Agadir city is located on the southern Moroccan Atlantic coast between 30 ° and 31 ° north latitude 9 ° 40 'and 9 ° 30' west longitude (Fig.1). It is a completely renewed city after the earthquake of 1960. It is limited to the north by the southern fallout of the high western atlas, to the west by the Atlantic Ocean and the basin of Souss Massa in the east; indeed its extension is towards the east and towards the south-east.

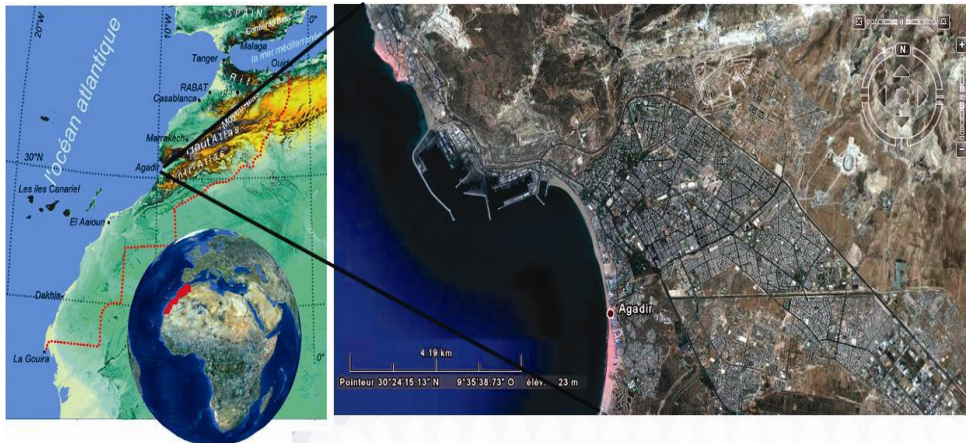


Fig.1 :Situation of the study area

2. Geology of the study Area:

The Agadir city is located on the south-western border of the high atlas, intra-continental chain which owes its current structure to compressive movements of essentially tertiary and plio-quaternary age. It straddles the mountainous area belonging to the "southern pre-Atlas zone [4] and on the northern limit of the plain of Souss. The area where the maximum intensities were observed during the 1960 earthquake is geologically quite complex. There are three compartments separated by two NE-SW steering accidents: the faults of the Kasbah and respectively Tildi wadi Fk and Ft (Fig.2).

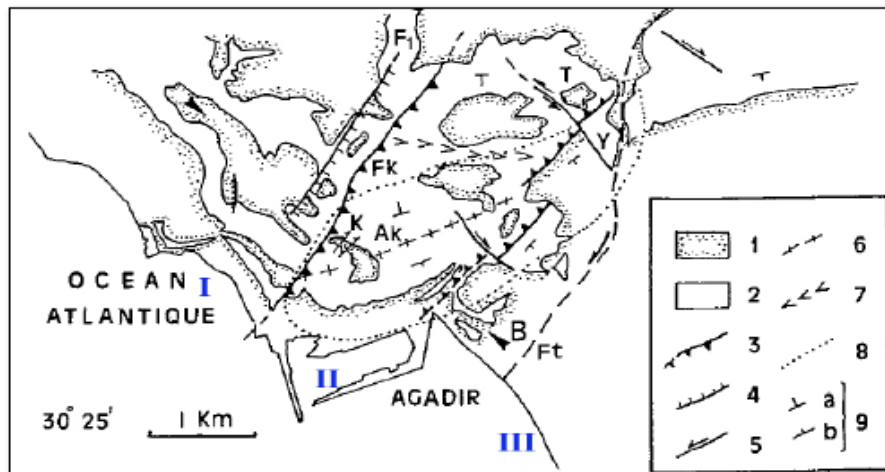


Fig. 2: structural schema of the Agadir region.1: tertiary and quaternary; 2: Cretaceous; 3: reverse fault, 4: normal fault; 5: setback; 6: anticlinal axis, 7: synclinal axis, 9: dip, a: weak, b: strong; Fk: Kasbah Fault, Ft: Tidili Wadi Fault, AK: Kasbah Anticline, k: Kasbah, y: Yahchach (DUFFAUD, in DAFFAUD et al., 1962). [15]

The compartment NW, of simple appearance, includes weakly dipping monoclinial layers towards the

NW, without any other compilation that has a fault NE-SW F1, parallel to the fault of the Kasbah, with apparent normal game slumping compartment SE. The central compartment, the most complex, houses a syncline axis N100 north west, an acute anticline of axis N070 further south the anticline of the Kasbah. The southern flank of the latter is straightened and affected by longitudinal fault (fig.3) bringing into contact the Cretaceous and the Pliocene. Other faults oriented this time NW-SE, are indicated on the geological map of Agadir (fig.4): geological map (R.AMBROGI, 1962). Finally, the compartment SE is also simple, where the layers are generally south-dipping. The complexity of these structures can be explained by the existence of many superimposed phases, the last of which, neotectonic, are reflected dramatically by the differential staging of marine terraces along the Atlantic coast [16].

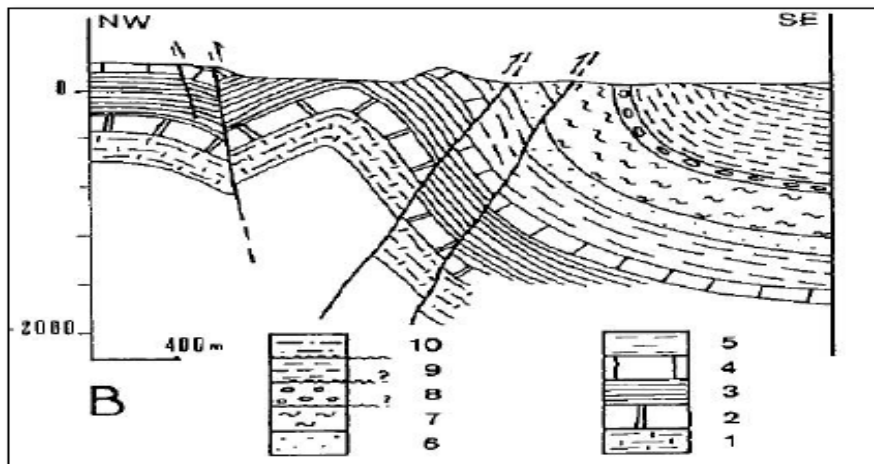


Fig. 3: NW-se section through the region of Agadir: 1 to 7 Cretaceous; 8. Oligocene; Miocene; 10. Pliocene and quaternary. : According to (DUFFAUD et al, 1962).

The geological formations of the study area are as follows (**Fig.4**):

1. The cretace:

a. Aptian:

Is generally at the base marl-limestone above and becomes frankly marly limestone with small sandstone benches at the top; it is one of the most constant stages by its ammonite fauna;

b. Albian:

Beginning with clays and green marl cut from small sandstone levels: at the top, gray or white limestone, gray marl, calcareous alternate with marl: the floor ends with sandstone beds or sandstone limestone; its power oscillates between 180 and 300m; the lithographic limestones of the Upper Albian have been extracted from limestones in some quarries in the region.

c. The Cenomanian:

Not defined by any ammonite. Yellow marls, cut from some calcareous banks (300 to 400m) which surmount the albian;

d. The Turonian:

It corresponds to a strong dolomitic limestone bar 30 to 60 meters dense, very compact with many flint beds, its outcrops are used as construction materials in quarries north of Agadir.

e. The Coniacien:

With its predominant white or gray limestones alternates with yellow marls and benches of flint to barroisiceras;

f. The Santonian:

It is under a facies of marl cut from some banks of siliceous limestones;

G. The Campanian:

Represented by soft formations (100-150m) of yellow marl, sandstone more or less marly;

h. The Maestrichian:

It's made up of flinty white siliceous marls with perfectly spherical calcareous concretions. All stages of the Cretaceous excluding the Cenomanian and the Campanian are defined by faunas of ammonites. During this period a sea rich in cephalopods occupied the high western atlas. At mid and late Cretaceous ammonite facies have become rare in the profile of oyster facies.

2. The Tertiary and Quaternary

a. the Oligocene:

Has been identified by Ambroggi in the region of Agadir; it is white conglomerates (30m); it passes to the east to lacustrine limestone.

b. The Pliocene:

It is transgressive and discordant on the Oligocene or Cretaceous, it is represented by marls and clays gis-blue mollasse and limestone shellfish;

C. The Quaternary:

In the region of Agadir, there are two types of quaternary: the marine quaternary between Cape Ghir and Agadir and the continental quaternary in the Souss valley. The first type of quaternary consists of

conglomeratic shell sandstones and soft lumachelles, while the second is formed by silty terraces, marls, lacustrine limestone and conglomerates.

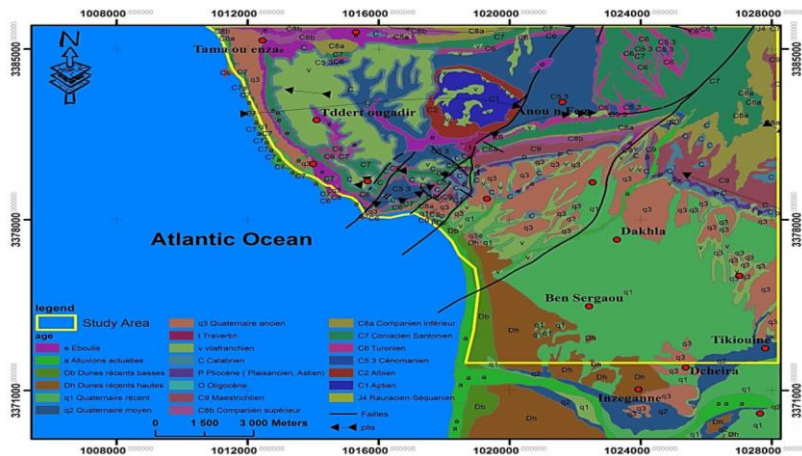


Fig.4: geological map of the study area;

3. The Climate of the region:

The relief, the oceanic coast and the Sahara are in general, the three factors that make the arid to semi-arid climate of the Souss region. The interaction of these factors makes the climate of the region very complex and its characteristics difficult to specify. The climate of the region is arid to semi-arid; it varies from humid type, to cold winter on the summits of the Western High Atlas to pre-Saharan, to cool winter, in plain. The proximity of the Atlantic Ocean and the influence of the cold Canary current mitigate the climate of the area and the mountainous barrier of the Anti-Atlas contributes to its protection against the winds of the South (the chergui) [17]. In order to approach the different climatic components of the study area, meteorological records from the Agadir-al-Massira station were used which are located less than 10 km as the crow flies (table.1).

Table.1: The characteristics of the station:

PLUVIOMETER	Z	LAT_WGS84	LONG_WGS84
AGADIR AL MASSIRA	60	30,330883	-9,424022

Rainfall in the study area is low and irregular both in time and in space, with an annual average of about 243 mm. The figure below (Fig. 5) illustrates the year-to-year distribution of precipitation in the area over the period 1933 to 2006.

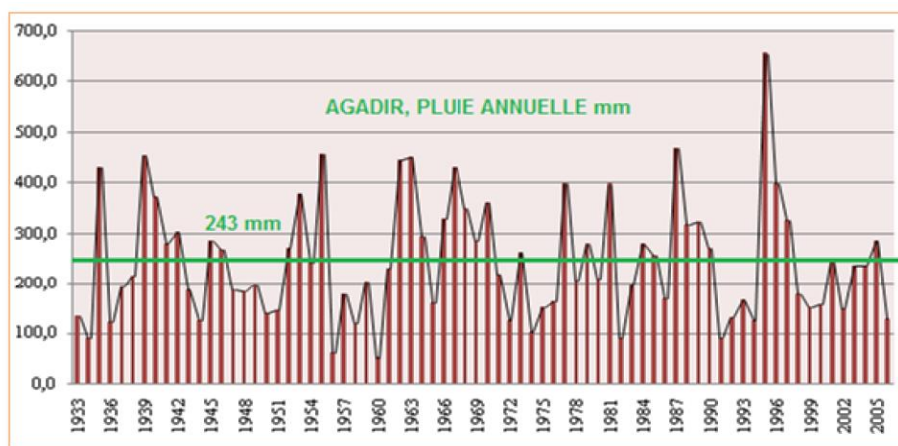


Fig. 5: annual rain in Agadir Al Massira (Source: Souss Massa Hydraulic Basin Agency, 2006)

In this zone, precipitation occurs mainly in the form of brief and violent storms, and irregularly distributed during the year. In general, one can distinguish a rainy season from October to April when the zone receives almost 97% of the total volume of precipitation and a dry season from May to September (fig.6).

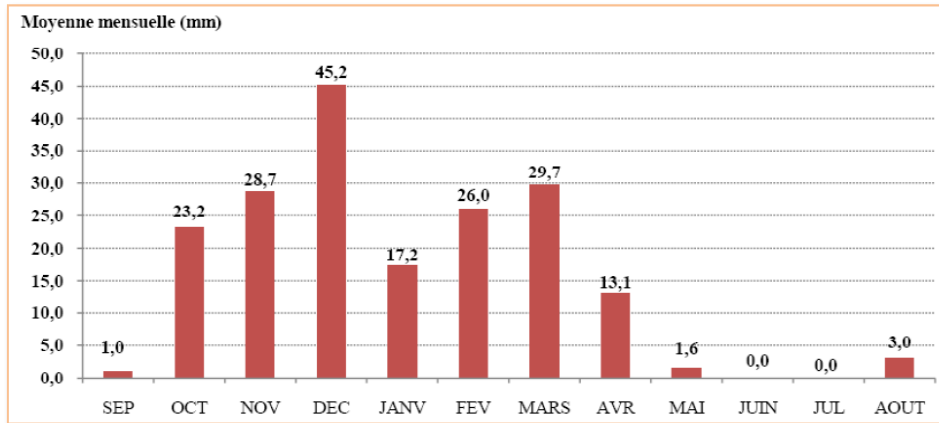


Fig. 6: monthly distribution of rain in Agadir Al Massira (Source: Souss Massa Hydraulic Basin Agency, 2006).

III. MATERIALS AND METHODS

The hydrological study of the Agadir basin was conducted on the basis of the modeling, by the use of Geographical Information System (GIS) and, more precisely, the contribution of Digital Elevation (DEM), its derivatives and the satellite image. The DEM is used to define the slopes, the hydrographic network, and the delimitation of the watersheds. The digital data differences obtained in the form of digital information layers constituting basic information and useful for hydrological modeling. **The Digital Elevation Model** dating back to the 1950s is currently taking a strategic place in digital mapping. It is a digital representation of relief, in the form of a computer file. This artificial geometric surface is only an approximation of the real surface of the ground. Knowledge of the digital terrain model is an important element of the management of a municipality or region. It plays a decisive role in controlling problems as diverse as water management (distribution, sanitation, watersheds delimitation and runoff), land use planning, land reclamation and finally flood management. The Digital Elevation Model of study Area shows that the city of Agadir is built on low altitudes between the Atlantic Sea and the mountain of the Western High Atlas (Fig.7).

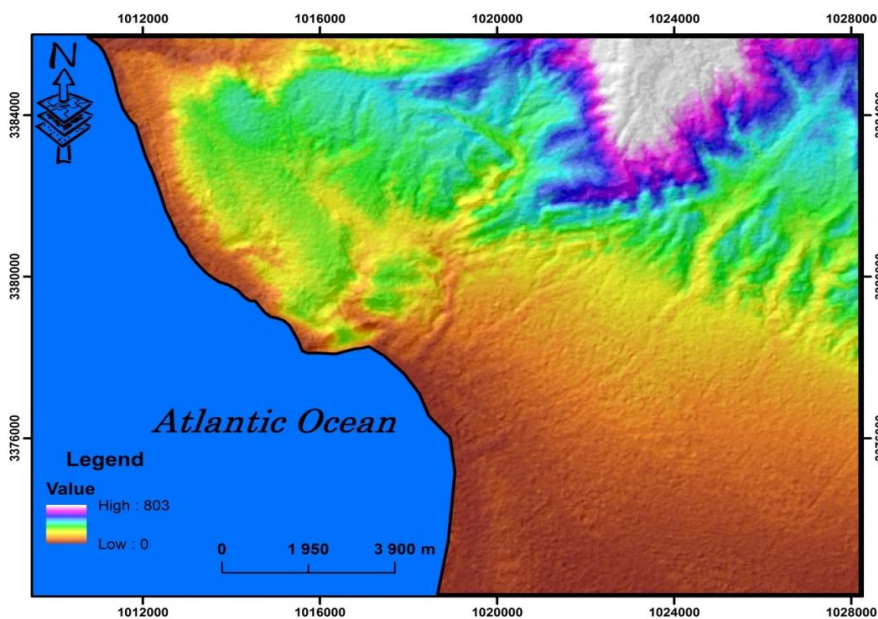


Fig.7: DEM of the study area

The study of the flood phenomenon is complex and it seems useful to specify the parameters taken into account in the semi-mountainous region of Agadir. These parameters consist of environmental and natural variables whose susceptibility to produce a flood is effective. These are modeled, slope systems, flow direction, hillshade, lithology, and land use. In this study, the calculation is based on the Lee formula (KHMIRI et al [18].) All parameters of the formula must be in RASTER mode to obtain the flood risk map (Fig.8). The flowchart below illustrates the steps taken in this study namely:

- ✓ Generate the maps; slope; direction of flow and hillshade from a DEM (digital elevation model).
- ✓ Preparation of the permeability map related to the lithology from the geological and pedological maps of the study area.
- ✓ Classification after treatment of the satellite image of the study area to obtain the land cover map.
- ✓ All parameters will be sorted and converted to Raster mode before the built-in equation.

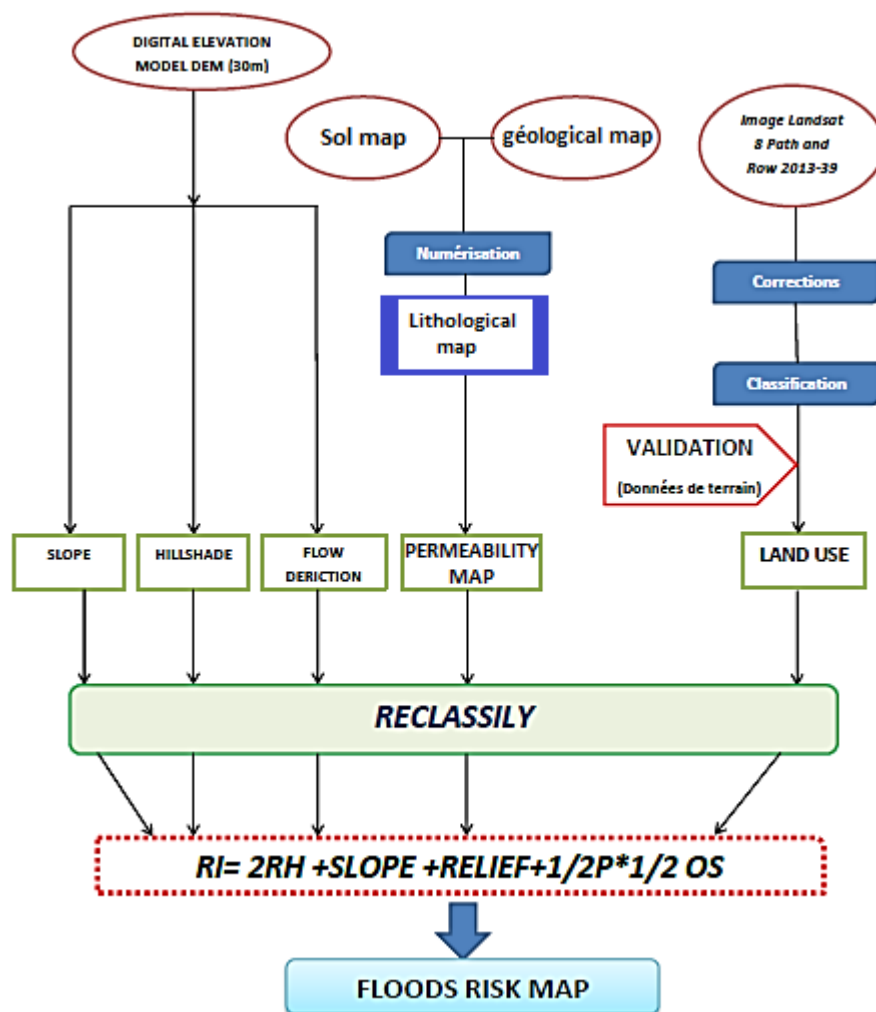


Fig.8: Flowchart of mapping the flooding risk.

IV. RESULTS

The different plans obtained from DEM are:

1. Slope:

We applied to Agadir's DEM the slope function of GIS software on all its pixels to obtain a map of slope as well as degrees in percentage (fig.9). This information will be used in flood modeling. Slope is the most important parameter controlling runoff velocity and flow / seepage ratio.

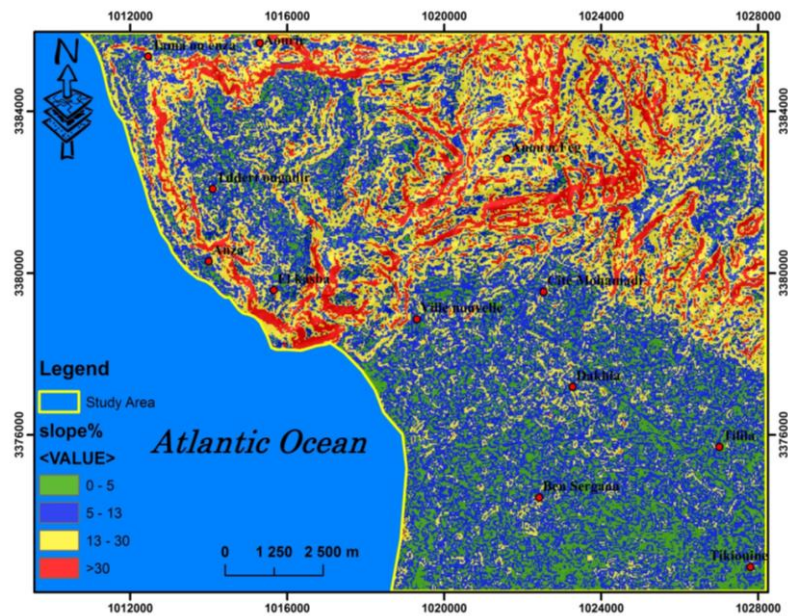


Fig.9: slope map of the study area

A quick review of this information plan leads to the following conclusion:

The city of Agadir occupies a low slope area of no more than 15% surrounded by a belt of steep slope formed by the fall of the chain of the high western atlas. This shallow slope will be the most important factor that causes flooding in the city of Agadir.

After the characterization of the morphological sets, the slopes of the terrain are extracted from the MNA and are organized into four classes: weak (0-5%), moderate (5-13%), strong (13-30%) and very strong (> 30%).

2. Hillshade:

The Shading tool provides the hypothetical illumination of a surface by determining the lighting values for each cell in a raster. This function defines the position of a hypothetical light source and calculates the lighting values of each cell relative to neighboring cells. Shading greatly improves the visualization of a surface when viewing analyzes or diagrams, especially if you use transparency. By default, shadow and light are shades of gray associated with integers from 0 to 255 (from black to white) (Fig.10).

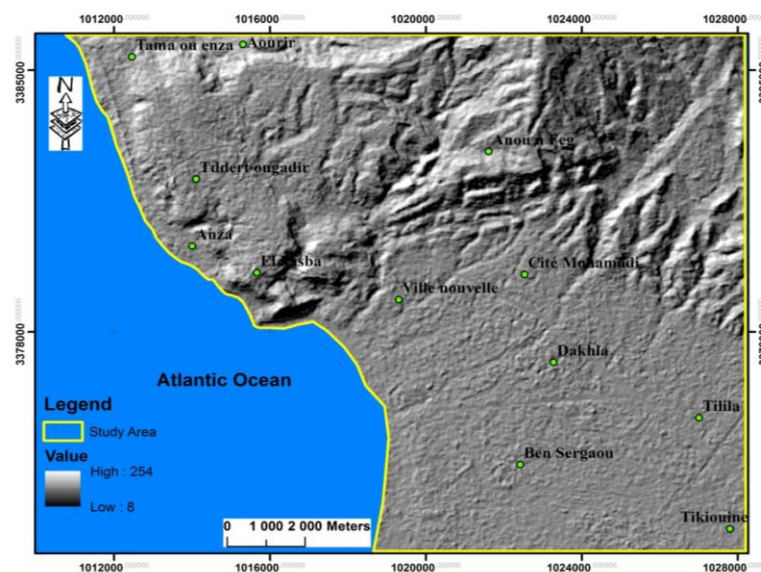


Fig.10: Hillshade map of study area;

3. Hydrographic networks

The majority of the city of Agadir is located in the Tamri-Tamraght basin, but its extension is also in the Souss basin, which is crossed by several streams whose flow is seasonal and a large number of thalwegs. (Fig.11) which drain the waters are coming from the high atlas towards the Atlantic and towards Oued Souss.

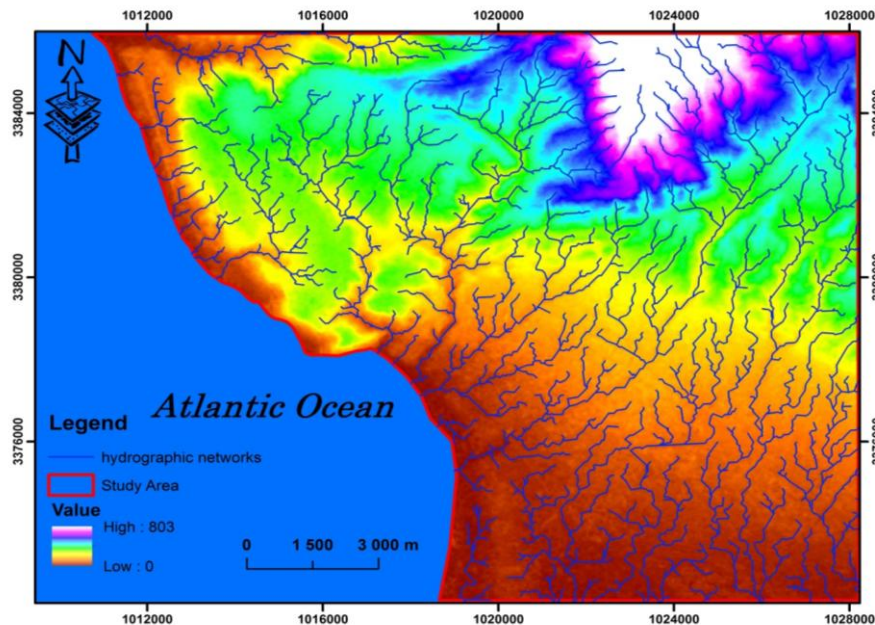
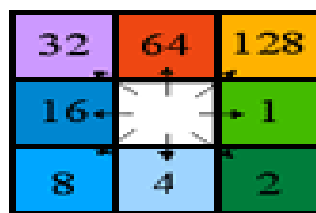


Fig.11: Hydrographic networks.

4. Flow direction

The principle is to establish to which cell the water flows, from the central cell. For that, it calculates the slope between the central cell and the 8 surrounding cells whose values vary from 1 to 255. It considers that the water flows towards the cell which has the strongest slope [17].



Direction coding

The coding of the direction of flow

We have established the flow map of the study area. The cells flow to their nearest neighbor along one of the 8 cardinal directions labeled as E = 1, SE = 2, S = 4, SW = 8, W = 16, NW = 32, N = 64, NE = 12. The results obtained (Fig.12) are in most between 4 and 16 which means directions; S, SW and W.

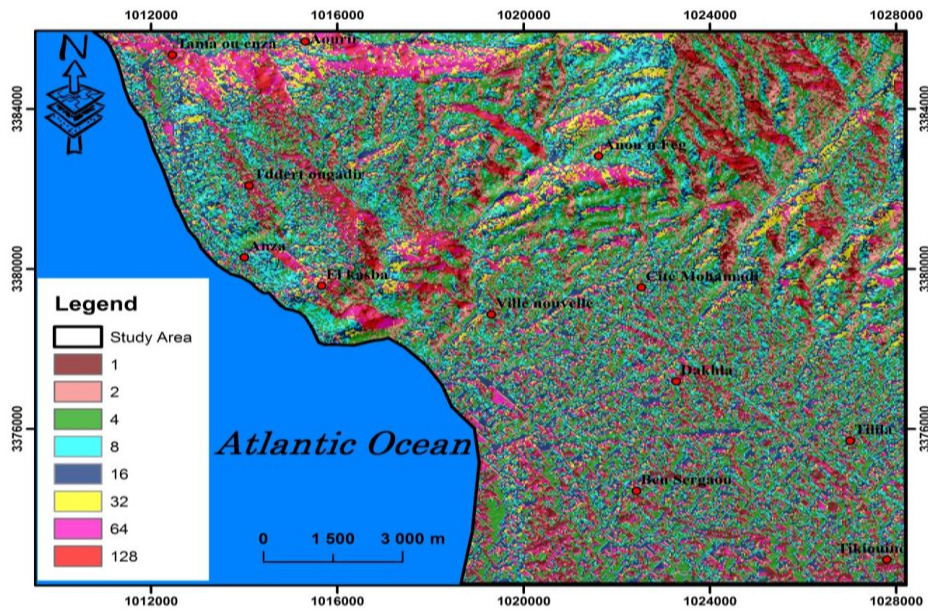


Fig.12: flow direction map

5. Satellite imagery and mapping of surface states:

Mapping of surface states is done using Landsat 8 imagery. The resulting map is the land use map, which is one of the factors involved in mapping flood risk areas. The map provides information on the typology of vegetation cover and the state of land use. The first stage of processing consisted of geometric and atmospheric corrections of the image. Concerning the mapping phase of the surface conditions, the classification carried out was completed and validated by the field surveys. The different classes are: argan forest, dense vegetation and gardens, greenhouse mosaic and euphorbia, mosaic-roads, bare ground, and water (Fig.13); this map is involved in the analysis of surface flow waters.

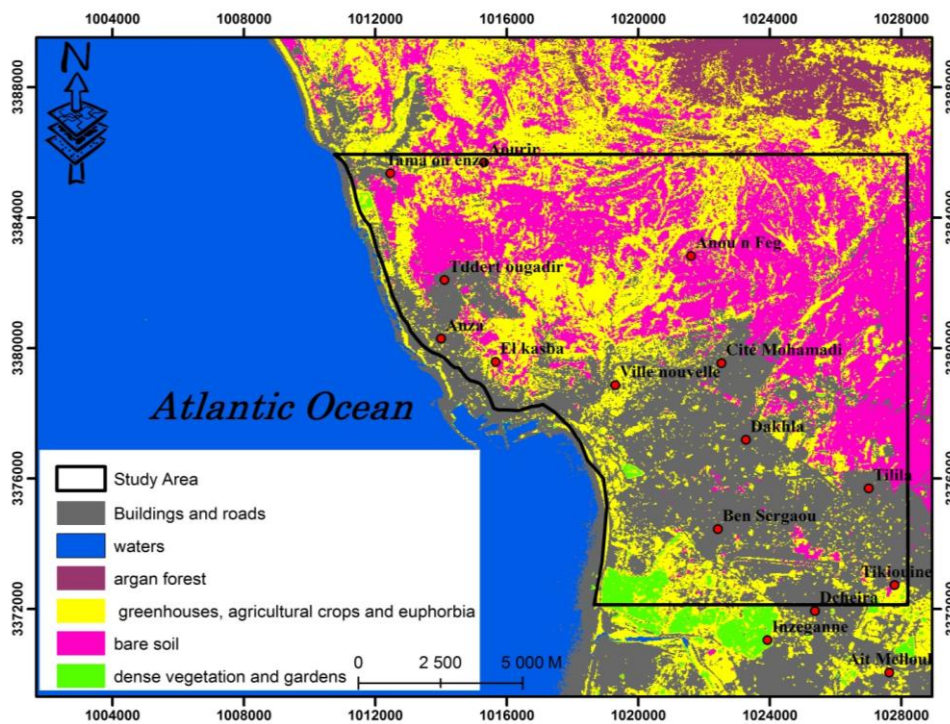


Fig.13: Land use map study area

6. Litho-permeability map:

The permeability map, being a parameter involved in the flood phenomenon, was created following the adaptation of the Geological Map of Grand Agadir and the lithological map to extract the Lithological map from which the Permeability map was created to deduct of the degree of permeability of each lithology according to its components. The permeability map obtained (Fig. 14) shows that the Agadir zone has mostly permeable soils, the impervious sites are in the northwestern part of the study area. The permeability map is classified in three classes:

- ✓ Permeable land;
- ✓ Semi-permeable land;
- ✓ Waterproof land.

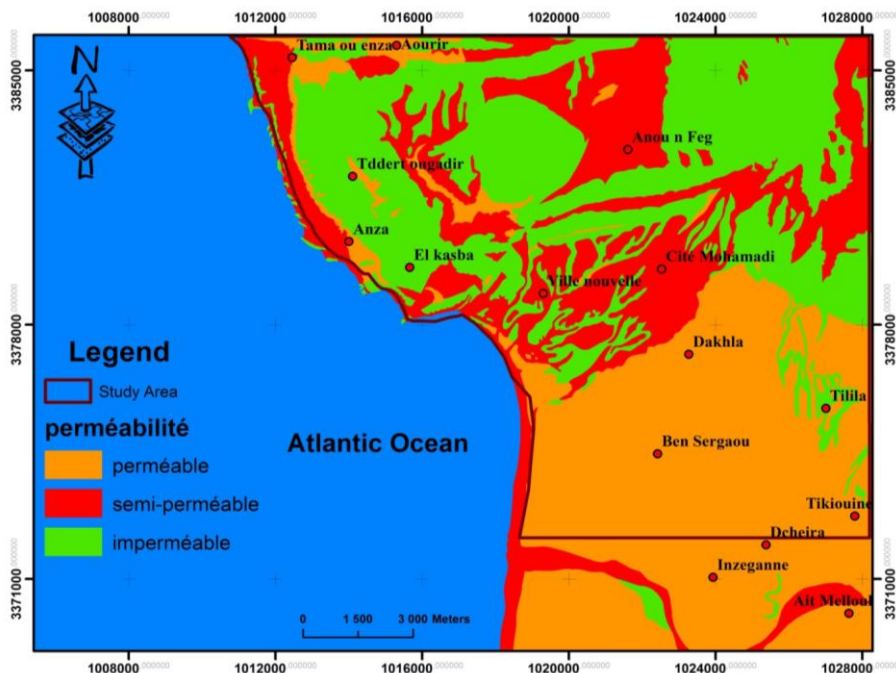


Fig.14: litho-permeability map

7. Map of areas at risk of flooding

After preparing the five parameters that will be exploited in our study, the risk of flooding will be evaluated by Lee's equation (2007) [18].

$$RI = 2RH + SLOPE + RELIEF + 1/2 P + 1/2 OS$$

With:

RI	Risk of flooding ;
RH	Drainage ;
P	Permeability ;
OS	Land Use.

All factors are declassified into four classes (low, medium, high and very high) according to their intervention in the flood phenomenon, only the permeability map will be reclassified into three classes (permeable, semi-permeable and impervious). The flood risk map obtained has four classes whose risk varies from low to very high (Fig.15).

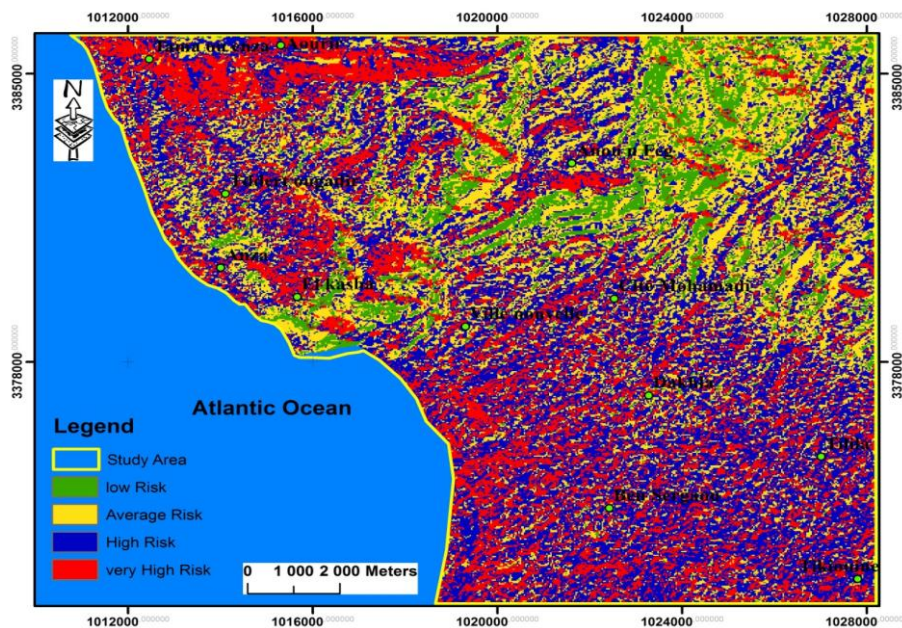
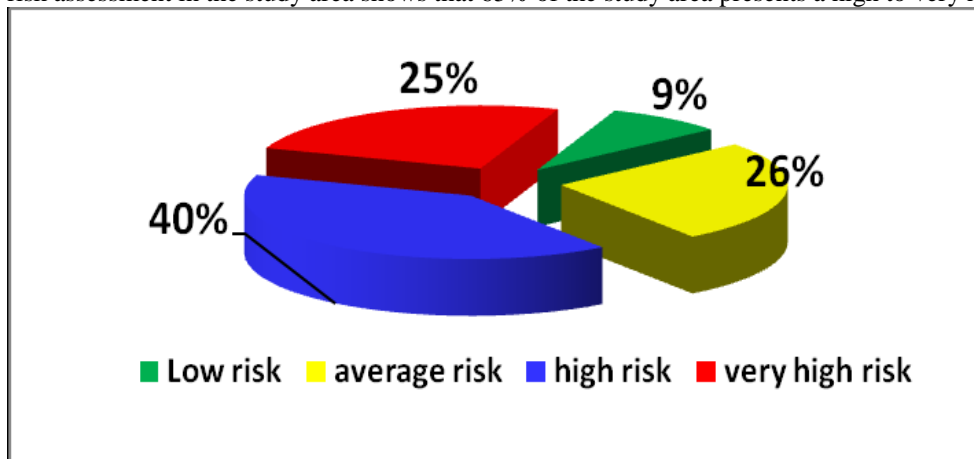


Fig.15: map of the flood risk in the Agadir area.

The flood risk assessment in the study area shows that 65% of the study area presents a high to very high risk.



V. DISCUSSION

Low to medium risk areas covers the peaks of the high atlas and areas of high to high risk covering most of the city of Agadir and the municipalities of Anza and Aourir. These zones present an obvious risk during floods; these zones correspond to the plains and the major beds of the rivers which cross the city of Agadir. The obtained risk map shows the extent and magnitude of flooding in the study area. This map can provide a solid foundation for populations and authorities responsible for any developments. The methodology adopted in this study exploits different types of multi-source data the question of the quality of the results obtained is important and deserves to be emphasized. The spatial resolution of the DEM and the other plans used has significantly improved our results as well as the satellite image adopted allows the mapping of land cover types. These different information plans were validated by exogenous data from the field before the development of the flood risk map. For the slope we have no measure to test its reliability. The final map obtained makes it possible to delimit the areas at risk of flooding. The city of Agadir appears as an area with a very high risk of flooding. Slightly sloping areas represent the major part of high and very high risk areas.

VI. CONCLUSION:

The integration of satellite data and products derived from the digital model of the ground has allowed the mapping of areas at risk of flooding in Agadir city. The map of the risk obtained shows that most of the studied area represents a high to very high risk which requires a more detailed cartography of this zone. At the

end of this work and according to the hydrological modeling carried out in the Agadir area, the results obtained make it possible to map areas at risk of flooding. The prevention of floods therefore remains an urgent priority, so that the principles of dynamic deceleration can be:

- avoid the installation of Quarry Stone in stream beds which increases flow velocity ;
- Avoid diversions of the hydrographic networks.
- Upstream watershed management through reforestation to stop soil loss which increases solid input.
- The integration of other factors, namely precipitation and fracking, will be a perspective research that will improve and refine the map.

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