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Mapping of Areas at Risk of Flooding in the Driouch City Kert Basin North East of Morocco

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Abstract:- Floods are a recurring problem in the Mediterranean region, and understanding their frequency and severity is crucial for local decision-makers. This paper presents a methodology for assessing flood risk at the watershed scale, using the frequency of floods and land-use vulnerability as key factors. The study focuses on the Kert basin, which includes the urban area of Driouch, and aims to produce a flood risk map for the region. The methodology involves a hydrological study to determine the maximum flow rate and a hydraulic study using HecRas software to calculate the speed and height of centennial floods in the Oued Kert. The results are presented as thematic maps using ArcGIS 10.7 software, enabling planners and local authorities to propose mitigation measures and respond more effectively to floods. The study found that the region is highly susceptible to flooding, particularly as urbanization and infrastructure continue to expand. The paper concludes by emphasizing the importance of flood risk management for the region's sustainable development.

Keywords: *Hazard, Flood, Cartography, Modelization Hydraulic, Vulnerability, Kert , Management Of Risk.*

I. INTRODUCTION

Floods are a major risk in the contemporary world. They rank first among natural disasters in the world, causing approximately 20,000 victims per year [1]. Like the rest of the world, the Mediterranean region has experienced multiple threatening floods. Rainfall often exceeds 200 millimeters in 24 hours, and sometimes in less than six hours [2].

At the beginning of the 21st century, Morocco experienced major floods which caused significant human and material damage in several regions of the country. The catastrophic floods in the Ourika Valley in 1995, the Martil plain in 2000, the Mohammadia region, Berrechid and Settat in 2002, the Tangier region and the Driouch region in 2008, the Gharb in 2009, the Taza region in 2010 and the Khenifra region in 2011, testify to this.

The Kert watershed (north-eastern Morocco) is highly exposed to the risk of flooding. Indeed, the bad weather recorded in this region shows to what extent flood protection has become a major issue. It is therefore a major challenge in the management of water resources. Indeed, the strong irregularity of the hydrological regimes of the Kert basin, the nature of the land cover (soils), which are often impermeable, and the disparity between a mountainous relief upstream and a vast alluvial plain downstream explain the generation of runoff as well as torrential and violent floods. These factors can cause flooding that leads to life loss and significant material and environmental damage [3].

In addition, climate change increases the susceptibility of the Kert watershed to be affected by floods threatening the economic development, infrastructure, and natural ecosystems of the region. Indeed, these changes clarify the increase in the frequency of floods in the Mediterranean coastal areas, the rise in sea level, and the extension of the drought period [4].

The risk of flooding is also linked to anthropogenic factors, in particular the intensification of industrial activities and the growing urbanization in the province of Driouch. These socio-economic activities have favored the construction and the installation of numerous activities along the Kert wadi, thus leading to modifications in the distribution of sediments and to a degradation of the natural environment of these areas.

The main objective of this work is to map the flood zones of the Driouch region located in the downstream part of the Kert basin. Then we can evaluate the risk of flooding in order to provide the necessary information for local actors to establish a strategy and protect themselves against the harmful effects of floods.

II. MATERIAL AND METHODS

- *Presentation of the Study Area:*

The watershed of the Kert wadi belongs to the Riffian domain. It is limited to the north by the djebel Tistoutine, to the west by the Temsamane massif, to the south by the djebel Driouch and to the east by the Gareb plain. It is geographically located between the two parallels -3°37′ and -3°85′N, and the two meridians 34°60′ and 35°00′ W (Fig. 1).

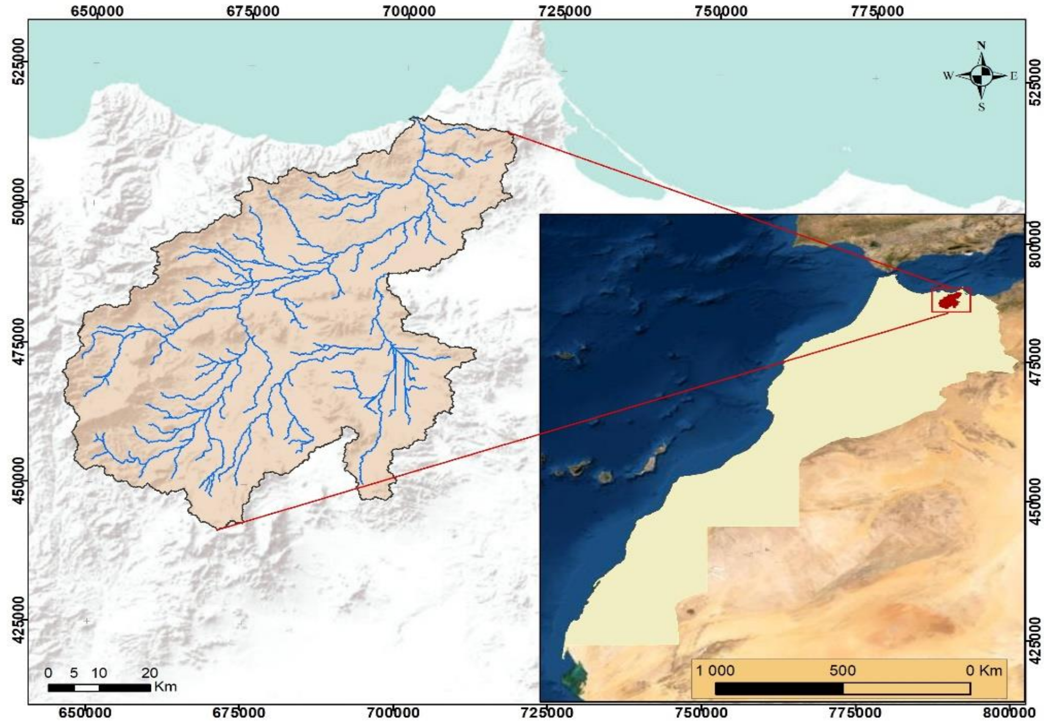

Fig 1 Geographical location of the Kert Basin

The Kert basin is a Mediterranean basin characterized by a relatively large surface area and a varied morphology. Its surface is 3014.85 km ^{2} corresponding to a perimeter of 391 km. The basin, depending on the existing stations, is subdivided into 3 major sub-catchments.

The altitudes and slopes of the Kert basin are very variable due to the position between the Rif range and the Mediterranean Sea. Indeed, the altitudes vary between 0 m on the coasts and the plain to 1807 m in the extreme south of the Chemmar sub-basin and the average altitude is around 903 m (Fig.2).

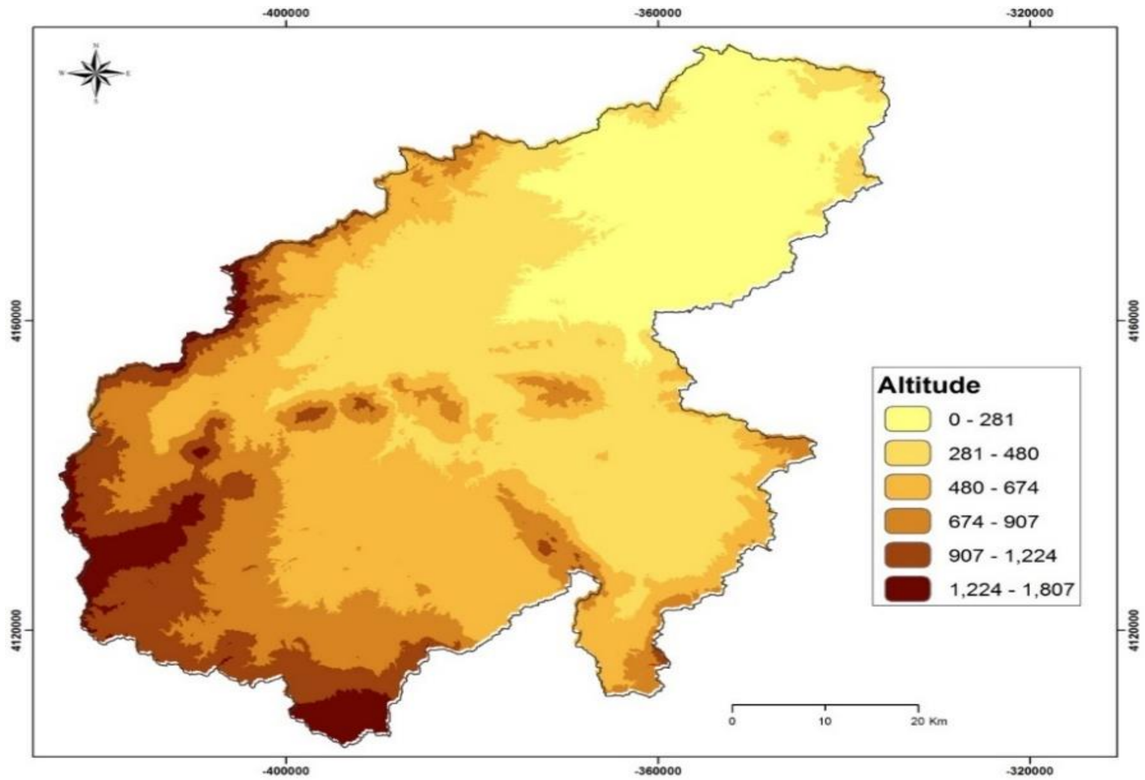

Fig 2 Map of the Kert Watershed

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The slopes vary between 0 and 186% with a shape index Kg = 2 and a fairly dense and well-branched hydrographic network (Fig.3).

The climate of the study area is characterized by two very different seasons: the first is wet, it extends from October to April; the second, sub-humid and hot, begins in May and lasts until the end of September [5]. Precipitation varies in height, intensity, and geographical distribution. Annual rainfall averages 221 mm per year. This rainfall obviously increases with altitude; and can exceed 371 mm per year at upstream of the basin at the Telat station Azlaf [3].

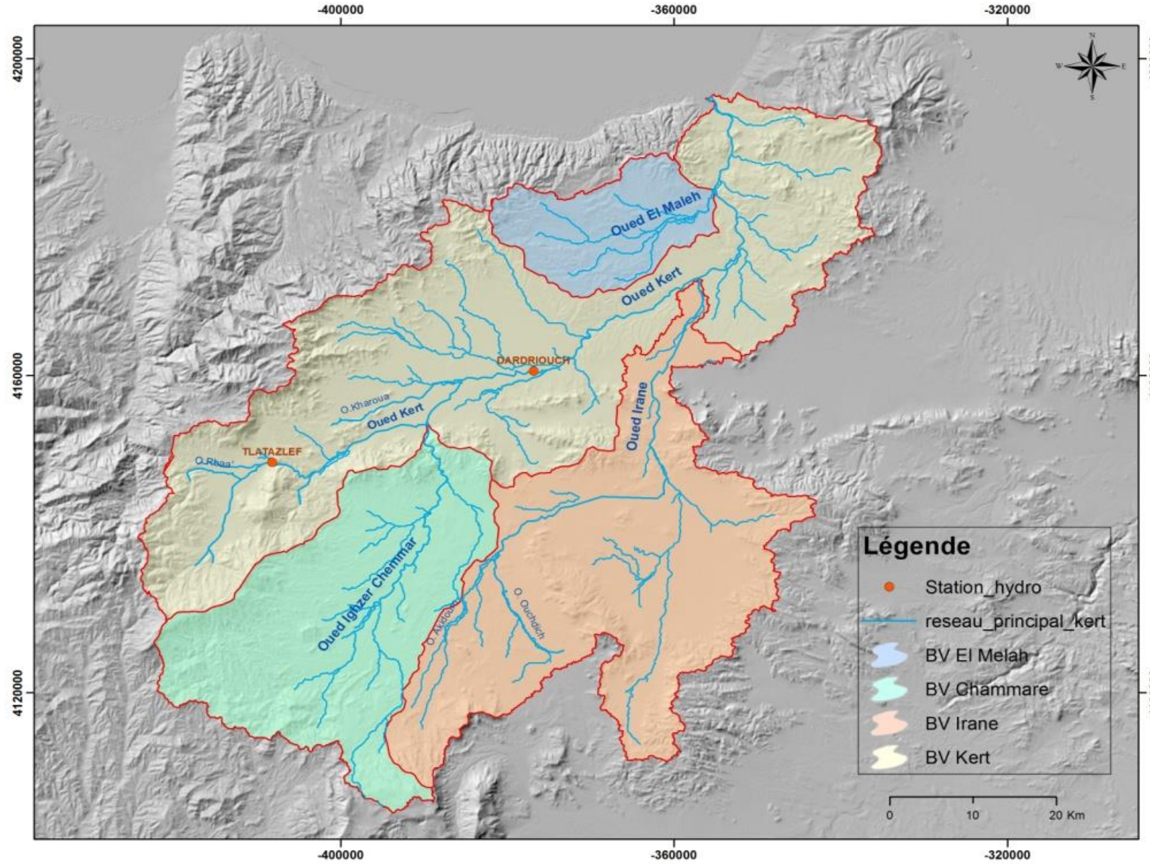

Fig 3 Map of the Kert basin Stream Network

Geologically, the watershed of Oued Kert is part of the area of the Eastern Front Country. In the structural division of the Riffian domain, this zone is part of the pre-Riffan zones.

On the northern edge of the Kert, there is a metamorphic series of conglomerates and brown limestone, then to the east of Kebdani, the metamorphic miocene transgressively covers the schisto-sandstone series. Then comes the Messinian transgression in unconformity on this Miocene, represented by non-metamorphic deposits: molasses, then marls and sandstones and above we encounter Pliocene continental deposits.

The autochthonous comprises at the base a very thick red schist–sandstone formation (over 500 m in borehole 1635/6 located 2 km east of Driouch) of probable Callovo–Oxfordian age, which is topped by a marl–limestone dated Upper Jurassic. The limestone beds are cracked enough to allow water circulation but the whole series is very compartmentalized.

The Cretaceous appears to the east at the height of the Irane wadi with the marl-sandstone Neocomian surmounted by limestone.

The basic Miocene is either conglomeratic or micro-conglomeratic, or in the form of detrital limestones (transgressive facies). It continues through marly-sandstone and marly facies, alternating with conglomeratic beds. At the top of the series, the marly levels develop and become thicker and thicker (drillings 1635/6 and 1636/6).

The oldest levels of the Quaternary can be seen at the foot of the heights bordering the plain of Kert, made up of Villafranchian conglomerate. Towards the center of the plain, these formations change laterally to white or yellowish marls alternating with conglomeratic slabs. (Fig.4) [6].

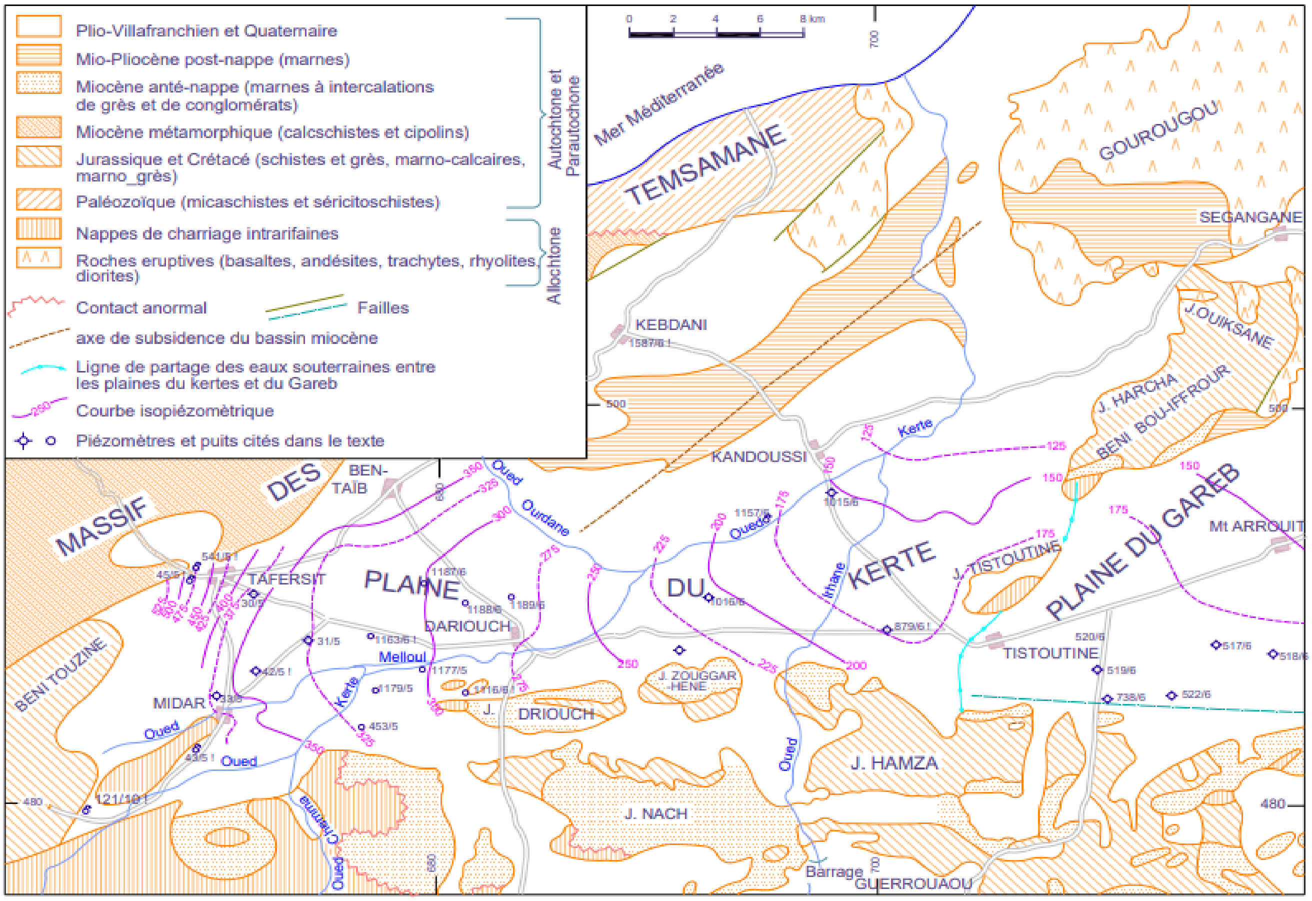

Fig 4 Geological map of the Kert Watershed

From the hydrogeological point of view, an unconfined aquifer extends under the Middle Kert plain and flows over the blue marls of the Miocene. The aquifer consists of gravelly and clayey silts, poorly consolidated conglomerates with marly cement of Villafranchian age, as well as fluvial alluvium in the sub-flows of wadis. The characteristics of the water table are well known, especially in the Driouch region where the density of wells is high. The groundwater is at an average depth greater than 10 m in most of the plain; reaching 60 m between Tafersit and Ben -Tieb, it has a depth of less than 10 m to the N and W of Tafersit, at Midar along the Kharoua wadi and especially in a strip 15 km long and 1 km wide. 2.5 km away, located to the E and W of Driouch, and along the Kerte wadi .

The general shape of the water table is convex, but disturbed by depressed zones which correspond to natural drainage axes; there is one in the central part of the plain and another NE of Midar . The most convex zones of the piezometric surface generally correspond to the sectors supplied by the wadis, but they can also correspond to sectors of low permeability. The Kerte wadi feeds the water table upstream of its confluence with the Kharoua wadi to the E of Midar , it drains the water table downstream of Driouch. The aquifer flows from W to E with a variable slope: around 4% upstream (Tafersit), it decreases at the level of Driouch where its average value is 0.5%, more to the E it increases and reaches 1%.

- *Methodologi:*

The concept of risk is in itself quite complex and it can be expressed in semi-quantitative (classification) or quantitative (monetary) terms. However, it can only be defined by considering simultaneously, and on the same space, flooding and the social use of this space, which suffers (or benefits) from a surplus of water. This has led cindynic theorists (science of the study of risk) to define risk as resulting from two reputedly independent factors, namely hazard and vulnerability. This approach is almost universally accepted today [7] [8]. It should be noted that this breakdown of the risk is a first conceptual modeling of the object studied, which therefore includes its share of simplification [9].

The flood risk assessment in the Kert basin is based on a semi-quantitative approach in which the objects to be protected are classified according to the degree of protection they need. The purpose of this method is to establish intervention priorities in areas in need of protection. The protection objectives are defined according to the category of objects and the return period of the phenomenon.

In the literature, another widely used approach is inspired by economics and aims to quantify risk in monetary terms (monetization) in order to measure the appropriateness of mitigation measures. We are talking about a cost-benefit analysis which is a generic method for evaluating public

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policies, weighing the costs and benefits that they imply [10].

➢ *Hazard Factor:*

The hazard represents the flood as a physical, natural and uncontrollable phenomenon, independently of its potential effects on human activities and the environment. The hazard depends on the hydrological behavior of the watershed and the hydraulic functioning of the hydrographic network.

The hazard is represented by a map which makes it possible to identify the areas where flooding is likely to occur, more or less extensively and frequently [11]. It is based on the combination of the following two notions: the recurrence of a flood and submersion.

The recurrence of a flood is linked to a period of return of flood flows, which involves frequency calculations on a historical series of flows or on a synthetic series reconstituted from precipitation measurements via an integrated hydrological model. Thus, three categories of recurrence have been distinguished on the basis of the return period, namely: a low recurrence for floods whose return period is between 50 and 100 years, A medium recurrence for floods whose return period is between 25 and 50 years, and a high recurrence for floods whose return period is less than 25 years (Fig.6) [12].

Based on the historical flood analysis of the study area, the Kert Basin often experiences sudden and violent pulsations of its main stream and its tributaries. The extreme hydrological events of 2008 remind us of the challenges of hydrological risks. These events were caused by very intense precipitation. The rains were exceptionally violent, reaching a historic value of 2,400 m3 per second. This unusual violence caused the collapse of several houses in the eastern region, particularly in Driouch. The submersion of a flood is characterized primarily by its extent and depth in the overflow basin. As a result, three categories of submersion are distinguished according to their depth: low submersion, the depth of which is less than 0.3 m, medium submersion, the depth of which is between 0.3 and 1.3 m, and high submersion, the depth of which exceeds 1.3 meters (Fig.5) [12].

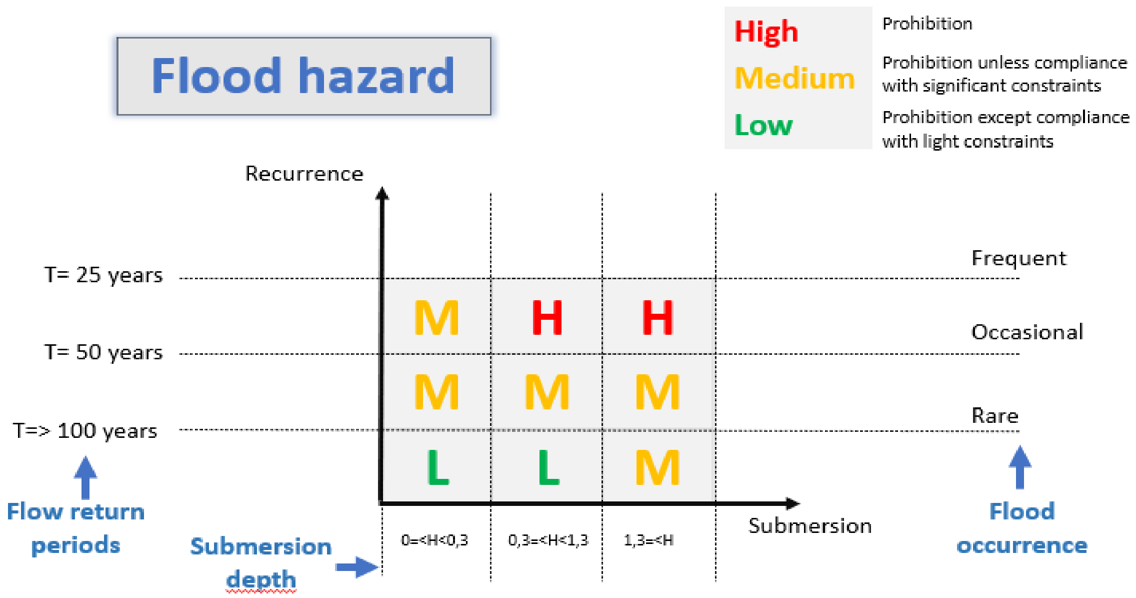

Fig 5 Diagram for determining the Flood Hazard [12]

A flood, in the sense of a hazard, is a very complex natural phenomenon whose analysis requires powerful and elaborate tools such as hydrodynamic models, for example in the context of flood management, hydrodynamic modeling has become a common tool [13]. It aims to numerically predict the spatio-temporal evolution of the hydraulic characteristics of a river during a flood (flow, currents, water height, flooded surfaces, etc.). It is a tool of great educational interest (creation of flood maps to raise public awareness), and/or prospective (decision-making tool: protection and prevention [14].

At the level of the urban perimeter of the study area, the overflows of the Kert wadi have been mapped, using a digital terrain model which represents the topography. The 2D modeling of the flows was carried out by the HecRas software (open source).

The hazard map obtained represents all of the areas liable to flooding for the 100-year recurrence flood, ranked according to water level. Finally, according to the combination of the recurrence and submersion values, the flood hazard values are defined (low, medium, high). For example, in the case of frequent flooding at high submersion depth, we will obtain a high hazard and vice versa.

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➢ *Vulnerability Factor:*

Vulnerability is the second component of risk. This notion has sparked an arduous scientific debate. Some scholars approach it from the potential consequences for human lives and property (direct damage); others apprehend it according to the factors favorable to damage or influence the ability of societies to respond to a catastrophic situation [15].

There are two approaches, analytical and systematic, to assess vulnerability. Analytical approaches determine the direct and indirect causes of a disaster. While systemic approaches are based on explanatory or predictive modeling of a complex system [16] [17].

According to [18] [19], vulnerability expresses the degree of damage of an issue subjected to a given hazard of intensity and occurrence. This damage can be of several types [20]:

- Loss of human life and effects on human health;
- Direct material damage;
- Impacts related to operating, exchange and communication difficulties (qualified as indirect impacts).
- In our case, we use the criteria below to determine the vulnerability classes [12]:
- Low vulnerability: natural forest, matorral, reforestation, bare ground and sand dunes;
- Medium vulnerability: cropland;
- High vulnerability: agglomeration, housing, economic and transport infrastructure.
- The vulnerability map was developed from the land cover map. The latter is carried out by the interpretation of satellite images and topographic maps 1/50000, and on a field study.

➢ *Risk of Flooding:*

The flood risk is calculated by the combination of flood hazard and vulnerability. The diagram (Fig.6) shows the degree of risk according to hazard and vulnerability.

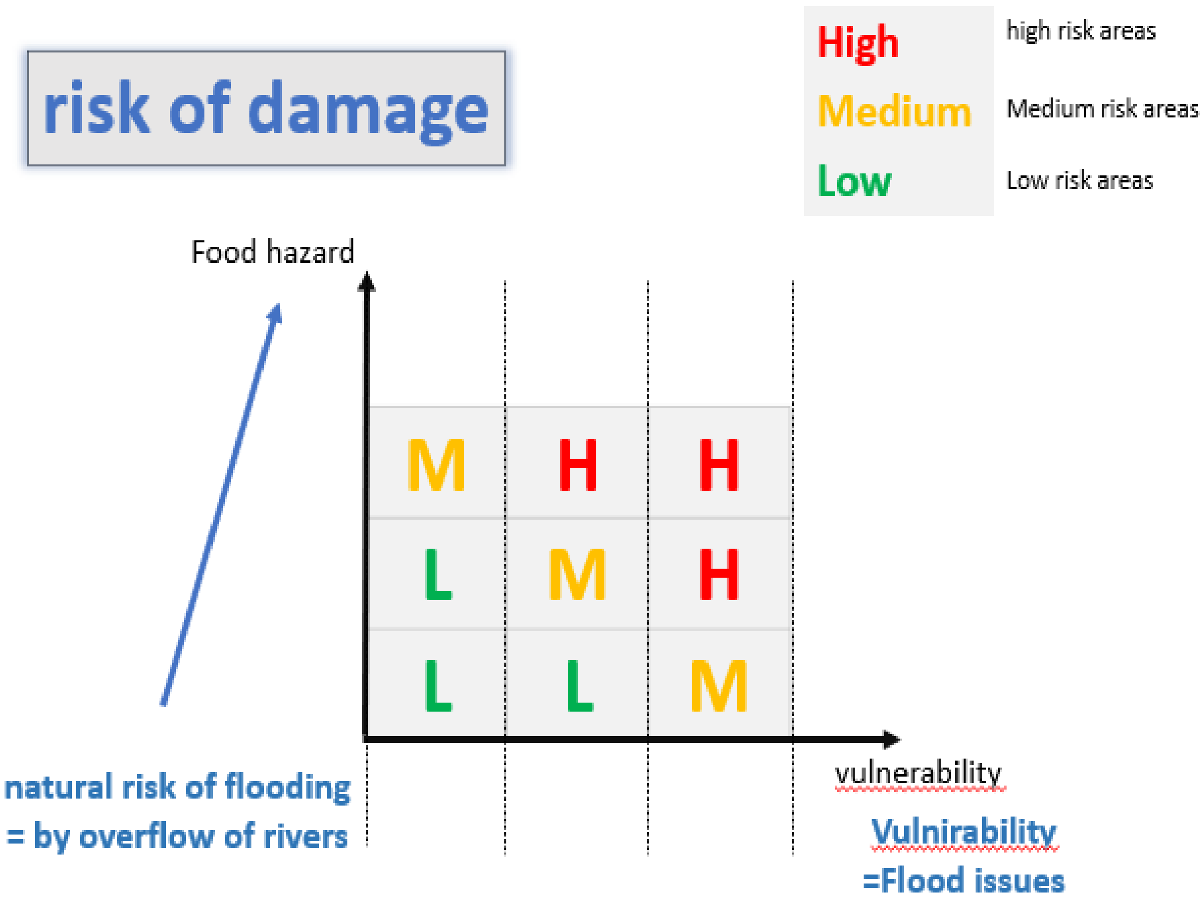

Fig 6 Diagram for Determining the Risk of Damage Due to Flooding by Overflowing Watercourses. [12]

The flowchart (Fig.7) shows the different steps to draw up the flood risk map of the Kert basin.

III. RESULTS AND DISCUSSION

The flood risk map is obtained by applying the flowchart above; the results are presented in terms of three maps: hazard map, vulnerability map and risk map.

➢ *Hazard Map:*

The flood hazard map depicts areas where there is potential for flooding, even where no flooding is historically known. The interest of this map is to assess the extent of flooding at the scale of the urban perimeter of the city of Driouch, and to generally determine the areas vulnerable to flooding given the lack of long-term observations. (Fig.8).

- *The Modeling Results (Fig.8) show that:*

✓ For a low hazard with a depth of less than 0.3 m, the area likely to be flooded is around 21.76% of the study area.

✓ For an average hazard with a depth between (0.3 m - 1.3 m), the area likely to be flooded is around 47.44% of the study area.

✓ For a strong hazard with a depth greater than 1.3 m, the area likely to be flooded is around 30.78% of the study area.

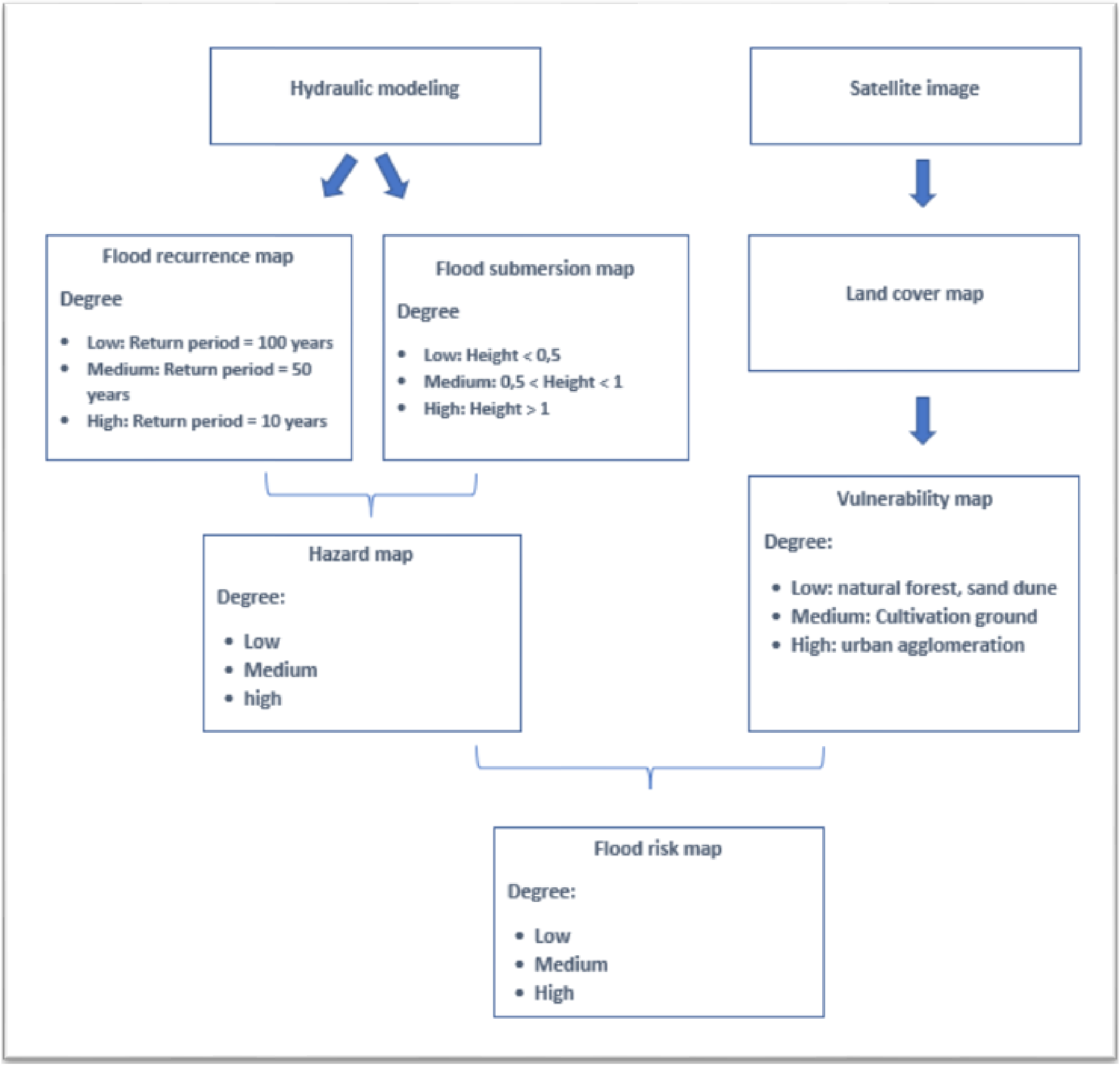

Fig 7 Flow Chart For Developing The Flood Risk Map

Through these results, the area concerned by the floods is significant. The most affected areas are largely in the plain next to the banks of Wadi Kert.

This result is explained by the relatively flat topography of the plain, in addition to the importance of water inflows from the Kert wadi, giving rise to large areas of water spreading during periods of flooding (Fig. 8).

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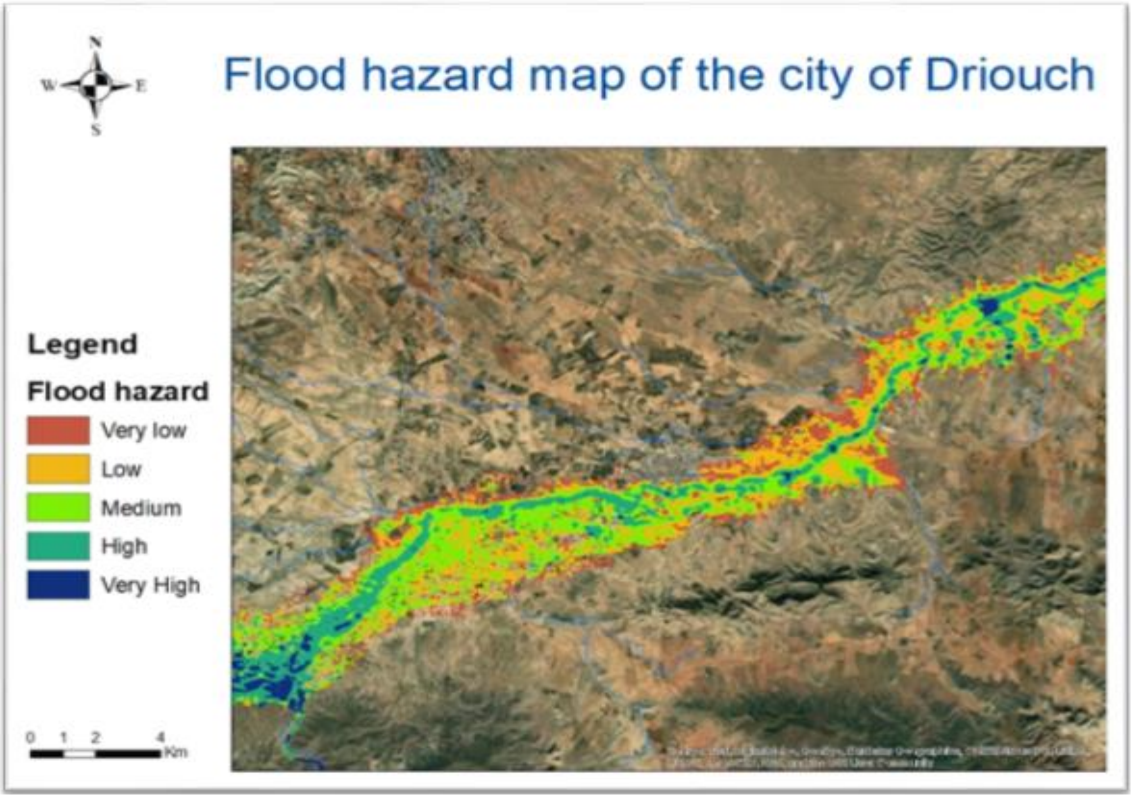

Fig 8 Kert Basin Flood Hazard Map

➢ *Vulnerability Map:*

The urban perimeter of the city of Driouch is occupied by the forest, and marshy areas. Agricultural land is the main land use; consisting mainly of cereal monoculture, some market gardening of fodder, and legumes. Also the urbanized areas, many agglomerations and infrastructures of the city of Driouch have developed near or on the major bed of wadi Kert, amplifying the consequences of the floods (Fig 9).

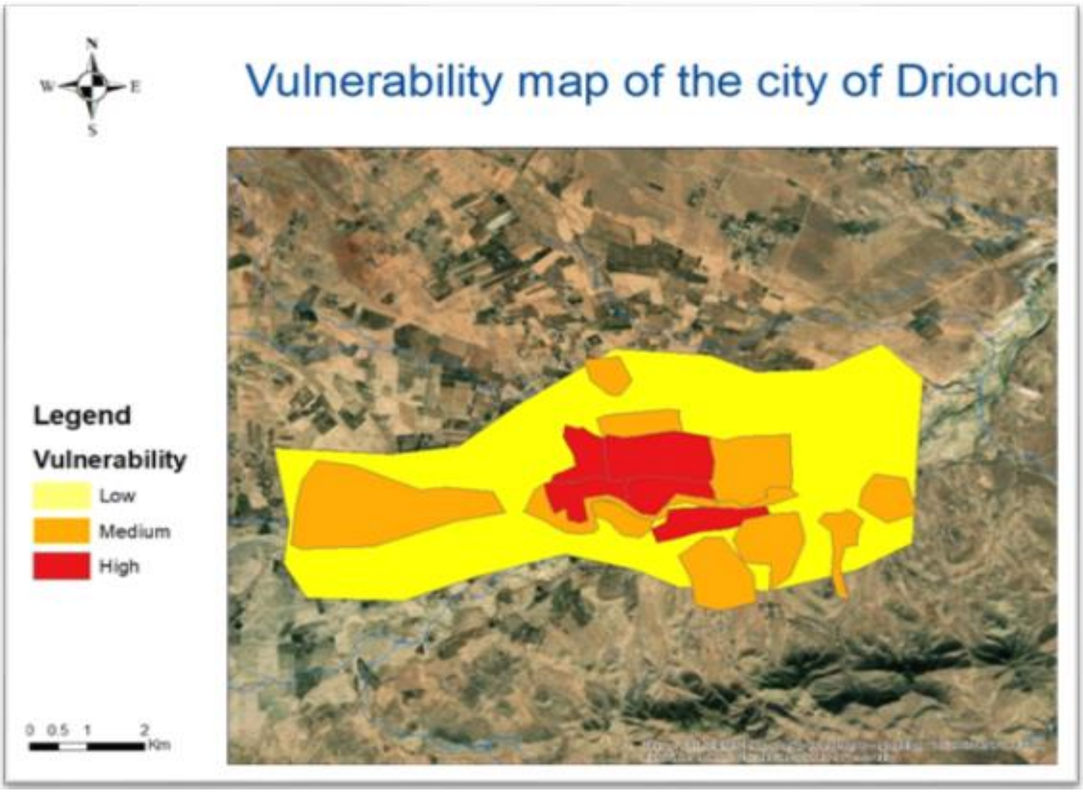

Fig 9 Kert Basin Flood Vulnerability Map

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However, vulnerability to flooding is increasingly felt with galloping urbanization that has continued to grow throughout the city. The risk of flooding is often forgotten by populations and public authorities. Developments have contributed to increasing the stakes considerably. If the hazard is not a quantifiable notion, the stakes are.

- *The Vulnerability Factor was Distributed within the Urban Perimeter as follows:*
- ✓ Low vulnerability over an area that is worth 51% of the total area of the urban perimeter.
- ✓ Average vulnerability over an area worth 34.8% of the total area of the urban perimeter.
- ✓ High vulnerability over an area worth 14.2% of the total area of the urban perimeter.

➢ *Flood Damage Risk Map:*

The flood risk map presents three zones whose risk varies from low to high. The most vulnerable neighborhoods are those located on the route of Oued Kert, from the risk map of the study area (Fig.10), we have determined the risk areas of the city of Driouch.

In general, the strong urbanization of these areas, the incompetence of the sanitation network, the existence of constructions, the clogging of the restitution works, and also the condemnation of the connection of the retention basins to the sewerage network, are the major factors of flooding and this can be seen in the districts which are located on the banks of the Kert wadi.

In this context, the management of the risk of flooding must, consequently, be jointly established by taking into consideration the hazard and the vulnerability. It must meet two main objectives, namely: limiting the location of buildings and people in highly exposed areas and protecting what already exists. Similarly, in flood risk management, it is possible to distinguish two complementary aspects which differ in the level of urgency of the means to be implemented. On one hand, prevention and experience feedback which intervene outside of a crisis context, and crisis forecasting and management which intervene in a flood situation on the other hand.

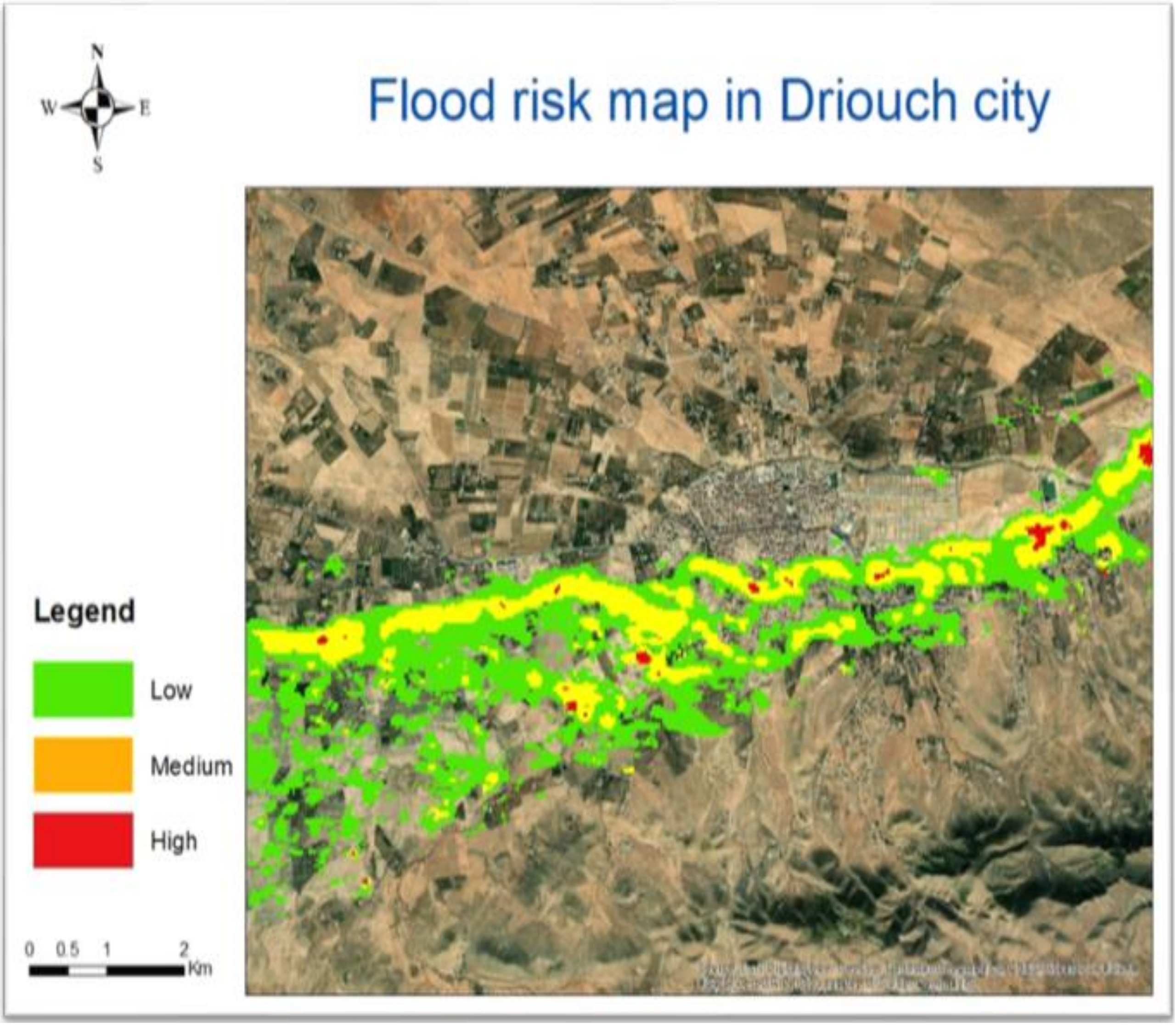

Fig 10 Kert Basin Flood Risk Map

To remedy this situation, improving flood forecasting and prevention remains an essential step. Better information for exposed populations and reducing the vulnerability of property located in flood-prone areas should be given priority. In addition, protection against flooding is a major focus. The aim is to generalize flood warning systems so as to meet the growing needs in terms of hydrometeorological forecasts and the prevention of risk situations, to make corrections to situations inherited from the past which have enabled the installation in high-risk areas and to integrate flood risk into development plans.

IV. CONCLUSION

The natural context of the region participates in the genesis of floods in upstream areas and floods in downstream areas. The geomorphology, which characterizes the region, is very favorable to the genesis of floods. These are raised areas with strong relief upstream and a flat area downstream sealed by urban invasion. This geomorphology offers all the ingredients for the genesis of floods, especially in a very contrasting climate characterized by torrential rains of significant intensity.

The hydrological study of the Kert watershed shows that this basin is characterized by a torrential hydraulic regime marked by remarkable concentration times. Such speeds of concentration of rainwater constitute a real risk to the citizens of the areas located in the watershed.

Anthropogenic factors constitute aggravating factors and have a fundamental role in the formation and increase in the flow rates of watercourses. Many agglomerations and infrastructures of the city of Driouch have developed near or on the minor and major bed of the Kert wadi, modifying its hydrological balance. Such a modification is marked by: the reduction of the natural fields of flood extension, the sealing of the soil and the reduction of the concentration time. This makes citizens face a real risk.

Flooding is a predictable risk in its intensity, but it is difficult to know when it will occur. The remedies provided by the Moulouya hydraulic basin agency in the study area are quite satisfactory in the short term, but prove to be inconsistent with the growing development of urbanization, hence the updating of the mapping of the areas. flooding is essential. In addition, the infrastructures put in place require continuous monitoring and maintenance.

In the present study, we developed a methodology allowing us to arrive at an objective knowledge of the risk of flooding. This will help to make relevant development choices to respect the diversity of issues present along a watercourse and promote land use planning that better takes into account the risk of flooding.

Finally, we concluded that the areas located on the banks of the Kert wadi are the most vulnerable areas to the hazards of flooding by torrential floods from the Kert watershed. This vulnerability to flooding is essentially linked to the topography and the incompetence of the sanitation network.

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