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Mainstreaming Climate and Environmental Considerations into the Management of Industrial Reception Spaces – The Case of the Industrial Area of Aït Melloul (Morocco)

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ABSTRACT

Industrial reception spaces (IRSs) are receptacles for a large part of the national socioeconomic activity in Morocco. They contribute substantially to sustaining economic growth and national dynamics of industrialization. These areas are increasingly faced with several constraints, notably deficient infrastructure, competitiveness, and compliance with the new environmental legislation. These constraints stem from the proven and potential impacts of CC on both individual industrial units and the IRS as a common space. There is an urgent need to make these spaces environment-friendly and more resilient to current and future climate risks through appropriate methodological approaches, leading to effective climate risk management and implementation of proactive CC adaptation strategies. This was the context in which this study was conducted. As a case study, the industrial area (IA) of Aït Melloul, located near the city of Agadir in Morocco, was based on a participatory approach of climate risk assessment involving a task force representing the main socio-economic and state operators concerned by this IA. This was accomplished by analyzing the risks and vulnerabilities of the IRS and the agri-food units within it. The analysis provides key elements for a future strategy for business sector resilience and energy transition. The new project to requalify Ait Melloul IA would provide an opportunity to incorporate these elements as well as to capitalize on lessons learned from programs at the local level, particularly about energy efficiency and building the adaptive capacity of businesses.

Keywords: industrial area, companies, environment, adaptation, climate change, resilience, risk assessment, risk management.

INTRODUCTION

The manufacturing sector is one of the main engines of growth in Morocco, representing 17% of the GDP and employing over 10.4% of the labor force (HCP, 2020). The launch of the Industrial Acceleration Plan (IAP) stimulated industrial processing toward an increase in the share of high- and medium-technology exports, such as the auto and aerospace industries, with the continuation of traditional sectors such as agri-food. Growth in the industrial sector has been accompanied by a strong increase in energy demand and a continued increase in water requirements and pollution from various industrial activities (MDE, 2015). The adverse externalities of industrial activities on the environment are often not adequately addressed, including air pollution and the release of liquids and solids (GIZ, 2015). In this respect, IRSs are essential tools for catalyzing the implementation of the IAP while promoting socially and environmentally responsible industrialization (UNIDO, 2019).

In this context, climate change poses an additional threat to the achievement of the strategic goals of the domestic industrial sector. From this perspective, climate risks are multiple, both direct and indirect, ranging from simple physical damage to industrial infrastructure and production sites to a complete shutdown of the business following recurring malfunctions due to CC (GIZ, 2017; Jaouhari, Stour, & Agoumi, 2021).To overcome this impasse, it is necessary to opt for systematic integration of CC adaptation across all components of the industrial sector. This inevitably implies the development of approaches and implementation of effective strategies for the analysis and management of risks and opportunities, both at the level of the IAs and the companies established therein.

With this in mind, the IRS could be an appropriate place to address climate change, consistent with the goals of the Paris Agreement to minimize greenhouse gas (GHG) emissions from these areas and prepare them for the consequences of CC (UN, 2015). Choosing such mitigation and adaptation approaches offers undeniable opportunities for companies, especially in terms of reducing the impact and burden generated by CC (Biagini & Miller, 2013).

This study provides an appropriate methodological approach for managing risks and opportunities within an IRS, considering both the local context of this space and the specific characteristics of the industrial units installed in it. This approach was applied to Aït Melloul IA and conducted in consultation with a broad range of institutional and private stakeholders.

LITERATURE REVIEW

Policy and regulatory framework

Over the past two decades, Morocco has built an advanced legal arsenal for environmental protection (water, waste management, air pollution, and environmental impact studies) (Kingdom of Morocco, 2003a, 2003b, 2006, 2016). The framework law N°99-12 places climate measures at the heart of the state's action in terms of environmental protection and sustainable development (Kingdom of Morocco, 2014). This determination has been expressed through a series of reference documents, such as the National Climate Plan to 2030 (PCN 30) (SEDD, 2019), the updated version of the Nationally Determined Contribution (CDN), which targets a reduction in industrial sector energy consumption of around 17% in its unconditional scenario (MEME-Env, 2021), and the New Development Model (CSMD, 2021), which aims to consolidate Morocco's position as a benchmark for decarbonized, responsible, and sustainable production.

More recently, a new law on IAs, Law no. 102-21, has come into force (Kingdom of Morocco, 2023). This law fills the gap left by the absence of a normative framework for industrial infrastructure, while developing a range of IAs in line with companies' needs. In addition to providing investors with suitable developed land, Law 102–21 emphasizes the need to improve the quality, competitiveness, and attractiveness of IAs by introducing tools to ensure their sustainable and efficient management. The new law also establishes a national plan for IAs and general regulations for their planning, development and marketing (Oukerzaz, 2023).

Typology and evolution of IRSs

IAs are spaces equipped and developed in accordance with current urban planning laws and regulations intended for establishing industrial units. These areas are supposed to be equipped with the basic infrastructure and equipment required for efficient operation of industrial units. The design, construction, and management of IRSs have evolved largely in line with developments in the industrial sector. This evolution has seen a gradual shift from a basic industry with low levels of specialization and support to a high-performance, resource-intensive industry underpinned by a supportive technological and technical ecosystem. Currently, we are witnessing the emergence of industrial infrastructure with a systematic consideration of economic, ecological, and social dimensions during the various phases of its implementation (GIZ, 2017; MHUAE, 2010). Figure 1 provides an overview of the typology of IAs in Morocco based on their functional vocation and degree of integration.

To promote the IRSs, Morocco has developed several plans and programs (Figure 2) since the 1980s, namely the National Industrial Area Development Programme (PNAZI), Plan Emergence, National Industrial Emergency Pact (PNEI), and Industrial Acceleration Plan (IAP) (MICIEN, 2016). The implementation of these programs and plans has led public authorities to mobilize a sufficient and appropriate land supply while at the same time putting in place tax and customs incentives

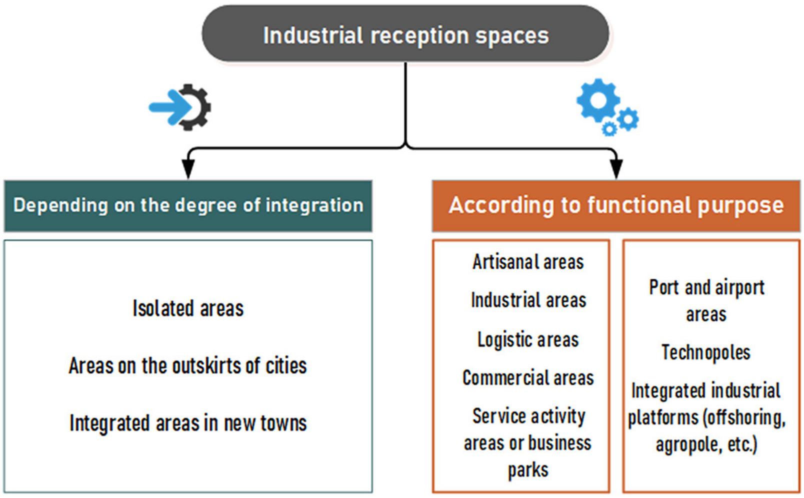

Figure 1. The typology of Industrial Reception Areas (IRAs) in Morocco (MHUAE, 2010 adapted by the authors)

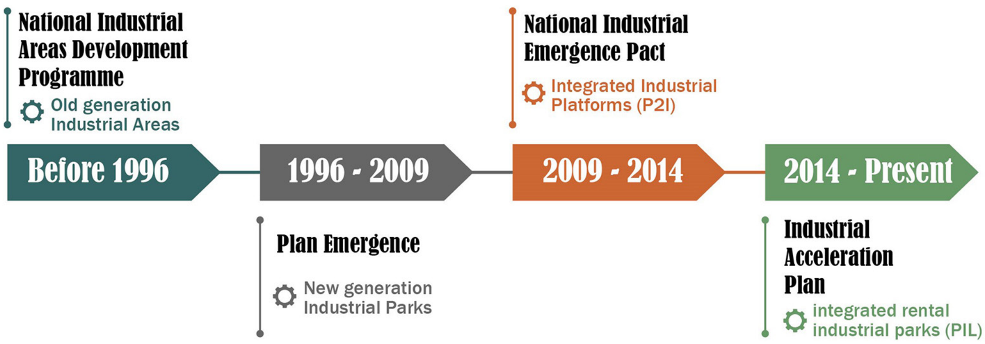

Figure 2. Evolution of the national policy for industrial spaces

and granting subsidies. Thus, each new plan attempted to address the deficiencies observed by its predecessors, particularly in terms of industrial infrastructure put in place, development, and governance. The IAP stands out for its innovative approach to creating high-performance ecosystems considering value chains and the consolidation of local relationships between large companies and SMEs (MICEVN, 2021a).

Barriers to IRS sustainability and resilience

In the context of CC, international best practices show that eco-industrial parks (EIPs) have very competitive advantages, particularly for the mitigation of CC, the reduction of operating costs, the improvement of productivity, and greening supply and value chains (UNIDO, GIZ, & WBG, 2017). EIPs are industrial spaces that ensure sustainability by considering social, economic, and environmental quality factors in site selection, planning, operation, management, and decommissioning. In these spaces, the business community seeks to improve environmental, economic, and social performance through collaboration in the management of environmental and resource issues. In this respect, the collective benefit to this community is greater than the sum of the individual benefits that each company achieves by optimizing its individual performance alone (Lowe, 2001). Recently developed by GIZ (GIZ, 2021), the sustainable industrial area (SIA) sustainability criteria grid offers the advantage of being detailed, specific, and meeting the real needs of IAs. This grid incorporates the rules of good practice to be adopted during each life-cycle phase of the IA, including the theme of climate change (UNIDO et al. 2017).

Despite the realization in Morocco of a handful of Industrial Eco-parks (Industries.ma, 2021; UNIDO, 2018), the design and realization of new sustainable IRSs as well as upgrading existing IRSs is a long-term process that requires multidisciplinary expertize and a substantial effort on the part of many stakeholders, whether at the local or central level. Recent studies and evaluations

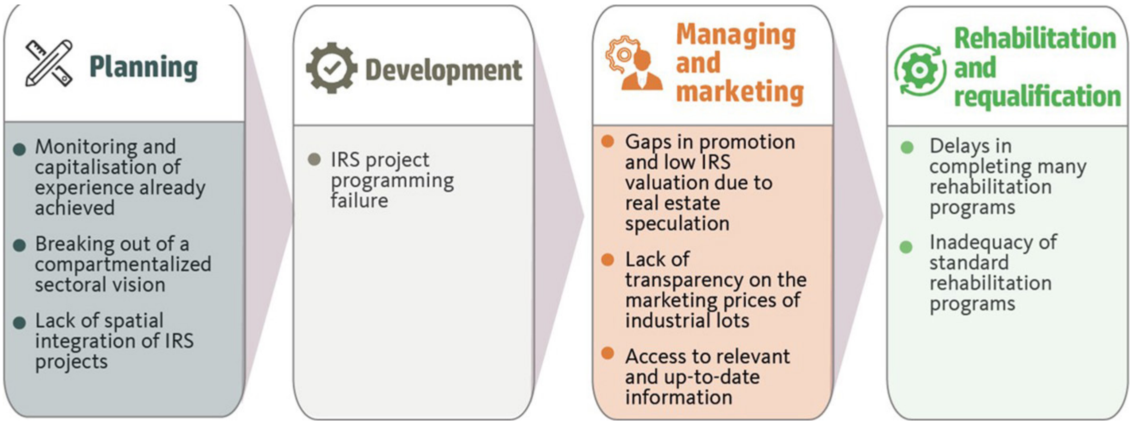

Figure 3. Issues to be addressed according to the planning and implementation phases of the IRS

have pointed to some dysfunctions hindering the integration of sustainability criteria in Moroccan IRSs, including the siting of IA and how they are designed, which is often referred to as housing real estate transactions (Cour des comptes, 2018). Figure 3 summarizes the main challenges to be considered during the different phases of planning and implementation of IRSs.

A guide for Moroccan IAs was published in 2017 (Reinfeldt & Boulejiouch, 2017) to overcome these obstacles and facilitate IRS transition. This document stresses the progressive nature of the implementation of such a transition approach, which must be based on the realities of the field and medium- and long-term strategies. Nevertheless, there are key entry points to move forward with confidence in this direction, including multiscale and multidisciplinary communication and coordination between relevant stakeholders, improving IRS planning, and strengthening management structures.

MATERIAL AND METHODS

Study area

The IA of Aït Melloul, created in 1984, is located 15 km from the city of the Agadir and belongs to the agglomeration of the Grand Agadir (Figure 4). It is one of the most important in Morocco,

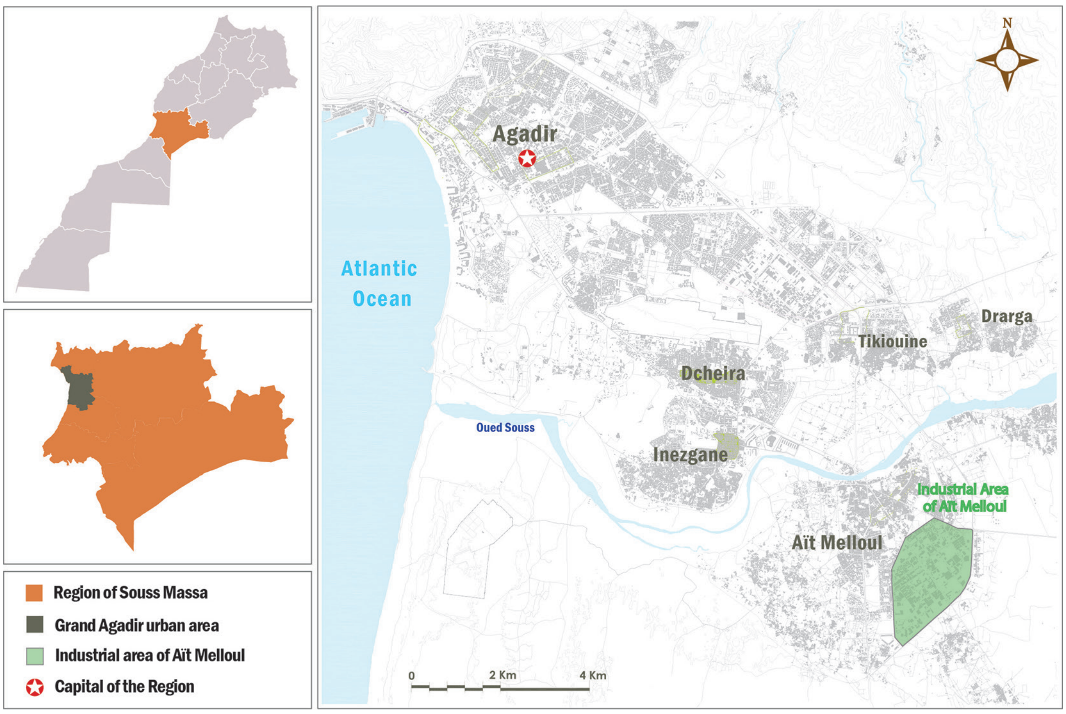

Figure 4. The location of the IA of Aït Melloul

covering an area of 354 ha divided into 778 lots in the Commune of Aït Melloul (CRI Souss Massa, 2021). The agri-food sector occupies an important place in the industrial fabric of the Aït Melloul IA and is based on the processing of agricultural and fishery products, where processing activities account for 47% and fish processing accounts for 30%. The sector also includes two large dairies, a soft drink plant, and some 04 meat processing plants. Private management of the area is provided by the Association of Investors of the IA of Aït Melloul (ADIZIA). ADIZIA is a platform for dialog with public authorities and IA partners that aims to mobilize public authorities to modernize AI and meet the infrastructure and service needs of economic operators.

Methodological approach

The deployment of the approach

The analytical approach followed the conceptual framework for assessing and managing climate risks established in the IPCC Fifth Assessment Report (AR5) (IPCC, 2014). The analysis was carried out on three distinct levels: the first level concerns the local climate and environmental context, which makes it possible to define the general framework and the object of the analysis; the second level involves the IA as a space shared by companies with essential equipment and services, and possibly the interactions this space has with the production and distribution zones for manufactured and packaged products; and the third level concerns the industrial units themselves, with a specific analysis of the representative sectors of activity located in the IA. This analysis was structured into four successive stages (Figure 5).

The screening step defines the scope of the study, identifies the stakeholders, and identifies the relevant documentation required to perform the subsequent steps.

The second step consisted of characterizing the local climate profile of the study area based on available climate data, records, and history of extreme weather events that affected the Aït Melloul IA.

The third step focuses on climate risk assessment by characterizing the most relevant risks for both the IA as a whole and the industrial units located therein. This step also identified potential opportunities for these units to improve their commercial competitiveness.

The final step proposes the key elements of the IA adaptation strategy, including the integration of adaptation and sustainability considerations into the IA requalification plan.

Applied methodological tools

The aforementioned approach was based on two analytical tools that were applied according to the level considered, namely, the Climate-Proofing for Development Tool (CP4Dev) and the Climate Expert Tool.

Climate-proofing for development tool (CP4Dev)

This is based primarily on key principles from the Policy Paper on CC Adaptation and Development Cooperation (OCDE, 2009).

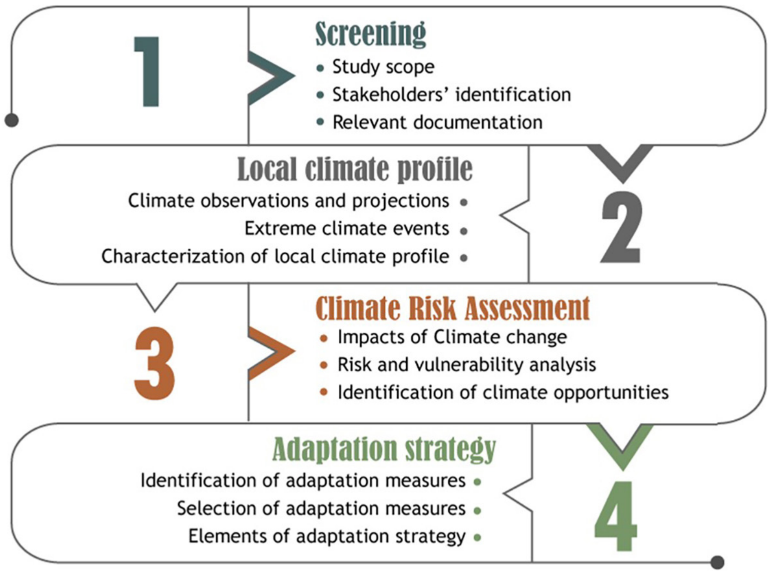

Figure 5. Methodological approach

In the context of this study, CP4Dev (GIZ, 2011) was primarily used to analyze the impacts and risks of climate change and to define an adaptation strategy specific to the study area. CP4Dev has been widely deployed in the Moroccan context and at different levels, whether in sectoral programs (agriculture, water, human development, etc.) (Agoumi, 2011; Jalil et al., 2013), territorial plans (Jaouhari & Fanzi, 2016), or diverse local projects supported by local development associations and cooperatives (Behnassi, 2013; Jaouhari, 2016).

Climate expert (CE) tool

Based on a practice-oriented approach, the CE tool (Strasser & Mewes, 2013) aims to characterize companies' vulnerability to CC, identify business opportunities arising from CC, and implement effective and efficient adaptation strategies to respond to climate risks with a cost–benefit analysis. It is designed to help companies improve their competitiveness, while ensuring long-term survival and growth. The CE has been tested in the Moroccan entrepreneurial context through a series of case studies covering 20 Moroccan companies operating in the agri-food and textile sectors with the technical assistance of the German Agency for International Cooperation (GIZ) and the International Trade Center (ITC). The online platform www.climate-expert.org includes a dozen case studies of SMEs worldwide, around half of which are conducted in Africa.

Stakeholders involved

The analysis of IA vulnerability was carried out by a Task Force made up of key actors involved in the management of IA, divided into three thematic groups (Table 1). During this work, the outputs of the Task Force's work were entirely revised considering the adjustments and harmonization made to the methodological framework. These outputs were also updated, enriched, and clarified, considering the primary data collected as well as the analysis and capitalization of specific studies on the region and study area, as well as the evaluation reports carried out at the individual company level.

Data collection

The data collection focused on key institutions supplying data and statistics related to the study area, mainly climate data, statistics, urban planning, and basic infrastructure and services (Table 2).

Table 1. Composition of the task force

Fields	Theme 1: Site and Infrastructure	Theme 2: Companies & employees/populations	Theme 3: Environmental and market management
Institutions and local authorities	• Prefecture • Regional direction of environment • Hydraulic basin agency • Commune	• Autonomous multi-service agency of agadir (RAMSA) • Regional direction of meteorology • Regional investment center • Regional chamber of commerce and industry	• Prefecture • Moroccan-German cooperation project (ACCN- GIZ)
Private sector	• Association of Investors of the Industrial Area of Ait Melloul (ADIZIA) • Companies		

Table 2. Contacted Institutions and types of data

Fields	Contacted institution	Data type
Climate data	• Regional Direction of Environment • Regional Direction of Meteorology	• Data on climate extremes • Climate observations and projections
Reference plans and miscellaneous statistics	• Region • Prefecture • Office of the High Commissioner for Planning	• Regional Development Program • Provincial Development Program • Communal Action Plan • Monographs and statistical yearbooks
Data and information specific to the IA	• Prefecture • Commune • Urban Agency of Agadir	• Thematic reports and situations • Studies and technical data sheets • Master plans, manuals, standards and regulations
Water, sanitation, and waste	• Commune • Autonomous multi-service agency of Agadir (RAMSA) • Hydraulic Basin Agency • Regional Direction of Environment	• Statistics on drinking water consumption and sanitation • State of the Environment Studies • Integrated Water Resources Management Master Plan • Hydrological and hydroclimatological studies • Solid Waste Management Master Plans

RESULTS AND DISCUSSIONS

Climatic hazards and their impact on the IRS

The study area is characterized by a semi-arid climate with low precipitation, moderate temperatures, and medium to fairly high humidity, especially in summer, which experiences fog (DMN, 2014). Analysis of the collected data suggests that the IA is subject to a wide range of climatic phenomena and hazards that have a proven impact on the future of socioeconomic activities in general and the proper operation of industrial infrastructure in particular.

Upward trends in observed climate parameters

At the Agadir station, the observed daily maximum temperature (Tmax) and daily minimum temperature (Tmin) data showed a clear upward trend over the period 1961–2014, with low interannual variability (Figure 6) (Krause, Ezzine, & Messouli, 2016). The rainfall pattern in the Grand Agadir Area is semi-arid. The annual rainfall is around 200 mm, with a wet period concentrated between October and March, accounting for 90% of the annual precipitation. The coastal fringe makes the area particularly watered and humid with the presence of a temperate microclimate characterized by high atmospheric humidity all year round under the effects of dew, mists, and fog. Furthermore, analysis of the evolution of cumulative annual precipitation at the Agadir station over the period 1961–2014 showed a downward trend associated with a narrowing of the wet weather period (Krause et al., 2016).

More intense heat waves

Regarding extreme temperatures, the Provincial Meteorological Centre (CPM) noted a marked upward trend in daily maximum temperatures. In July 2020, a record high of 49.5 °C was recorded by CPM (station located less than 5 km from the study area), making it one of the warmest years in the region. The annual normal number of days with daily temperatures greater than or equal to 35 °C was 19 days. These temperature levels are exacerbated by the Cherrgui phenomenon, which occurs for an average of 57 days per year (DMN, 2014).

Episodes of recurrent droughts

Between 1940 and 1979, there were five droughts over 40 years in the study area, whereas there were 10 between 1980 and 2002 (Jaouhari & Fanzi, 2016). Dry periods are set to become longer, exerting pressure on the water and agricultural resources. On a regional scale, modeling the phenomenon of drought based on return periods indicates a certain severity of drought on the scale of the territory every 50 years (Krause, Ezzine, & Messouli, 2015). Vulnerability to drought is considered moderate every five years, but remains significant in the Souss Plain. These drought episodes are often accompanied by scorching hot temperatures, which in some cases exceed 44 °C.

More intense and frequent floods

In recent decades, the rainfall pattern in the study area has changed, with heavier, more frequent, and concentrated rainfall in October and November, and a substantial reduction in rainfall during the rest of the year. Because of intense

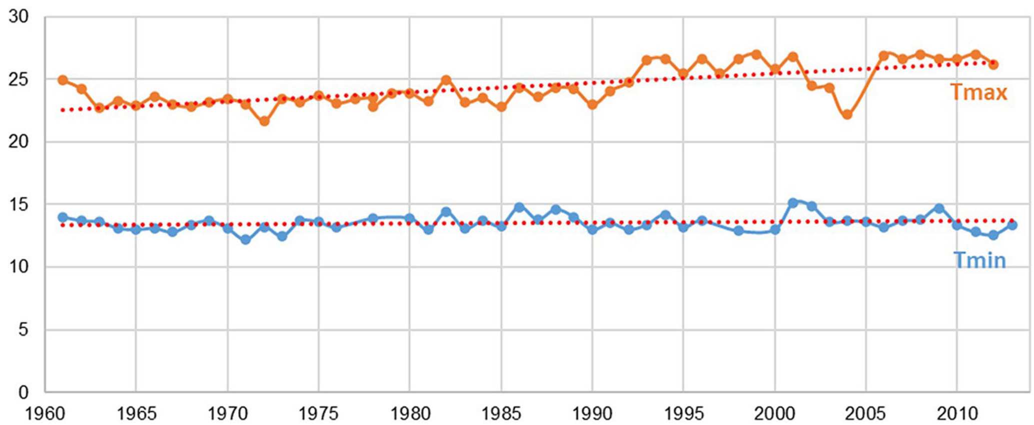

Figure 6. Evolution of daily maximum (Tmax) and minimum (Tmin) temperatures during the period 1961–2014

rainfall and thunderstorms, the study area experienced two major periods of severe weather. The first was in February 2010, when the peak flow of the Oued Souss reached 3,200 m^3/s (Aït Melloul hydrological station). Rainfall recorded at that time reached 563 mm in just three months (between 17/12/2009 and 19/02/2010), exceeding the average annual rainfall of 220%. The second period occurred in November 2014, with a peak flow of the Oued Souss of around 2,253 m^3/s (Aït Melloul hydrological station). During the same month, the area received a cumulative rainfall of 334.1 mm, with a daily peak of 116.9 mm recorded on November 28, 2014. These two values represent record levels never reached during a period of at least 30 years (1991–2021) (DMN, 2014).

Despite the benefits to water resources, these events have caused significant damage to agriculture, fisheries, road infrastructure, and habitats. The damage caused by flooding in 2010 was estimated at 113.8 billion MAD, and 8,250 dwellings were completely or partially destroyed (Conseil Régional SMD, 2010). The events of November 2014 helped focus attention on risk mitigation rather than the response to the crisis when it occurred (Zurich Insurance Company Ltd et Targa-AIDE, 2015).

Future climate trends

According to two IPCC GHG emission scenarios (RCP 4.5, RCP 8.5), precipitation projections to 2050 applied to the national context, compared with the average annual precipitation observed between 1981 and 2018, show that precipitation is likely to fall by between 10% and 20% over most of the country, including the study area (Figure 7) (MTEDD, 2021).

As for average annual temperatures, the results show that temperatures are likely to rise by

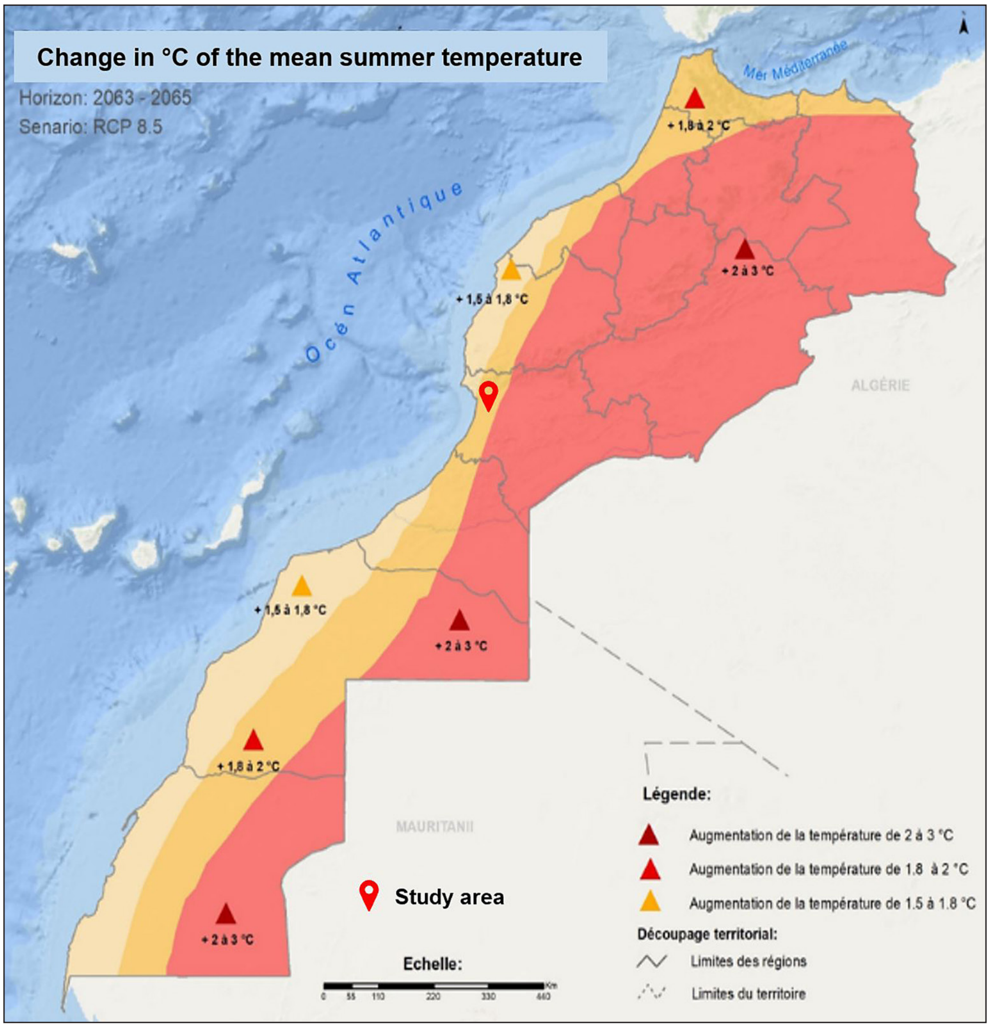

Figure 7. Evolution in (%) of the average annual rainfall for the period 2036–2065 for the IPCC scenario RCP8.5 (MTEDD, 2021)

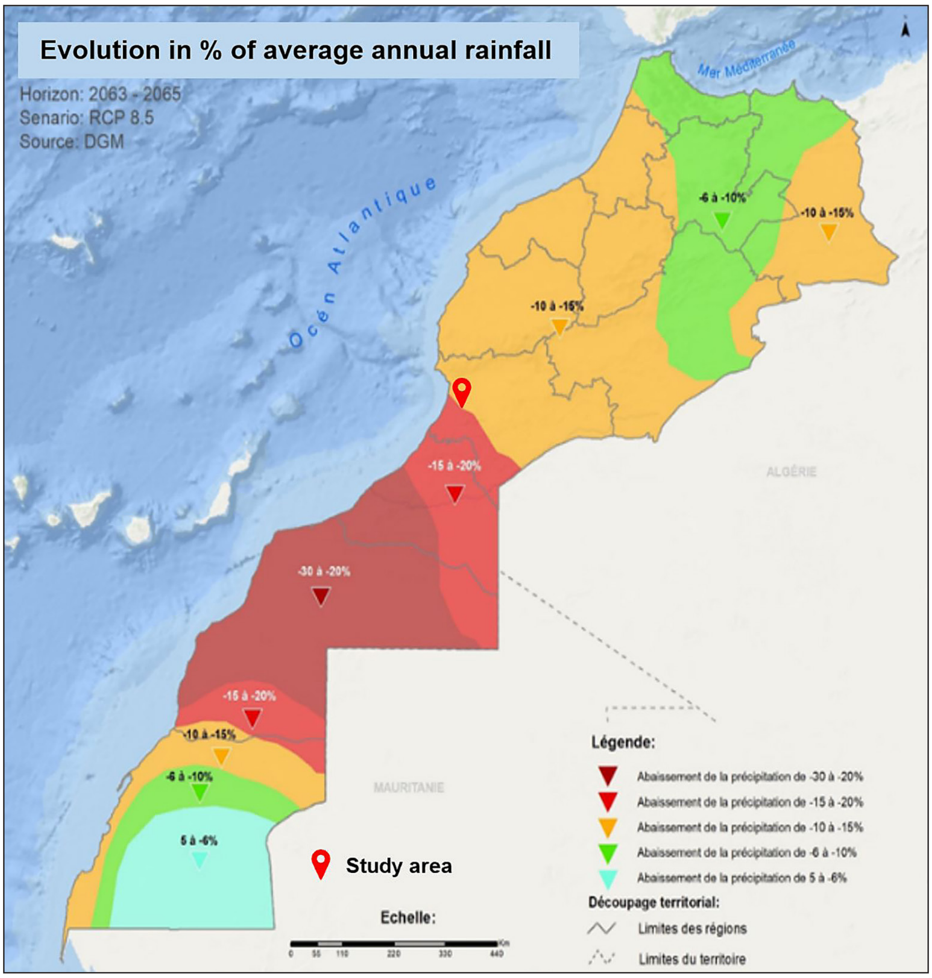

Figure 8. Average annual temperatures projected for the horizon (2063–2065) according to the RCP 8.5 scenario (MTEDD, 2021)

2050 across the whole country, for both RCP 4.5 and RCP 8.5. In the study area, the increase in average summer temperature could reach between +1.5 and +3 °C according to the RCP 8.5 scenario by 2063–2065 (Figure 8) (MTEDD, 2021).

At the scale of the study area, a study conducted in 2014 (MASEN, 2014) on the impacts of climate change on water resources by 2050 predicted an increase in mean annual temperature for all climate models considered, taking 1971–2000 as the historical reference period. With regard to monthly temperatures, all predictions point to an increase in monthly temperatures for the entire year, except for the DMI models, which predict a decrease in temperatures from September to November. In terms of precipitation, all the considered climate models simulated average annual precipitation below the historical conditions for the entire region. With reference to the 1980–2010 period, simulations of rainfall deviation projections for 2020–2040 indicated a decline between (20%) and more than (30%) in the study area. This decline tends to worsen and spread spatially according to scenario RCP8.5 (pessimistic) scenario (MAPM, DMN, & FAO, 2023).

Vulnerabilities of the infrastructure components

The area has hosted several canneries formerly located in the urban center of Agadir, also allowing the expansion of the industrial sector in the region through the provision of private investors' access to developed land. Nevertheless, the desire to develop the industrial sector has quickly encountered several technical obstacles, such as the lack of equipment and maintenance, and the lack of management and monitoring of operations (UN-HABITAT & PNUD, 2004). Despite the significant improvement in the number of valued and active industrial lots, from 88 lots in 2000 to approximately 395 lots in 2018. This rate barely exceeds 50% of the total number after more than three decades of creation in the area (PIAM, 2019).

In terms of infrastructure reinforcement, the IA experienced its first requalification operation in 2006 as part of the decentralized management of investment, with a budget of 20 billion MAD. This operation concerned the strengthening of drinking water and sanitation networks, renovation of roads, and strengthening of public lighting networks. In 2018, a project was conducted with a lower budget for strengthening road networks and signage. More recently, the Commune of Aït Melloul developed a technical study of the requalification of the area (CID, 2018), which served as the basis for the assessment of the sensitivity of the infrastructure components of the IA to climatic hazards. This work was supplemented and enriched through interviews with local technical managers. Thus, a grid was drawn highlighting the main malfunctions and vulnerabilities to assess the level of sensitivity to the aforementioned climatic hazards. Table 3 summarizes the evaluation results.

Characterization of climate risks and opportunities at the IA scale

Generally, climate risks affecting IRS and businesses can be categorized into three broad categories: i) physical risks to CC activities, ii) transition risks resulting from the impact of the implementation of a low-carbon economic model on economic actors, and iii) risks of liability associated with possible legal proceedings for climate inaction (Carney, 2015). Nevertheless, the dimension of physical risks could, as costs and opportunities are characterized, provide an incentive to reassess the value of various company assets. In the present case, the analysis focused on the physical risks identified and assessed in consultation with key stakeholders and based on relevant data and information collected from the relevant sector services and institutions. Figure 9 provides an idea of mapping these risks and their probability of occurrence and possible damage.

Table 3. Sensitivity of the infrastructure components of the IA to climate hazards

Components	Overview of the situation	Sensitivity to climatic hazards
Road network	• Condition of the pavement: stretching over a total length of around 25 km, the pavement shows various types of surface deterioration (deformations, pull-outs and cracks). • Condition of sidewalks: In several places, they suffer from various types of damage, including subsidence, deformation, and a deterioration of the concrete surface. • Condition of roadsides: Most are in an advanced state of deterioration. On some stretches of road, roadsides have been removed or filled with concrete or earth to make it easier for vehicles to park on sidewalks. • Car parks and parking areas: On the whole, they are in a very degraded state and require resurfacing and surface dressing with parking area markings. • Crossroads and roundabouts: Most of these crossroads are simple three- or four-way intersections, with a lack of appropriate signage at most of these junctions.	High
Wastewater and rainwater sewerage network	It is a combined sewer network. It suffers from some deficiencies, in particular the presence of several damaged or clogged drains, poor maintenance of drains and manholes, and insufficient manholes, mainly at low points. The drainage of rainwater is hampered by the state of the gullies which are often degraded or clogged.	High
Drinking water system	With a total length of around 34 km, the drinking water network is made up of polyethylene and PVC pipes serving all the lots. There are no notable anomalies.	Average
Power grids	• Street lighting: provided by high-pressure sodium lamps (HPS-type) mounted on concrete poles, which in some places are used for low-voltage distribution. At night, illumination is poor due to the deteriorating performance of the aging luminaires. It should also be noted that several poles have been destroyed and sections of the power cable damaged. • Distribution network: Low- and medium-voltage distribution is underground. This distribution network is operational with no notable anomalies.	Average
Green spaces and plantations	More than 3,800 trees have been identified along various roads. Landscaping is very heterogeneous, with green spaces lining the main boulevards and areas laid out by certain industrial units on adjacent sidewalks.	High
Fire protection	53 hydrants exist, of which 16 are damaged. Reinforcement is needed to cover the entire industrial zone and combat fire risks.	High

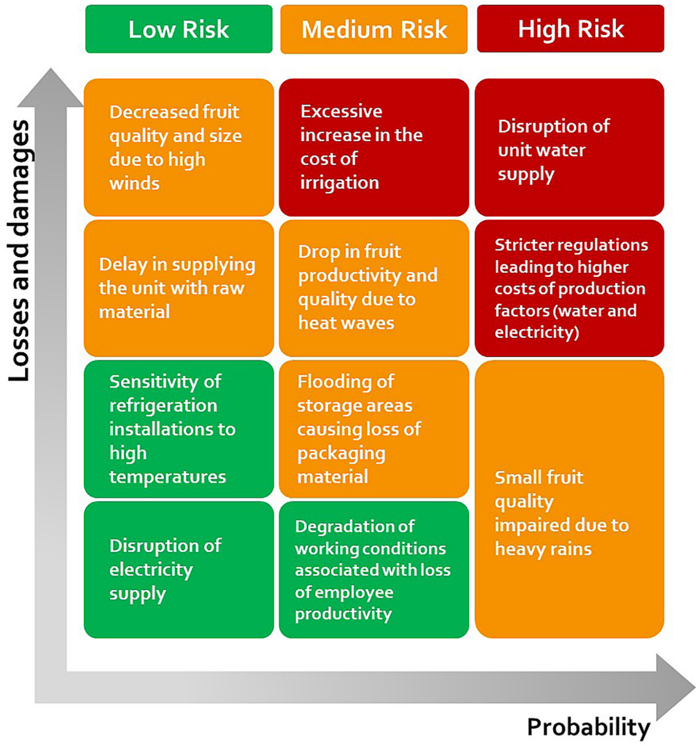

Figure 9. Risk matrix related to the CC in the IA of Aït Melloul

Risk linked to the demand and availability of water resources

Increased demand and pricing of water

According to the forecasts of the RAMSA, the demand for drinking and industrial water in the Grand Agadir will increase from 49.2 Mm^3/year in 2009 to 89.8 Mm^3/year in 2030 (RAMSA, 2005). This evolution reflects demographic and urban development and profound changes in the habits and lifestyles of the population of the Grand Agadir area. In terms of the production of drinking water, the total production capacity is on average 1,800 l/s, coming from 86% of surface water resources and 14% of underground catchments (RAMSA, 2021b). In addition, the extraction of drinking and industrial water from the Souss aquifer increased during the period 1979–2007 from 8.1 Mm^3 to 26 Mm^3 (ABH-SMD, 2007). In the study area, the category of large consumers of drinking water invoiced by RAMSA showed that 30% consumed an annual volume of less than 1,000 m^3, 50% consumed an annual volume between 1,000 and 10,000 m^3, and 20% consumed an annual volume of more than 10.000 m^3 (RAMSA, 2020b). In terms of pricing, the rate of increase in industrial water charged by the RAMSA is estimated to be 50% every five years (Mangin & Jaouhari, 2015; RAMSA, 2014). The rate of increase in the cost of wastewater treatment is estimated to be 10% per year. This upward trend also marks the pricing of electric power, which currently costs between 0.8 and 1 MAD/KW.

Depletion of underground resources and risk of marine intrusion

In addition to the water invoiced by RAMSA, a large proportion of industrial units draw their water needs directly from groundwater through a network of wells and boreholes. However, since the 70s of the last century, the Souss water table has shown a downward trend in some thirty piezometers in the Souss plain. This trend was particularly pronounced in the Middle Souss, with an average drawdown rate of more than 2 m per year (ABH-SM, 2008). In recent years, the pace of lowering has slowed relatively slowly owing to efforts made in resource governance and management. Nevertheless, the projections of the difference in inflows between now and 2070 compared with historical levels predict a drop in recharge of the Souss water table of approximately -27.1%, according to the "optimistic" scenario (RCP4.5), and -33.1%, according to the "pessimistic" scenario (RCP8.5) (ABH-SM, 2019).This predicted drawdown significantly increased the risk of saline intrusion on the coastal fringe, particularly in the Grand Agadir area. In fact, these water deficits point to an increase in freshwater salinity levels in several sectors of the study area, which are considered to be at a high risk of marine influence. Comparing annual water demand considering CC and annual water demand without CC confirms this trend, with an increase in water demand of between 4% and 15% in all basins of the region (MASEN, 2014).

Deterioration of water quality

The Souss Massa region has experienced significant industrial growth in the recent decades. This growth is essentially linked to the development of the agri-food sector based on the valorization of agricultural and fishing resources. The region's agricultural sector is characterized by intensive farming practices involving the excessive use of fertilizers and plant protection products. Livestock production has progressively moved toward intensive breeding, generating organic and inorganic discharges that pollute groundwater. The agri-food sector accounts for 91% of the total water consumption in the Souss Massa region and liquid waste from this sector represents 89% of the total waste. In terms of pollution, the pollutant load from the agri-food sector represents 99% of the total pollutant load. Regarding the spatial distribution of pollution, the study area had the highest BOD_5 and COD values compared to the other provinces in the region (ABH SM, 2003). Upstream of the agri-food sector, agricultural production generates nearly 2,200 tons of leached nitrogen per year, generated by large-scale cereal and forage crops and, to a lesser extent, citrus fruits and market gardening. The study area is responsible for approximately 45% of the industrial pollution recorded in the Grand Agadir, with 5,500 tons/year of BOD_5 equivalent to the pollution produced by 250,000 population equivalents (RAMSA, 2014, 2020a, 2021a). The industrial units located in this area discharge an annual effluent volume that exceeds 2 million m^3. At least seven of these units are classified as polluting, all of which are in the fish processing sector. All of these units are connected to the Grand Agadir drinking water and liquid sanitation network, and at least three of them have no on-site sewage treatment plants or pre-treatment facilities. Note that many problems and malfunctions are caused by the discharge of these industrial effluents directly into the sewerage network and the treatment plant serving Grand Agadir:

- Clogging of the network downstream of industrial unit outlets
- Accelerated and long-lasting deterioration of pipes and sewage treatment works, particularly due to the release of hydrogen sulfide
- Overloading with organic matter and suspended solids caused substantial disruption to the operation of the Grand Agadir wastewater treatment plant.

Risk associated with the intensification of urban heat islands

In the Grand Agadir, the extension of the building at the expense of the Argan forest (*Argania spinosa* L.) is a real scourge. Natural areas have been gradually transformed into land reserves to accommodate real estate projects, basic infrastructure, and industrial infrastructure. This was accompanied by the emergence of urban centers that were under-equipped and particularly overcrowded, such as the center of Lqliaa (adjacent to the study area). With the increase in soil waterproofing, the processes of urbanization and industrialization have led to a considerable change in the surface area and atmospheric properties of the city, and consequently to the storage of solar energy and its restitution in the form of heat, creating a new climate called "urban climate" (Oke, 2002; Oke et al., 1992).

In concrete terms, this Urban Heat Island (UHI) effect translates into a warmer and thicker urban boundary layer (UBL) at higher elevations in the afternoon than in the surrounding areas (Lauffenburger, 2010; Oke, 2002). Following a macroanalysis, one UHI (Jusuf, Wong, Hagen, Anggoro, & Hong, 2007) concluded that industrial land use has the most obvious influence on the urban surface temperature during the day because of the extent of open concrete surfaces and buildings with metal and high-density concrete roofs. In the context of global warming, UHI tends to intensify further, and excess heat has direct consequences on the health (hyperthermia, respiratory illnesses, cardiovascular diseases, etc.) of populations, including employee performance and efficiency (Cassadou et al., 2004). At the same time, these extreme temperatures considerably increase peak and total electricity demand. (Santamouris et al., 2015) showed that the actual increase in electricity demand per degree of temperature increase varied between 0.5% and 8.5%.

Although there are no conclusive studies on this subject specific to the study area, interviews conducted with industrial operators show the relevance of considering the UHI phenomenon in risk and vulnerability analysis. This observation was confirmed by studies conducted at sites similar to the study area. Based on the processing of land surface temperature from LANDSAT 8 data Essalek et al. (2019) showed that UHIs are localized in sectors characterized by high building density and industrial activity, particularly in sectors with heavy industrial activity. Hassani et al. (2019) estimated that the temperature difference is +4 °C to +7 °C between IAs and the city center and between the coastal area to the west and IAs. During the night, heat restitution is much more pronounced to the west of the city, particularly in IA.

Risk related to the management of industrial and household waste

Three types of waste were generated in the study area: (i) waste similar to household waste, often from non-processing activities; (ii) non-hazardous industrial waste from packaging and transformation processes; and (iii) sludge from sewage treatment plants operating in industrial units. The first waste fraction was managed by the commune. However, unoccupied lots often become black spots over time or even landfill sites, with the accumulation of dirt and waste (Nakhli, 2015). This is harmful to neighboring units because of the risk of fire, product contamination, and odor nuisance. For the second and third fractions, which are subject to an authorization procedure applied according to nature and quantity, the fractions produced at the IA are sent to the Tamelast landfill, 20 km from the study area. The industrial waste recycling sector remains informal and poorly organized (CID, 2019; Jaouhari, 2019). Thus, neighboring units are harmed because of the risks of fire and contamination of products and odor nuisances.

At the regional level, projections of industrial waste production forecast an average increase of approximately 30% by 2030 compared to 2017 (CID, 2019). According to the same forecasts, the olive and agri-food industries would lead to waste-generating industries in the Souss Massa Region. The by-products of olive oil production (olive pomace and sludge) and waste from the agri-food industry will increase successively to 19,000 tons and 22,800 tons by 2030, representing an increase of 111% and 71%, respectively. Nevertheless, non-hazardous industrial waste has undeniable potential for energy recovery using the methanization technique of the organic fraction of this waste.

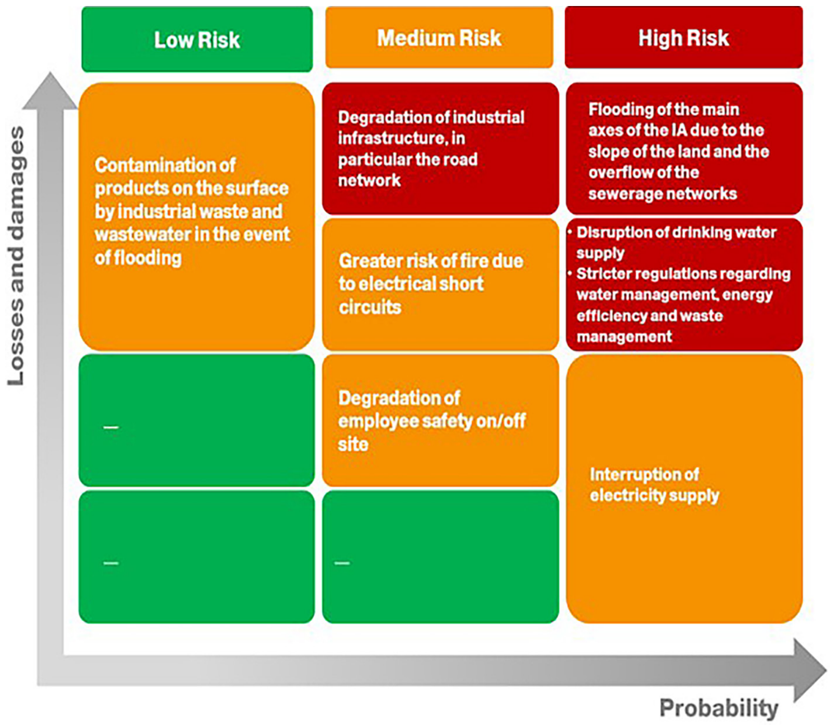

Figure 10. Risk matrix inherent to agri-food industries in the IA of Aït Melloul

Risks inherent in the agri-food industries

The study area is home to industries that are heavily dependent on natural resources, generating externalities that are harmful to the urban environment (air pollution, liquid and solid discharges, and various nuisances) and increasing pressure on water resources. Climate risk and opportunity analysis of the agri-food units showed that the "supply chain" impact area is particularly affected by CC, directly affecting the quality and size of agricultural products, practicability of production sites, and distribution chains for these products (Jaouhari et al., 2021). The availability of water both at the level of the industrial units and at the production sites remains a particularly "high risk." In addition, new environmental and energy regulations are also prioritized as a "high risk" due to the cost of the required upgrading investments and the upward trend in water, sewage treatment and electricity tariffs. Figure 10 provides an overview of the risks inherent in the agri-food industries in the study area.

Opportunities arising from climate change

Addressing climate risks can represent non-negligible economic opportunities for companies, particularly in relation to the emergence of markets for new energy technologies and new trades and skills (Nicolaï & Faucheux, 2007). However, examining these opportunities within the agri-food businesses located in the study area is a risky endeavor in the absence of a Research & Development function capable of keeping a technology watch and developing or having developed specific technologies to meet the new demands imposed by the CC. In fact, the evaluated companies do not generally have comprehensive market strategies that would allow them to take advantage of the business opportunities that could arise from CC. To overcome this situation, companies are called upon to carry out, individually or in a concerted manner, the tasks of technological monitoring with the aim of developing or having developed specific technologies that meet the new needs imposed by the CC.

Elements of an environmental and climate change adaptation strategy

The development of an environmental and adaptation strategy is the final step in the process of risk and vulnerability analysis. This strategy must consider all prioritized risks and appropriate responses in terms of environmental and climate considerations, structured according to the time horizons of implementation (short-term, medium-term, and long-term). In accordance with the methodological approach, this analysis should not lose sight of the three levels considered, namely the local climatic and environmental context, IA as a whole, and industrial units located in. Ultimately, this strategy ensures that the obtained environmental and adaptation measures are implemented consistently and effectively across the time horizons and levels considered. It would also be appropriate to identify potential barriers and conflicts in the implementation of the proposed measures by proposing ways to overcome these obstacles and ensure the integration of these measures in the action plan of industrial units (GIZ, 2016).

At the level of the IA

In view of the risks identified above, the Multi-Stakeholder Taskforce was given the task of creating a climate change adaptation plan specific to the study area. To this end, a series of participatory workshops were organized to define adaptation options in response to the priority risks identified in the previous stage. These options were prioritized using a multi-criteria analysis based on the effectiveness of the measures, their technical and financial feasibility, and their potential side effects. The measures selected were then documented, specifying the time horizon and the responsibilities for implementation and coordination for each measure. As part of the present work, the proposed strategy was reviewed and enriched in light of recent data, studies, and achievements related to IA and the Region.

At the level of industrial units

Referring to the cases of the companies evaluated, it appears that three main criteria were considered for the prioritization of adaptation measures, namely the effectiveness, urgency, and cost of these measures. Cost-benefit analysis has been of great assistance to business leaders in making investment decisions regarding proposed adaptation measures based on economic indicators such as the return on investment and the amortization period. The review of assessment reports for companies showed that almost all of the proposed measures relate to the areas of the "process", "government and regulation", "employees and community, and "building and location" (Jaouhari et al., 2021). For agri-food companies, the chosen measures focus primarily on sustainable water management, the use of renewable energy, particularly at the farm level, and securing production sites against flooding.

Environment and adaptation action pathways

The strategy is based on priority measures that can effectively address identified climate risks and environmental deficiencies, both at the level of IA as a whole and at the level of individual industrial units. These measures fall into three main categories: the first category includes technical and infrastructure measures; the second category includes green solutions to strengthen the resilience of the IA and its ability to adapt; and the last category brings together the so-called "soft" measures that generally focus on raising awareness or integrating environment and climate risk into management processes and institutional structures (GIZ, 2016). Figure 11 summarizes the distribution and scope of these measures according to the areas considered.

CONCLUSION

The Moroccan companies are entering an era of industrial transformation. It is characterized by an increasing share of high- and medium-tech exports while maintaining the traditional sector, especially the agricultural sector (Harraou, 2019). This dynamic results in a sharp increase in energy demand and a continued increase in water resources and pollution from various industrial activities (MDE, 2015).

In this context, CC stands out as a major challenge with unpredictable impacts on all economic sectors. Its impact affects the human and physical resources of companies, supply chains, market demand, finance, and insurance. On the one hand, CC can significantly affect the development, competitiveness, and survival of Moroccan companies in the medium and long term. However, mitigation and adaptation options can be an undeniable opportunity for companies that choose to implement them (Biagini & Miller, 2013). Furthermore, provisions announced by the EU imposing a carbon tax on imports to foreign companies exporting to its territory are now challenging for Moroccan companies to engage in decarbonization and adaptation to CC (LPJM, 2021; MICEVN, 2021b).

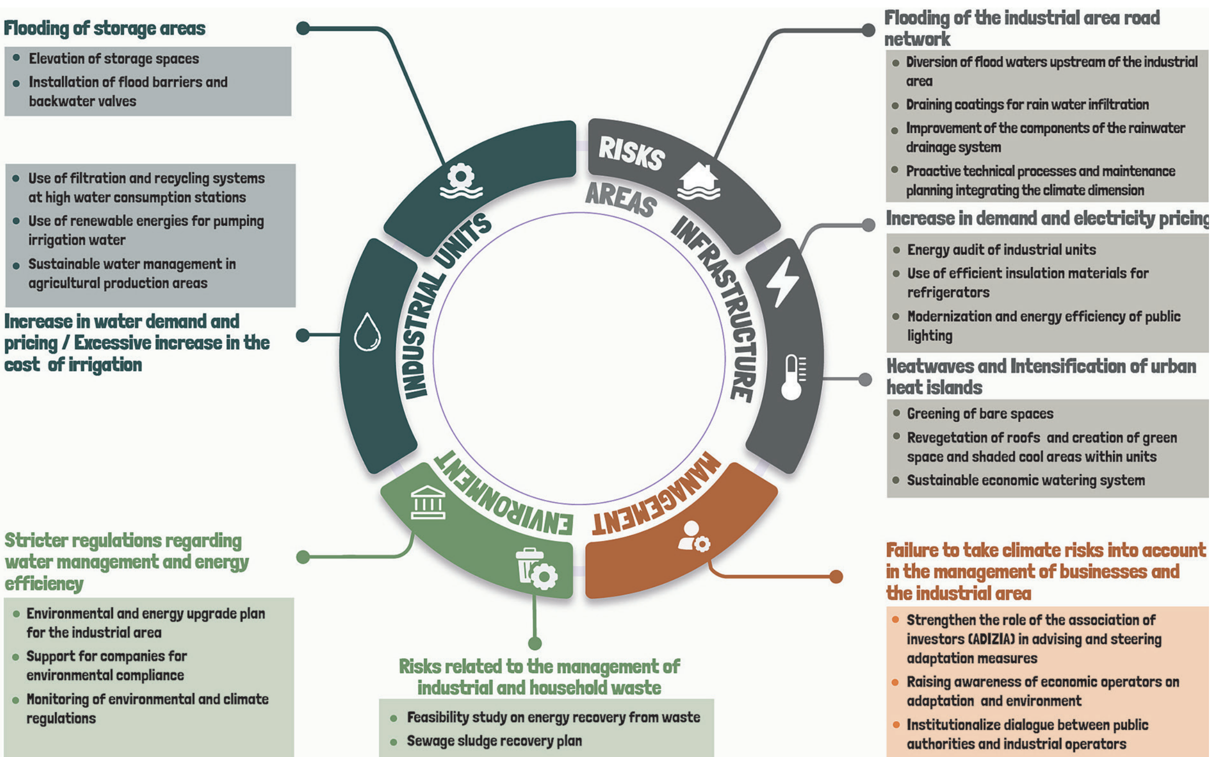

Figure 11. Elements of an Environmental and Climate Change Adaptation Strategy of the IA of Aït Melloul

To seize these opportunities and effectively take action against the negative impacts of climate change, IRSs are essential tools for achieving the goals of climate resilience and sustainable development (UNIDO, 2019). IRSs could also be a niche for climate action in line with the Paris Agreement goals of reducing greenhouse gas emissions from these regions and preparing for the consequences of CC (UN, 2015; UNIDO, 2019). To make these EAIs more resilient, this work proposes a proactive approach to analyzing CC-related risks and vulnerabilities, developed in close collaboration with stakeholders involved in the management of the IRS and the industrial units concerned. At the end of this analysis, key elements are developed to set up a customized strategy of adaptation to CC integrating environmental considerations, and based on the typology and particularities of the IRS and the industries that are established there.

The case study presented in this paper underlines that the desired transition requires two essential links. These are energy environment upgrades at the scale of the IA, and strengthening and perpetuating the governance structure of this area. To accomplish this environmental and energy transition, it is recommended to launch an urgent program for requalification of the IA based on the criteria of sustainability and resilience to the CC. A technical study of requalification conducted recently by Commune hints at the need for a profound revision integrating the highlighted vulnerabilities and risks. This will remedy the considerable deficiencies in the basic infrastructure and create conditions for the desired transition.

Regarding industrial units, this study shows that raising awareness remains a sine quinone condition for ensuring their involvement in this dynamic. This means taking real ownership of the risks and opportunities associated with CC and the requirements for sustainable development. To achieve this, it is recommended to set up advice and support services for managers regarding climate change.

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