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VULNERABILITY AND ADAPTATION STRATEGIES TO CLIMATE CHANGE ON WATER RESOURCES AND AGRICULTURE IN MOROCCO: FOCUS ON MARRAKECH-TENSIFT-AL HAOUZ REGION

[1]Kholoud KAHIME*, [2]Abdelkrim BEN SALEM, [3]Abdelmonaim EL HIDAN, [2]Mohamed MESSOULI & [4]Abdelghani CHAKHCHAR*

[1]Laboratoire des Sciences Appliquées à l'Environnement et au Développement Durable, Ecole supérieure de Technologie, Essaouira, Université Cadi Ayyad, Marrakech, Maroc,

[2]Laboratoire d'Hydrobiologie, Ecotoxicologie et Assainissement, Faculté des Sciences Semlalia, Université Cadi Ayyad, Marrakech, Maroc,

[3]Faculté des Sciences Semlalia, Université Cadi Ayyad, Marrakech, Maroc,

[4]Laboratoire de Biotechnologie et Bio-ingénierie Moléculaire, Faculté des Sciences et Techniques Guéliz, Université Cadi Ayyad, Marrakech, Maroc.

*Corresponding Author

ABSTRACT

The ecological, environmental and socio-economic importance of the Marrakech-Tensift-Al Haouz region in Morocco faces several challenges to climate change. This region suffers mainly from water scarcity and unsustainable management of water resources. Nonetheless, the institutional and technological solutions dedicated are insufficient. Thus, the demographic pressure and anthropogenic actions on the resources of the region are worsening the effects of climate change. This study is based on field observations and interviews with population and stakeholders. We also proceeded to trace a profile of environmental vulnerability Marrakech-Tensift-Al Haouz by calculating the environmental vulnerability index (EVI), using 50 indicators to capture the key elements of environmental vulnerability. In a way, our approach consist to contribute to identify the perception levels of local population and stakeholders and to assess their different strategies to adaptation as well as the level of the policy makers involvement in the fight against climate change. According to this study, we recorder a score of EVI=318 classifying Marrakech-Tensift-Al Haouz as a region at risk and highly vulnerable. Moreover, the indicators related to the human activities showed that the anthropogenic effects in the region are greater than induced by climate change. These imbalances are often worsened by lack of governance and supporting legislative tools. Increasing pressure on water resources in the region encompasses various challenges: Ecological, Governance and Socio-economic challenges.

Keywords: Marrakech-Tensift-Al Haouz, Vulnerability, Sustainability, Climate change, Water resources, Environmental vulnerability index

1. INTRODUCTION

In arid and semi-arid Mediterranean regions, including Morocco, the scarcity of water resources is nothing new (De Châtel et al., 2014). In fact, Morocco has not been spared from the known droughts that have affected the Mediterranean basin in recent decades, manifesting themselves particularly in a severe and persistent manner, and with remarkable extent (Sebbar et al., 2011). Morocco has experienced rainfall deficits, leading to severe drought with significant imbalances of water resources in the country, quantitatively and qualitatively. Several regions of Morocco have experienced a series of dry periods since early 1980 resulting to significant economic consequences (Driouech, 2010).

Indeed, Morocco has experienced significant increase in temperatures during the period between 1961 and 2008 with a general trend toward droughts being observed. Most annual trends are between 0.2°C and 0.4°C per decade (Driouech, 2010) and decreased rainfall is almost the case throughout the entire Moroccan territory. Grâce à l'étude des écarts de précipitations par rapport aux précipitations annuelles moyennes au Maroc (1934-2000), des précipitations irrégulières et une diminution significative de l'approvisionnement en eau depuis 1980 ont été enregistrées (Amraoui et al., 2004).

Global climate change scenarios indicate an increased trend of the occurrence and impact of droughts in the near future (Watson et al., 1997). As climate change becomes more prevalent globally, the future availability of water resources for human consumption, agricultural production, and manufacturing becomes more uncertain (Woznicki et al., 2015; Holzkämper, 2017). Several other studies of future climate projections using climate models show that Morocco is one of the countries that are most likely to be affected by climate change and would record a reduction in cumulative rainfall by the end of the current century (IPCC, 2007). Climate projections by the National Directorate of Meteorology predict an increase in average summer temperatures by 2°C to 6°C and 20% reduction in average rainfall by the end of the century. This data can reflect a negative impact on Moroccan agriculture, particularly in Marrakech-Tensift-El Haouz region. This region is located in mid-west Morocco, which contains the High Atlas Mountains that act as a hydraulic reservoir and the semi-arid central plain of Haouz, which benefits of the Oueds tributaries. Agricultural irrigation accounts for more than 85% of water uses (ABHT, 2015). The climatic regime of the watershed is arid, essentially conditioned by altitude and to a lesser extent by the continentality (Riad, 2003). Rain is often concentrated

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during fall and winter. It is generally irregular and intense. Concerning the water resources of the region, the specific contributions of the aquifers are globally evaluated at 326 Mm^3. The Al-Haouz aquifer represents almost two-thirds with 196 Mm^3 and 49 Mm^3 for the Bahira. The water balance of the aquifers shows a deficit of -149.6 Mm^3. With the aquifers of Essaouira Province, all the other aquifers are deficient and present a state of overexploitation rather advanced. The case of the Haouz and Bahira aquifers are the most representative, with a total mobilization volume of approximately 795 Mm^3/year, the total discharge volume was 954.6 Mm^3 (MEMEE, 2015). In fact, the sustainable management of land and water resources in arid and semi-arid regions is of concern as a result of increased population pressure and the need for more food and fiber (Sakadevan and Nguyen, 2010). The present study deals with the assessment of climate change risk, impacts and adaptations strategies to agriculture and irrigation in the Marrakech-Tensift-Al Haouz region (Morocco).

2. MATERIALS AND METHODS

2.1. STUDY AREA

Marrakech-Tensift-Al Haouz is formerly and administratively divided into six prefectures and provinces; including the entire prefecture of Marrakech and Al Haouz, Chichaoua and Essaouira provinces, and parts of the provinces of El Kalaa des Sraghna and Safi. Due to its size, landscapes and topography, the region is characterized by a highly differentiated climate zones, influenced by both the distance from the sea and the closeness to the Atlas Mountains. Consequently, its climate is semi-arid with a winter influenced by the cold Canary Current in the Essaouira region, semi-arid continental to semi-temperate in the Bahira plain, hot semi-arid in Jbilet and Mouissate, and arid continental in the Haouz and Mejjate plains.

The Tensift river basin is one of the most important watersheds of Morocco where significant socioeconomic activities are developed, including agriculture and tourism. It is surrounded by the crest of the High Atlas Mountains on its south side by the small mountains called "Jbilet" on its north side, by the watershed line on the east and by the Atlantic Ocean on the west where the outlet is located (Figure 1). This Tensift watershed covers an area of 20,450 km².

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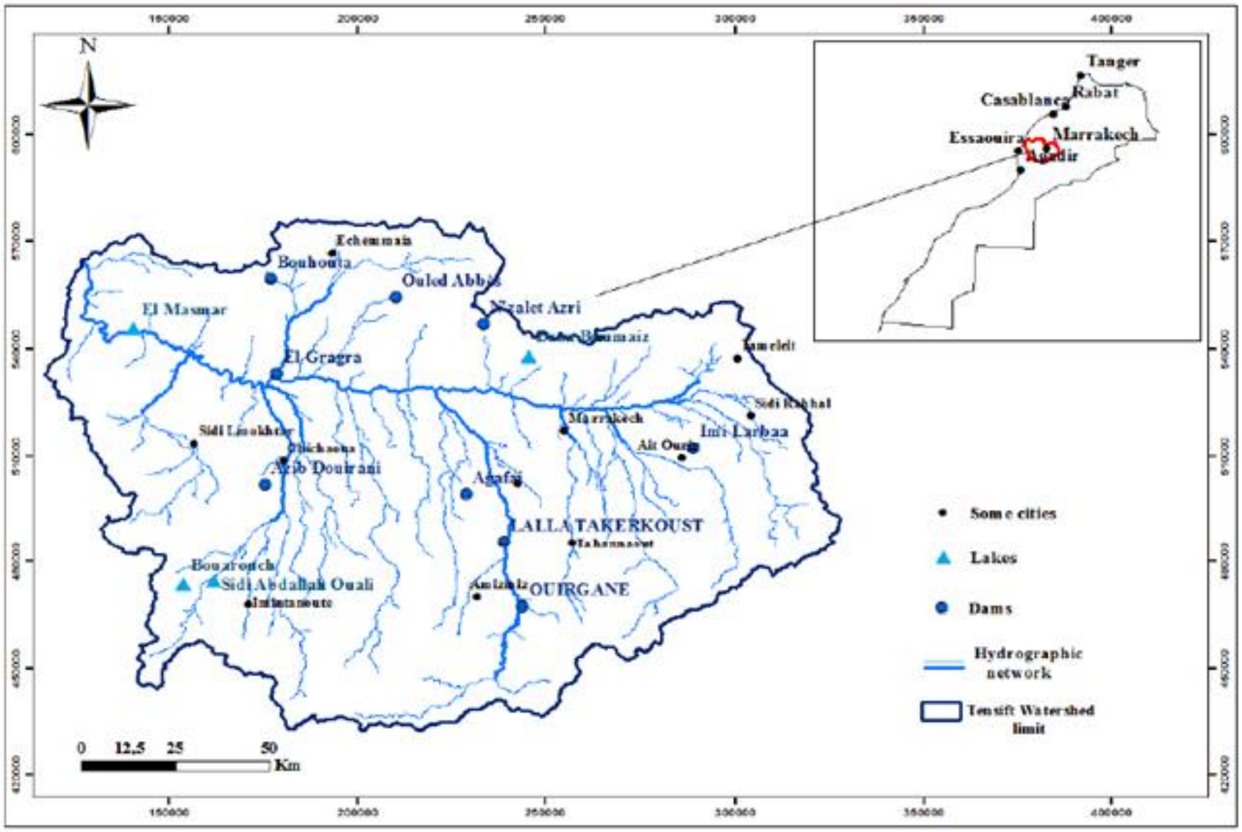

Figure 1: Presentation of the Tensift watershed in the Marrakech-Tensift-Al Haouz.

2.2. DATA

The data used were provided by several sources including the Regional Office of Agricultural Development of Marrakech (ORMVAH), which own meteorological stations in several centers of agricultural development (CMV), scattered throughout the Tensift watershed; the Hydrological basin agency Tensift website (ABHT); the Food and Agriculture Organization (FAO); the Moroccan Ministry of Environment and the data we collected based on our survey with farmers on climatic risks and its potential impacts. We collected irrigation data (available for 2014) from seven farms located in the study area.

A database has been established for the region of Marrakech-Tensif-Al Haouz to evaluate the selected indicators. The raw data availability for EVI is classified by sector (Table 1), the percentage are determined by the EVI application after data entry. Total availability of data is 98%.

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Table 1: Data availability related to sub-indices in Marrakech-Tensif-Al Haouz region.

Policy-relevant sub-indices	Data availability (%)
Climate Change	100
Exposure to Natural Disasters	100
Biodiversity	100
Desertification	100
Water	100
Agriculture / Fisheries	95
Human Health Aspects	100

2.3. METHODS AND PROCEDURES

The input environmental variables were processed using the GIS software (ArcGis v.10). These variables are as follows: 1) air temperature (minimum and maximum) and precipitation that were both downloaded from World-clim data-base. 2) The normalized difference vegetation index (NDVI) (minimum, mean and maximum) Moderate Resolution Imaging Spectroradiometer (MODIS)'s vegetation index product (2014 series data). 3) Elevation map downloaded from the database of the www.Cartograf.fr website that offers all the geographical maps from around the world. 4) Bioclimatic zones metadata map were downloaded from the website of Moroccan Ministry of Energy, Mines, Water and Environment (http://www.environnement.gov.ma/index.php/fr/bd/bd-onem) and 5) soil texture shapefile was extracted using the Food and Agriculture Organization soil map that covers the study area. For that, we converted the FAO classification into type of textures using the table of components in sand, silt, and clay. The results were given in 10 maps, each depicting the distribution of the corresponding factors that might impact the water resources and agriculture in study area.

The EVI is based on 50 indicators for estimating the vulnerability of the environment of Marrakech-Tensift-Al Haouz region to future shocks. Indicators were specifically selected to ensure that information on three aspects (risks associated with hazards, resistance and acquired vulnerability (damage)) is incorporated into the measure of the overall vulnerability of countries. There are 32 indicators of hazards, 8 of resistance and 10 that measure damage. Data for each indicator is located within an EVI scale which ranges between 1-7, where the value EVI=1 indicates low, while, EVI=7 indicates extreme vulnerability. After the EVI Calculator (www.vulnerabilityindex.net/), the 50 indicators are grouped into seven sub-indices. The climate change indicators include 13 indicators, the Biodiversity (19 indicators), the Water (12 indicators), the Agriculture/Fisheries (20 indicators), Human Health Aspects (6 indicators), Desertification indicators (11 indicators) and Exposure to Natural Disasters (11). For most indicators, signals are based on average levels observed over the past 5 years, but may include

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data for much longer periods for geological events. EVI requires a minimum of 80% of data returns over the 50 indicators for a valid environmental vulnerability index evaluation.

3. RESULTS AND DISCUSSION

The Intergovernmental Panel on Climate Change (IPCC) report indicates that the warming of the climate system is unequivocal as is now proved by observations of increases in global mean air temperature (IPCC, 2013). The report emphasizes on decrease in precipitation and moderate climate change in the entire Mediterranean basin including Morocco. In a scenario of moderate climate change, the poor and landless agricultural based population of rural areas is the most vulnerable to these climatic changes (FAO/IFAD, 2006). These moderate changes affected the demand and supply chain of food and water, resulted into potential catastrophic environmental and socio-economic consequences (Imhoff and Bounoua, 2006), such as water scarcity will increase due to decrease in precipitation and high demand of water of ever increasing population.

The patterns of precipitation (235 to 380 mm) showed maximum area under aridity condition with strongly affected by climate change and variability (Figure 2). During last decade, the variable temperature and decrease in precipitation heavily influenced the agriculture (Tanouti and Molle, 2014; MEMEE, 2015). In fact, the plain in our study region is an agricultural area of 52,000 hectares. Thus, a growing North-South gradient of precipitation was noted (Figure 2).

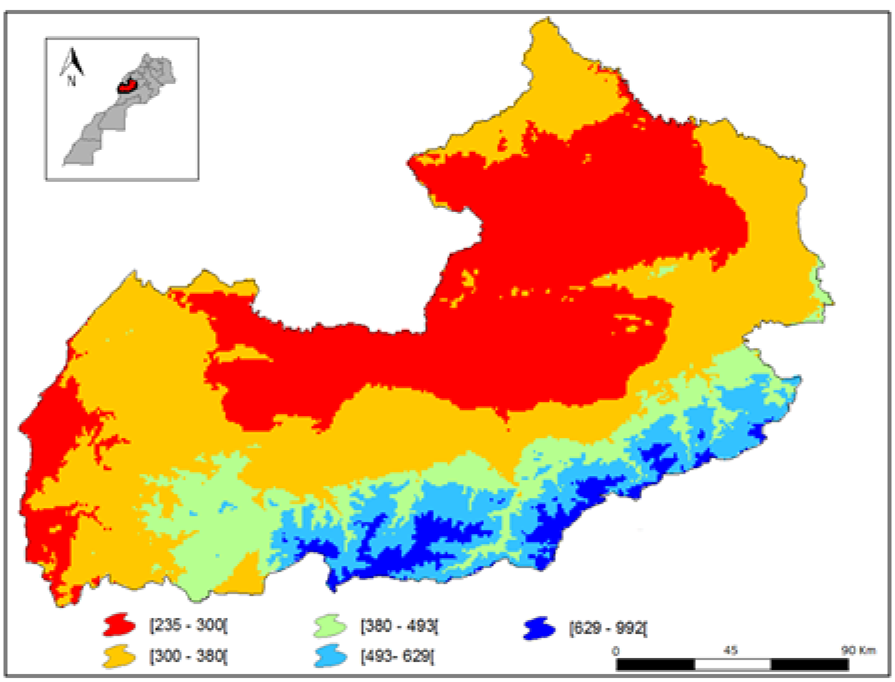

Figure 2: Map of annual precipitation (mm) in the Marrakech-Tensift-Al Haouz region.

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The precipitation rate is gradually increasing from plain to mountain range of High Atlas. Obviously, the precipitation is observed more in sub humid and humid climatic zones. (Figures 3 & 4)

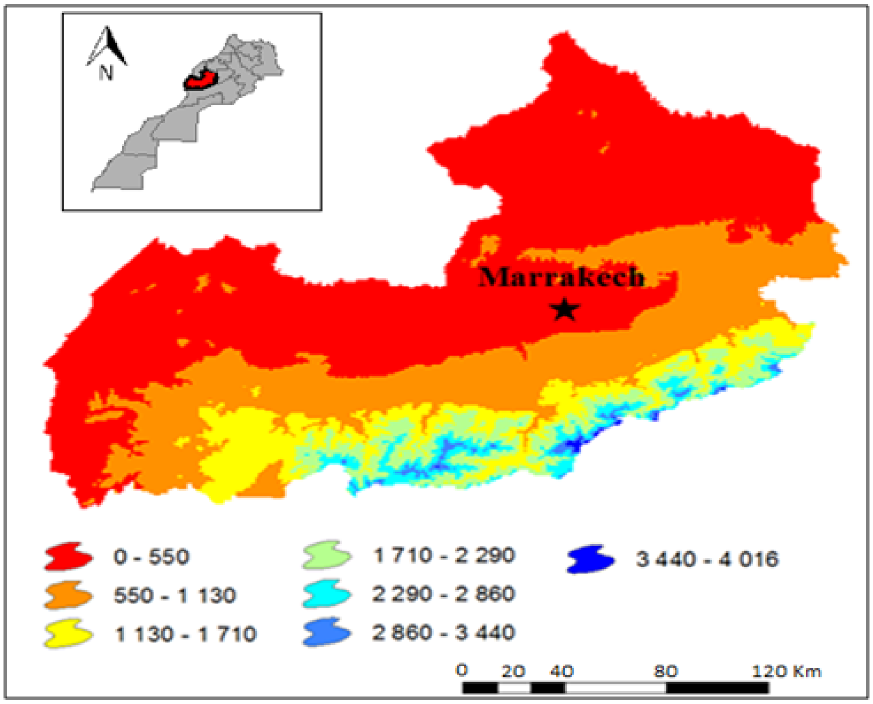

Figure 3: Map of altitude levels (m) in the Marrakech-Tensift-Al Haouz region.

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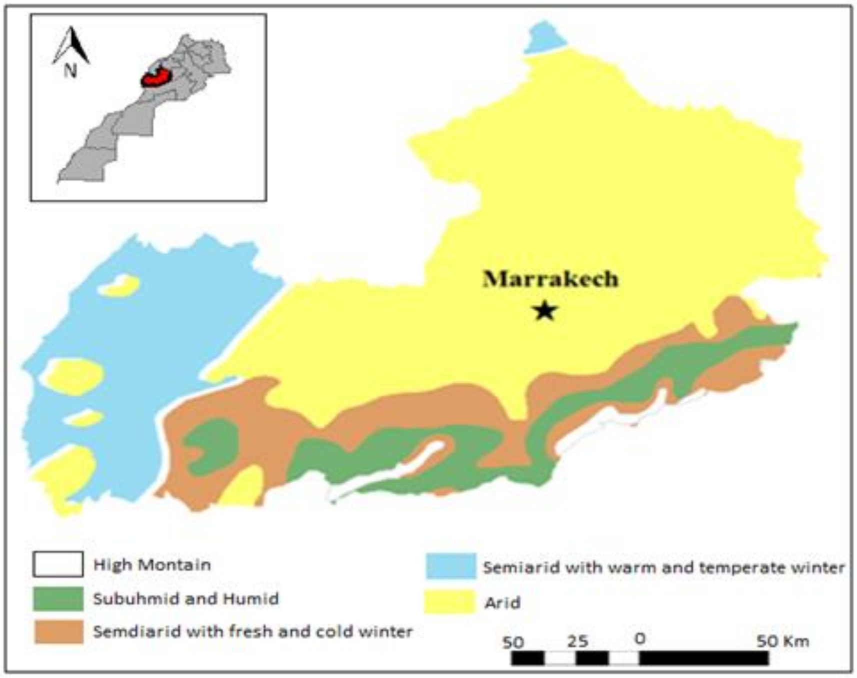

Figure 4: Map of Bioclimatic zone in the Marrakech-Tensift-Al Haouz region.

NDVI map shows uneven distributions of vegetation, the thicker vegetative formations are characterized by positive values of about 0.6 (Figures 5, 6 and 7).

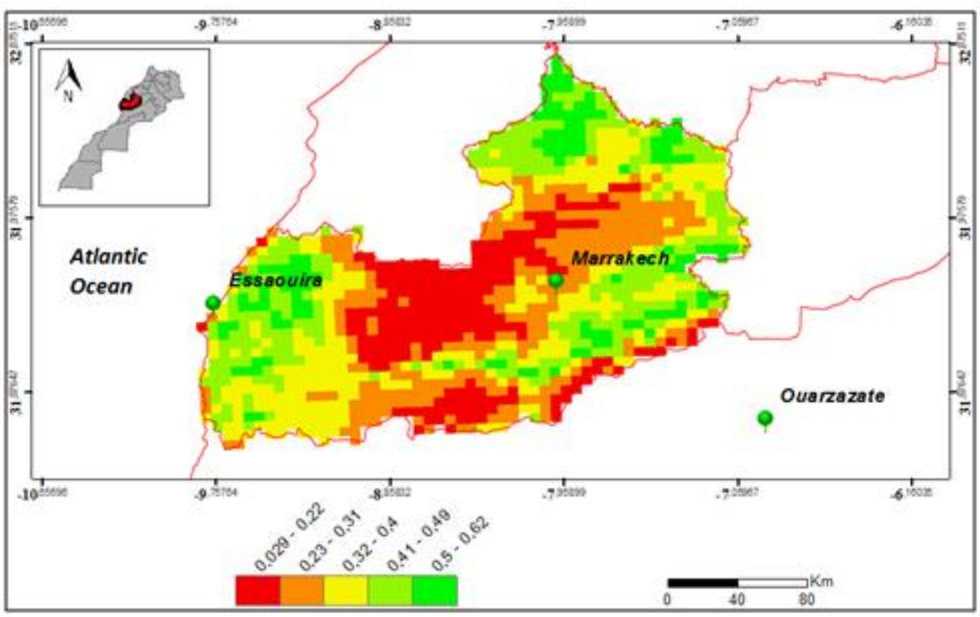

Figure 5: Map of NDVI max in the Marrakech-Tensift-Al Haouz region.

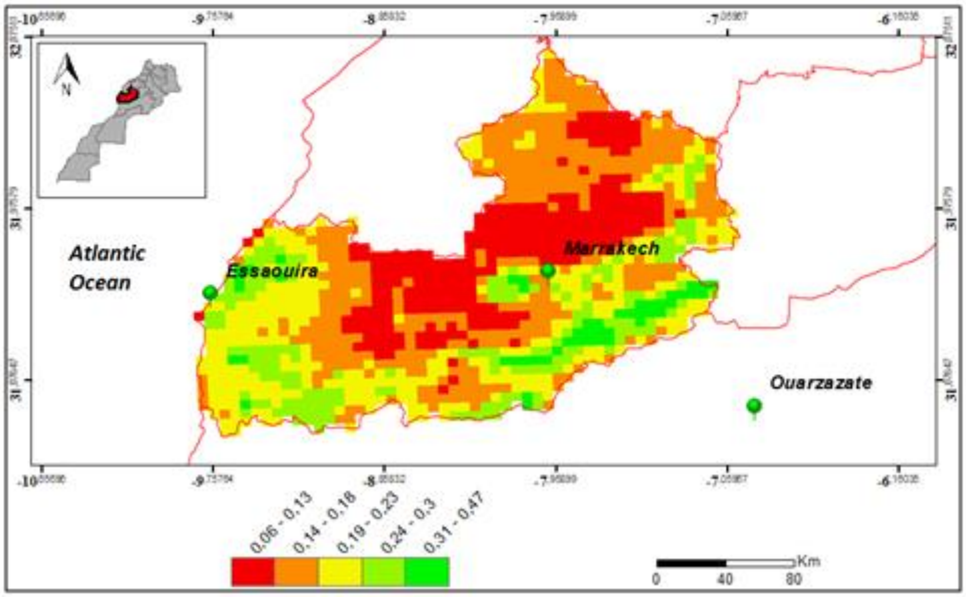

Figure 6: Map of NDVI min in the Marrakech-Tensift-Al Haouz region.

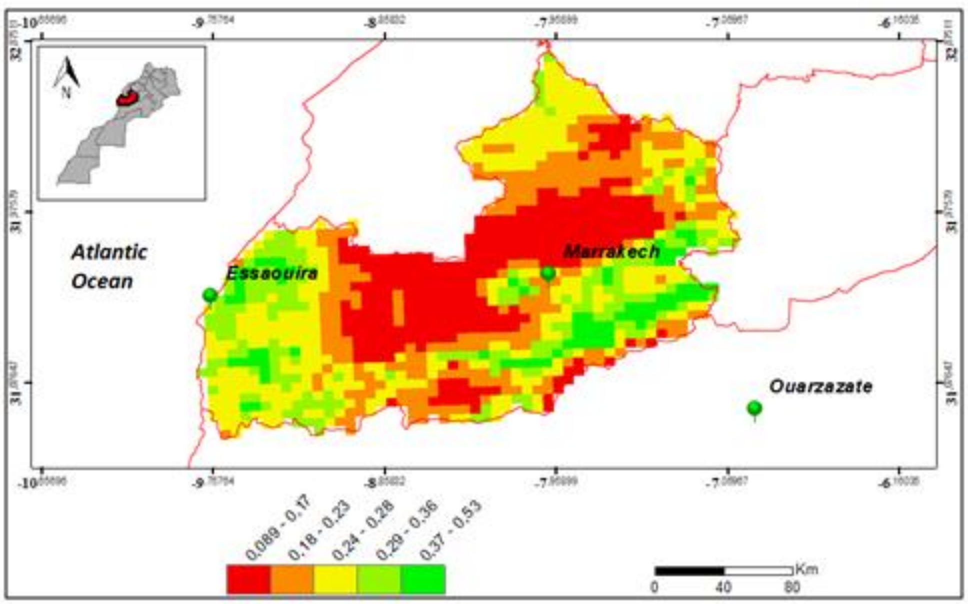

Figure 7: Map of NDVI mean in the Marrakech-Tensift-Al Haouz region.

These dense formations are located primarily in the Western coastal part, the North East part and the South- East part. This distribution is linked mainly to the crop land and agricultural activities. In the other hand, salinity is one of the main factors responsible for the degradation and reduced

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productivity of agricultural lands. The saline soils constitute an unfavorable environment for the growth of several crops (Sakadevan and Nguyen, 2010).

Globally, it is estimated that almost 800 million hectares of land are affected by salt, either by salinity (397 million hectares), or by sodic conditions associated with sodium levels (434 million ha). Indeed, salinity spans more than 6% of the total area of the planet (Manchanda and Garg, 2008), of which 3.8% are in Africa (Eynard et al., 2006). In Morocco, soil salinization affects nearly 500 000 ha and causes significant losses in agricultural productivity. Secondary salinization which is the form of degradation of the fastest soils in irrigated areas, affects about 160 000 ha or 16% of irrigated land (MEMEE, 2015).

The region of Marrakech-Tensift-Al Haouz in Morocco is characterized by a semi-arid to arid climate with low rainfall. The low rainfall compels farming community to use unfit underground water for irrigation and resultantly soils are becoming problematic for agricultural activities in the coming years. (MEMEE, 2010b). The classification of soils based on texture is shown in Figure 8, indicates more soils with texture in sandy clay loam and sandy loam as compare to loamy and sandy soils in Morocco (Xiaopeng et al., 2014).

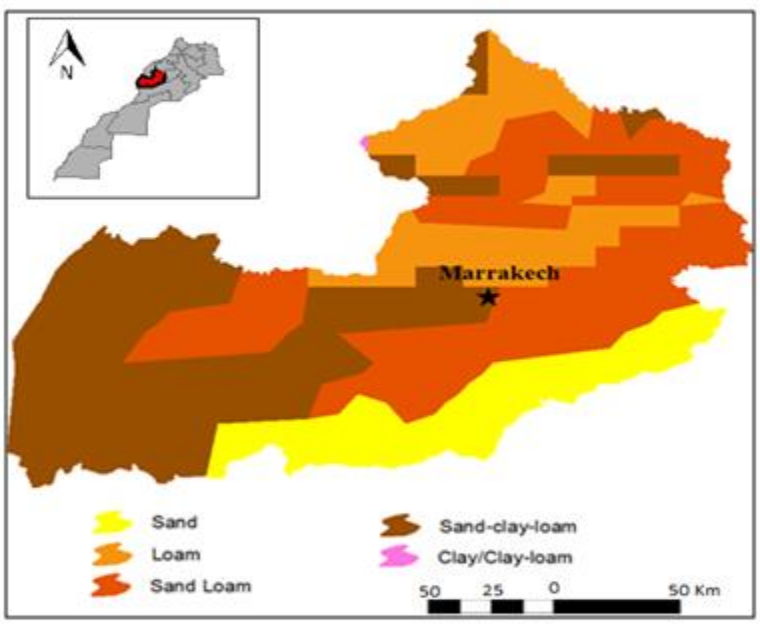

Figure 8: Map of soil texture in the Marrakech-Tensift-Al Haouz region.

The distribution of irrigation water consists of complex hydraulic structures. During study and survey, several schemes and distributions were observed which were out dated. (Ouzine and Kharrou, 2004). The Haouz plain located in the river basin of Tensift has benefited for a long time from water for irrigation, evolving from traditional practices and tenures of using and sharing water among users to innovative processes built on modern techniques and structured institutions. This transition promoted by the State has led to profound changes in the allocation and sharing of water resources among various uses and users. Indeed, water management in the Al Haouz area becomes more sensitive and critical during periods of water scarcity induced by structural periods of drought. When the resource is limited, conflicts of uses and interests around the distribution and allocation of water become more pronounced and latent conflicts tend to be active ones. The results of study revealed the impact of climate change on water resources. These impacts resulted in drought and reduction in arable land. Thus, the region has a high intrinsic vulnerability that affects the underground and groundwater and natural river system.

Data related to water quantity in the study area showed that the Tensift flows, for the past four decades, are relatively irregular in parts of the foothills and downstream of the basin. This suggests that the impact of drought in the area of watershed Tensift tends to increase. Indeed, the decline in surface water intakes is increased by decreasing and erratic rainfall and the increase in temperature. In addition to the irrigation of the plain from these surface waters, the study area includes groundwater located in a shallow aquifer. Moreover, the surface waters are almost all mobilized, and a significant share of developed areas in the study region cannot receive all the water needed for irrigation. To overcome this deficiency, the use of pumping ground water thus intensifies and causes overexploitation. Mean decreases in water levels observed in 20 years were in the range of 0.8 to 1.6 m/year in the areas of N'fis and central Al Haouz and 0.2 to 0.5 m/year in the eastern sector (CSEC, 2001). The lack of rainfall in arid and semi-arid area, as the case of Marrakech-Tensift-Al Haouz region, limits considerably agricultural development despite the existence of large areas of arable land (Debbarh, 1995). Groundwater is then sought where available, with frequent risk of overexploitation. In this context, the estimation of pumping is essential information for rational management of water resources.

Based on surveys of farmers in the region, the majority of wells for irrigation have been overexploited during the last decades. This depletion of the ground water is accentuated primarily by reduced rainfall and increasing temperatures. In fact, the study area is known nationally for its agriculture. Actually, irrigated agriculture is an essential component of the region, in terms of economic development, with tourism and handicrafts. It requires more than 85% of the water consumption of the available water resources. This sector is considered as the main factor for regional development. However, considering the frequent droughts occurring during last 10 years, the available resources are currently insufficient to meet the demand in sustainable means. So, these changes and ever increasing population are problems for agricultural production systems, especially in the absence of balance between supply and demand (Holzkämper, 2017). Currently the agricultural industry is considered as the biggest user of water through irrigation, which represents about 70% of water consumption in the world

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(Fischer et al., 2007). According to cultivation practices, irrigation requirements were projected to increase by 40-250% by the end of the 21st century accompanied by decrease of water availability and increased evapotranspiration (Woznicki et al., 2015). Moreover, the increase in air temperature can induce a decrease of the water intended for irrigation and also increase atmospheric CO_2 concentrations that could have adverse effects on crop yields.

We proceeded to trace a profile of environmental vulnerability of Marrakech-Tensift-Al Haouz by calculating the environmental vulnerability index (EVI). EVI result for this region are organized as a single-page, information-dense report card (Figure 9). The information available on the report includes an overall EVI score in points, with percent of data over which it was calculated and a classification of overall vulnerability. The classification, shown in Table 2, quickly identifies whether the environment of a region is highly vulnerable overall.

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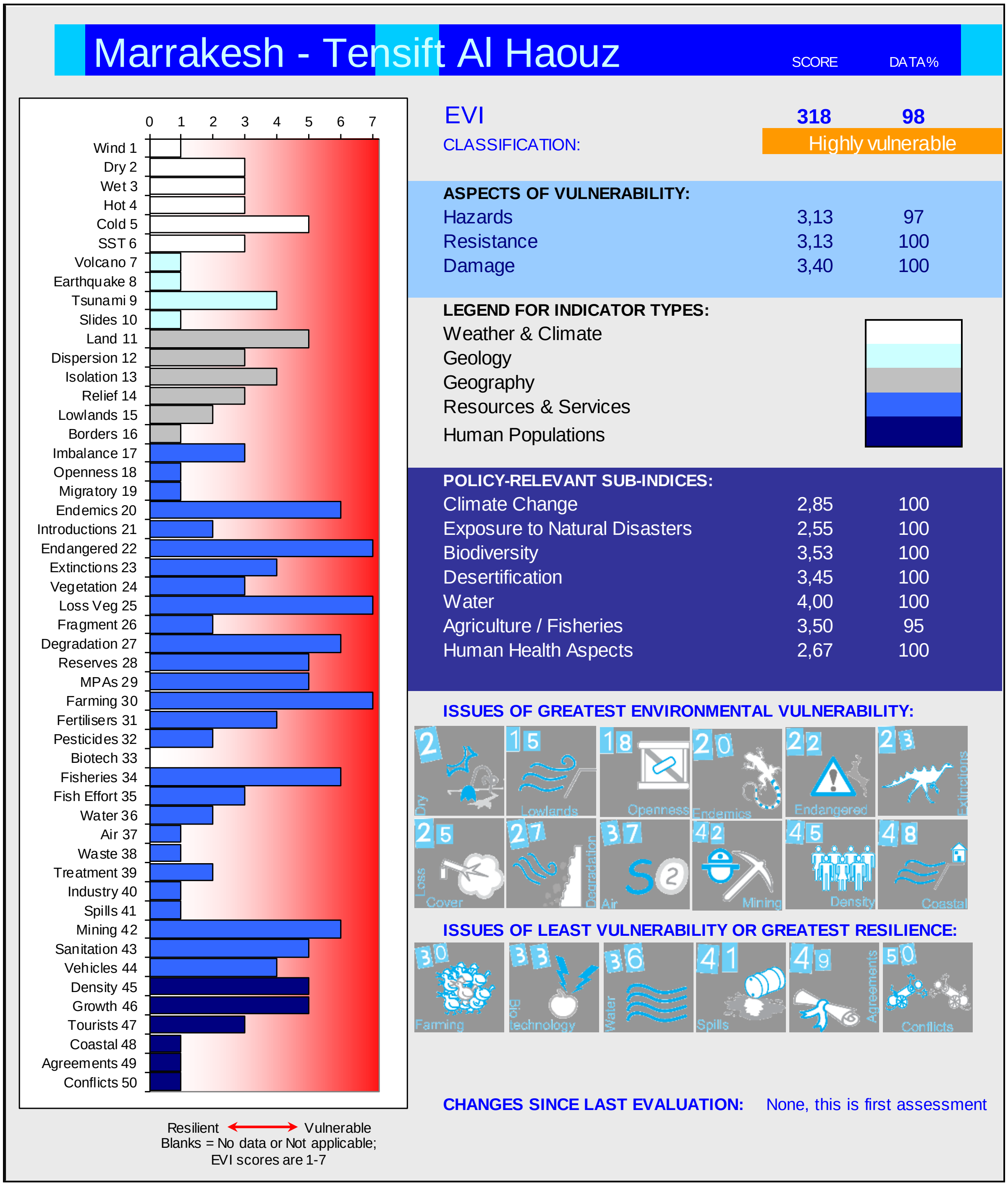

Figure 9: Environmental vulnerability index (EVI) profile and scores for the Marrakech-Tensif-Al Haouz region.

Table 2: EVI scores calculated (from www.vulnerabilityindex.net/).

1	Extremely vulnerable	365+
2	Highly vulnerable	315+
3	Vulnerable	265+
4	At risk	215+
5	Resilient	<215

According to this study, the region has a score of EVI=318, classifying Marrakech-Tensift-Al Haouz as a region at risk and highly vulnerable. This score differs significantly from the 287 value assigned to all of Morocco in the SOPAC report (SOPAC, 2005). EVI values for the sub climate index showed that there is a slight change in the last five years compared to the average of thirty years (1984-2014). These results are consistent with the fifth Assessment Report (AR5) of the IPCC (IPCC 2017) predictions. In this paper, we also extracted and compiled the score of each indicator for the studied region and rank them in sub-indices (Figures 9 & 10). The indicators with the highest scores were water followed by biodiversity, agriculture/fisheries and desertification. Regarding the "Water" indicator for this region; it indicates the risk to terrestrial and aquatic ecosystems. It focuses on sustainable use of surface free water and groundwater and damage through salinization, and extraction. On the other hand, irrigated agriculture is one of the main components of the economic development of the Haouz Plain, along with tourism and craft industry. It represents more than 85% of water consumption in the Tensift catchment. The dry climates, as well as the recurrent periods of drought during the past ten years, have led to an increase in the use of surface and ground waters, used mainly for irrigation (Abourida et al., 2008).

According to our results (Figures 9 and 10), the indicators that exceed value 4 are: Growth, Density, Sanitation, and Reserve with a vulnerability score of 5, Degradation with a vulnerability score of 6 and Loss of vegetation with a maximum score of 7. Density indicator or population density is a measure for pressure on the environment resulting from the number of humans being supported per unit of land and the production of wastes and physical disturbance of the environment (SOPAC, 2004). This indicator characterizes mainly the studied region. In this later, the anthropogenic activities have a greater impact than that induced by climate; it accelerates the process of vulnerability (Ben Salem, 2014). Nonetheless, the common vulnerability indicators are firstly the 'Human Population Growth' that is the damage caused by all human activities relating to the increasing rates of habitat damage, and the exploitation of natural resources, and secondly the 'Tourists' indicator which is associated with international visitors. Tourists place additional pressure on the environment through increasing demands on local resources and through chemical and physical disturbances of the environment.

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For degradation and loss of cover indicators, in Marrakech-Tensift-Al Haouz region, the salinization particularly affects the soils of the Tessaout Aval and the salinity of the water gradually decreases towards the East. 14.3% of the Tessaout Aval soils are affected by salinity in the western part of the perimeter. The soils of the central Haouz perimeter are often salty and / or alkalized (MEMEE, 2015). Terrestrial reserves indicator captures the increase in resilience, function of pollution attenuation, groundwater recharge, limits to losses of biodiversity and refuges afforded by the presence of adequate terrestrial reserves in a region (including aquatic ecosystems located within the land area). Marrakech-Tensif-Al Haouz region has an ecological diversity with a wealth of landscapes and natural environments of high quality. It is home to endemic flora and fauna that must be conserved and managed to maintain sustainability for the benefit of current and future generations. Some endemic plant species have developed adaptive mechanisms to tolerate the semi-arid and arid conditions found in this region (Chakhchar et al., 2015). In Marrakech, the Sites of Biological and Ecological Interest (SIBE) are identified to safeguard the maintenance and conservation of heritage and resources (flora, fauna and cultural aspects). Their co-management is decisive and essential. Further, we have taken safe sanitation as an indication of at least some pretreatment of sewage before it enters stream, groundwater recharge and coastal and land areas. If sanitation is of a low standard, ecosystems downstream have a higher risk of being polluted with sewage that has not been broken down and which will contain high levels of urea, ammonia, nitrites, pharmaceuticals and pathogens (SOPAC, 2005). In 2010, the Marrakech prefecture rejected the largest volume of wastewater; it represents 66% of total volume discharged by the region. Other provinces had little significant releases, they presented between 5% and 8% of total releases in the region. The Marrakech prefecture is one that exerts the most pressure on wastewater discharges, it should be noted that this is the most urbanized province, and therefore better connected to the sewage system and drinking water. Other provinces, being mostly rural, are hardly connected to these networks.

Concerning the intensive farming indicator, it allows capturing the risk of pollution, eutrophication, ecosystem loss or damage and the risk of diseases and plagues. This indicator is significant in the studied region (Figures 9 &10). It focuses on lands being used for intensive agriculture, which we define as those in which the wastes produced over the land are in excess of the ability of that same land area to attenuate them. In Marrakech-Tensift-Al Haouz region, livestock is one of the most important sources of income of the rural population; the number of livestock is in the order of 5118 thousand head and represents 18% of the total workforce at the scale National (MIM, 2015).

According to our analyzes, there is a potential risk for fishing in this region. The productivity overfishing and marine reserves indicators allow to highlight the effects of ecological overfishing which would be especially important if there are interactions with other on-going human and natural impacts. The marine fishing sector in the studied region is mainly located in the Essaouira province. The sector remains artisanal and under-equipped; and its contribution is small compared to the national production. As part of a comprehensive comparative study, Allison et al. (2009) report that among 133 countries, Morocco is located in the 11th row of the most vulnerable countries to climate change in the fisheries sector. According to these authors, the results of the analysis show that Morocco is highly vulnerable, with a low level of adaptability. This vulnerability to climate change in the fisheries and aquaculture sector depends on the exposure, sensitivity and adaptive capacity.

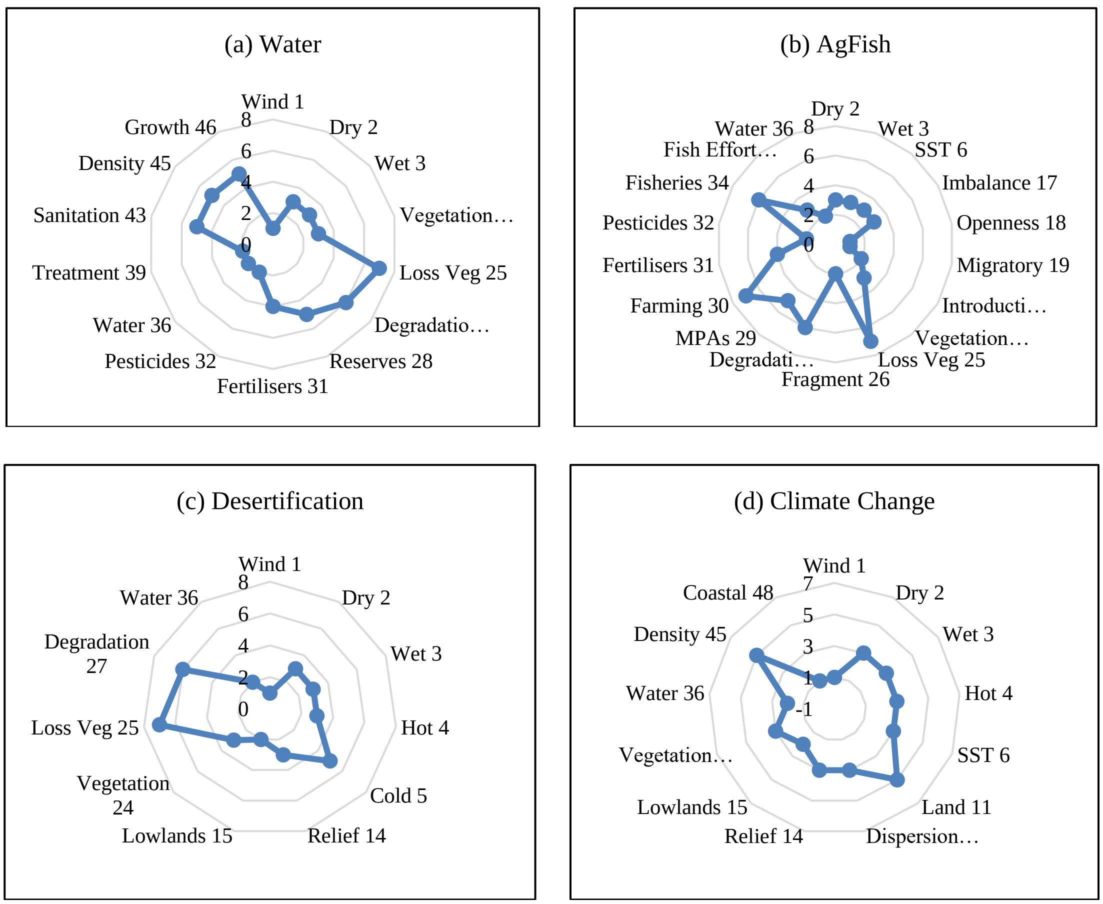

Figure 10: Environmental vulnerability index (EVI) of studied sub-indicators for Marrakech-Tensift-Al Haouz region.

Therefore, adaptation measures need to be taken into account in the studied region in terms of the use of water resources in irrigation and agriculture-related practices. Because of the importance of the thematic and the need to understand more accurately the effects of climatic variability in irrigation areas, it is important to highlight that some appropriate measures need to be adopted in the region for managing agricultural water use in order to minimize the future impacts to a great extent. Indeed, we tried to establish a schematic diagram illustrating some methodologies and good practices that can give important mitigation strategies in the study area against climate change impacts (Figure 11).

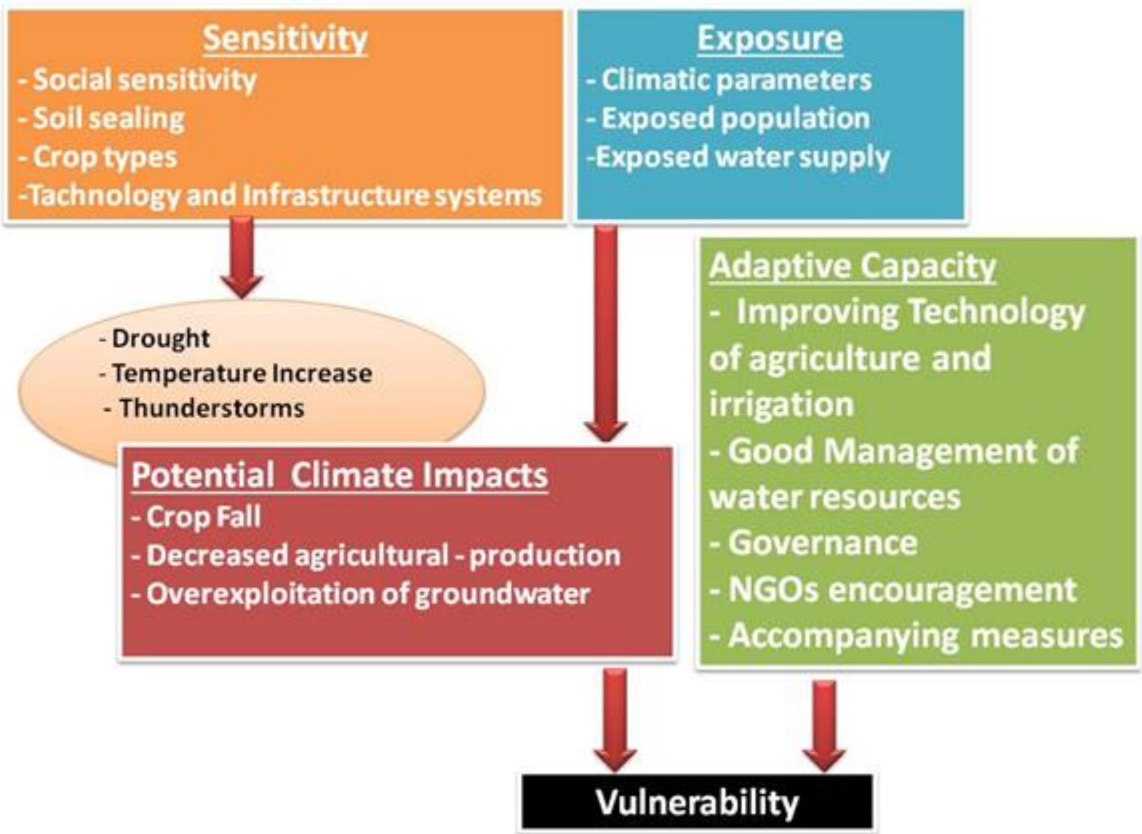

Figure 11: Impacts chain of climate change on agriculture and water in Marrakech-Tensift-Al Haouz.

4. CONCLUSION

The potential impacts of climate change in the study region can be summarized as follows: i) the reduced rainfall and increased evapotranspiration (linked to rising temperatures): has a direct consequence on the decline in the flow of water resources during the summer months particularly dry and / or hot; ii) a temporal change in rainfall and flows, with longer dry spells and / or more frequent; iii) a change in snow cover in the mountainous part especially in the High Atlas (height and duration of snow cover, appearance and snowmelt); iv) a decrease in the groundwater level with, as a corollary, the increase in mineral concentrations of aquifers, and soil salinity; v) modification of ecosystems dependent on rain water and / or groundwater and vi) decrease of agricultural production and alteration of crop performance. The results show also that sectoral approach to water management, centralized decision-making and a lack of institutional mechanism for effective consultation among stakeholders are still persistent and needed to manage efficiently the water resources in the study region.

DECLARATION ON CONFLICTS OF INTEREST: No potential conflict of interest was reported by the authors.

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REFERENCES

1. ABHT, Agence du Bassin Hydraulique du Tensift (2015). Publication links, http://www.eau-tensift.net/x/publications/annee-2009.html
2. Abourida, A., Vincent, S., Errouane, S., Sighir, F., Berjami, B. and Sgir, F. (2008). Estimation des volumes d'eau pompés dans la nappe pour l'irrigation (plaine du Haouz, Marrakech, Maroc). Comparaison d'une méthode statistique et d'une méthode basée sur l'utilisation de la télédétection. Revue des sciences de l'eau/ Journal of Water, 21:489-501.
3. Allison, E.H., Perry, A.L., Badjeck, M-C., Neil Adger, W., Brown, K., Conway, D., Halls, A.S., Pilling, G.M., Reynolds, J.D., Andrew, N.L. and Dulvy, N.K. (2009). Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries, 10: 173-196. doi:10.1111/j.1467-2979.2008.00310.x
4. Amraoui, F., Razack, M. and Bouchaou, L. (2004). Comportement d'une source karstique soumise à une sécheresse prolongée: la source Bittit (Maroc.). Comptes rendu Géoscience 336:1099-109.
5. Ben Salem, A. (2014). Vulnérabilité et adaptation aux changements climatiques dans les oasis du Tafilalet - Maroc. Thèse de doctorat. Faculté des Sciences Semlalia Marrakech.
6. Chakhchar, A., Wahbi, S., Lamaoui, M., Ferradous, A., El Mousadik, A., Ibnsouda-Koraichi, S., Filali-Maltouf, A., El Modafar, C. (2015). Physiological and biochemical traits of drought tolerance in Argania spinosa. J Plant Interact, 10:252-261.
7. CSEC, Conseil Supérieur de l'Eau et du Climat (2001). Plan directeur pour le développement des ressources en eau du bassin du Tensift, 9ème session.
8. De châtel, F., holst-Warhaft, G. and Steenhuis, T. (2014). Water Scarcity, Security and democracy: a Mediterranean Mosaic. 2014 by Global Water Partnership Mediterranean, Cornell University and the Atkinson Center for a Sustainable Future. Printed in Athens, Greece, and Ithaca, NY. ISBN 978-1-4951-1550-9.

9. Debbarh, A. (1995). Irrigation et développement durable : aspects environnementaux = Irrigation and sustainable development: environmental aspects. Acte de l'Atelier sur les Aspects Economiques de la Gestion de l'Eau dans le Bassin Méditerranéen, /17-19, Marrakech (Maroc).
10. Driouech, F. (2010). Distribution des précipitations hivernales sur le Maroc dans le cadre d'un changement climatique. Thèse de Doctorat de l'Institut national polytechnique de Toulouse, 163 pp.
11. Eynard, A., Lala, R. and Keith, D.W. (2006). In Encyclopedia of Soil Science, (CRC Press) Chapter: 323 (2006) 1538.
12. FAO/IFAD (2006). Water for food, agriculture and rural livelihoods. Chapter 7 of the 2nd UN World Water Development Report: Water, a shared responsibility. FAO and the IFAD.
13. Fischer, G., Tubiello, F.N., van Velthuizen, H. and Wiberg, D.A. (2007). Climate change impacts on irrigation water requirements:effects of mitigation, 1990-2080. Technol. Forecast. Soc. 74:1083-1107.
14. Holzkämper, A. (2017). Adapting Agricultural Production Systems to Climate Change-What's the Use of Models? Agriculture, 7:1-15.
15. Imhoff, M.L. and Bounoua, L. (2006). Exploring global patterns of net primary production carbon supply and demand using satellite observations and statistical data. *Journal of Geophysical Research*, 111, D22S12, doi:10.1029/2006JD007377
16. IPCC (2007). The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. (eds.)). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 p.
17. IPCC (2017). IPCC Fifth Assessment Report (AR5) Observed Climate Change Impacts Database, Version 2.01. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC).
18. IPCC, (2013). Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., Qin, D., Plattner, G-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
19. Manchanda, G. and Garg, N. (2008). Salinity and its effects on the functional biology of legumes. Acta Physiologica Plant, 30:595-618.

ISSN: 2455-6939

Volume:04, Issue:01 "January-February 2018"

20. MEMEE (2010a), Rapport de Diagnostique de l'Etat de l'Environnement au Maroc (Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement, Chargé de l'Eau et de l'Environnement Département de l'Environnement). http://www.environnement.gov.ma/index.php/fr/etat-env
21. MEMEE (2010b), Rapport National sur l'Etat de l'Environnement: Région Marrakech-Tensift-Al Haouz (Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement, Chargé de l'Eau et de l'Environnement Département de l'Environnemen) http://www.environnement.gov.ma/index.php/fr/etat-env?id=129
22. MEMEE (2015), 3ème Rapport Sur l'Etat de l'Environnement du Maroc (Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement, Chargé de l'Environnement. http://www.environnement.gov.ma/PDFs/Rapport-reem.pdf.
23. MIM (2015), Ministère de l'Intérieur, Direction Générale des Collectivités Locales. Monographie Générale de la Région de Marrakech-Safi 2015.
24. Ouzine, L. and Kharrou, M.H. (2004). Conception participative de projets d'irrigation dans le périmètre du Haouz. Séminaire sur la modernisation de l'agriculture irriguée. IAV Hassan II, Morocco, 11 pp.
25. Riad, S. (2003). Typologie et analyse hydrologique des eaux superficielles à partir de quelques bassins versants représentatifs du Maroc. Thèse de doctorat, université des sciences et Technologies de Lille & Université Ibnou Zohr d'Agadir, 154 pp.
26. Sakadevan, K. and Nguyen, M-L. (2010). Extent, impact, and response to soil and water salinity in arid and semiarid regions. Advances in Agronomy, 109:55-74.
27. Sebbar, A., Badri, W., Fougrach, H., Hsain, M. and Saloui, A. (2011). Étude de la variabilité du régime pluviométrique au Maroc septentrional (1935-2004). Sécheresse, 22:139-148.
28. SOPAC (2005), Building resilience in SIDS. The environmental vulnerability index (EVI), Technical report, South Pacific Applied Geoscience Commission, Suva.
29. Tanouti, O. and Molle, F. (2014). Réappropriations de l'eau dans les bassins versants surexploités Le cas du bassin du Tensift (Maroc), Etudes Rurales, 2013/2 n°192:79-96.
30. Watson, R.T., Zinyoweraand, M.C. and Moss R.H. (1997). The Regional Impacts of Climate Change: An Assessment of Vulnerability. Cambridge University Press, Cambridge, 517 pp.
31. Woznicki, S.A. Nejadhashemi, A. P. and Parsinejad, M. (2015). Climate change and irrigation demand: Uncertainty and adaptation. Journal of Hydrology: Regional Studies 3:247-264.
32. Xiaopeng, L., Chang, S.X. and Salifu, K.F. (2016). Soil texture and layering effects on water and salt dynamics in the presence of a water table: a review. Environ. Rev. 22:41-50. dx.doi.org/10.1139/er-2013-0035

