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Simulation and Localization of the Risk of Flooding. of the Ourika Valley for The Prevention of Disasters Related to these Floods

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ABSTRACT

The main objective of this article is essentially to identify areas vulnerable to flooding and to analyze exposure in the Ourika Valley, notably through three methods: 1. Methodological (diagnostics of the valley in question). 2. Operational (visualize the risks and identify avenues for prevention). 3. Incentives (replicate in other sectors in Morocco). The vulnerability of the Ourika valley was assessed in three most frequented regions through a hydrogeomorphic study, a human frequency survey and a building-scale risk index including the results of the field survey identify high-risk areas. Finally, an evacuation plan has been proposed to allow easy access to possible shelters in the event of flooding.

Keywords: Vulnerability, Evacuation Plan, Risk Index, Ourika Valley.

INTRODUCTION

Flooding is an increasingly recurring natural risk across the world and in various types of climate; recent decades have been marked by painful and fearsome flood events. To this end, the development of flood maps and risk prevention plans is of capital interest for decision-makers in terms of territorial planning and effective crisis management on the ground, the mapping of these flood zones must rely on reliable qualitative and quantitative data (*DEM map of good resolution, long period and large number of flood events, etc*).

In Morocco, the Ourika watershed has experienced floods infamous for their destructive and deadly effects, subject to a semi-arid to subhumid climate, and being under the influence of formidable summer storms, the valley often experiences brutal and violent pulsations of its main watercourse and its tributaries. The extreme hydrological events of August 17, 1995, October 28, 1999, and November 22, 2014, for example, drew attention due to their exceptional peak flows (respectively 1030, 762, and 343 m^3/s).

In this regard, the main objective of this article is to fill this gap to guide institutional actions in the face of said events, therefore the location of the flood hazard in the Ourika valley, aiming for better management of exposed and vulnerable areas.

The location of the issues in the Ourika valley, and analysis of their vulnerability and finally by proposing an evacuation plan based on the risk components, as well as the study of the probabilities of submersion of the provincial road connecting the town of aurr to the tourist valley of Ourika, The approach will consist of a simulation of extreme flows along the valley and the spatialization of the submergence according to the frequency of these flows.

Study Environment

The Geographical Position of the Watershed

The Ourika watershed is located in the High Atlas of Marrakech, between 31°N and 31°20N and 7°30W and 7°60W (Figure 1), Covering an area of **684** square kilometers, the altitudes range from **985** m at Aghbalou to **4003** m at the highest point of the upper basin, as well as The slopes are generally steep and the tributaries varied from 11% to 40% (Table 1), For this reason, the wadi moves quickly and is prone to flash floods, while shaping its course by eroding hard crystalline rocks upstream and more brittle sedimentary layers downstream. The exposure and orientation to the north and northwest allow the said watershed to be well watered by rainwater. This study will cover three main areas of the valley: Aghbalou, Oulmes, and Setti-Fadma (figure 02).

Historical Context

The Ourika River has a low flow rate. On average throughout the year (4.5 m³/s), with an increase in flow during the snowmelt in spring, the time for the water level to rise generally lasts between 4 and 10 hours, but faster enrichment times have been recorded. Nevertheless, there have been numerous major floods in the history of the river valley, such as the flood on October 28, 1999, whose peak flow reached 762 m³/s. But we will specifically mention the devastating flood that struck the Ourika Valley on August 17, 1995, The flood lasted only 4 hours with a very brief rise time of 15 minutes (Figure 03), during which the peak flow at the Aghbalou station reached 1030 m3/s, and the flash flood officially killed 200 people and left around 500 missing.

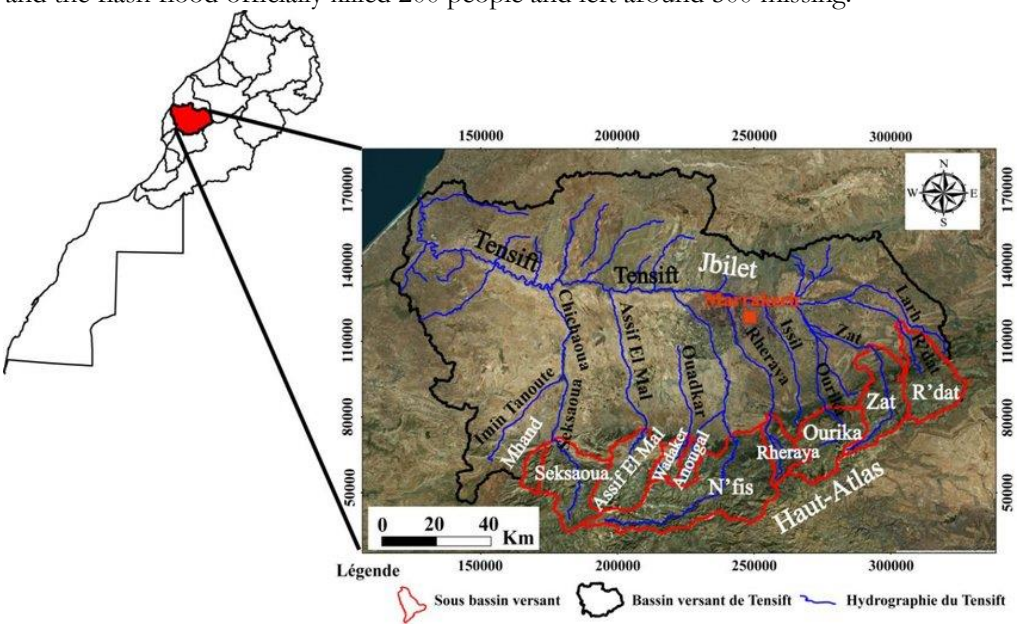


Figure 1: Geographic location of the Greater Tensift Watershed
https://www.researchgate.net/Bassin-versant-de-Tensift

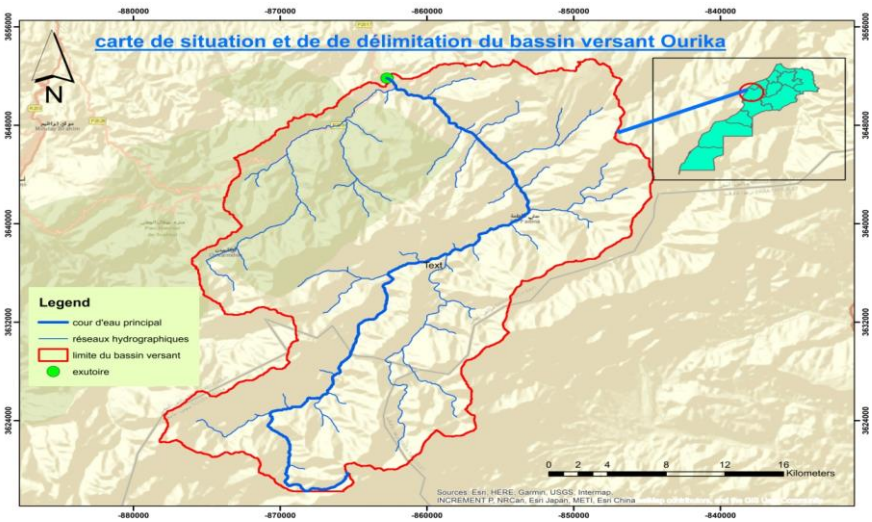


Figure 2: Delimitation of the Ourika Watershed. (S.saber)

Table 1: Characteristic of the Ourika watershed "Aghbalou" station

Perimeter (km)	181
Superficie (km2)	684
Capacity index	1,93
Length of main course (km)	59,5
Equivalent rectangle length (km)	39,2
Width of equivalent rectangle (km)	12,8
Maximum altitude (m)	4003
Minimum altitude (m)	985
Average altitude (m)	2500
Average slope of the main course	2,15%
Average slope of the main influencers	9,35%
Average slope of the mountain slopes	35%
Drainage density (Km per Km²)	1.18
concentration time Tc (min)	303.54

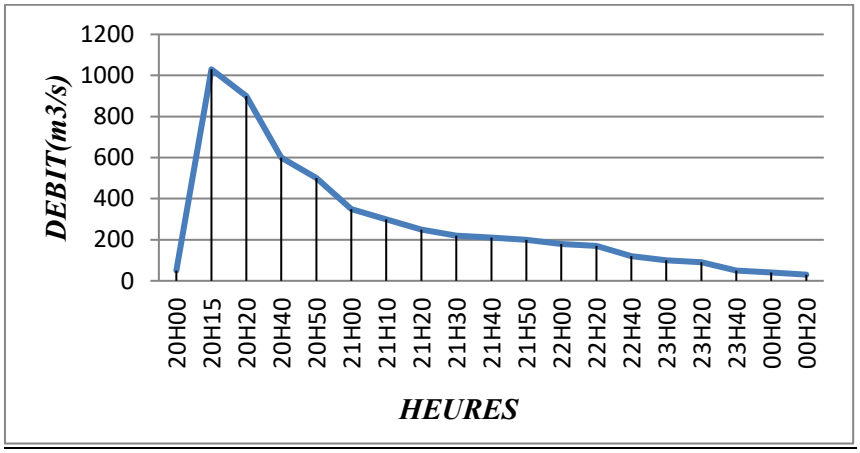


Figure 3 Hydrograph and characteristics of the Ourika flood which occurred on August 17, 1995 in Aghbalou

There are many ways to define, conceptualize or quantify vulnerability, which are based on authors, criteria and/or indicators of vulnerability (Barroca et al. 2005; Fattaletal. 2007; Kuhlicke et al., 2011; Rufat et al., 2015; Tapsell et al., 2002; Vinet et al., 2015), which allows the creation of vulnerability indices. Attempts have been made to assess global vulnerability to various hazards (United Nations Development Program, 2004; Dilley et al, 2004).

To model vulnerabilities, several methods have been developed by different researchers. For example, in the Mediterranean region, the floods of the last 15 years suggest the need to add hydro-geomorphic approaches to hydrological and hydraulic approaches (Ballais, 2015). This approach consists of determining the outer limits of the flood plains which constitute the periphery of these floods.

Field work allowed us to adopt this approach in the Ourika Valley. Additionally, in order to determine the impact of building damage on economic losses, it is necessary to determine the physical vulnerability of the construction area ; the type and height of the building, the distance and height of the bed, which will be diagnosed based on the dimensions of the bed. The quantification of these elements will result in a vulnerability index.

Data Used

The major objective of this work was to collect all the data relating to the study area, due to the lack of scientific data, in particular the lack of Geographic Information System (GIS) and statistical data in this area. , for this purpose It is therefore essential to organize field surveys to collect information, observations and carry out interviews with the local inhabitants of the valley or local authorities.

Location of the Flood Hazard by Hydro-Geomorphological Method

the conceptual basis of the hydro-geomorphic approach is simple (coque, 1993; Garry et al, 2002), the channel is characterized by the existence of three river beds: minor bed, middle bed and major bed, The minor bed of water are frequently occupied by water (bravard and petit, 1997; garry et al, 2002), with a few exceptions, as in the case

of the wadi (ballais, 1995; veyret, 1998; garry et al, 2002), as well as the flood zone for this study was determined by defining the limits of the main bed of the relief (Balais, 2006).

In addition, to reconstruct the river dynamics of the wadi, hydro-geomorphic analyzes were carried out by traveling through the study area and observing the topography, sediments, vegetation and land use.

Characterization of the Issues

Vulnerability of Buildings.

The "European Flood Risk Prevention Center" has proposed methodological guidelines for diagnosing vulnerability. Its approach is based on the definition of the capacity of a building to withstand particular physical constraints, the existence of shelters adapted, the accessibility of emergency buildings, the identification of risks linked to equipment and changes in the environment. This approach has the advantage of being easy to apply, but requires an in-depth analysis of the building site to obtain detailed information on a case-by-case basis (Leone et al, 2012). Furthermore, to construct a vulnerability index, different structural, human or territorial analysis methods exist.

Vulnerability (Vinet et al, 2015), Table II shows the standard hierarchies whose points are used to obtain the vulnerability index. The scores assigned to each criterion are then added, the numerical scale which prioritizes these factors gives a degree of vulnerability (low, medium, high and very high) and allows its spatialization, the classic equation is that the risk is the product of hazard and vulnerability. We then chose to use a laser range finder to integrate exposure criteria such as the height in relation to the minor bed and the height in relation to the natural terrain (Figure 3):

$$\text{Exposure} = (W\,\text{Min} * (H\,\text{Min} - S) + S * W\,\text{Maj.}) + D\,\text{Min.}$$

"W Min"= is the width of the minor bed.
"H Min"= is the height in relation to the minor bed.
S= area.
"W Maj"= is the width of the major bed.
"D Min"= is the distance to the minor bed.

Human Exposure and Frequent Occurrence.

Human exposure to flooding depends on how the population density of the area changes over time. Areas with a high population density are more vulnerable (Camarasa and Soriano, 2012), in this context the study of human issues and the use of different places is important. Therefore, it would be more interesting to focus our diagnosis on the most sensitive and common areas. This is done by calculating the number of places available in restaurants and hotels. For restaurant terraces, several counts at different times make it possible to construct attendance statistics. Additionally, we obtained quantitative information on the number of vehicles by counting vehicles visiting the area. By inference, we estimated the number of visitors as well as qualitative information on means of transportation.

Figure 4. Aerial view of the Aghbalou site (Ourika Valley) Fuente satelital de Google

Safety Zones and Evacuation Plan

Once the problem has been identified and located and the number of people at risk has been quantified, it is important to identify evacuation plans and shelters to reduce mortality in the event of a crisis. The first step is to find potential shelters, assess their mass and calculate their capacity. Several refuge area criteria are proposed, such as altitude, availability, capacity and connectivity. The method followed was adapted from Péroche et (al, 2014) for

tsunami evacuation planning. The graphic design of the evacuation map prototype follows the symbolization rules optimized by (Girres et al 2018). In mountainous environments, the refuge zone must be outside the risk zone. Evacuation is often more difficult in this situation due to the steep slopes. Therefore, possible shelters are limited and may sometimes only be a narrow road immediately adjacent to the exposed area.

These characteristics often make it difficult to quantify its capacity, in order to obtain For these refuge areas, access points must be identified and their quality assessed. To do this, we assign certain characteristics to each path, including type, area, roughness and width. All this information allows for better planning of the quickest evacuation routes, especially from the most dangerous target areas.

RESULTS

Hazard Mapping

The hydro-geomorphological formula when judging the maximum extension of the floods at the very moment, proved to be of little validity with regard to natural spaces, of which the Oued Ourika rises particularly the coarse deposits present on the place.

Characterization of the Issues

Exploitation of Space:

In the last decades, the natives of the Ourika valley (Berbers) openly separated any place from the wadi to maximize the space of cultivated fields, fruit trees were mainly planted on the lower side of the wadi, following which The field has changed slightly, as the fields are now taken over by houses and other buildings.

At the Aghbalou locality, the bottom of the valley still allows agricultural activities due to the width of its bottom (figures 5 and 6), while the areas which are marked by tourist activities are divided into three sub-parts, one at the entrance (northwest), one in the center and one upstream.

In the locality of Oulmes, we distinguish two types of landscapes, the entrance to the village of which is built on an alluvial fan. going upstream, the valley narrows and only the road and a few restaurants are at the bed of the wadi, while at the locality of Setti-Fadma, the valley opens up a little and leaves enough space for tourist use.

The Precariousness of Buildings in the Study Area

The Aghbalou college and the Setti-Fadma mosque are only thick and resistant buildings due to their location above the high-risk zone, unlike the other related houses in the said valley which are self-built in concrete, which gave rise to the observation that there is serious uncertainty as to the capacity of these houses to withstand a flood, even if a second floor is built.

Likewise, most houses which contain a second floor provide theoretical security for their occupants, nevertheless in the flood of 1995, we find among the damage buildings made of large stones and thick walls, for this purpose we can consider that the Vertical evacuation via tall buildings located inside the area is not an adequate solution.

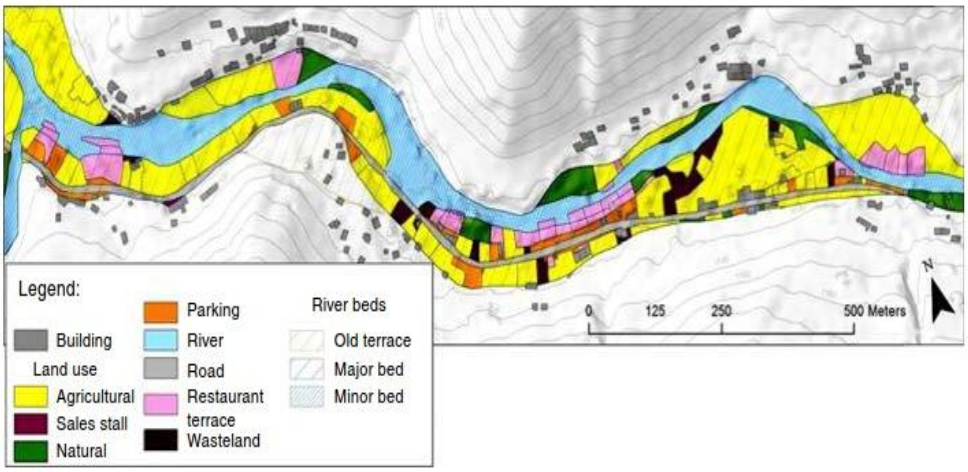


Figure 5. Land use in the Ourika Valley at Aghbalou
Source E.DRUON

The building risk index is a little high in the Aghbalou locality, because the width of the wadi bed at this location has more space to expand, whose floods cannot reach the same levels of water than upstream, therefore buildings with a high risk index are often restaurants built of wood and recycled materials, as evidenced by those destroyed on May 5, 2016 (plate 1), in Oulmes, concerning setti-fadma, all Exposed buildings are either restaurants or hotels have the highest risk indices.

The Location of Human Contact with the Valley:

The research undertaken on 31 March 2021, within the framework and against the background of interviews, with the local inhabitants of the valley in question concerning the human connection of tourist areas made it possible to note that outside the tourist season, the functioning Restaurants and other public places are only for weekends, while weekdays are often quiet.

Generally, at this time of the year, the occupancy of restaurants is less than 30% occupancy in total, in addition to the analysis of vehicle traffic, the terrace counts, also made it possible to deal with the crowds in the valley, but this calculation was made following a rainy week which had brought a lot of snow upstream; to the extent that the proximity of the valley was strongly impacted.

Concerning the locality of Setti-Fadma, the attendance is not exactly the same as that of Aghbalou even if the occupancy of the terraces was still less than 30% in total. Including cars. the total traffic peak (entrances and exits combined) took place between 3 p.m. and 4 p.m. from this graph (figure 06), however we can consider the situation of the valley being completely congested in summer.

Plate 1. Location of restaurants swept away by the flood of May 5, 2016, in Oulmes Fuente ABHT

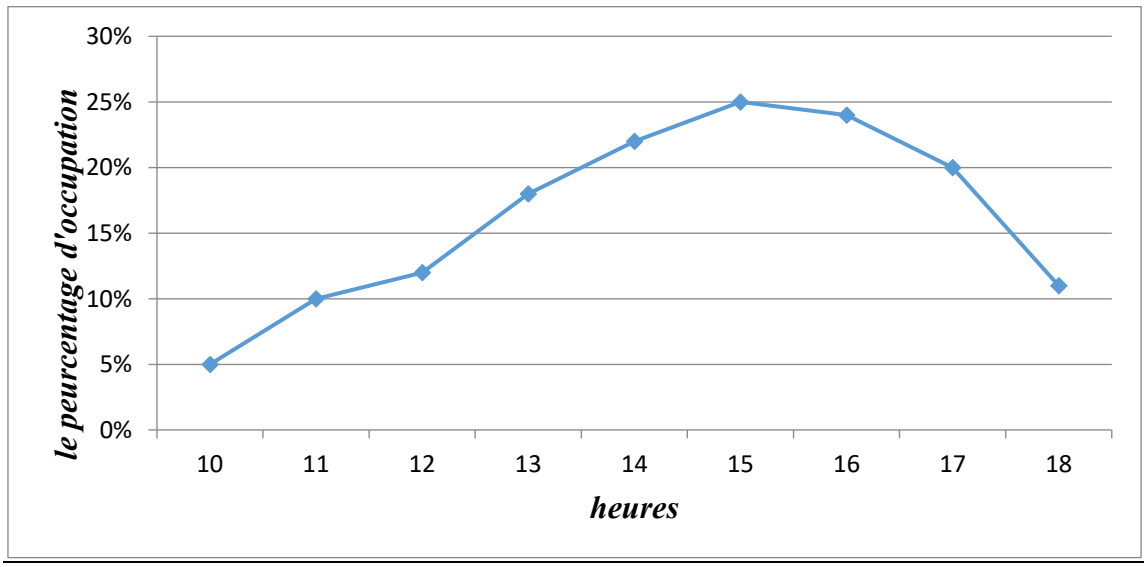
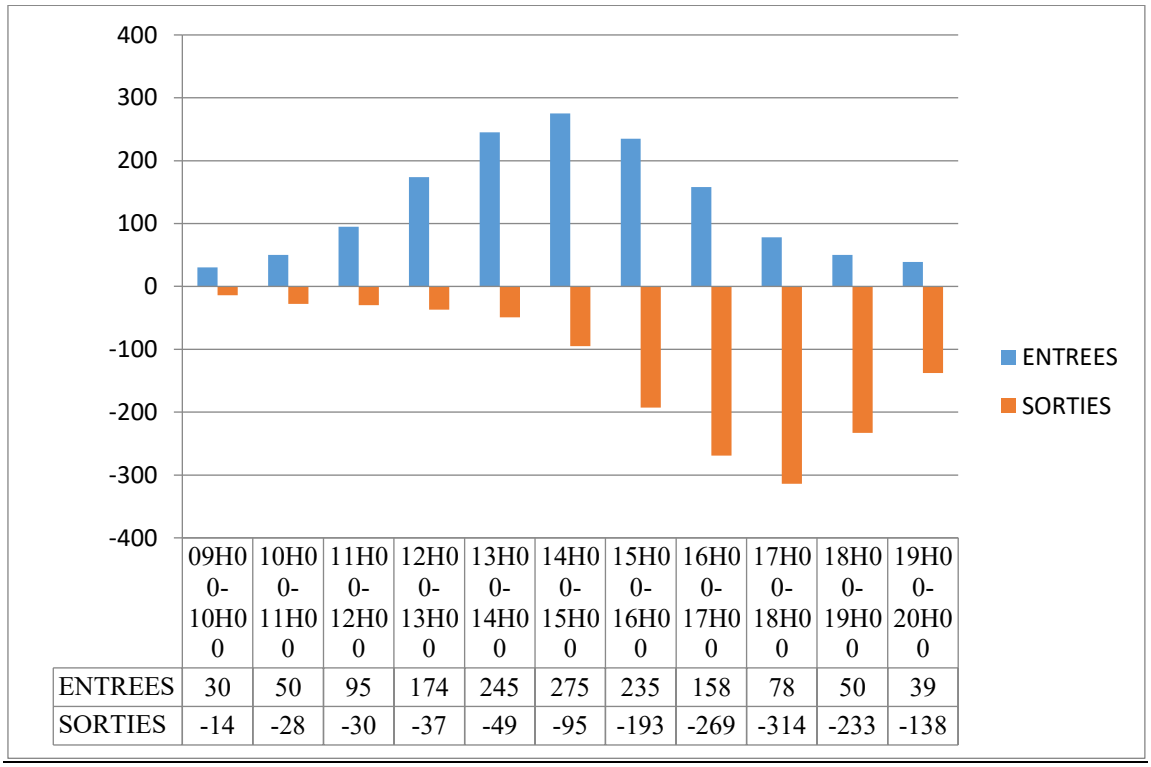


Figure 6. Occupancy of restaurant terraces in Aghbalou on 31 March 2021

The village of Oulmes is characterized by a concentration of restaurants and apartments for rental purposes, marked by a great vulnerability of these buildings, while Setti-Fadma is marked by the most populated area (Figure 7), or L The place is almost entirely dedicated to tourist purposes, as most of the victims of the 1995 flood were there.

Shelters and the Evacuation Plan in the Valley

The necessary specificities of shelters or refuge areas are determined according to their effectiveness and the power to accommodate very high numbers of people (local inhabitants and visitors), in the event of a flood, we can consider educational establishments including boarding schools can shelter people threatened by flooding given their characteristics, in particular their capacity and necessary logistics (beds, sheets, tables, kitchen, etc.) in the event of a large influx, in the same way as there are places of worship which also offer a place of refuge, thanks to their systematic construction at height and its services which facilitate accommodation.



	09H00-10H00	10H00-11H00	11H00-12H00	12H00-13H00	13H00-14H00	14H00-15H00	15H00-16H00	16H00-17H00	17H00-18H00	18H00-19H00	19H00-20H00
ENTREES	30	50	95	174	245	275	235	158	78	50	39
SORTIES	-14	-28	-30	-37	-49	-95	-193	-269	-314	-233	-138

Figure 07: Vehicle traffic in the Ourika Valley on Sunday, April 19, 2020

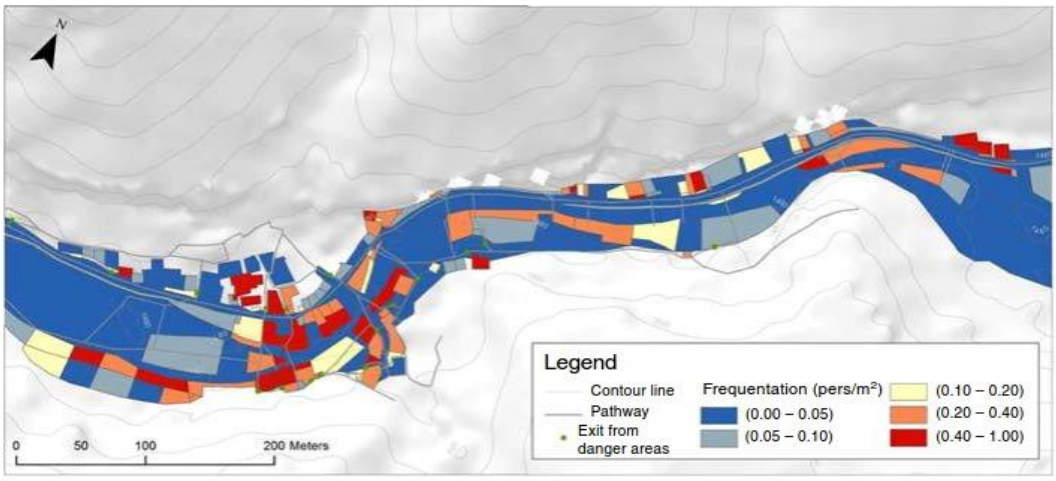


Figure 8: Human use of outdoor spaces and buildings during the day in the Setti-Fadma region

On the ground, the valley contains a significant number of refuge areas which are characterized by its poor quality and difficulty of access, plus its poor location on the wadi bank which creates a problem for evacuating people in the event of a threat. flooding, similarly we also find the problem of small bridges which are part of the normal traffic network of the valley for local residents who often have to cross the wadi, however, most visitors are not used to walking on these narrow passages and can take several minutes to cross them, while adding that some of these bridges are already dangerous.

For this purpose the use of these bridges must be restricted as much as possible in the event of a flood, given that some are temporary and others are designed to resist flooding, emphasizing in this context that there are 04 types of these bridges: one built in wood very exposed and very vulnerable to flooding, suspension bridges which are raised well above the river bed compared to the first category; metal frame bridges, more stable and fixed to the concrete at the foundation which will not be damaged, finally we can emphasize the existence of real bridges which allow the road to pass above the wadi and also to constitute an obstacle to flows.

Plate 2. Diagnosis of the risk of the flood of May 2016

Responding to the explanation of the speed of the 1995 flood, local residents gave their point of view that the accumulation of trees and solid waste on a metal bridge belonging to the locality of Setti Fadma is broken by the very high flow. wadi, while noting that this temporary clutter of debris had perhaps created a deadly wave.

In the village of Aghbalou, we can indicate that mage the presence of bridges with a very tense risk, we find other suitable solutions including flat places which could temporarily accommodate the population in the event of evacuation, like A garden and small plot of land which were chosen as shelters on the road despite offering a very limited capacity and being difficult to access.

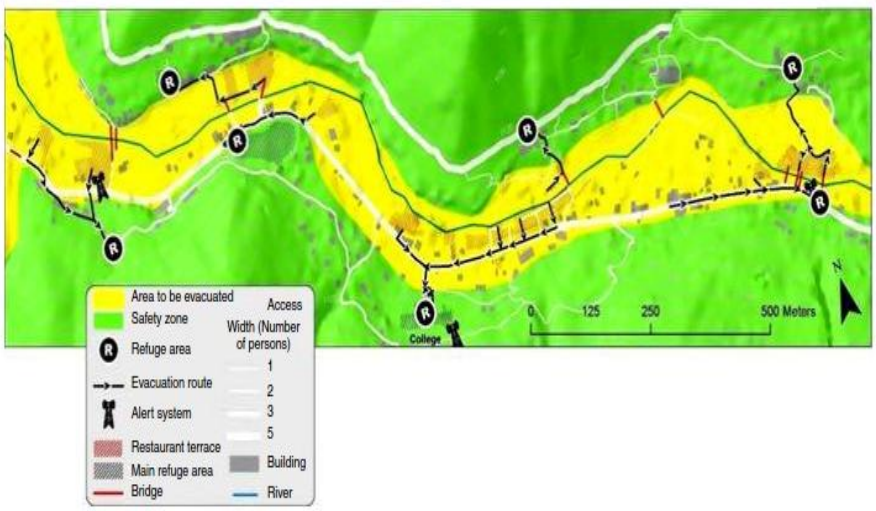


Figure 9. Prototype evacuation plan in Aghbalou

The evaluation of shelter sites at the level of oulmes whose possibilities are really limited in the heart of this village, like a staircase leading to a refuge area where the number of people who can accommodate is too small, there is also a vacant lot located 60 meters above the level of the wadi whose path to access it is uneven, so this terrain makes it impossible to evacuate people threatened by flooding with reduced mobility.

In Setti-Fadma, a building containing "the village mosque" could be a secure shelter, while the shelter sites are unsuitable to the extent that the paths leading there are too narrow to allow a large number of people to cross them in a short time, in the face of this situation and in order to establish rapid and safe evacuation of flood-prone areas, in the face of a major issue and challenge to ensure a minimum loss of life during the next serious flood.

Debate

Among one of the characteristics influencing the Ourika Valley is the overload of tourist fields at the level of the river bed (plate 03), the evaluation of the problems of the said bed is linked to the development of tourism at the said valley, whose tourists arrive at the wadi coast to revive themselves, so it is natural that the cafes and restaurants spread out with more tables closer to the bed.

Likewise, an evolution of the villages relating to the valley has appeared, where they have undergone significant changes in particular the increase in the capacity of the boarding school of the Aghbalou village which considers it to be the most suitable shelter, however, the problems largely remain in the entire territory of the valley with a high probability of continuing to develop in the future, in case the terraces of restaurants or public places are not rebuilt exactly after a flood which causes the diversion of the river, where they are located right next to the bed, so it is imperative to focus on the attendance at the level of the area, given that the hours of contact points this correspond to the number of vehicles and visitors of this leisure place, the data of which could be used in the simulation of evacuation plans in the event of a flood.

Plate 3. Human encroachment on the river bed at Setti-Fadma

According to the declarations of the local population, the Ourika Valley experienced permanent traffic jams during the days of the summer season, the roadsides of which are used for parking cars, which causes the risk of human loss to multiply. in the event of a flood, although the local inhabitants are well aware of the degree of risk, as well as the major concerns, it is necessary to involve the said inhabitants, including the owners of the restaurants, in the management of the valley, as well as visitors in coordination with tourism agencies, on the possible risks of flooding, the weather developments in the valley and this, to minimize damage in the event of a flood.

They also shared that the floods are part of their daily life, of which it is very common to mark in the river the presence of tables and chairs, while specifying that in recent years the inhabitants have stopped their activities near of the watercourse, and took refuge at the moment when they noticed the signs of threat from the clouds, unlike nowadays where the situation is more dangerous, since all visitors rely on the alert system.

As for emergency exits and shelters, the Ourika Valley is cruelly lacking in these types of shelters, most of which accesses using to exit the flood zone are inaccessible for people (residents and visitors) who will find it difficult to move, so it is essential to create passable paths and small refuge sites at the exit from dangerous areas, likewise evacuation routes must be indicated by explicit signs in collaboration with the authorities local authorities and representatives of the population, in order to develop an appropriate and sustainable evacuation plan.

CONCLUSION

Based on the low-cost method, the location and distinction of the risk of flooding in the valley, offers a rational framework in order to reduce the risks and damages of this natural disaster on the valley in question.

The locality of Setti-Fadma was the most vulnerable area in the valley, to the extent that the signs of risk are higher, because of its very narrow watercourse as well as its infrastructures and buildings are put in danger, particularly those addressed to tourist activities, however the Aghbalou area is characterized by its wide bed of the wadi and its low flow, the risk of which is limited, which pushes the restaurant owners to spread out their tables near this wadi, so that in the locality of ulemas where the degree of danger changes depending on the side of the road connecting the valley to the city of Marrakech, all of whose buildings had a higher risk index in the same way that the road is often threatened throughout the territory, noted the insufficiency of the refugee sites, which are of poor quality and their access is very difficult, to the extent that most of the bridges are built by hand and do not support the high flow rates, and in order to put in place an effective evacuation plan and in the event of the collapse of these passages due to heavy flooding occurring in the valley, the impossibility of crossing the river, it is necessary for this purpose to establish passages which can provide access to shelter areas, like the great mosque of Setti-Fadma and the university building in Aghbalou, for this purpose, and in the event of a flood the population will generally not be in danger. safety, even if the presence of the warning prevention system due to the existence of steep slopes, therefore it is imperative to build new shelter sites, evacuation accesses as well as solid bridges in order to to make better communication.Based on the low-cost method, the location and distinction of the risk of flooding in the valley, offers a rational framework in order to reduce the risks and damages of this natural disaster on the valley in question.

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monitors meteorology and identifies risk areas and proposes preventive measures, through coordination with the various ministerial departments and territorial officials, to ensure the mobilization of material resources and logistics as well as maintaining a high level of affected populations while adding, the national monitoring and coordination committee that the Ourika valley is one of the most vulnerable areas, particularly on the banks of the river due to tourist activities, this research is not based only on diagnostics or investigations in the area, but also by determining the vulnerability of buildings, which also has the alert prevention system (sap), by broadcasting alert sirens in the event of immediate flooding, in this regard this article reinforces this structure through a global diagnosis by putting as a solution an evacuation plan, based on the decrease in exposure and vulnerabilities, and the increase in resistance capacities.

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