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A spatial and integrated flood risk diagnosis

Relevance for disaster prevention at Ourika valley (High Atlas-Morocco)

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Abstract

Purpose – The purpose of this paper is to identify vulnerable areas for flood hazard and to analyze stakes exposed in touristic valley of Morrocan mountains. The three goals are: methodological (low-cost diagnosis without starting data), operational (to show the risk and identify avenues of prevention in Ourika) and incentive (to reproduce this on other sectors in Morocco).

Design/methodology/approach – The vulnerability of three areas of the Ourika valley (the most frequented) was assessed by a hydro-geomorphological study, human frequentation surveys and risk indices at the building scale.

Findings – Surveys carried out in the field allowed the identification of areas with high risk, the evaluation of the buildings' vulnerability and the frequentation of the valley. Evacuation plans, allowing easy access to potential refuges in case of flood, were finally proposed.

Originality/value – The reproducible, inexpensive and relevant nature of the approach (integrated and spatialized) helps in decision making and facilitating dialogue for prevention.

Keywords Vulnerability, Evacuation plan, Ourika valley, Risk indice

Paper type Research paper

1. Introduction

In recent years, there has been an increase in the impact of natural disasters. This results from a combination of extreme natural events and exposure of vulnerable populations (Ruin *et al.*, 2008; Fekete, 2009; Vinet *et al.*, 2011; Rufat *et al.*, 2015; Mavhura *et al.*, 2017). Extreme floods have always been one of the most important natural hazards with a great deal of material damage (Gaume *et al.*, 2004, 2009; Tramblay *et al.*, 2014). Every year floods cause large amounts of damage around the world. During the last

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decade of the twentieth century, floods killed an estimated 100,000 people and affected more than 1.4bn people. These statistics come from the Centre for Research on the Epidemiology of Disasters in Brussels in cooperation with US Office for Foreign Disaster Assistance (Jonkman, 2005). In fact, the economic damage caused by floods and the number of people affected are very significant, in particular, in African countries (Di Baldassarre *et al.*, 2010; Merz *et al.*, 2010; Chung and Adeyeye, 2018). In Mediterranean countries, floods have been witnessed since ancient times, but they are becoming a scourge, more and more dreaded (Provitolo, 2007; Vincendon *et al.*, 2010; Llasat *et al.*, 2013). Morocco has, for example, witnessed terrible floods with destructive and deadly effects. The country is often struck with brutal and violent floods (Rifai *et al.*, 2014; Karmaoui *et al.*, 2016; Bennani *et al.*, 2016; Vinet *et al.*, 2016). But studies of these floods often focus only on their physical part. Modeling their dynamics and predicting their frequencies has often been the ambition of researchers who have neglected the geographical component of the floods. As a result, territorial diagnosis is rarely addressed, and the vulnerability of buildings and economic activities to floods, especially in rural areas, is poorly documented. Vulnerability is not only based on a conceptual model but it is also evaluated on a field-based diagnosis. The evaluative approach, which initially made a reference to a level of damage (Leone *et al.*, 1996), is now being developed into a systemic approach (Becerra, 2012).

The main objective of this work is to fill this gap to guide institutional actions to deal with flood events. Thus, spatializing the flood hazard in the Ourika valley, aimed at a better management of the exposed and vulnerable areas, will be accomplished by locating the stakes, analyzing their vulnerability and finally proposing an evacuation plan according to the risk components, as defined by Defossez *et al.* 2017 (Figure 1).

Although the recurrence and kinematic of floods direct the focus on mathematical approaches and intrinsic properties of these floods, these approaches sometimes lack a more descriptive view of the field and its human and material occupants. The hydro-geomorphological approach undertaken in this paper responds precisely to this concern. Coupled with analyses of the occupation in the territories bordering the Wadi and their human attendance, this approach will complement the purely physical work (Boumenni *et al.*, 2017; El Alaoui EL Fels *et al.*, 2018; El Khalki *et al.*, 2018) on tourist valley of Morocco.

On August 17, 1995, the valley was hit by a flood that occurred in a brutal and unexpected manner. In a short time, this flood had reached a peak flow of 1,030 m^3/s and caused significant human losses and enormous material damage (Saidi *et al.*, 2003). Since this disaster, some structural and nonstructural measures have been implemented, such as the setting up of warning system and protection walls upstream of the basin. But the best strategy to reduce flood risk is to reduce human exposure in flood-prone areas (Hooijer *et al.*, 2004; Roy *et al.*, 2003; Kreibich *et al.*, 2005).

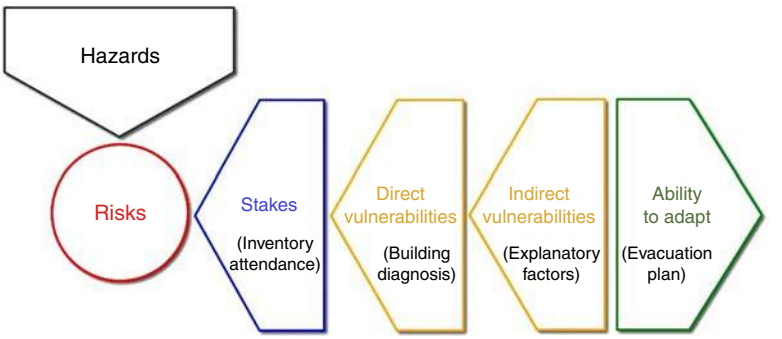

Figure 1.
Components of the risk diagnosis

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2. Study area

2.1 Geographic location

The Ourika watershed is in the High Atlas of Marrakech, located between 31° and 31° 20 North and between 7° 30 and 7° 60 West (Figure 2). With an area of 503 Km^2, the altitudes vary from 1,070 m in Aghbalou to 3,996 m at the highest point upstream of the basin. The slopes are generally steep. The slopes of the main tributaries are between 11 and 40 percent (Table I). Because of those slopes, the Wadi is torrential and prone to flash floods. The Wadi has shaped its course by incising hard crystalline rocks upstream and more friable sedimentary formations downstream, sculpting deep valleys. The exposure and the orientation toward the north and north-west allow the Ourika watershed to be fairly well watered by rainwater (Saidi *et al.*, 2010). The three main zones in the valley will be treated by this study: Aghbalou, Oulmes and Setti-Fadma (Figure 2).

2.2 Historical background

On average, the Wadi has a low flow rate throughout the year (5 m^3/s) with an increase in spring during snowmelt. The rising time of the water levels usually lasts for 4–10 h, but much faster concentration times have already been recorded (Saidi *et al.*, 2012). The history of the valley has been marked several times by strong floods such as that of November 2, 1987, whose peak flow reached 650 m^3/s and the flood of October 28, 1999 with a peak flow of 762 m^3/s. But we will particularly cite the devastating flood that hit the Ourika valley on August 17, 1995. It is one of the most deadly and devastating floods in the modern history of Morocco. The flood only lasted for 3 h and the rising time was particularly short (between 15 and 30 min). The peak flow reached 1,030 m^3/s at Aghbalou (Figure 3). This flash flood had officially caused 200 deaths and about 500 people were missing.

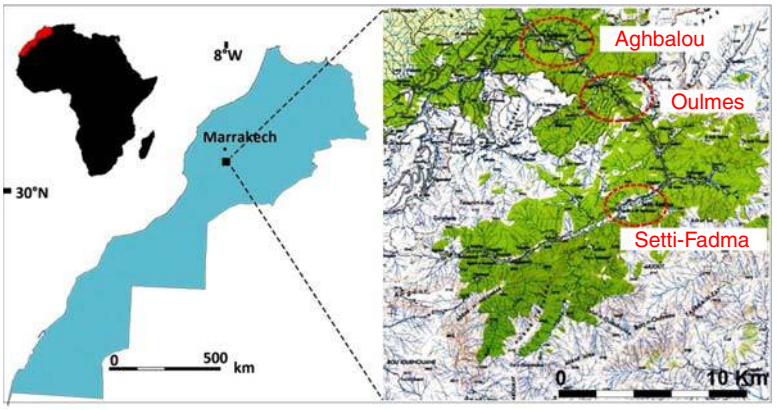

Figure 2. Geographical location of the study area

Surface	503 Km^2
Gravelius compactness index	1.3
Minimum altitude	1,070 m
Maximum altitude	3,996 m
Average slope	35%
Average annual rainfall	546 mm
Maximum rainfall months	March, April, May
Flood occurrence	Spring 45% Fall 25% Summer 24%

Table I. Characteristics of the Ourika watershed at Aghbalou

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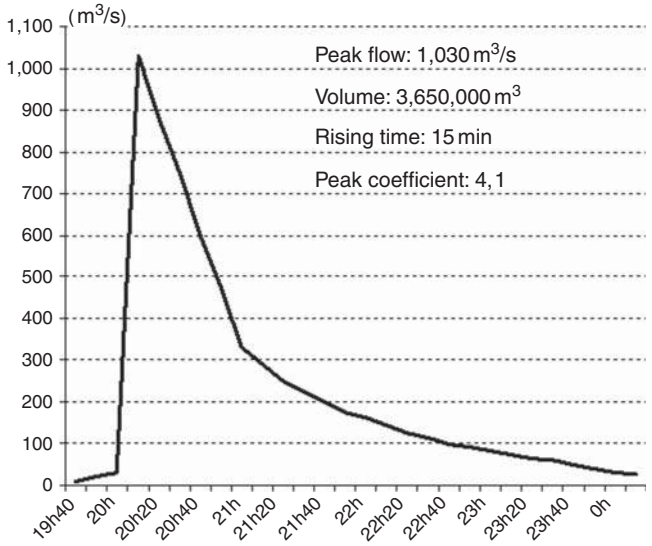

Figure 3.
Hydrograph and characteristics of the Ourika flood of August 17, 1995 in Aghbalou

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3. Methodology

There are many ways to define conceptualize or quantify vulnerability. Assessment is based on descriptors, criteria and/or indicators of vulnerability (Barroca *et al.*, 2005; Fattal *et al.*, 2007; Kuhlicke *et al.*, 2011; Rufat *et al.*, 2015; Tapsell *et al.*, 2002; Vinet *et al.*, 2015), enabling vulnerability indexes to be created.

Trials of world assessment of vulnerability to various hazards have been attempted (United Nations Development Programme, 2004; Dilley *et al.*, 2004). To model vulnerability, several methods have been developed by different researchers. In Mediterranean regions, for example, the recent floods over the past 15 years have shown the need to add the hydro-geomorphological method to hydrological and hydraulic ones (Ballais, 2015). This hydro-geomorphological method consists of determining the outer limits of the floodplain that constitute the outer envelope of these floods. The fieldwork allowed us to undertake this methodology in the Ourika valley. Moreover, given the effect of building damage on economic losses, it is necessary to determine the physical vulnerability of built areas. For Ourika valley, in addition to building types and their heights, a diagnosis of their distance and elevation from the river beds will be made, considering the dimensions of these beds. Quantifying these elements will lead to a vulnerability index.

3.1 Data used

The challenge of this study was to collect all the data related to the study area as there is a lack of scientific knowledge and, in particular, the absence of Geographical Information System (GIS) and statistical data in this area. Therefore, field surveys were necessary to extract information from our own observations and interviews with local population or authorities. We then compiled them in a GIS as accurately as possible, using Google Earth images (Figure 4).

3.2 Flood hazard spatialization by hydro-geomorphological method

The conceptual bases of the hydro-geomorphological method are simple (Coque, 1993; Garry *et al.*, 2002). Streams can be characterized by the existence of three river beds: minor bed, middle bed and major bed. Minor bed is constantly occupied by water (Bravard and Petit, 1997; Garry *et al.*, 2002), with some exceptions, as in the case of Wadi (Ballais, 1995;

Veyret, 1998; Garry *et al.*, 2002). Determining the flood-prone area for this study was therefore done by determining the boundaries of major geomorphological bed (Ballais, 2006). Furthermore, to reconstruct the river fluvial dynamics, the hydro-geomorphological analysis was carried out by crossing the study areas by foot and observing the topography, sedimentary deposits, vegetation, and land use.

3.3 Characterization of stakes

3.3.1 Vulnerability of buildings. The European Prevention Center of Flood Risks proposed a methodological guide to diagnose vulnerability. Its methodology is based on the definition of the building's ability to withstand exceptional physical stresses, presence of appropriate areas for refuge, relief buildings accessibility and identification of risks associated with equipment as well as those related to environmental change. This methodology, which has the advantage of being easily applicable, nevertheless requires an in-depth field analysis of the buildings in order to obtain detailed information on a case by case basis (Leone *et al.*, 2012). Furthermore, to establish a vulnerability index, different methods exist for structural, human or territorial vulnerabilities (Vinet *et al.*, 2015). The example in Table II shows a hierarchy of criteria and their points used to obtain a vulnerability index. The points assigned to each criterion are then added together. A numerical scale of prioritization of these factors provides a level of vulnerability (low, medium, high and very high) and makes its spatialization possible. The classic equation is that risk is the product of hazard and vulnerability. We then choose to incorporate exposure criteria such as height relative to the minor bed, and the elevation compared to natural terrain using a laser range finder (Figure 5):

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

where "W Min" represents the width of the minor bed; "H Min" the height relative to minor bed; S the superelevation, "W Maj" the width of major bed; and, finally, "D Min" represents the distance to the minor bed.

3.3.2 Human exposure and frequentation. Human exposure to floods is determined by population density of the area over time. Areas with a higher population density are more exposed (Camarasa and Soriano, 2012). It is in this context that the study of human issues and therefore the frequentation at different locations are important. Thus, it was more interesting to concentrate our diagnosis on the most sensitive and frequented areas. It was done by counting the amount of places available in restaurants and hotels. For restaurant terraces, several counts at different periods made it possible to establish statistics on attendance. Moreover, we obtained quantitative information on the number of vehicles by counting vehicles that visited the area. By extrapolation, we estimated the amount of visitors as well as qualitative information on the means of transportation.

Source: Google satellite

Figure 4. Aerial view of the Ourika Valley (Aghbalou)

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Code	Criteria	Responses	Index
Num – slab	In which slab is the building located?	Number	
Isolation	Is the building isolated?	Yes	2
		No	0
Ground floor opening	Does the building have a large opening on the ground floor	Yes	1
		No	0
Nbr of floor	The number of floors of the building	0	2
		1	1
		2+	0
Materials	What materials are the buildings made of?	Stone	0
		Concrete; bricks	1
		Sheet metal	2
Closing wall	Is the building surrounded by an impermeable, strong and over a meter wall?	Yes	−1
		No	0
Wire rack	There are wire racks at the windows?	Yes	1
		No	0
Area 100	Is the building area greater than 100 m^2?	Yes	−1
		No	0
Vulnerability index	Vulnerability = isolation + ground floor opening + nb of floor+ materials + closing wall + wire rack + area 100	Number	
H_F_Wc	Height of floor relative to the Watercourse	Number	
surelevation	Height of the building compared to major bed	Number	
*W*Maj	Width of major bed at the building level	Number	
*W*Min	Width of minor bed at the building level	Number	
*D*Min	Distance between building and minor bed	Number	
Exposure index	exposition = (Wmin × (H_F_Wc – surelevation)) + (Wmaj × surelevation) +Dmin	Number	
Exposure classes	(000–100)	Very high	2
	(100–200)	High	1.50
	(200–400)	Medium	1
	(400–600)	Low	0.75
	(600+)	Very low	0.50
Risk index	Risk = vulnerability × exposure	Number	

Table II. Criteria vulnerabilities of buildings facing the torrential floods

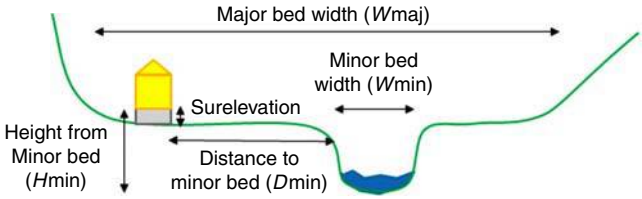

Figure 5. Schematic representation of the exposure index

3.4 Safe areas and evacuation plan

Once stakes are identified and localized and the number of people at risk quantified, it is important to define evacuation plans as well as safe havens to reduce death rates in crisis events. The first step is to locate potential safe havens, assess their quality and calculate their capacity. Several criteria for refuge zones are proposed, such as altitude, availability, capacity and connectivity. The followed methodology was adapted from Péroche *et al.* (2014) for tsunami evacuation plan. The graphical design of the evacuation map prototypes follows symbolization rules optimized by Girres *et al.* (2018).

In a mountainous context, areas of refuge must be outside the hazard zone. Evacuation is generally more difficult in this context because of the steep slopes. Thus, the possible refuges are limited and can sometimes just be a narrow road located right off the exposed areas.

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These characteristics generally make it difficult to quantify their capacity. In order to reach these refuge areas, it is essential to identify the accesses as well as to assess their quality. To achieve this, we attributed certain characteristics to each path including type, surface, roughness and the width. All this information allows to better consider the fastest evacuation routes, especially from target areas with the greatest risk.

4. Results

4.1 Hazard mapping

The hydro-geomorphological method to determine maximal flood extension has proved very effective for natural areas. Due to steep slopes, the Ourika river has deeply dug the landscape over time and is finally tucked into the bottom of the valley. The bed of the Ourika Wadi is mainly distinguished by the coarse deposits regularly present in the Wadi. The middle bed differs from the minor bed by observation of the microtopography. Nevertheless, after observing a small flood, it appeared that the identified middle beds were ephemeral. In urbanized parts, the inhabitants had built terraces, which made it difficult to distinguish these river beds.

4.2 Characterization of stakes

4.2.1 Land use. In the past, Berbers (local inhabitants) clearly separated each area of the valley to optimize space. Crop fields were on the valley floor. Fruit trees were mainly planted on the bottom of hillslopes. Finally, where nothing could grow, the Berbers built their villages. Currently, the pattern has changed slightly: fields are now invaded by homes and other buildings.

At Aghbalou, the width of the valley floor still allows agriculture to expand (Figures 6 and 7). Touristic areas are divided into three sub-parts, one at the entrance (North-west), one at the center and one upstream. In Oulmes, we distinguish two kinds of landscapes. First, the entrance of the village is built on an alluvial cone. Going upstream, the valley narrows and only the road and some restaurants are found at the Wadi's bed. In Setti-Fadma, the valley opens a little and leaves enough space for touristic use.

4.2.2 Exposure and vulnerability of buildings. Overall, no massive and very strong buildings can be found in this area. The only two massive and resistant buildings in the valley are the Aghbalou College and the Setti-Fadma Mosque, which are both above the high-risk zone. Most houses are self-built out of concrete. There is a serious uncertainty on the ability of these buildings to withstand a flood, even in the case of the presence of a second floor. Indeed, many buildings have a second floor and therefore they offer theoretical security to their inhabitants. Nevertheless, knowing villas that were taken away in 1995 were made of large stones and had thick walls, we can consider that taking refuge in high buildings within the risk zone (i.e., vertical evacuation) is not a solution.

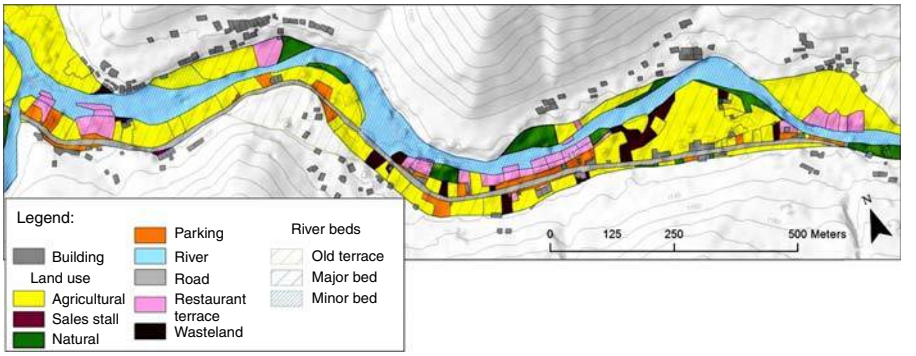

Figure 6. Land cover typology of the Ourika Valley at Aghbalou

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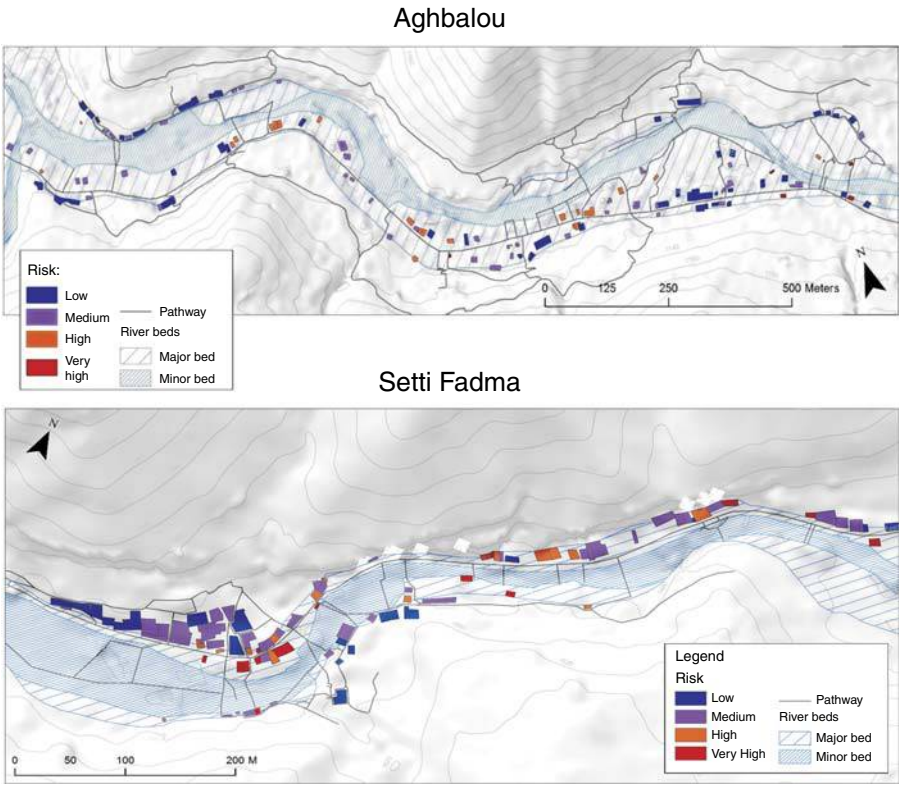

Figure 7.
Risk index for buildings at Aghbalou and Setti-Fadma areas

In Aghbalou (Figure 7), not many buildings have a high-risk index. This is partly due to Ourika's bed width at this location. Having more space to spread, floods cannot reach the same water levels as upstream. Buildings with a high-risk index are often restaurants made of wood and recycled materials as exemplified by those destroyed on May 5, 2016 (Plate 1). In Oulmes, in contrast to the right side of the road to Marrakesh, buildings on the left one have a low or medium-risk index. In Setti-Fadma, all the exposed buildings are either restaurants or hotels. Setti-Fadma buildings are those with the highest risk indices.

4.2.3 Attendance and spatialization of human frequentation. The interviews with residents revealed several essential information regarding frequentation of touristic areas. As noted above, outside the touristic season, week days are often quiet and restaurants do not really work until the weekend. Overall, at this period of the year, restaurants are not very busy (less than 30 percent occupancy in total) (Figure 8). In addition to terrace countings, analyzing vehicles circulation also helped to visualize affluence in the valley, but this counting followed a rainy week that had brought a lot of snow upstream; therefore, attendance in the valley was strongly impacted. Frequentation dynamics in Setti-Fadma are not exactly the same as in Aghbalou even though terraces' occupation was still below 30 percent in total.

Concerning cars. The peak of total traffic (entrances and exits combined) took place between 3 p.m. and 4 p.m. From this graph (Figure 9) and interviews with residents, we can consider the situation of the valley completely bottled in summer.

At the entrance of the valley, some restaurants at the center of Aghbalou attract visitors, but the rest of this area remains uncrowded. The difference between night and day is also noticeable.

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

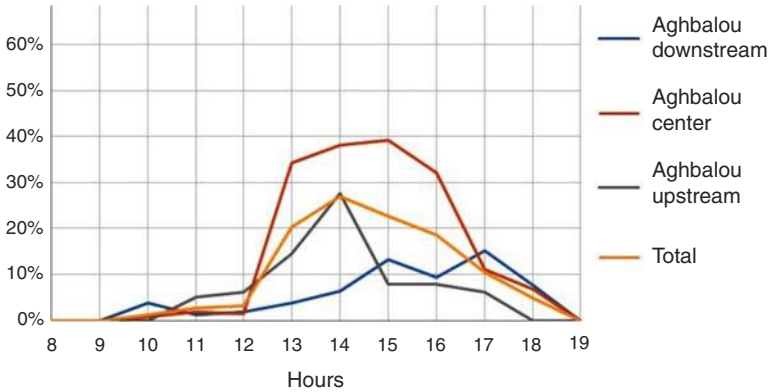

Figure 8. Occupation of the restaurant terraces in Aghbalou on Saturday, March 19, 2016

The village of Oulmes is characterized by a concentration of restaurants and apartments for rent, leading to high vulnerability. Setti-Fadma stands out as the area housing the most people (Figure 10). This place is almost entirely dedicated to touristic purposes. In 1995, most victims were located there.

4.3 Refuge zones and evacuation plan

Except rare exceptions, the refuge areas are still "default refuge places." They are either an academic institution, the roof of a building or a flat land above a hill. Except a large college, the rudimentary features of these refuge areas would limit their capacity and effectiveness. They require more appropriate developments to the high number of the valley visitors. However, the college (which partly serves as a boarding school for local students) is much larger, solid and built in height, sheltered from the water. It is composed of several floors and has the necessary logistics in case of massive affluence (beds, sheets, tables, kitchens, etc.). In addition, the mosques can also offer a place of refuge, thanks to their systematic construction in elevated areas and the amenities can be found there (furniture, sanitary facilities, drinking water, etc.).

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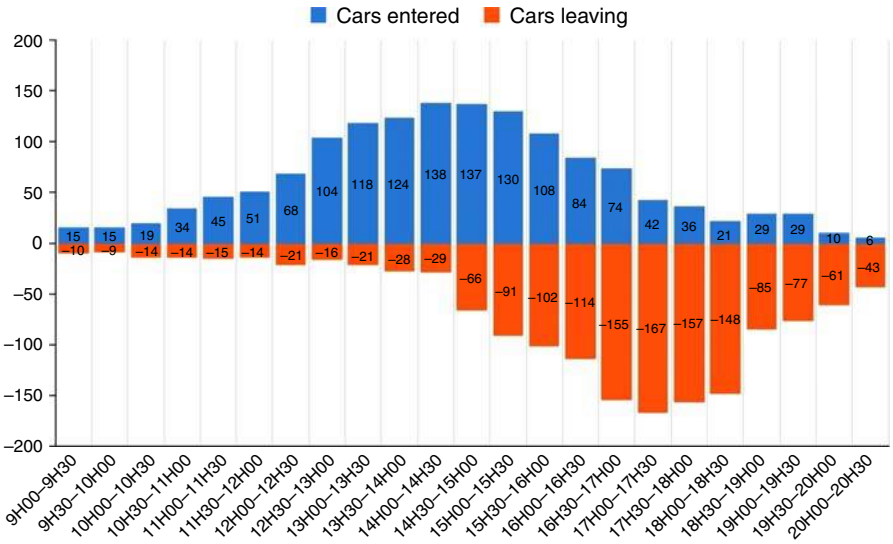

Figure 9.
Traffic of cars in the Ourika on Sunday, May 1, 2016

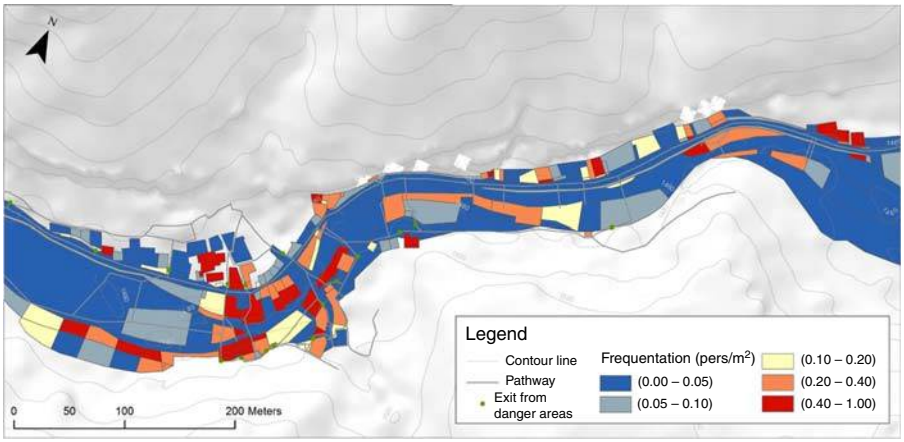

Figure 10.
Human frequentation of outdoor spaces and buildings during the day at Setti-Fadma area

But throughout the valley, refuge areas are of poor quality and are difficult to access. In addition, being on the wrong bank of the Wadi in case of flooding can be an issue for evacuation, as there is a road only on one river side. There are many small bridges in the valley and they are a normal part of the network for residents who often have to cross the Wadi. However, most tourists are not used to walking on these narrow bridges and can take several minutes to cross them. In fact, some of these bridges are already dangerous; therefore, their use should be limited as much as possible in case of flood. Some are temporary and others are designed to withstand floods. Four types of bridges can be found in the valley: wooden bridges that are highly exposed and very vulnerable to flooding Plate 2 suspended bridges that are raised well above the river bed compared to the first category; bridges with metal frames, which are more stable and attached to concrete

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Plate 2.
Bridge swept away by the flood of May 5, 2016 at Aghbalou

foundations and can only be damaged by severe floods; and finally, there are some concrete bridges that allow the road to pass over the Wadi.

Despite their usefulness to cross the river, the bridges can also be an obstacle to flows. The most frequent explanation given by the population for the very high velocity in river discharge during the 1995 flood is the accumulation of debris and trees on a metal bridge over Setti-Fadma. When broken by the river flow, this temporary woody debris jam had possibly created a murderous wave.

At Aghbalou, even if slopes around the area of risk are very steep, we have found some flat places that could temporary accommodate population in case of an evacuation. As an example, an orchard and a small field have been selected. Shelter zones on paths or on a high track on the right bank have also been retained, but they offer a very limited capacity and are difficult to access (Figure 11).

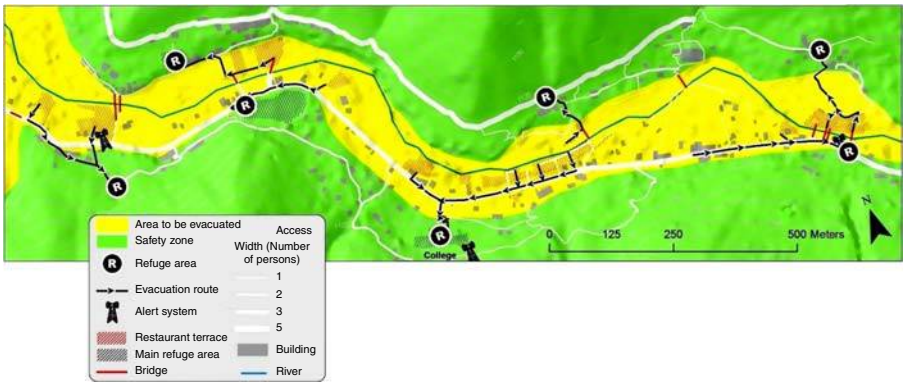

Figure 11.
Evacuation plan prototype at Aghbalou area

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At Oulmes, the possibilities are really limited. At the heart of the village, a staircase leads to an official safe refuge area. Unfortunately, it is too small to accommodate a large number of people. A wasteland nearby is large enough to accommodate many people; however, it is located 60 meters above the level of the Wadi and the path to access it is uneven. A considerable effort is required, making it impossible to evacuate people with reduced mobility.

In Setti-Fadma, an imposing building "the mosque" could be used as an improvised shelter. Otherwise, other refuge areas are just as unsuitable as in Oulmes and Aghbalou and paths to reach them are too narrow to allow a large number of people to use them. Overall, in this very constrained context, quick and easy evacuation of the flood-prone areas, a major challenge is to ensure minimum loss of lives during the next severe flood.

5. Discussion

One of the Ourika features is the overexposure of tourism infrastructures in the minor river bed (Plate 3). Overall, the development of stakes in the river bed is closely linked to touristic development. Visitors are coming to be refreshed by the river, so it is natural that restaurants thrive in this kind of place.

The landscape at the bottom of the valley is altered with each flood (Plates 1 and 4). Villages are also in constant evolution. In a few months, they underwent important changes such as the expansion of Aghbalou's boarding school (the most suitable shelter). More than a precise spatialization, a global vision is therefore necessary. Nevertheless, stakes remain overall in the same places with a great likelihood to continue to expand in the future. If the terrace of a restaurant is not rebuilt exactly at the same location after a flood that caused a river deviation, it is likely that it will be implemented just next to it. For the purpose of prevention, it is therefore essential to focus on the frequentation of these areas.

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

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Plate 4. Location of coffee terraces swept away by the flood of May 5, 2016 at Setti-Fadma

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Peak times of attendance were identified with vehicles and people counts in different places and times. This information could be used as an input while modeling evacuation scenarios. Discussing with inhabitants, it appeared that Ourika is subject to almost perpetual traffic jams during summer days. The road edges serve as parking along the valley, which increases exposure to risk. Since the local population is well informed and aware of the risk, the main concerns are for outside visitors and tourists. For an optimal management, it seems essential to exploit local knowledge and involve local actors (restaurant owners and inhabitants). Raising awareness among visitors could be done in partnership with tourist agencies. If there is a better communication regarding potential meteorological evolutions and flood occurrence, a minimization of the risk is possible. Moreover, visitors do not necessarily need to identify evacuation areas and paths to get there if restaurant owners are able to direct them.

Regarding evacuation routes and safe areas, the valley is sorely lacking refuges. Furthermore, the majority of paths coming out of the flood zone are impracticable for people having difficulties to move and it seems difficult to improve the situation. It is still possible to create practicable and marked paths and maybe to develop small refuge areas at the exit of the hazardous areas. Evacuation routes have to be marked with explicit signs and validated in cooperation with local authorities and population representatives. It is a prerequisite condition to make suitable and sustainable evacuation plan.

During discussions with inhabitants, an idea emerged: floods are part of their daily life. It is very common to observe the presence of tables and chairs in the river. Furthermore, in the past, people stopped their activities near the stream and took shelter when they spotted threatening clouds, while today the situation is more dangerous since everyone mostly relies on the alert system.

6. Conclusion

Based on a low-cost methodology, this spatialization and discrimination of flood risk in the Ourika valley offers a first relevant framework to disaster risk reduction of this touristic valley. Risk indexes showed the Setti-Fadma site as the most vulnerable. Because of its narrow river

banks, its buildings and infrastructure are too exposed, especially those built recently and intended for local and international tourism. In Aghbalou area, the wider Wadi bed lowers the flow level to a maximum possible limit and therefore lowers the risk overall. Some restaurants owners yet choose to settle too close to the Wadi, exposing themselves even more. In Oulmes, the degree of risk is different depending on the side of the road. On the right banks, toward Marrakech, all the buildings have a high-risk index and the road itself is often threatened. Throughout the valley, shelter areas are not sufficient, of poor quality and difficult to access. A lot of bridges are handmade and do not withstand strong flows. For the implementation of an evacuation plan, destruction of those bridges by the flows and the impossibility to cross the river should be assumed. For this purpose, some safe places can serve as shelters in case of a great flood, such as a large academic building in Aghbalou and a big mosque in Setti-Fadma. We also proposed potential evacuation itineraries on elevated terraces that could be prepared and made accessible. Indeed, the current situation is that population will generally hardly be able to be safe in case of an alert. The slopes of the banks are often too steep and a good physical capacity is required to stay safe. The establishment of new refuge sites, addition of other evacuation routes and building of strong bridges, as well as effective flood risk communication, are therefore absolutely necessary.

The approach taken in this paper can be extended to other watersheds or to areas of larger scale, given the ease of implementing this type of "low cost" analysis, provided to have the necessary expertise. This can lead to very concrete and operational applications, such as evacuation plans. In addition, the multi-criteria vulnerability index developed in the manuscript could be used elsewhere, regardless of the climatic environment. For the practice, the assessment of the flood vulnerability would be a precondition for a better anticipation and hazard management planning. For this purpose, Moroccan national policies for flood risk management are organized at different scales: A national scale, represented by a national surveillance and coordination committee; a local scale represented by local oversight committees; and advanced command posts. At the national level, the coordination committee ensures the monitoring of weather reports and the identification of risk areas. It proposes preventive measures and ensures the coordination of the action of various ministerial departments and territorial officials, in particular the Walis and Governors. Finally, the forward command post ensures the identification of the damage, the supervision of the affected populations, the mobilization of material and logistical means as well as the maintenance of a high level of vigilance. Admittedly, the National Committee for Monitoring and Coordination indicates that the Ourika valley is one of the most vulnerable areas, but vulnerability at the scale of activities in the vicinity of the river and at the building scale is not addressed. This study fills this gap, not only by diagnosis and surveys of attendance and land use but also by the quantification of the buildings vulnerability. In addition, the Ourika valley has a flood warning system, emitting alert sirens in case of imminent flood. This study strengthens this system through the diagnosis and proposal of an evacuation plan.

This case study shows that progress in risk prevention can be made without necessarily having all the input data on hazards. Priority should be given to the reduction of exposure and vulnerabilities, and the increase in resilience capabilities.

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