Analysis of natural hazards in urban areas: The city of Bou Saada as a case study in Algeria

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Abstract. Dealing with major risks has become one of the most important challenges for sustainable urban development in the light of rapid urbanization, which touched most of Algerian cities and led to a doubling of human, material, economic and environmental losses, which in turn led to the deterioration of the urban fabric. Since the early 1960s the city of Bou Saada underwent a fast, chaotic and unplanned urban evolution over 65% of its surface, most of which is located on slopes - slopes of mountains, of valleys - and near the sand dunes, being thus exposed to the risk of flooding, rockfalls and desertification. A morpho-dynamic analysis shows that this is linked to the physical environment on the one hand and, on the other hand, human activities like rapid population growth in urban areas, the ambiguity of the real estate Algerian slums and the various irresponsible types of configuration carved these dangers and increased their severity in the urban system. In order to reduce their harm, these natural hazards must be understood, their impact on the urban area determined and the urban agglomerations must be protected from their effects.

Keywords: natural hazards, urban environment, flooding, rockfalls, desertification.

1. Introduction

The city is an integrated urban unit closely linked to the environment surrounding it and thus Man had to deal with natural and environmental hazards. Wherever they are in the world, they are the inevitable result of the growing population, but functional and technical studies should be adopted by cities in this expansion trend, taking into the rights of easements from natural hazards on the one hand and, on the other hand, the rational management of the resulting environmental risks. Natural hazards have a great influence on the urban environment, the impact on the physical side and on the city limit being the demolition of buildings and the occurrence of breaks in the urban fabric and the emergence of pockets of gaps inside. "The lives of human beings are threatened continuously as a result to what the world is witnessing: disasters and events are annually causing material and considerable human losses and with the beginning of the sixties multi-natural hazards won the largest share in articles, studies and scientific researches and university conferences at the beginning of the sixties" (Moral, 2006). Natural hazards, including earthquakes, have caused heavy losses of lives and property and infrastructure in many parts of the world . For example, the earthquakes between 1960-1990 are the most deadly and destructive disasters that have killed about half a million people worldwide and caused losses estimated as totaling $ 65 billion dollars; estimates indicate the presence of about one million earthquakes in each year (Ahmad, 1998; Houcine, 1984; Essaid, 1981). The phenomenon of drought wiped out nearly half a million people, all from developing countries in the period between 1974 and 1990 and increased total economic losses across the whole world from about 10 billion $ in the sixties to about 30 billion $in the seventies, and to 93 billion $ in the eighties (Attoui, 2001, 2002; Ahmad, 1998; Farouk, 1994), "For example, the area prone to flooding in France is not less than 1/10 of the total area, where the cost of losses resulting from the flooding is of 230 million Euros per year which adding to the 74% of municipalities exposed to flooding and 3 million inhabitants located in the threat zones" (Chikouche, 2008).

Algeria, like other countries of the world, is subject to many risks, where reports indicate that recent flooding caused the collapse of 400 houses in minutes. In Adrar alone, the number of families affected is 100 in addition to the losses in agriculture. On November 10, 2001, a black day in the history of Bab El Oued in the capital, torrential floods left about 733 casualties and the destruction of many of the facilities and infrastructure. Similar

is the case of the recent floods of Ghardaia, on October 30, 2008. The earthquake of May 21, 2003 in Boumerdes, where 2278 persons were killed, 130,000 remained homeless and losses were estimated at 100 million $, exposed the fragility of the urban fabric and the lack of planning in the field of disaster management and risk (Attef, 2002; Traves, 1997; Mohamed, 1996).

The diversity of its natural terrain, induced by the nestling of the city between the mountains as well as by the hydrographic network density and the sand dunes besetting them, make the city of Bou Saada an area prone to flooding, desertification and rockfalls, as well as to environmental hazards, the most important of which is pollution caused mainly by waste and sewage. The latter one has become a concern for residents of the city, where the lack of management increased the gravity of the situation especially in conditions of chaotic and unplanned neighbourhoods.

In the light of what has been stated, the major problem is the presence of most of the urban agglomerations in areas prone to natural hazards, and several other problems, including:

- the deterioration of the situation of urban neighbourhoods in the city of Bou Saada and the overall shape of the urban fabric;
- implications of natural hazards occurring in the non-built-up space of the city .

The overall objective of the study is to understand how to deal with natural hazards in the urban area through:

- inventorying natural hazards and determining their impact on the urban domain;
- protecting urban communities from the effects of natural hazards.

The study is based on two hypotheses:

- the hypothesis of urban nature: chaotic neighbourhoods are the most vulnerable to natural hazards;
- the hypothesis of regulations and management: the neglection of natural hazards as a compulsion in the decision making process while initializing urban agglomerations, with the absence of techniques for the management of urban disasters caused by these threats.

The study has adopted a descriptive and analytical methodology to address the problem of management of natural hazards in the city of Bou Saada, describing the phenomena to be studied and determining the causes and effects to validate the hypotheses.

2. Management of natural hazards

2.1. Means of managing of natural hazards

In the early nineties analysis and management tools appeared, in particular Geographic Information Systems (GIS), Remote Sensing, digital elevation models (DEMs). Being the most widely used framework in new risk approaches, serving for data collection and inventory and estimation of hazard patterns based on multiple criteria, the Geographic Information Systems (GIS) are an important tool in the management of emergency situations. Their importance lies in the speed of defining damaged items in areas of risk and of defining multiple places for the event in a very short time. They are also known as IT tools working on the definition of the environment and on the management and exploitation of local data through the integration between machines and networks, operating systems and database information.

The specialists in geographic maps also confirm the role of geographic maps in the management of technological dangers in the centers of urban systems, the maps serving as a pillar in the definition of the central danger. They also propose analytical maps in scale 1/25000 which are related to the type of risk and commend the establishment and use of compositional maps which combine natural hazard and technological risks (Chorowicz, 2007; Grecu, 2002, 2009; Grecu et al, 2012 a, b; Moral, 2006 etc).

2.2. Management of natural hazards according to the Algerian law

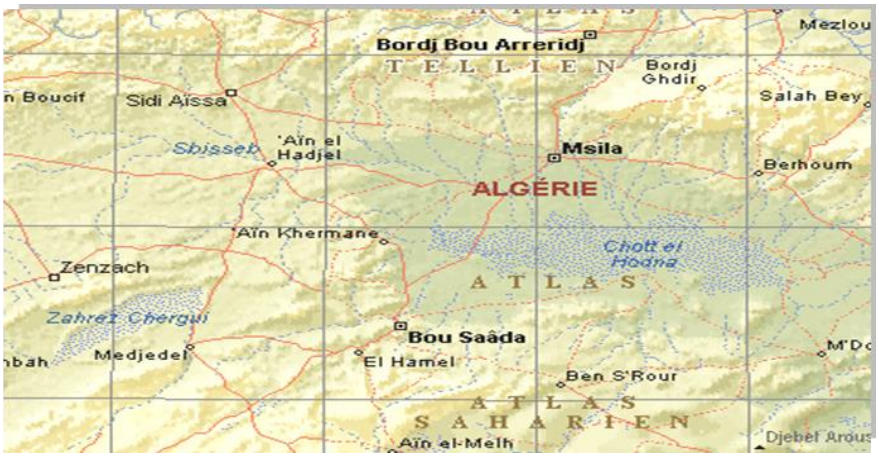
The Law 04-20 of the 25th December 2004 on risk prevention and disaster management in the context of sustainable development, consisting of 75 legal items, aims at enacting rules of prevention of major risks and managing disasters in the context of sustainable development. Article 9 states that the law is a comprehensive system initiated and supervised by the state, implemented by public institutions and regional groups, in consultation with the tradesmen, economists and social scientists and the involvement of citizens. This system aims at (M. H., 1990, 2003, 2004, 2006):

- improving the knowledge of the threats and promoting their control as well as the media development of preventive measures against these threats;
- taking into account the threats in land use and construction and reducing the exposure of persons and property;

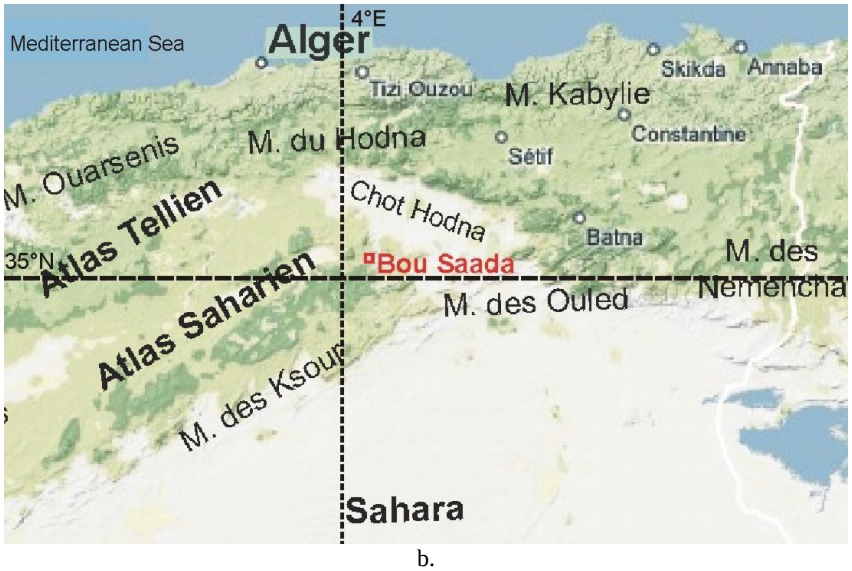
- designing harmonious and integrated and adapted management works to every disaster.

3. Study area

The municipality of Bou-saada is administratively situated in the southern part of M'sila. It is bounded to the north by Ouled Sidi brahim, to northeast by Maarif, to the east by the Houamed municipality, to the west by the municipality of Tamsa, to south-east and south-west by the municipalities of Oultem and El-Hamel. It covers an area of 255 km^2 with a population 143 236 inhabitants and a population density estimated at 483 inh/ km^2 according to figures of 2008. It is characterized by the strategic location in terms of its presence on the axis of the National Road 08 Algiers – Bou Saada and National Road 46 Biskra - Djelfa , i.e. between the north and the south of Algeria (Salamani, 2009; Faid, 2009; Nouibat, 2009) (Fig. 1).



a. (source: URBA, 2005)



b.

Fig. 1. **The administrative (a) and geographic (b) location of the Bou Saada city**

4. Applied research study

Bou Saada city occupies the slopes of north-eastern Ouled Nail mountains in the Saharian Atlas between blocks of mountain in the north and north-west as well as in the south and low-lying areas in the south-east and east. It is located in the southwest of the Shot El Hodna basin, on the East longitude of 4.11° and North latitude of 35.13° (Fig. 1).

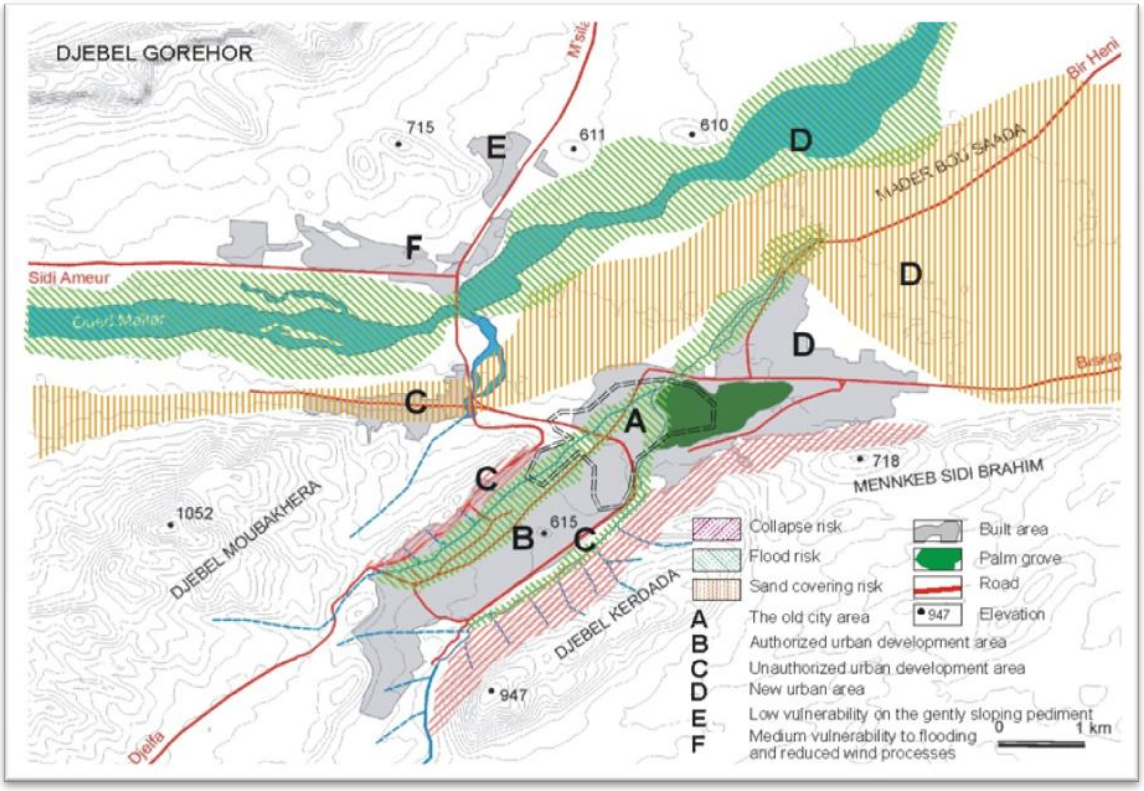


Fig. 2a. **The vulnerability map of the Bou Saada city** (after Grecu et al., 2012)

Fig. 2b. **Slope-related hazards**

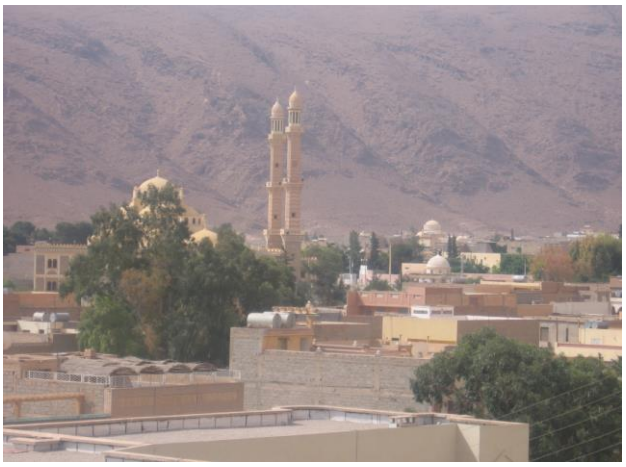
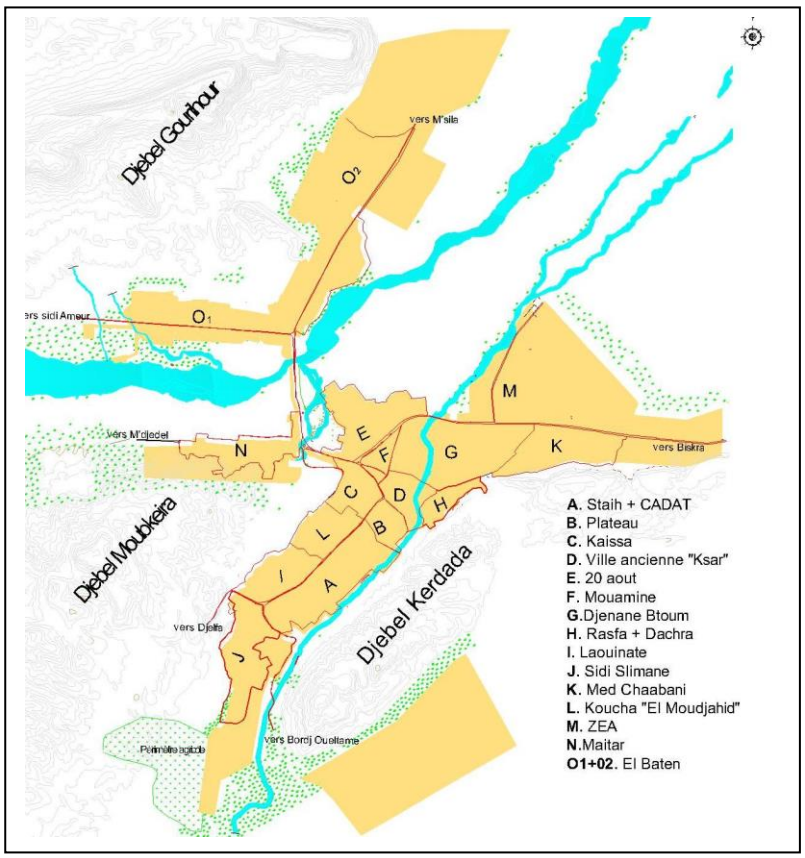


Fig. 2c. **Old city of Bou Saada**

Table 1. **Elements at risk by natural hazards in the urban agglomeration of Bou Saada**

Neighborhood	Urban data					risk %	AR (ha)	BR (ha)	NBR (ha)	PR	DR
	TDA (ha)	DBA (ha)	NBD (ha)	NP	ND						
Sidi slimane	104	30	84.2	22771	3946	RI	41.6	25.6	30.5	5921	846
						RE	12	3.46	8.54	2626	1138
Louainet	71.2	23	48.2	8731	1247	RI	38.1	12	26.1	4555	651
						RE	8	2.6	5.4	987	141
Maitar	30.2	15	15.2	1400	200	RI	16.2	8.1	8.1	756	108
						RE	12.2	6.1	6.1	559	81
Koucha andKaissa	55.2	29	26.2	19694	2188	RI	27.49	14.4	13.03	9779	1086
						RE	8.2	4.3	3.9	5433	601
Dachra and Rasfa	41.9	16.4	25.4	8362	1063	RI	8.8	3.4	5.4	1733	220
						RE	15	6	9	3059	389
Djnan Btoum	119	3.8	115.2	1741	229	RI	15.36	0.5	14.86	229	30
						RE	/	/	/	/	/
Mouamine	38.2	11	27.20	6609	944	RI	12.20	3.50	8.70	2102	316
						RE	/	/	/	/	/
20 Aout	80.5	25	55.8	12720	1817	RI	20.9	6.5	14.4	3307	472
						RE	/	/	/	/	/
Staih and CADAT	130	38	92	17132	2447	RI	20.6	13.33	7.27	2646	378
						RE	/	/	/	/	/
Mohmed Chabani	90.7	25	65	1054	1506	RI	21.3	5.8	15.5	1446	349
						RE	13.2	3.63	9.57	1530	219
Ksar	27.1	16	11.1	5739	1187	RI	9.3	5.6	3.7	2009	415
						RE	/	/	/	/	/
Plateau	61.5	25	36.5	4963	109	RI	20.6	13.33	7.27	2646	378
						RE	/	/	/	/	/



Legend:

TDA: Total District Area
DBA: District Built-up Area (in hectar)
NBD: Non-built district area (in hectar)
NP: number of people
ND: number of dwellings
AR: area at risk
BR: built-up area at risk
NBR: non-built-up area at risk
PR: people at risk
DR: dwellings at risk
RI: flood risk
RE: risk by rockfalls

Fig. 3. **Location of the Bou Saada neighborhoods**

In this part, the most important natural hazards, that urban agglomerations in Bou Saada are exposed to, have been identified. In order to verify the hypotheses put forward, the hazard ratio for each district was computed, the current status of urban agglomerations and the extent of exposure to natural hazards have been identified, focusing on floods, rockfalls and desertification (Figs. 2, 3, 6-10).

Through the analytical study of natural hazards and environmental factors that affect the urban space in the neighbourhoods of Bou Saada, threat zones, that increase the disaster-caused loss of material and human resources, have been identified. This zoning relies on important terrain maps of the city: the 1956 military map, the 1972 and 2009 aerial photographs and the Director Plans and the Bou Saada city Urban Plan. From the historical evolution of neighbourhoods of Bou Saada it became obvious that the expansion of these neighbourhoods was not adopted in the master plan that identifies the reconstruction rules. As a consequence, unplanned (chaotic) neighbourhoods appeared which do not respect the barriers between urban space and natural areas, therefore allowing the infiltration of natural threat zones into the urban system. The study results prove that the proportions of natural threats are significantly higher in the unplanned neighbourhoods than in the planned ones, due to their location between the mountain foothills, valleys and dunes, where a larger share of the area at risk is included (flood risk, risk to rockfalls in the presence of the steep slopes and desertification risk).

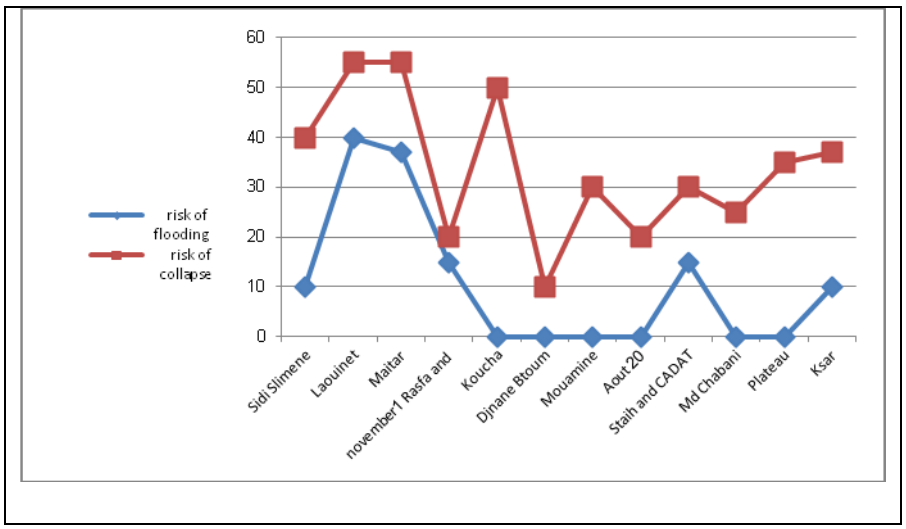


Fig. 4. **Percentage of the flood risk and rockfall risk at the level of city districts**

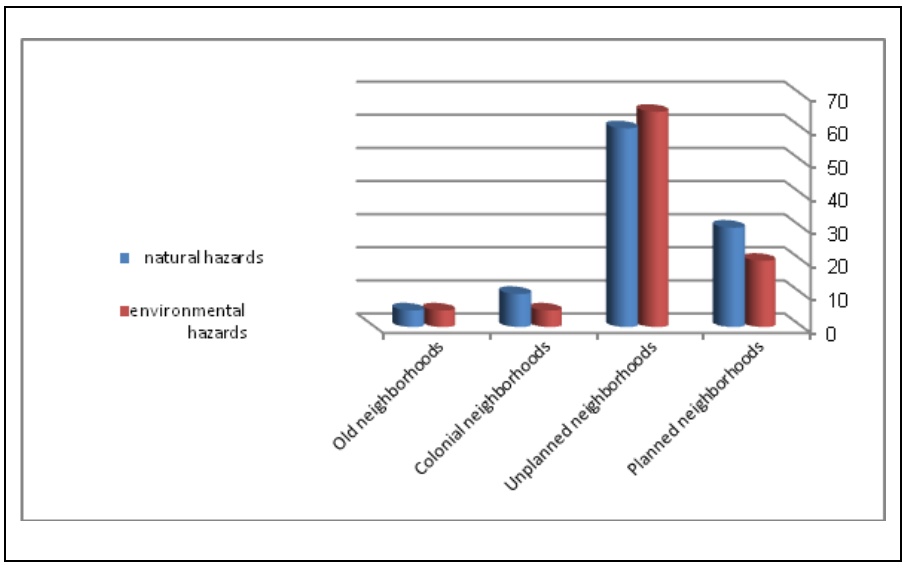


Fig. 5. **Natural and environmental hazards for different neighbourhood of the Bou Saada city**

Figures 4 and 5 illustrate the ratios of natural hazards in the neighbourhoods of Bou Saada, demonstrating that the proportion of natural and environmental hazards are higher in the unplanned (chaotic) neighbourhoods. This validates the hypothesis that the marks of anarchism are the most vulnerable to natural hazards. The exposure to natural hazards in planned neighbourhoods also validates the second hypothesis of the neglection of natural hazards during the completion of the the initialization and reconstruction schemes of Bou Saada (Figs. 4 and 5).

5. Conclusions

Based on the results of the analytical study of the Bou Saada neighbourhoods in terms of natural hazards, the identification of areas prone to the severity of the risks and according to the law easements within the disaster prevention law 04-20, we advance a set of suggestions and recommendations that will limit the risks (human and material losses) resulting from the hazards affecting the urban agglomerations of the city (Table 1, Fig. 3):

A - Areas located in slopes:

- In sands areas, areas located in on valleys´ banks and hazardous slopes, where the severity of the risk is stronger, communities must be protected from sand burying as well as through the foundation of bilateral channels for sewage and storm water drainage. These recommendations should be applied to some neighbourhoods like the Maitar and Sidi Slimane districts, where the sand and debris materials have their origin on the mountains slopes.
- The conversion of the steep slopes to nature reserves (afforestation) would provide benefits through the allocation of internal recreational spaces to the residents of a particular neighbourhood and to the city's population in general.
- The establishment of a supporting wall along the edges of the Maitar valley.

B - Areas at risk to rockfalls should be protected by a completion belt along the mountain in addition to the establishment of a strip of landscaping.

C - Areas prone to the risk of skidding vehicles:

- Works for the completion of an external belt with a length of 4.41 kilometers from the junction leading to Algiers to the road leading to Djelfa behind the Azzedine Mount. This would reduce the sliding trucks on the road and turn the way to a utilitarian motorway. This is the case according to the director and urban plans of the Bou Saada city for the year 2008.

Taking into consideration the establishment of green and forested areas and green belts on the outskirts of the city in the north-eastern side (20 Aout district, Mohamed Chaabani district, 1-ZEA 01 activity and storage area, "North West" Maitar district, 2 -ZEA 02 activity and storage area.

Fig. 6a. **The Maitar Oued**

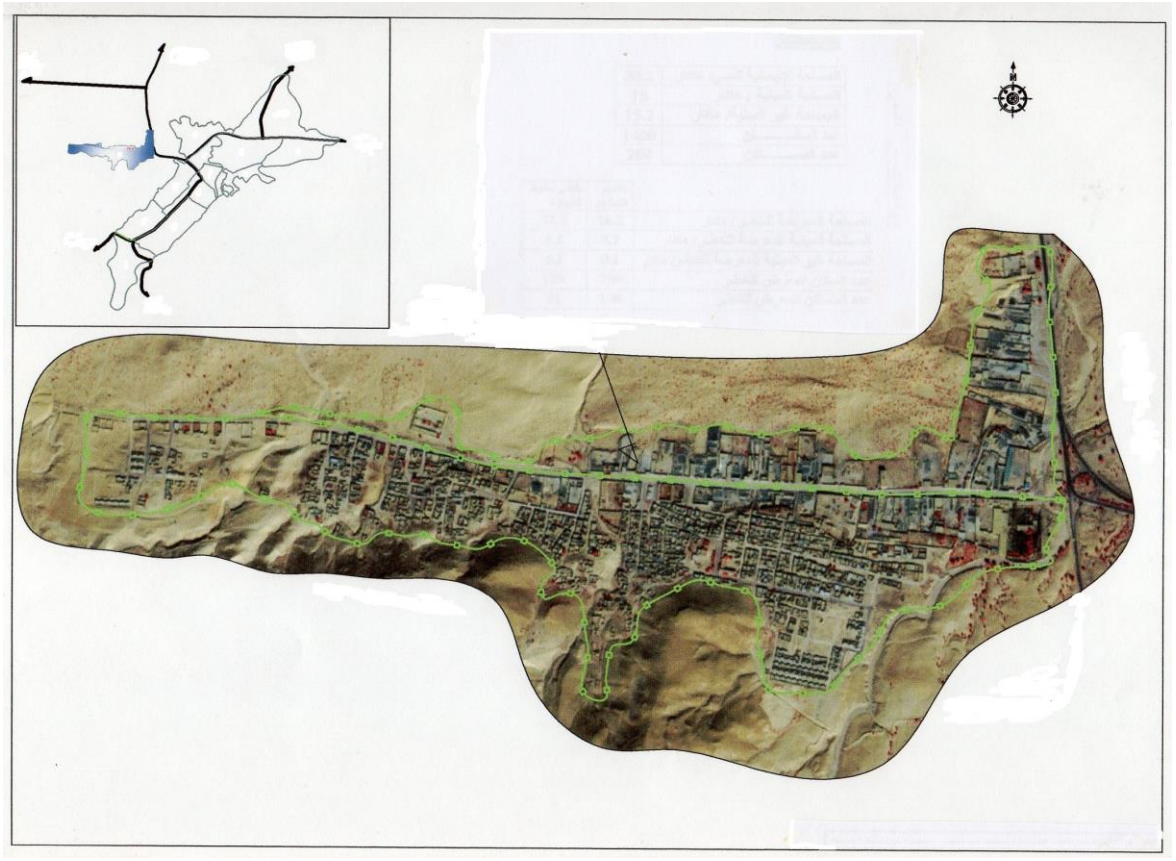


Fig. 6b. **Aerial view of the Maitar district**

Fig. 7. **Aerial view of the Koucha and Kaissa districts**

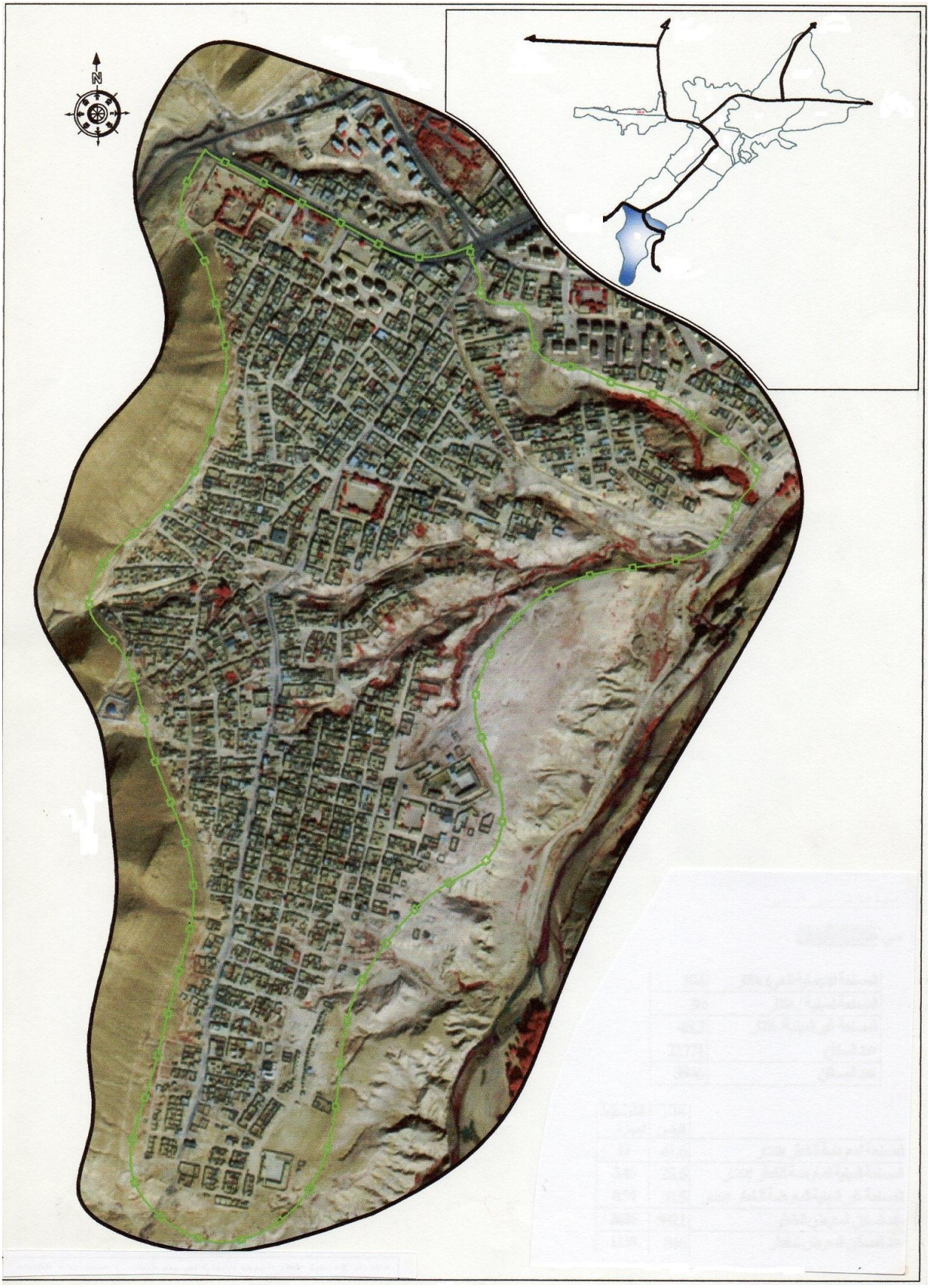


Fig. 8. **Aerial view of the Sidi Slimane district**

Fig. 9. **River pollution**

Fig.10. **Degradation of oasis vegetation**

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