Riesgo de inundaciones y estrategias de mitigación en los suburbios del sudeste de la ciudad de Fez (Marruecos)

Flood risk and mitigation strategies in the southeastern suburbs of Fez City (Morocco)

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INTRODUCTION

The goal of achieving sustainable urban development emerged in the last decades among major scientific and developers' preoccupations. It is conditioned by the achievement of environmental equilibrium and security (Burton *et al.*, 1993; Holden, 2006), the economic efficiency, the social equity and the regional sustainability (Beck, 2002; Ramos, 2009). Branscomb (2006) focused on Safety and security to define the sustainable cities. Their districts must balance ecological, social, and economic needs. The environmental investigation is becoming among approaches that seek better means of assessing urban trends on the basis of risks' prevention and human wellbeing (Besson, 1996; Schmidt-Thomé, 2005; Camfield *et al.*, 2009; Douglas *et al.*, 2010; Radojevic, 2012).

In the last decade, the analysis of vulnerability to hazards dominated by the engineering approaches, have been criticised as it failed to engage with the social, political and structural causes of vulnerability within society (Adger, 2006, p. 271). Human ecologists attempted to explain why the poor and marginalized have been most at risk from natural hazards (Hewitt, 1983; Watts,

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1983; Cutter et al., 2003), Poorer households tend to live in riskier areas in urban settlements, putting them at risk from flooding, disease and other chronic stresses. Assumptions that marginal areas and social groups are most exposed to the environmental risks are tested and confirmed in several areas in the world (Calvo García-Tornel, 2001; Aguilar, 2008; Furey and Lutyens, 2008).

In Morocco, water has been studied as a resource and as a factor of risks in rural and urban areas (Laouina, 1995 and 2007; El Jihad, 2005; Bouaicha et Benabdefadel, 2010; Gartet et al., 2010; Saidi *et al.*, 2010). In the suburbs, where degraded environment and flooding risks are spectacular, the explaining factors are either human-induced or linked to the urban expansion in lowlands (Akdim *et al.*, 2003). The climatic and the global change factors are also evoked among drivers of urban flood risks (Snoussi *et al.* 2008; Trambly *et al.*, 2012). However urban water, as issue of sustainable cities is still rare either in academic investigation or in terms of operational research and guiding the decision-making. The urban flooding risk appears among the major environmental preoccupations of actors, in resources' management and land planning (Matueh, 2002; AEBS, 2005 and 2007; Reynard *et al.*, 2011).

In Fez, most spatial dysfunctions in the city resulted from a lacking urban governance during the last decades (Ameur, 1993; Barrou, 2005) engendering marginal districts where environmental and social risks are frequent. As occurred in most metropolitan cities in the developing countries, accelerated population growth in Fez had many negative environmental consequences (Boukir, 1995; El Bouaaichi-Nadri *et al.*, 2002) and of these, informal and spontaneous settlements are of great importance. In the past, the city experienced several types of environmental risks (slopes' instability and habitat collapse in its northern districts, floods in the south). They are of physical and anthropogenic origins. The environmental risks were emphasized in the environmental monograph of the northeastern region (SEE, 2002). Waele *et al.* (2004) focus on the geo-environmental risk in the upper valley of the Oued Sebou and present a detailed description of land degradation in the northern vicinity of Fez. El Bouaaichi-Nadri (2004a and 2004b) and Gartet (2007) reported that in the Fez suburbs, the urban increasing is not generally mastered. Consequently, vulnerable districts such as Aouinate El Hajjaj in the southeastern part, Hay El Hassani in the northern zone and Zouagha in the southwest developed. They show diverse risk's indicators due to the hydrologic factors, the geomorphic context and the low degree of settlements' equipment that degrade the quality of life and require attention. Hamdouni Alami (2004) and El Harchaoui (2008) studied the environmental impacts of the under equipment in selected districts and in the Medina of Fez, but the flooding risk was not

treated. The combination of multiple factors in the risk genesis had been experienced in Fez in the past.

The case of Aouinate El Hajjaj district, in the southeastern suburb is significant. It is located in a sensible site as it forms the upstream land of the Wislane projected tourist zone, which is planned to be a major tourist area of Fez in the future. The flooding risks in Aouinate El Hajjaj district is compounded by the topographical and meteorological factors. It expands on the left valley flank of Oued Boufekrane, and extends to its bottom. This local factor is determinant for the district's vulnerability. In addition, the socioeconomic characteristics of its population such as unemployment and poverty favor this vulnerability, as households have other priorities (habitat and work), most urgent than environmental security or quality of life.

In this article we argue that mastering urbanization should be among the best ways to lower the intensity of potential flood risks in urban areas. The urban environmental vulnerability worsened more and more where regulation (the urbanism law) is ignored or badly applied. We evoke the complexity of the urban flooding risk in its physical and social dimensions and the potential impacts of the regional context that should be considered in urban planning.

The article aims to present the results of a field research led in the perspectives of applied urban development in the Fez suburbs. General assumptions considering that anarchic urban development reinforce vulnerability in marginal zones are tested. The study focuses on the following issues:

- Identifying causes of flooding in the studied areas and its context.
- Evaluating adopted strategies in urban development and potential risk increasing.
- Apprehending their potential to manage urban drainage and reduce flooding in the district.
- Discussing alternative conceptions, including social and spatial approaches to reduce the future impact of urban flooding on people and the environment.

We discuss propositions and alternatives to develop a sustainable strategy against flooding risks.

THE GENERAL CONTEXT

The city of Fez is located in the Saïs plain, a low land which links the Rif mountain in the north, to the Middle Atlas in the south (figure 1). It is formed

FIGURA 1
LOCATION AND CONTEXT OF THE STUDY AREA

Source: authors' elaboration.

of many contrasted districts and fragmented territories. Its total population in 2004 was 944.376 residents. The highest population density in Fez is in the marginal districts. Approximately 80.000 residents live in the Aouinate El Hajjaj district located in the administrative commune subdivision of Saïs (156.550 residents).

The watershed of the Oued Fez is located in the Saïs plain. Its watershed total surface is 700 km² extending in the Saïs plain, south of the city of Fez. It is alimanted by multiple tributaries such as Oued Zitoun, Oued Boufekrane, Oued Chekko and Oued Himmer. These oueds are converging to Fez (figure 2) and are regularly alimanted by the Ain Smen and Ain Chkef springs. Their catchments are relatively homogeneous in terms of geomorphic characteristics and substrates, because they generally extend within the same context

(the Saïs plain and the Middle Atlas margin) and are submitted to similar human factors and land use. The Oued Boufekrane (whose catchment area is 52.40 km²), converges to Oued El Mehraz (its catchment area is 137.7 km²) and form a braided bifurcating hydrologic system that, in downstream, influence the lowest part of the Aouinate El Hajjaj district. The width of its valley varies. It attains locally 3 kilometers, but in most sites it becomes less than 900 meters. Downside the dam, in the urban area of Fez, the Oued El Mehraz valley is only 50 meters wide. The reduced capacity of the channel to convey water during high flows in this transect increases the height of the water surface, and causes the banks inundation, and therefore the flood hazards in the low part of Aouinate El Hajjaj district. The geomorphic hydraulic geometry of the channels is trapezoidal but the valley is dissymmetric because the western's gradient is more important. The major geologic layers of the Saïs plain are the Liasic carbonate rocks, the Miocene thick marl and the Pliocene sandstone and carbonate rocks. The Quaternary conglomerates and sedimentary terraces extend locally on the surface, along the valleys and fans. The Oued El

FIGURA 2

THE TOPOGRAPHIC CONTEXT OF FEZ AND THE CATCHMENTS
OF OUED EL MEHRAZ AND OUED BOUFEKRANE

Source: authors' elaboration.

Mehraz dam construction was a new hydrologic parameter as it regulates water flow and sediments' deposition, but it becomes ineffective in periods of intense rainfall when the dam's retaining capacity is exceeded.

The Oued Boufekrane drains the Southeastern part of Fez, extending from El Gaâda plateau. It converges with Oued El Mehraz and Oued Zitoune in the entry of the Rçif district (in the ancient Medina). Its outflow is weak, but the discharge becomes torrential in periods of strong rainfall causing the flooding risk along Oued Boufekrane, mainly in the Aouinate El Hajjaj district.

The district was formed in the eighties of the last century, as a result of rapid urbanization in most Fez peripheries. Different environmental problems

TABLE 1

THE GENERAL CHARACTERISTICS OF AOUIATE EL HAJJAJ DISTRICT IN FEZ

Area	2.8 square kilometre (approximately constructed area 200 Ha).
-Slope inclination on the western flank supporting the district (the transect between the river and the plateau surface). -The inclination along the rivers profile	35 per cent 2.7 to 2.8 per cent.
Geologic substrate	Quaternary flank deposits and terraces, Pliocene sand and aggregates and Miocene marl.
Population number in the district	Approximately 80 000 persons, 12500 households.
Rehabilitation	Restructuring projects (road network and purification) achieved by Al Omrane in 1993 with an investment of 19.74 Millions DHS.
Discharge (instant max.) in Boufekrane wadi at the Aouinate El Hajjaj district	63 m3/s in September 25, 1950 and 20 m3/s in October 13, 1989 (DRH-Fez); 20 m3/s December 2008.
Major apparent problems	Poverty, unemployment, pollution, flooding hazard.
Most recent inundations in Oued Boufekrane and Oued El Mehraz	September 28th, 2008; february 13th, 2009; May 18th, 2011 (50mm rain/day); November 01st, 2012.

Source: authors' elaboration.

FIGURA 3

ANNUAL TOTAL RAINFALL IN FEZ STATION (IN MM)

Source: authors' elaboration based on data issued from Sebou Hydraulic Agency.

appear, such as the insalubrious habitat, the water pollution and solid wastes, the lack of some urban services, the deterioration of existing infrastructure and the lack of welfare conditions. The major problem in the low part of the Aouinate El Hajjaj district was however the flooding risks.

The local topographic and hydrologic conditions favour the hydrologic vulnerability of the district. It is open to the upstream drained through streets in the district and is exposed downstream to Oued Boufekrane in periods of heavy rainfall.

The climatic context in Fez is semi arid. The rainfall tends to be irregular in the last two decades with annual rainfall averages fluctuating between 180 and 580 millimeters (figure 3).

The extreme hydroclimatic events may occur in all seasons. However, the frequently humid months are between October and April (figure 4); but flooding risks and disasters in the urban areas may occur in any season and are linked to the extreme meteorological events that happen on the watershed in a daily time scale. In most cases, the rainfall may become a factor of the flooding risk when it is over 30 mm/day.

FIGURA 4

MONTHLY MEAN AND MAXIMUM RAINFALL AT FEZ STATION (1979-2008)

Source: authors' elaboration based on data issued from Sebou Hydraulic Agency.

Most flood hazards in Fez were linked to the daily or instant heavy rain. In October, the 13th, 1989 for example, floods in the area were explained by the rain concentration, as it attained 37,6 mm in the Ain Timedrine station, 40,6 mm in Sefrou and 28 mm in the Fez Saïs station. In May the 18th, 2011, several districts were flooded in Fez following the heavy rain that attained 52 mm in the city (Météorologie Nationale, 2011).

However the problem appears only when flooding has an impact on human settlements and activities. The link between social, spatial and natural factors are strong as they intervene together in the flooding disasters in the area.

The dominant habitat is informal because it appeared in the eighties of the last century when the expansion of spontaneous settlements had been alarming. But the increasing of the district in the same way was continuous over time due to speculation and non respect of urbanism rules (Fejjal, 1994 and Darkaoui, 2009). Two current forms of urbanization were observed in Aouinate El Hajjaj and in most Fez suburbs they converge with those underlined by Qadeer (2004) and are: (i) the lateral growth due to emigration and

(ii) the urbanization by implosion, which builds up urban spatial organizations through the densification of human settlements. In both cases, urbanization and high density population induce transformations in spatial organizations in three ways: the infrastructure needs' increase; the changes in the landscape and settlement system; and the restructuring of land economy and land uses.

Since 1981, the Aouinate El Hajjaj district has been restructured and offered basic equipment needs such as drinking water, electricity and other common public needs. A dam had been built in its upper proximity zone (the Gaada Dam), but the area is still vulnerable to flood risks and is environmentally degraded.

Nowadays, these settlements are demanding better living conditions in a more secure environment and a better restructured area. The concepts of "environmental equity and security" are emerging as basic concepts in these peripheries.

METHODS

The flood risk in the studied area is approached using historic evidence and mapping to produce spatial data that are pertinent to future flood management. The historic and mapping approaches are pertinent in the flooding study (Cœur and Lang, 2008; Koivuma *et al.*, 2010). The recently submerged areas were delimited in the field work. The historic information was reviewed basing on administrative archives. Data was completed by directed questionnaires addressing risk issues in the district.

The interactions between physical and socioeconomic factors through local and regional scales were investigated. The approach is global and multi-factors integrating (Asté, 1994; Akdim and Laaouane, 2006; Gartet, 2007; Hansson *et al.*, 2008; Jacobson, 2011). It allows the study of local characteristics and other significant contextual factors influencing the flooding risk genesis and management.

A comparison of the aerial photographs' restitution (1991) and the aerial photographs taken in 1987 and 1998, with more recent flooding events reported by the AUSF (Urban Agency of Fez), allows a precise reconstitution of the flooded zones in the valley of Oued Boufekrane at the Aouinate El Hajjaj district. The households' chiefs were interviewed concerning the housing process, the flooding risk factors and the perceptions of the risk and floods' management. The interviews were conducted using an oriented questionnaire

apprehending the past of the district, the present-day environment and the challenges and the future perceptions. The questions are mostly open-ended to explore all possible horizons. Interviews were led out by the Master's students from the University Sidi Mohamed Ben Abdellah, Fez in March 2009 and April 2010. They were briefed on how to conduct the interviews and the study objectives. The senior researchers in the group were permanently present during the field work and their repeated visits permit to further investigation on emerging questions at time. The direct observations of the flood phenomena were collected during the last five years at each heavy rain.

The results of the most recent census of the population and habitat (HCP, 2004) were used, but they are not detailed concerning the proportion of Aouinate El Hajjaj district's population, compared to the whole population of the administrative subdivision Saïs. More detailed data on the district was collected in the administrative archives, mainly the Saïs commune services and from the reports of the Urban Agency of Fez and the Water Agency of Sebou Basin.

ENVIRONMENTAL RISKS LINKED TO URBAN DEVELOPMENT IN THE SOUTHEASTERN SUBURBS OF FEZ

Since five decades, the flooding risks have been intense in the Fez agglomeration. Their impacts were important either inside the urban area or in its immediate peripheries, where population densities are progressively high. The southeastern Fez suburbs experienced episodic flooding risks since 1950. A severe flood disaster occurred in 1989, when Oued Boufekrane frightened the extending habitat in its valley bottom and engendered several human victims. In October the 12th, 2008 an abrupt rise of the Oued's discharge caused considerable material loss in the area. Most suffering settlements are informal houses in the district of Aouinate El Hajjaj and in the Medina. The latest disaster happened in February the 13th, 2009, when the district was flooded in the river's vicinity and three victims were reported in the Medina.

The extreme discharge values have been estimated to 63 m³/s for the rise in the water level of Oued Boufekrane in September the 25th, 1950 and to 20 m³/s for the rise in the water level in October the 13th, 1989 (MATUEH, 2002; AEBS, 2005 and 2007; Reynard *et al.*, 2011).

These discharges are often violent and unforeseeable. Water level attained the constructions situated in the low parts of the district Aouinate El Hajjaj and affected them severely. The main limits of the flooded surface over time

FIGURA 5

VULNERABLE AREAS IN THE AOUINATE EL HAJJAJ DISTRICT,
BASED ON HISTORIC FLOOD DATA

Nota: 1) Current channel; 2) Area of torrential flow; 3) Potential risk area when the dam capacity is exceeded; 4) Flooded area in October the 13th, 1989; 5) Area currently open to urbanization after 2005.

Source: authors' elaboration based on the urban plan of Fez.

were defined using the comparison of the aerial photographs of different dates (1991, 1987 and 1998) with indications deduced from the reports of the Urban Agency. The reconstitution of the flooded zones in the valley of Oued Boufekrane at Aouinate El Hajjaj district is presently well known. They are significant. In 1989, the local authorities have shown that numerous constructions and roads, situated in the valley bottom have been flooded and that the damages were important.

Since the construction of the Dam Al Gâda in 1992, the drainage of the Oued Boufekrane in its downstream is weakened and most population, mainly the most recent migrants, ignores its potential risks. The dam seems

generating a false sense of security. It is certainly controlling most, but not all hydrologic risks because its retaining capacity is limited. The downstream of the dam is still opened to receive critical discharges from uncontrolled small catchments that are potential sources of risks. This may occur for example in the Mokhtar Essoussi School. Its external wall (200 m of length) is very close to the oued's bottom, and is built on a non consolidated embankment, where increasing encroachment can cause a slip down when raining or following any released water of the dam. We note that urban practices in these cases ignore the potential hydrologic risks and don't respect the urbanism laws (laws 12-90 and 25-90), the water law (law 10-95) and even the recently adopted laws of environment (2003).

This critical situation has been observed in 2001 while testing the effect of dam water releasing. A discharge of 300 l/s caused the flooding of several buildings in Aouinate El Hajjaj district in the river bank proximity. The human occupation of the riverbanks activates erosion and sedimentation in the talweg and causes changing velocity and water level, accentuating therefore the risk of flooding. The human factors of risk in the district are multiple. The population density, the structure of the streets facilitating water flow down, mainly after the rehabilitation program in 1993 (all streets were concreted and increase surface drainage of water). The spontaneous occupation of land following the speculation and the construction without respect of technical and urban planning norms are among social and spatial factors of the risk in the district.

Downstream the district of Aouinate El Hajjaj, the oued flows out following a sinuous tracing, in the valley where farming activities developed. Waste deposits reinforce the Oued Boufekrane discharge which reach Oued Zitoune, and change the name as it is called Boukhrareb until the transect crossing the Medina. Along this tracing, down bridges are filled by the waste deposits and vegetation debris and sediments. It sometimes hinders water flow in these intermediate basin sections. These factors explain the most critical hydrologic situation in the bridge section of the railroad track toward Bab Ftouh, whose discharge has been estimated to about 1 m³/s. The system of floodgates permitting the confluence toward Oued Zitoune, engender flooding problems in the vicinity whenever the water level rise. This is also observed in the section situated to the uphill of the floodgates close to the parking lot Bab Jdid whose capacity is lower than 6 m³/s. Flood threats are therefore frequent along the valley between the Aouinate El Hajjaj district and the Medina.

Most interviewed population converge on the idea that potential flooding risk is understood and know that the district is vulnerable, but they consider the public actors (mainly the commune) as responsible of the situation and

should resolve their problems. «I understand the serious risk of flooding I am exposed to, in the district, but I don't see any solution to change my situation» said a respondent. The focus was often put on the low income and poverty, preventing any individual initiative. «The public authorities are well equipped to resolve the problem and should find alternative habitat to the district stakeholders» said another. The flooding risk is generally perceived; the speculation in land tenure is invoked as a major factor of the district's situation in the past; but living there is accepted even it is risky. It is considered a transitory experience that may offer future opportunities to gain individual interests from the public supporting programs in habitat and resettlement.

THE PRESENT DAY STRATEGIES OF THE FLOODING RISK MANAGEMENT IN FEZ

To face urban flooding risks in Morocco, panoply of strategies have been adopted in the last decade. Among these strategies (i) the technical protective measures, that modify, in a given vulnerable place, the level of the risk (discharge, height of water, flooded surface, time of submersion, etc.) and (ii) the measures of prevention that have, as the main goal, to limit the vulnerability of a given site, by a better knowledge of the risk, a mastery of the extension of the vulnerable zones and a better organization of the intervention in periods of crisis.

In Fez, important actions were adopted after the flooding disaster in 1989. Among these measures we note the following:

- The two dams' construction on Oued El Mehraz. These have been built because of the often concentration of rain on the Kandar mountain and its consequent hydrologic impact on the rivers' discharge flowing from the south to the city of Fez. The dams have been constructed within the strategy of the protection of Fez city from flooding. Two collinear dams on the Oued El El Mehraz (the Moulay Arafa dam and the dam Oued Boufekrane, near the Village El Gâada) have been built. After the Sebou basin water Agency, the total water volume capacity of the dams is 145.750m³ for the first and 248.850 m³ for the last dam. The two dams are joined by a deviation channel. These two dams could already avoid new flooding problems in the sectors very strongly urbanized in their valleys and, beyond, in the Medina. Nevertheless, the capacities of the dams remain, today, modest considering the rises in the water level that are probable.

FIGURA 6

PHOTOGRAPHS SHOWING POTENTIAL FLOODING RISKS EMERGING
FROM NON SUSTAINABLE WATER TRANSFER AND EQUIPMENTS

Source: authors' elaboration..

- The deviation channel from Oued El Mehraz to Oued Boufekrane (figure 6) has been conceived to drain water surplus from the dam Moulay Arafat on Oued El Mehraz to the dam built on Oued Boufekrane, in the vicinity of Aouinate El Hajjaj district.

The channel links the dam Moulay Arafat to the dam Bled El Gaada, near Aouinate El Hajjaj. Its length is 4.100 m. Its normal discharge capacity is 25 m³/s, but it may reach a maximum capacity of 35 m³/s.

These projects are important but not sufficient to prevent the city against the flood risks, because the strategy should take in account, the hydrologic particularities of the local context, mainly after the construction of the double road (highway) between Fez and Sefrou, which induced major changes in the

TABLE 3

THE GENERAL CHARACTERISTICS OF THE CHANNEL CONSTRUCTED
IN BOUFEKRANE AT AOUIATE EL HAJJAJ DISTRICT

Maitre d'ouvrage	Commune of Fez
Coordinates	34° 01' 20" N 4° 57' 55" W
Lenght	580m,
Width	4 m
Height	2.4 m
Average slope along the channel (the profile)	1.5‰
Date of construction beginning	Spring 2008
Considered frequency of floods	100 years frequency
The first degradation	September 2008
Streets orienting water flood to the low district	More than 30 streets, 2 boulevards
Approximate surface of drained area	200 ha
Distance downstream the dam	1 km
Distance before the tourist zone projected in Oued Wislane	3 km

Source: authors' elaboration based on data from field measures and maps.

local hydrography and directly guide water from external areas to the watershed of Oued Boufekrane. The geomorphology and erosion conditions of the local context affects also the dams' retaining capacity and reduce the channel's efficiency towards the flooding risk management.

After the flooding disasters in the Aouinate El Hajjaj district in 2008, the commune of Fez decided to build a channel along Oued Boufekrane, in the section crossing the district. Its characteristics are shown in table 3.

The main objective of the channel project is to evacuate water coming from a hundred-year frequency water rise in the river. The channel began from the dam Bled El Gaada and cross the district Aouinate El Hajjaj, on a length of about 580 m. Its cross profile is trapezoidal in shape, and is built in masonry to reduce the speed of out-flow and to better integrate the urban landscape.

Within the mitigation strategy of the flooding risk and following the rehabilitation program, most streets of the district were managed and concreted to avoid water infiltration and guide water downstream. However, considering

the important discharge coming from the convergent streets down, the homes near the built channel are often flooded after each heavy rain. The convergent streets facilitate down water flow concentration.

DISCUSSION AND ELEMENTS OF ALTERNATIVE DRAINAGE AND URBAN FLOODING RISK MITIGATION STRATEGIES

The study of flood risks in this case, shows the diversity of its acting factors. The physical factors are climatic, bioclimatic, hydrologic, geomorphic and geologic and intervene through the local and regional scales. The land use, population density, households' conditions of life and incomes are among the socioeconomic factors that influence their vulnerability and how people perceive the risk. The way adopted in land use and the regulation's respect are also evident as factors of risk genesis in this case, because spontaneous and informal development of the district amplified its environmental vulnerability.

The efforts to mitigate the flooding risk in the district are mainly technical in nature. As shown in the photographs (figure 4), the channel's wall magnified the engendered risk and the solution was to pierce the wall. Adequate technical solutions are important when appropriate but they are certainly not sufficient, because the socio economic factors should be considered. A more global strategy is needed to insure the environmental security and sustainable urban development in the area. Previous research on flooding risks point out the human responsibility in the case of the lower districts of Taza and Sefrou and in the city peripheries of Oujda and El Hajeb for example (Akdim *et al.*, 2003; El Hafid *et al.*, 2004). Several measures were suggested to face the land use deficiencies and the lack of preventive and maintenance measures in urban and rural areas. In the neighbor countries, mainly in Spain, the flood risk mitigation strategies have been studied in most critical areas (Gutiérrez *et al.*, 1998; Ayala-Carcedo, 2000; Calvo García-Tornel, 2001; Alcántara-Ayala, 2002; Olcina Cantos, 2004 and 2009; Heitza, 2009; Pérez Morales, 2010; Martínez Ibarra, 2012; Camarasa-Belmonte and Soriano-García, 2012). Corrective measures to reduce the vulnerability of urban areas to flooding risks were proposed (technical actions such as the drainage channels improving, the land use mastering, the flood warning systems and the drafting of emergency flood plans, flood studies at the local scale, maintenance work and monitoring of the fluvial systems, as well as introducing a real-time rainfall and drainage control system). The factors of the risk, either in Spain or in Morocco are complex and underline multiple possible actions to face the prob-

lems. Several important mitigation strategies have to be adapted depending on the needs of the specific situation in each site. The whole catchment must be integrated in the analysis, but different spatial scales of action have to be considered. The catchment subdivisions (the uppermost part, the intermediate areas and the valleys) and the urban area in Fez are major framing units to conceive actions.

The uppermost part of the rivers extends to the Middle Atlas Mountain flanks, formed of piedmont and margin fans that affect drainage. The physical context should be apprehended to understand its determinant factors of risk and conceive needed adaptations. The anthropogenic factors of flood risks in the area show high pressure on the resources and equilibrium destabilization due to erosion and vegetation cover degradation. Either in the Imouzzer plateau (elevated to 2.020 m) or/in the Sefrou mountain border (1.400 m), the land use have to be sustained to maintain the environmental system's equilibrium (adapted techniques to reinforce the vegetation cover, the soil and water conservation) and therefore reduce the flood hazard risks influencing the catchments downstream.

The intermediate surfaces formed of fans and local plateaus, extending to the Sais plain in the lower watershed (400-700 m), have a gentle curve (0.1%) from the south to the north. The sedimentary forms (terraces and debris flow) favor water flow through ephemeral drains that reinforce floods in periods of intense rainfall. These sections of the rivers influence the hydrology downstream and contribute progressively to the dams filling with sediments. The flood genesis affecting Fez is therefore favored. Actions of soil and vegetation stabilization and land use planning are useful to improve local runoff conditions in the intermediate surfaces within the catchments.

At a strict local scale, in the Aouinate El Hajjaj District, between the two dams, and in transect leading to the Medina, the mitigation strategies of floods must be at the same time technical (the drainage channel achievement following adapted norms), based on regulation (mastering the urbanism and environment management) and consider social aspects (information, awareness, organizing NGO to create efficiency stakeholders involvement, reinforce resilience and adaptation capacity).

The uncontrolled peri-urban development is a potential factor of flooding risk, mainly in lowlands (Konrad, 2003). In the Aouinate El Hajjaj district, the perspectives of sustainable urban development are conditioned by considerations of the whole Oued Boufekrane and Oued EL Mehras watershed characteristics and their local influence on risks' genesis. They are also linked to local factors (social, geographic and technical factors) that should

be understood, adapted and integrated in the planning tools and risk mitigation strategies.

Adopted management in urban planning and measures of flooding risk mitigation during the last decades in Fez fail as mentioned before. The rehabilitation of the district which began since 1993 and the technical solutions adopted to prevent flooding risks in Aouinate El Hajjaj have not yet assured environmental security in the area. The protective actions have to be conceived taking in account the complexity of risk factors, their types and changing nature, while respecting the principles of global and integrated management at the district level and in its regional context.

The protection plans for least flooding risks may therefore integrate the high probable discharges of Oued Boufekrane and its lateral submersion to define areas that may be opened to the construction projects and areas where they must be forbidden. After considering the technical criteria and the socioeconomic and environmental factors, the decision remains merely political.

Among priorities of flooding risk mitigation in the area, the whole transect of Oued Boufekrane from the dam El Gaada to the Medina (the future place of the tourist zone of Wislane) should be efficiently managed following a sustainable vision which consider the following parameters:

- The importance of the episodic discharge of Oued Boufekrane at the Aouinate El Hajjaj district and down should be considered, especially when the dam El Gaada is filled by water derived from the dam Moulay Arafa on Oued Mehraz.
- The environmental and socioeconomic vulnerability of the Aounate El Hajjaj district.
- The importance of future project planned for the zones extending from Aouinate El Hajjaj to the Medina, mainly the huge tourist zone of Oued Wislane.

Plans of action were suggested by the Water Agency of Sebou Basin (AEBS, 2005 and 2007) and other partners (the commune of Fez, agencies and authorities) are motivated to resolve the flooding problems in the area. However, a most integrated strategy considering the complexity of flooding factors is still lacking. The suggested technical actions are important but not sufficient. They must be supported by spatial, social and juridical actions to assure adequate functions of the territory either in its urban and regional systems.

The suggested technical solutions in the future consist of more derivation channels management and two more dams' construction to master water flow in the whole Oued Fez watershed until the entry of the Medina. Lessons

learned from the past show that they may suffer from lateral impacts of neglected variables in the global context. These are of spatial, social and juridical orders and should be considered in an integrated urban and regional planning.

The detailed local studies are useful in hydrology (Nafaa, 2005), but are not sufficient for the flooding risk apprehension. The spatial planning in a general framework is more pertinent to consider the total hydrographic networks and include all isolated actions within a hydraulic continuity (uphill-downstream consistency) and the capacity of out-flow and the propagation of the debits along the river and from its lateral tributaries, following «an integrated water management strategy to overcome conflicts between urban growth, water infrastructure and environmental quality global strategy» (Furey and Lutyens, 2008).

The regulation weakness and the lack of laws' respect in the studied suburbs development are also among environmental risks factors. The law of urbanism (law number 25-90) and the water law (the law 10-95) define minimal distances of 20-50 meters from the talweg «the hydraulic public domain». Its dimensions vary following the rivers' dimensions. These measures were not respected in the Aouinate El Hajjaj district as it was among informal and non authorized districts before its rehabilitation in 1994. Such negative heritage, linked to deficits in urban governance since several decades underlie the fact that «governance and regulation aspects» should be considered as basic elements in urban development and its environmental security and sustainability.

The social factors of the risk genesis and in the mitigation strategy are important. Their roles were important in the beginning (emigration, poverty, lack of participation, speculation, etc.) and are still important in the present day context, because they accelerate the valley bottom occupation. The severe impacts of these factors on the success and/or failure in the public strategies give evidence of their necessary integration in the flood risk mitigation strategies. The evolution and complexity of the social-ecological system and the changing behavior of the local context should be incorporated in the decision making, in conformity with the newly conceptual approach of the adaptive management presented by Allen *et al.* (2011).

Several actions are possible (sensitization and dialog stimulation to obtain consensus on the best land use and districts reorganization, participation to creation or repairing actions, respect of the urban planning norms, respect of the hydraulic public domain, co-financing environmental projects, etc.). It is clear that such participation is conditioned by acceptable socioeconomic conditions allowed by sustainable income of households and a satisfying formation and cultural level of women and men. Communication is becoming

among important factors of risk mitigation as it facilitate individuals to participate to risk management and mitigation (Milman and Short, 2008; Homa *et al.*, 2009). The social factors of risk mitigation are nonstructural and include the mitigation by householders who are encouraged to develop some form of resilience against future flooding (protection walls, door covers, sand-bags, connection to the adjacent sewer, etc.).

However, mitigation by forewarning is more reliable but should be adopted by authorities. The weather forecasting at a geographical and regional scale is pertinent and could be done using mapping flooded areas, GIS, studying previous flood events to apprehend their extension and deduce conclusions from actors' adaptations and resilience. Faced with the difficulty in controlling the hazard of flooding in this complex context, the Water Agency of Sebou Catchment (Fez) and the Swiss DDC realized recently a study and established a system of prevention and warning against floods in 2012, in order to minimize their eventual damage. But the system is not yet operational as it needs sufficient equipments that are geographically well placed and human empowerment and training to insure the best precision in the data collection and exploitation.

TABLE 4

COMPONENTS OF AN IMPROVED FLOOD RISK MASTERING STRATEGY IN FEZ

Preferred option in the past	Positive impacts of the ongoing strategies	Negative aspects of ongoing strategies	Suggestions to improve the future action
Pre-projects technical reports	Learning from experience	Expert (technical) knowledge still dominant Local actors neglected	Research and scientific monitoring development: Factors apprehension, study of processes and impacts, Zoning the risk in space, Studying the risk intensity evolution, Apprehending the prospective risk , Combining the scales' effects.
Projects of water transfer	Mastering discharges locally, following subdivisions and tributaries capacities within the watershed	Probable Instantaneous cumulative discharges	Master water flow in the river catchment scales and prevent sensible areas.
Dam building	Linking spatial and temporal regulation of discharges	Sediments deposition increase reservoirs' capacity loss,	New flood detention lakes are possible downstream

Preferred option in the past	Positive impacts of the ongoing strategies	Negative aspects of ongoing strategies	Suggestions to improve the future action
Sanitation and sewage networks in the main streets	District equipment, Qualitative and quantitative control	Networks investment and maintenance costs are high	Adapted sanitation and sewage treatment, Surface water flow decrease.
Preventing filtration in urban areas (restructuring programs)	Improve landscape quality, Prevent risks linked to humidity	May engender floods (the case of Aouinate El Hajjaj district)	– Using pavement and concrete, – It concentrate water flow downstream in the streets, – Parallel equipments are necessary to avoid hazardous situations.
Canal building	– Guide water flows and prevent vicinities from the risk – Permits water transfer	May engender new risks by obstruction of streets flow (Aouinate El Hajjaj)	Detailed studies should be undertaken.
Operational regulation, laws improvement and respect	The urbanism regulations, environmental and water laws are legal tools of the land use and environmental action	The rigid aspects of laws incite sometimes infractions. Laws should reflect real and sustainable needs of territories and societies	Laws and regulations should support sustainable governance and urban development. Local contexts should be considered
Land use management and control	The conflicting issues are apprehended and adapted functions are conceived for each spatial unit	Any misconception of land use may engender fatal and negative consequences on environment.	– Spatial planning and appropriate zoning, – Global conception in different scales, – Global conception in different scales, – Landscape quality and ecology
Social and socio-economic factors of the risk	Learn how to live rationally with floods. Mitigation measures, best practices, etc.	Long term and costly investment, large and diverse focus groups,	– Strengthening the social structure of the community – Improving income and sensibility to risk questions
Training	Improve individual and collective capacities to manage the risk	Immediate results uneven	Learning from experience Short term pro Developing scientific, technical and communicative abilities
Communication	Collaboration and motivation of actors is assured	Analphabetism proportion is a constraint, Appropriate communication methods should be developed	– Awareness of actors – Stakeholders engagement – Integration of the social factors of the risk

Source: authors' elaboration based on synthetic data.

The alternative risk's mitigation strategies should integrate a well defined zoning of risk vulnerability mapping «the limits of tolerance and adequate prevention» in each sector. Such zoning documents may correspond to the Plans of Prevention of the Risks (PPR) adopted in several countries. Their pertinence is certainly conditioned by prior further knowledge of the risks factors, basing on a scientific study and monitoring of indicators and their foreseeable flooding impacts in the future. As synthesized in table 4, the flooding mitigation strategies should be considered in their plurality. No single strategy may be sufficient and globally applied. The study argued on the interactive components of each strategy, depending on the technical aspects of the action, its regulation framework and its socio-economic impacts and consideration.

CONCLUSION

The critical review of the mitigation risk strategies previously adopted in the Aouinate El Hajjaj district (Fez) illustrate the limits of the technical solutions in presence of huge social and spatial dysfunctions. The risk analysis in this case shows that its factors are multiple and complex and therefore need multivariate mitigation strategies to be reasonably treated.

The district's evolution and structures were guided since the beginning by illegal transactions (speculation, land squatting, construction without respect to norms and regulations, etc.). The environmental worries were almost absent in such development. Since 1993, the public actors try to resolve the districts' crisis and reinforce its environmental security but adopted strategies were mainly technical. Sometimes they are useful, but in other cases they may amplify the flood risk. This case was observed in the Aouinate El Hajjaj district, when the built channel's wall formed a barrier preventing streets' flowing water under heavy rain to access to the channel. When these solutions are locally recognized to be useful in appropriate situations, they are not sufficient.

Other mitigating actions including reduction of physical vulnerability, reduction of socioeconomic vulnerability and strengthening the social structure of the community are discussed. These actions constitute elements of an alternative strategy in urban planning and development and must be framed by laws and regulations respect. Their use could be undertaken at individual, community, and State levels depending on the specific dimension of each measure. The global vision integrating local and regional scales is essential to conceive a more sustainable action and should be progressively adapted as demonstrated elsewhere (Homa *et al.*, 2009; Douglas *et al.*, 2010; Eakin *et al.*, 2010).

As underlined by Konrad (2003) flood mitigation strategies and «Stormwater managers can use streamflow information in combination with rainfall records to evaluate innovative solutions for reducing runoff from urban areas. Real-time streamflow-gaging stations, which make streamflow and rainfall data available via the internet and other communications networks as they are recorded, offer multiple benefits in urban watersheds».

The social action is also a major component of sustainable flood mitigation strategies as it offers useful elements to understand the floods' factors, elaborate sustained solutions and develop preventive actions. It includes the important role of non-governmental organisations, in the planning, managing and monitoring phases.

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RESUMEN

En los suburbios del sudeste de Fez (Marruecos) el riesgo de inundaciones responde a fenómenos de diversa naturaleza física y humana (topográficos, hidrológicos, climáticos, utilización del suelo, factores sociales y técnicos). En este trabajo se analiza la situación del distrito de Aouinate El Hajjaj, en donde diferentes procesos derivados de la ocupación de este espacio (especulación, proliferación de asentamientos informales, edificación sin respeto a las normas y reglamentos...) han constituido factores decisivos en la génesis de los riesgos de inundación que actualmente afectan a la zona. Aunque los esfuerzos públicos para resolver la crisis del distrito y reforzar su seguridad frente a las adversidades del medio natural comenzaron en 1993 (construcción de dos presas y de canales, pavimentado de calles, dotación y mejora de los equipamientos básicos como el abastecimiento de agua potable y de electricidad, obras de saneamiento, etc.), los factores de riesgo aún persisten. Las soluciones técnicas aplicadas han sido reconocidas por su utilidad, pero es necesario trabajar en otros ámbitos, como la reducción de la vulnerabilidad física, social y ambiental, y en el reforzamiento de la estructura social de la comunidad, lo que permitiría abordar el problema desde un punto de vista sistémico. Todos ellos constituyen los elementos de una estrategia alternativa en la planificación y el desarrollo urbano que deben ser enmarcadas por leyes y reglamentos. Su uso podría llevarse a cabo a nivel individual, comunitario y estatal —en función de la dimensión específica de cada caso—, con el fin de fomentar una estrategia de integración entre las escalas locales y regionales que contribuya a concebir acciones más sostenibles en los estudios de mitigación de los riesgos ambientales. Así mismo, el papel de las organizaciones no gubernamentales es importante en esta cuestión, y la política medioambiental, las acciones de los diferentes agentes que intervienen en el planeamiento urbano y la población local, deben estar sensibilizados y comprometidos con las estrategias para la prevención de inundaciones.

PALABRA CLAVE: inundación; mitigación de riesgos naturales; suburbios; vulnerabilidad ambiental; Fez; Marruecos.

ABSTRACT

The risk of flooding in the south-eastern suburbs of Fez (Morocco) was engendered by multiple factors (topographic, hydro-climatic, land use, social, technical). This

study focuses on the Aouinate El Hajjaj district and shows that the district's evolution, characterized by informal transactions (speculation, land squatting, construction without respect of norms and regulations) was a major factor in the genesis of flood risk as the district extended into vulnerable sectors. Public efforts to resolve the district's crisis and reinforce its environmental safety began in 1993 (2 dams and channels were constructed, street were paved and basic facilities were provided, such as drinking water, sanitation and electricity), but the risk factors persist. Technical solutions are locally recognized to be useful, but they are not sufficient. Other mitigating actions including the reduction of physical and socioeconomic vulnerability and the strengthening of the social structure of the community should be considered in a systemic point of view. They constitute elements of an alternative strategy in urban planning and development and must be framed by laws and regulations. Their use could be undertaken at individual, community and State levels depending on the specific dimension of each measure. A vision which integrates local and regional scales is essential in risk studies, in order to design a more sustainable action. The role of non-governmental organisations is important in flood mitigation and urban environmental policy. The incorporation of flood prevention as a parameter of urban planning should be considered by planners and the local population.

KEY WORDS: flood; mitigation of natural risks; suburbs; environmental vulnerability; Fez; Morocco.

RÉSUMÉ

Le risque d'inondation dans les banlieues du Sud-Est de la ville de Fez (Maroc) sont produits par des facteurs multiples (topographiques, hydro-climatiques, relatifs aux usages du sol, sociaux, techniques). L'étude vise le district d'Aouinate El Hajjaj et montre que son évolution, résultat de transactions informelles (spéculation, occupation illégale de terres, constructions ne respectant pas les normes et les réglementations), a joué un rôle majeur dans la naissance du risque d'inondation au fur et à mesure que le district s'étalait vers des secteurs vulnérables. Les efforts des autorités pour donner une solution à la crise du district et renforcer sa sécurité environnementale ont commencé en 1993 (construction de deux barrages et de canaux, pavement des rues, dotation d'infrastructures essentielles comme l'eau potable, assainissement et électricité), mais les facteurs de risque existent toujours. Les solutions techniques sont considérées utiles localement, mais elles ne sont pas suffisantes. D'autres actions correctrices, comme la réduction de la vulnérabilité physique et socioéconomique ou le renforcement de la structure sociale communautaire, devraient être envisagées d'un point de vue systémique. Elles représentent des éléments d'une stratégie alternative dans l'aménagement et le développement urbain et elles doivent être encadrées par des lois et des réglementations. Elles peuvent être entreprises aussi bien à l'échelle individuelle ou communautaire que par l'État, selon la dimension spécifique de chaque mesure. La vision qui intègre l'échelle locale et régionale est essentielle pour l'étude des risques afin de concevoir une action plus durable. Le rôle des organisations non

gouvernementales est important dans la mitigation des inondations et la politique environnementale urbaine. L'incorporation de la prévention des inondations comme un paramètre de l'aménagement urbain doit être prise en compte par les planificateurs et par les populations locales.

MOTS CLÉS: inondation; risque; mitigation; banlieues; vulnérabilité; Fès; Maroc.