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Climate change impact on stormwater systems in the coastal city of Casablanca, Morocco

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Climate change is nowadays a major challenge facing mankind. Yet difficult to assess, the consequences of this phenomenon are multiple, irreversible and exceed the response capacity of ecosystems that may be damaged or permanently destroyed. Morocco has experienced a significant change in precipitation with increasing frequency and intensity of extreme events of drought and flooding type. In this article, the impact of rainfall variability on the Casablanca city sewage network is studied. The city is ranked as one of the most vulnerable coastal areas to floods risks due to rapid changes in urbanization, demography and also the change in the rainfall regime induced by climate change. The combination of these factors has increased the occurrence of floods, causing damage to urban infrastructure and significant economic losses.

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Introduction

According to the GIEC, 2001, projected climate change will have beneficial and adverse effects on both environmental and socio-economic systems [7]. However, more the magnitude and the pace of these changes are important more the adverse effects are predominant.

Although Morocco is a low greenhouse gases emitter, the country is experiencing a real climate change which impacts are already visible as evidenced by series of dramatic floods and droughts in recent decades.

The available climate projections suggest a change of temperatures and precipitation for Morocco with increasing average rainfall and more frequent intense rains, by the middle of the century. This evolution may affect the performance of stormwater systems and may be even more exacerbated by the sea level rise which causes serious hydraulic problems in the network at the level of the coastal cities.

This situation may be also intensified in the case of strong urbanization and continuous population growth as in the case of the city of Casablanca, which during the last two decades had a rapidly sprawling urbanization with a population reaching more than 3 million inhabitants. In 2011, the city was ranked by the word among the most vulnerable coastal cities to urban flooding [1].

The problem of urban flooding will increase firstly by the increase of more frequent and intense extreme precipitation episodes bringing additional water overload in urban areas. Secondly, the galloping urban sprawl upstream of the existing urban areas leads to the appearance of new points of overflow because of the failure of existing collectors downstream to absorb additional flows.

This article analyzes the impact of climate change on the stormwater systems of Casablanca, Morocco. At first, climate

change observation in the region of Casablanca and its sewage system will be described. Then the impact of extreme events on the stormwater system will be discussed.

Study area: The city of Casablanca

Casablanca is the largest city in Morocco. It is the financial and economic capital of the country. The city houses the first financial center, one of the most important *ports* and one of the major *university campuses in the country.* It is located on the Atlantic coast about 80 km south of the administrative capital Rabat *(Fig. 1*). It is characterized by a semi-arid climate with average annual temperatures ranging from 12.5 ° C in winter to 22 ° C in summer. The annual rainfall totals, characterized by high variability, have annual mean of 427 mm. They can reach values lower than 200 mm or sometimes exceed 800 mm.

Fig. 1: Location map of Casablanca, Morocco

Climate change in the region of Casablanca

Several considerable changes of temperature, precipitation and sea level have occurred in the city of Casablanca in recent decades attesting climate change new reality.

Temperatures:
Casablanca has experienced warming temperatures during the past five decades. At the annual level, the average temperature has increased over the period 1961-2008, with a trend of 0.3 ° C increase per decade in Casablanca [2].

Future projections in 2030, assessed using models of descent of dynamic range on several scenarios of greenhouse gases evolution provide for Casablanca a *warming of 0.8 to 1.3 ° C at the annual level* accompanied by a small increase in the number of days of summer heat waves (Fig. 2a /2b).

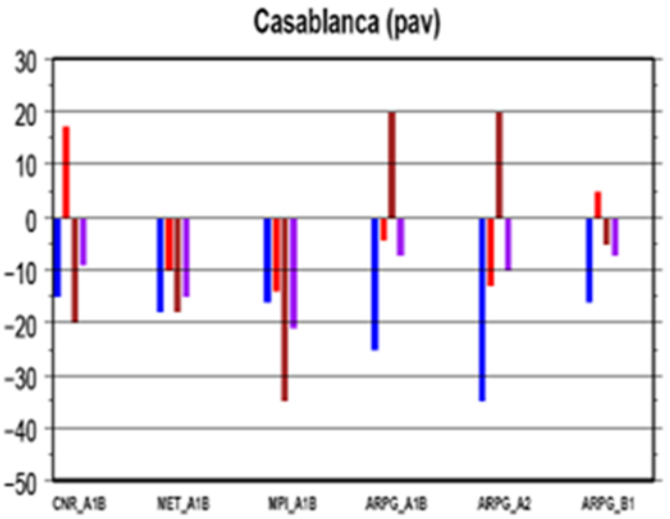

Fig. 2a: Projected changes, according to the different scenarios models, for seasonal and annual average temperatures (° C).

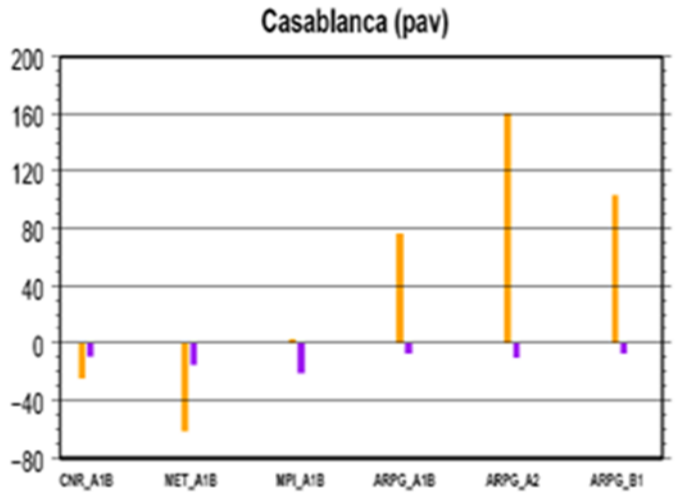

Fig. 2b: Projected changes, according to the different scenarios models, for the number of summer days of heat waves and winter cold waves.

Winter: Blue bars, spring: Red bars, summer: Orange bars, autumn: Brown bars, the year: purple bars.

Precipitation:
In rainfall terms, Casablanca shows a clear downward trend in the level of annual precipitations with a decrease of approximately 2.8 mm/yr.

In 2030, annual rainfall totals are expected to decline by 6 to 20%, those of winter by 15 to 35% (Fig. 3a/3b).

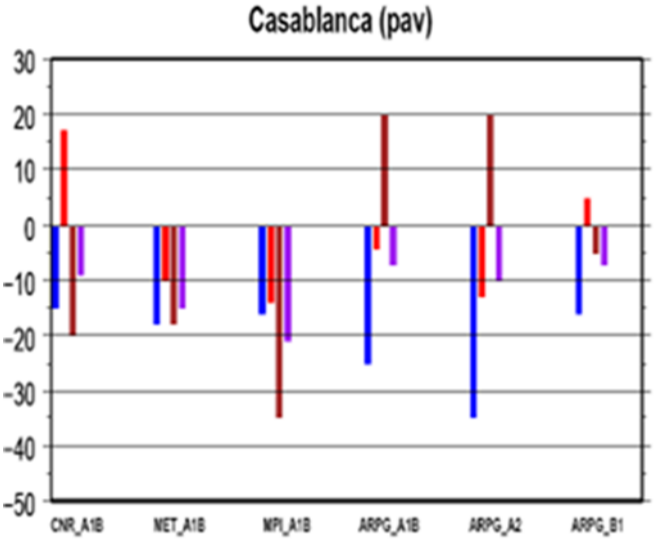

Fig.3a: Projected changes, according to the different models-scenarios for seasonal and annual precipitation

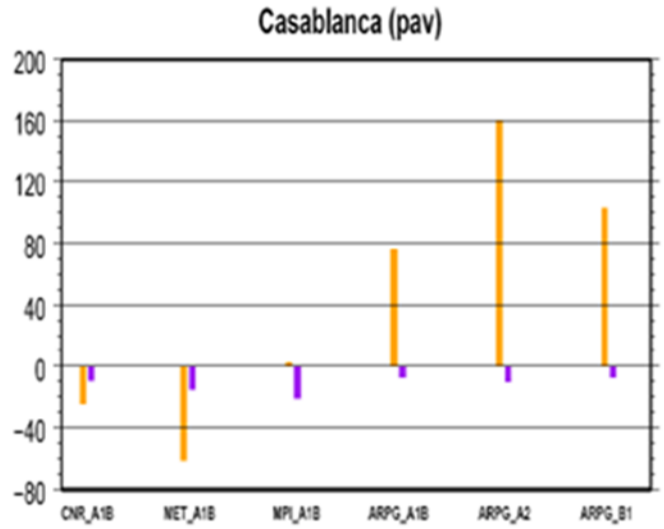

Fig. 3b: Projected changes, according to the different models-scenarios for seasonal and annual precipitation

Winter: Blue bars, spring: red bars, summer: oranges bars, autumn: Brown bars, the year: purple bars

Sea level:

An accelerated rise in sea level will be caused by global warming, through the phenomena of dilation of water masses and melting of polar ice caps. Projections in 2030 show an overall sea level rise of 20 cm [3].

It should be noted that it is a high level assumption, impossible to refine on the Moroccan Atlantic coast in the absence of tide gauge data over a long period.

Casablanca sewerage system

Sewerage networks management of Casablanca is delegated to LYDEC (Lyonnaise des Eaux, water private operator in Casablanca) since 1997. The concession contract covers an area of 120,000 hectares.

The network is a combined system in the older parts of the city and a separate one in recent parts [3]. (Fig. 4) shows the layout of the main collectors, the delimitation of the area where the network is combined and major drainage structures (storage basins, sewer outfalls and discharges in the ocean).The network pipes have a total of 4732 km predominantly a combined type with 4226 km of secondary and tertiary collection networks (diameter <800 mm), and 506 km of primary infrastructure networks (diameter ≥ 800 mm).

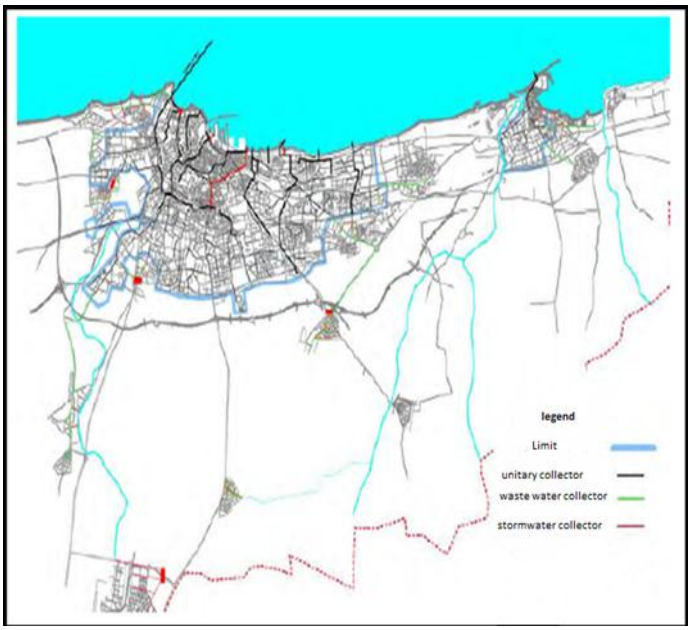

Fig. 4: Main collectors and sewerage system at the urban area of Greater Casablanca [3]

Methodology

Impact related to the extreme rainfall on the sewerage system

A. Frequency of overflows due to the sewerage network in Casablanca

The city of Casablanca has undergone regular flood disruptions, because of its level of protection, which is limited

to a five-year return period. This is due to inadequate drainage systems throughout the city and informal urbanization in catchment areas. A study carried out by the World Bank 2011 [4] found that floods are considered as a high risk in 2010 and in scenario 2030 as shown in the (Fig. 5) below: Is it possible to separate between areas with a protection period of less than 5 years (at the city center level) and extension areas with there is a protection period of 10 years (extension zone).

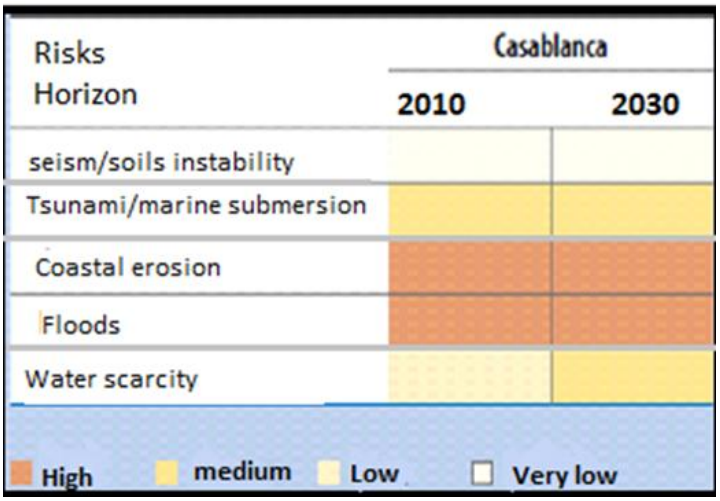

Fig. 5: The level of current urban risk and by 2030 in Casablanca.

B. History of floods in Casablanca

The history of the floods testified the importance of the disasters caused by urban floods that hit Casablanca. Exceptional rainfall in November 30th, 2010 with more than 220mm, the equivalent to 6 months of rain in 12 hours, paralyzed part of the territory of Casablanca, especially the industrial area of Sidi Bernoussi. Not to mention those of November 27th, 2010 that reached 195 mm in 24 hours, which represents 50% of the precipitation annual average that was totally recorded in only one day.

Casablanca also suffers from the floods of the urban river, of Oued Bouskoura.This natural water way is one of the major threats that hangs over the metropolis. The danger resides in the fact that the city of Casablanca is built on its natural Riverbed that crosses the city from east to west before discharging into the ocean at the old fishing port. When the river is high, it overflows on Casablanca (Fig. 6) because the riverbed has been obstructed by rapidly developing uncontrolled urbanization, and consequently, the flow section of the stream, when crossing the agglomeration, has been greatly reduced.

C. Assessment of flood damages

A study by the World Bank shows that for the period 2010-2030, the net present value of potential economic losses due to natural disaster and the impact of climate change for Casablanca are estimated at 1.39 billion dollars [4], which most would be associated with flooding. These losses represent 7% of current gross domestic product (GDP) of great Casablanca. The potential economic losses due to the effects of climate change are estimated at 18% of the total.

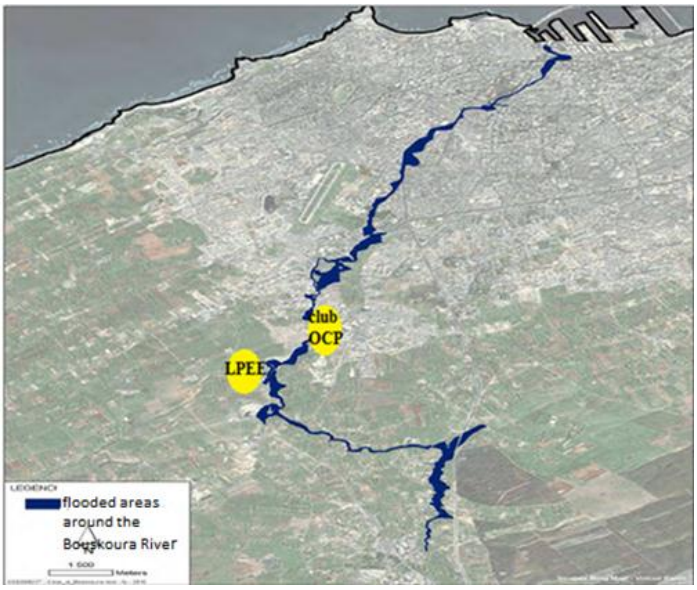

Fig.6: Map of flooded areas around the Bouskoura River

Table 1 summarizes the history of overflows in the Casablanca and their causes.

Tab. 1: History of Casablanca floods

Date	Flood areas	Daily recorded Rainfall	Causes
November 30th 2010	Industrial area of Sidi Bernoussi	220mm	- Low area -Exceptional precipitation
November 27th 2010	Casablanca	195mm	- Overflow of Oued Bouskoura - Torrential rains
November 24th 2013	Casablanca	50mm	Network obstruction
November 4th 2014	The highway of Casablanca at the level of Ain Sebaâ	31mm	Absence of an outlet for runoff from the highway

Tab. 2: Assessment of flood events damage in Casablanca since 2010.

DATE OF THE RAINY EVENT	DAMAGE
November 30 th 2010	- 85 companies were forced to stop their activities (figure 7) -The disruption of export programs -Most of the access roads leading to the industrial area have been flooded (fig. 8) -The losses are estimated between 21141.5 US$ and 2656786.37 US$ -The textile sector was particularly affected
November 27 th 2010	-The waters submerged the Hassania School of engineers, the biggest national phosphates production company (OCP) headquarter and several buildings in El Jadida Road area -Three laboratories of the main public laboratory of studies and testing of the country (LPEE) were severely damaged. -Power outage - Total panic in the streets -All roads were blocked(fig. 9) -Cars were blocked in garages -The traffic was paralyzed -The schools were closed
November 24 th 2010	-Stop of traffic -Damaged vehicles(fig 10)
November 4 th 2014	-Stop of traffic

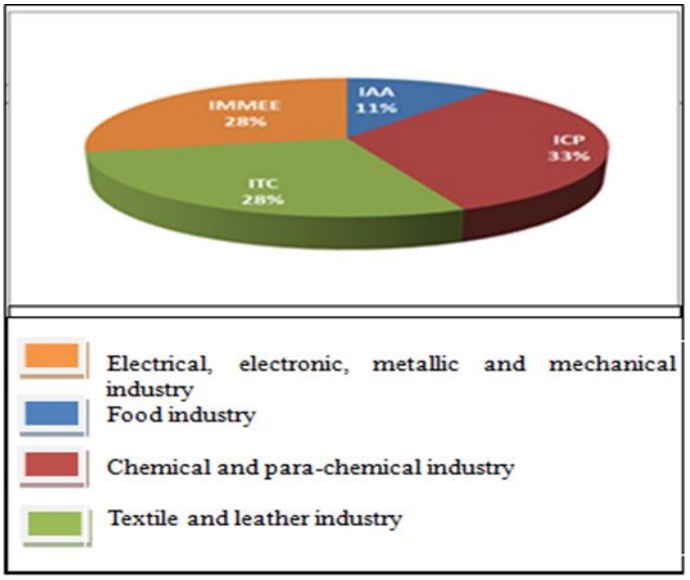

Fig. 7: Companies classified by industrial activity affected during 2010 floods in the industrial area of Sidi Bernoussi, Casablanca

Fig. 8: State of companies' after2010 flood

Fig. 9: Access roads to the industrial area of Sidi Bernoussi after 2010 flood

Fig. 10: The damage of floods in November 2010 in El Jadida road.

Results and Discussion

Adopted measures for urban flood protection: the stormwater system improvement

During the last decade, Casablanca sewerage network has become inadequate because of uncontrolled urbanization which is inconsistent with the network size and the increase of surfaces imperviousness in the city. Besides, the problem of climate changes has altered the rainfall regime. The combination of these factors has accentuated the occurrence of floods.

In order to sustainably combat the major black points of overflow in Casablanca, three strengthening systems have been proposed in the context of the Sewerage Master Plan of Casablanca [6]:

-West strengthening system: a gallery the 9.6 km length with diameters ranging from the DN 2, 7 m to the DN 4 m.

-East strengthening system: one primary pipe and 2 secondary pipes with a total length of 17.7 km Gallery with varying diameter from DN 2,4 m to DN 5 m.

-Super West Collector project: a collector for about 7 km including underground gallery for a flowrate of 65 m³/s.

Figures 11and 12 illustrate the measures proposed within the Sewerage Master Plan of Casablanca:

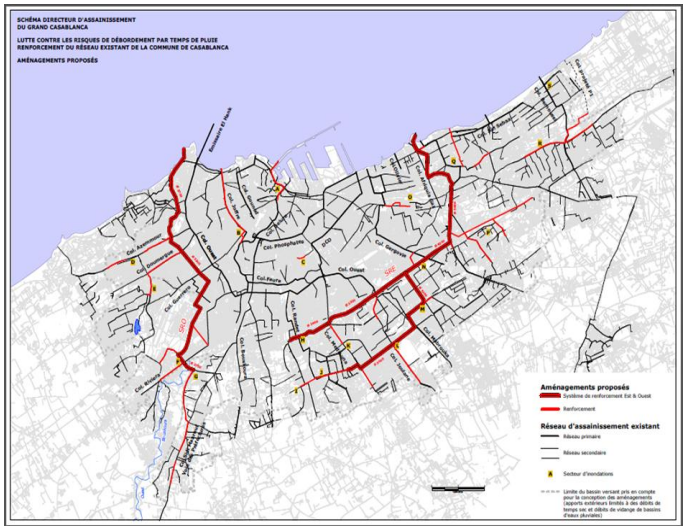

Fig. 11: The proposed measures in Casablanca

Fig. 12: Super West collector project in Casablanca

Conclusions

The construction of large infrastructure collectors has been able to limit overflows in areas where existing collector capacity was deficiencent, by shedding rainwater to the sea and relieving a large part of sewerage network.

However, the improvement of the network remains insufficient with regard to the impact of climate change on the frequency of intense rains. Therefore, the need to strengthen and increase the level of Casablanca protection against flooding and to reduce risk and cost in the future by other measures has become essential, notably by:

-the development of flood vulnerability and risk maps, in order to integrate them in all flood protection measures and in urban planning.

-the development of flood forecasting systems and contingency plans, through the generalization of hydrological telemetry and the implementation of models for flow prediction.
-take into account the impact of climate change on sanitation networks (qualitatively and quantitatively).
-the development of flood warning systems inside and around the city.
-raising awareness of investors and promoters to the need of taking flood risks into account in any investment project and to promote prevention and mitigation techniques for such risks.
-statistical adjustment of the IDF(Intensity duration frequency) curves to adapt them to changes in precipitation due to climate change because these curves allow the determination of the basic parameters to be transposed to flood and flow management models and to be used in design calculations of stormwater systems.

Références

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