Introducing Project-Based Climate Education in Moroccan Universities via a New Air Quality Monitoring Network in Rabat

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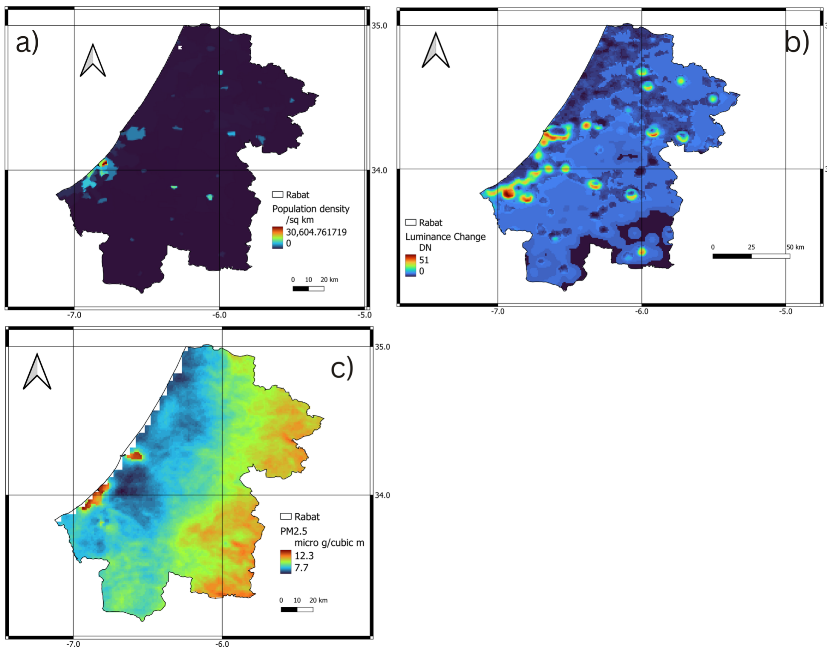
Abstract. Morocco's economy has recently seen an unprecedented growth, which made the country emerge into the 5th strongest economy of the African continent. As other countries at the same stage of development, Morocco is also undergoing rapid urbanization, which results in increased anthropogenic air-pollution levels. The geographical location of the country makes it vulnerable to both short and long-term impacts of climate change. Despite the elevated risk and vulnerability, the current air pollution and climate change monitoring strategy of the country needs improvement. The present paper introduces a novel strategy to improve the air quality monitoring system in the capital combined with developing a project-based climate education curriculum, and promises to raise public awareness to the risks related to air pollution and climate change. The sustainability of the project is guaranteed by the low cost of instruments and the educational aspect which ensures that future experts are well-trained for the maintenance of the system that we propose to install.

Keywords: Air Pollution, Climate Change, Environmental Education.

1 Introduction

Morocco is highly vulnerable to air pollution and climate change due to its geography as well as to its economic situation. Located on the West Coast of the African continent,, in the vicinity of the Sahara desert, Morocco is subject to extreme weather conditions, especially droughts, heatwaves[1,2] and extreme rain[3]. During the 2022 heatwaves episode, several cities in Morocco recorded temperatures exceeding 46℃ [https://www.moroccoworldnews.com/2022/07/350414/moroccos-weather-office-temperatures-to-exceed-45-deg-c-in-some-provinces]. Morocco is also an arid country with an annual average rainfall of 301.6 mm. Such small annual precipitation makes it more vulnerable to drought. Several rivers dried out completely or partially during the last year and the water levels of the largest water reservoirs dropped below 25% capacity [https://www.moroccoworldnews.com/2022/09/351313/dam-water-levels-decrease-to-25-amid-severe-droughts] . The projected annual precipitation for the year 2100 is predicting a 10%-20% decrease in annual average rainfall as compared to the 1986-2005 period [4]. The projected number of very hot days (greater than 35℃) is also expected to increase significantly during the May to September period according



to the same source [4].

Fig. 1. a) The population density of the Rabat-Salé-Kenitra province. b) Differential nighttime luminosity maps obtained from the difference between average nighttime luminosity in 2022 and 2012. c) Average PM2.5 levels in the Rabat-Salé-Kenitra province.

Morocco has experienced an economic boom during the last decade and is currently listed as the fifth largest economy of Africa with a per capita GDP of 3.715 USD [https://www.hcp.ma]. The economic development is accompanied by rapid urbanization and population growth of around 1% per year [5]. This economic situation makes Morocco susceptible to air pollution related issues also experienced by other regions in the world that follow the same dynamics of development. The largest city of Morocco, the well-known industrial and trading hub, Casablanca has experienced unprecedented population growth in recent years and other urban areas, such as Marrakesh or the capital Rabat are also undergoing constant growth. Population densities of urban areas in the Rabat-Salé-Kenitra province are shown in Figure 1 a) [6], the most highly populated area corresponds to Rabat. As a proxy for the rate of urbanization Figure 1 b) shows the change in nighttime luminosity taken from satellite observations over the last 10 years [7], suburban areas and agglomerates around Rabat have seen a significant increase of nighttime luminosity with respect to 2012 levels which can be correlated with the territorial growth of suburban areas over the past decade. By 2050 an estimated 73% of the population will live in major cities mentioned above, resulting in potential air pollution issues related to traffic, construction and increased electricity and fuel consumption. For instance, Casablanca is exposed to fine particulate matter pollution levels of ~31μg/m³ measured in terms of the concentration of particles whose diameter is lower than 2.5 µm (PM2.5). PM2.5 levels serve as a proxy to determine the health hazards related to air quality according to the current regulations of the World Health Organization (WHO)[8]. The level observed in Casablanca corresponds to the higher end of the 'moderate' interval on the air pollution scale. PM2.5 levels from satellite observation in the Rabat-Salé-Kenitra province are shown in Figure 1 c), high average pollution levels around the capital are related to anthropogenic emission sources while the higher PM2.5 levels of rural areas at the Eastern border of the province originate from natural sources (soil erosion, desert dust). Maximal values correspond to moderate mean pollution levels. The coastal climate of Casablanca and Rabat are favorable for removing air pollution, other large cities with less favorable topology, for example the touristic hub Marrakesh which is surrounded by mountains, are even more susceptible to experience dangerously high PM2.5 levels which likely persist due to the unfavorable geographical factors.

Main pollution sources in Morocco can be classified as anthropogenic (industrial) and natural. Anthropogenic sources include charcoal, waste and biomass burning, factory and power plant emissions, construction sites and traffic. A significant fraction of vehicles that make up the main road traffic have been manufactured prior to the introduction of stricter emission standards, and have higher emissions than modern cars. The largest natural pollutant source is desert dust. Dust is continuously pumped into the air by soil erosion but especially strong dust storms (so called dust events) also occur mostly during spring and autumn [9]. Plumes from such dust events are transported in the atmospheric circulation over thousands of kilometers reaching as far as Eastern Europe or North America [10].

Air pollution and dust in particular can cause impaired visibility, degradation of the natural and built environment as well as severe acute and chronic adverse health effects. Acute adverse health effects include allergic reactions (itchy eyes, cough and asthmatic symptoms), while increased dust is also associated with increased cardiovascular and respiratory disease and cancer [11-13]. According to recent data air pollution is responsible for an annual death of 5,000 citizens and an economic loss of €1 billion over the country[14].

Despite the severe vulnerability and the high risk associated with air pollution and climate change, Morocco still lacks an established air quality monitoring system. A national network of air quality monitoring stations counts merely 31 air quality monitors (https://fm6e.org/en/programme/qualitair/). In this paper we introduce a sustainable strategy to i) extend the air quality monitoring network, with focus on Rabat the capital of Morocco; ii) to increase the presence of environmental science in higher education and iii) raise public awareness of air pollution and climate change.

2 Methods

The project is built up of the installation of a network of air quality sensors and weather stations in Rabat accompanied by an educational and a public awareness campaign.

Air quality monitoring. Particulate Matter (PM) sensors are optical particle counters that correlate the light scattering of air samples pulled into the sensor using a fan with the particulate matter concentration[15]. Low cost air quality monitors allow for sampling air quality at much higher spatiotemporal resolution than standard methods. This is important for studying urban air quality, because particulate matter (PM) levels can change on much smaller scales than those covered by traditional air quality monitoring methods or satellite observations depending on local land use and typical activities in a given microenvironment. Low-cost sensors have the ability to measure human exposure to air pollution at spatiotemporal scales that are relevant for changes in PM concentrations in urban settings, or even down to the level of individual humans [15,16]. They are small, have a very moderate power consumption and come in forms that make deployment relatively easy [16]. They are known to be accurate for the finest fraction of particulate matter (PM1) and typically are applicable for detecting the PM2.5 fraction given that a careful calibration procedure is put in place [15]. Their disadvantage is that they are unreliable in detecting coarse mode particles (PM10) [16]. However, this is a small trade-off compared to the advantages of low-cost sensor based monitoring systems: easy installation, high spatiotemporal resolution and low maintenance cost.

A network of 10-15 low cost air quality monitors will be installed in outdoor locations having different land use patterns across the city of Rabat. We will use PurpleAir sensors that have the highest combined accuracy for PM1 and PM2.5 levels[15]. PurpleAir sensors are equipped with built-in wifi connection and an SD card that allows for both online presentation of real time data and data acquisition for further analysis. Some of the sensors will be co-located with weather stations that provide real time measurements of temperature, humidity and wind speed. Weather stations are important for developing a nowcasting system for extreme weather events by measuring e.g. precipitation and comparing it with threshold levels beyond which warnings should be issued. The locations of the sensor will be chosen to be representative to main land use types encountered in the city of Rabat: residential with high, moderate and low population density, commercial, industrial, agricultural and green areas as well as university campus. The land use types listed above are located on the city map of Rabat and Salé in Figure 2.

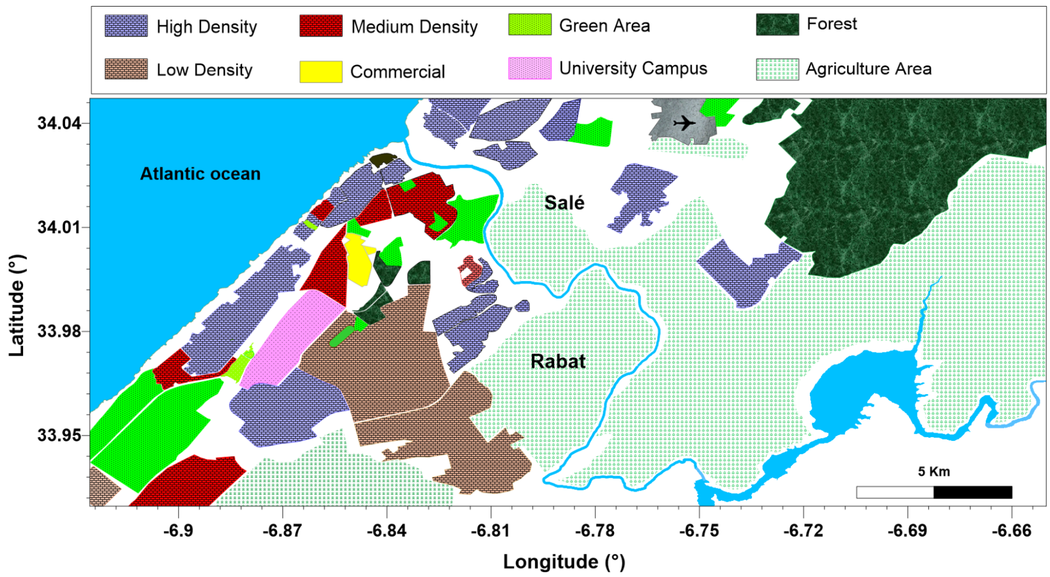


Fig. 2. Land use map of Rabat indicating major land use types (legend in the Figure)

Developing a higher education curriculum. The educational curriculum will be hosted by the Faculty of Science of the Mohammed V University in Rabat. The curriculum will build on two levels of training activities. On level 1, a University Climate Club (UCC) consisting of faculty members and students with areas of expertise related to climate change and air pollution (environmental science, chemistry, political science etc.) will be created. Members of this group together with the authors of this paper will be responsible for the installation and maintenance of the instruments that comprise the monitoring network described above. On level 2, the expertise shared in the UCC will be extended to a wider group of students on bachelor and master level through hands-on tutorials of data processing, analysis, interpretation and dissemination organized in the form of workshops open to students from all higher education institutes in Morocco.

Public outreach. Climate change and air pollution affects the whole population therefore it is important to extend the monitoring and education activity with significant outreach towards the citizens of Rabat. Our project aims to involve citizens in the form of open days/citizen science days organized by the University Mohammed V. Besides that ephemeral activity, we will also implement an instrument for continuous public outreach. A website will be created and maintained by the UCC which will contain the following information: i) the description of our activities; ii) sensibilization material about air pollution related risks, prevention and protection strategies and ii) real time data from the sensors and a nowcasting system for extreme weather events.

3 Timeline of the activities

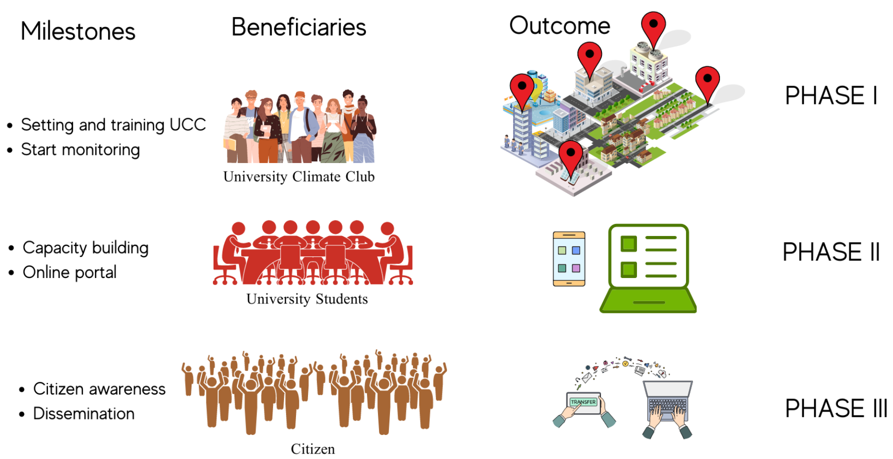


Fig. 3. A schematic timeline of the planned activities of the project

The project will consist of three main phases. In phase I, the University Climate Club (UCC) will be formed and the monitoring network will be installed. In phase II training and capacity building will be performed with hands-on tutorials and theoretical exposure to instrumentation, data analysis and climate preparedness. In Phase III, direct citizen involvement, technology and knowledge transfer and mass-scale sensitization will be achieved. A detailed description of each phase is documented below and activities are summarized in Figure 3.

Phase I: Formation and Mobilization of University Climate Club (UCC) The UCC unit will be formed comprising 10-12 university professional students and faculty members who will also act as "Master Trainers" and will be responsible for the long-term sustainability of the project. The first step will be focus group discussion with the UCC members on representative site selection for the installation of the instruments which will be followed by the installation of the instruments to measure different climate extremes such as heatwaves, drought, and air pollutants in the city by UCC members. The communication and two way knowledge transfer between the principal investigators (PIs) and the UCC will be ensured by regular meetings. The PIs will organize a training program on air quality and weather instruments for UCC members, followed by ground data collection and survey on sampling sites across the city. Hands-on tutorials will be designed together with UCC members on the use of informatics and data science for air quality and climate change related data analysis, including training on Geographical Information Systems and Satellite data for climate change and air pollution monitoring, as well as advanced statistics (R, Matlab) for time series analysis.

Phase II: Climate education through project-based learning An online open-sourced platform where live data from the instruments will be created.. Capacity-building workshops will be organized in this phase for about 100 participants on instrumentation, data analysis, visualizations and interpretations of climate change-relevant data from installed sensors. This workshop will be conducted by the UCC members in collaboration with the project PIs. Since the project is of a pilot nature, a follow-up survey will be organized to evaluate the course curriculum and facilitate implementation of improvements for later stages. In this phase students and UCC members will also be trained on the maintenance of the instrument, including detecting deviations and performing calibration.

Phase III: Citizen awareness and long-term sustainability. The final phase will focus mainly on outreach in the form of an open informational website as well as open-days targeting a large range of audience with a special focus on informing elementary and highschool students about air pollution with a possibility to visit the monitoring system in the form of guided tours. Besides outreach part of this phase will be devoted to scientific publication and naturally instrument maintenance will be also performed at regular intervals.

4 Preliminary results and future perspectives

The project presented here is a pilot in a running up phase that has just been accepted for funding in the bilateral project funding framework therefore all results listed here are preliminary and represent the initial steps of the collaboration.

After contact between the project partners had been initiated, the Mohammed V Univeristy in Rabat hosted an ice breaker session on the 15th of December 2022. The session included a brief introduction of the project, preliminary agreement about the placement of the sensors and the pre-selection of responsible PhD students and a seminar of information about the activities of the laboratory of the Swiss partners. The primary analyses to prioritize area for sensor placement over the city were performed. Satellite-based air pollution, population growth and distribution maps were created for the Rabat-Salé-Kenitra province (Figure 1), with a resolution of 1 km for 2019. The different land-use patterns within the municipality of Rabat and Salé were identified with a resolution of approximately 100 m (Figure 2) This latter data allows for a judicious selection of the sensor locations that covers all representative types of areas in the city.

While PM2.5 and PM1 are associated with the health risks of air pollution, the chemical composition of the particulate matter is also an important marker of pollution associated health hazards [17]. With this in mind we are planning to extend the monitoring network with instruments that allow for collecting samples of PM on filters (high volume samplers) that can then be further analyzed using laboratory techniques.

5 Conclusions

We have presented a running up project funded by Haute école spécialisée de Suisse occidentale Leading House pour le Moyen-Orient et l'Afrique du Nord, which aims to develop an extended high resolution - low maintenance air quality monitoring system with an educational and outreach program centered around the instrumental base. The project will extend the existing air quality monitoring network of Morocco (31 sensors) by more than 30% and will ensure a sustainable use of the sensors by extending the collaboration beyond the level of faculty personnel (i.e. by the involvement and training of Master and Bachelor students). The project fills in an important data gap about urban air quality of the Moroccan capital, which is crucial for designing plans for urbanization, which is expected to continue at even larger rates in the future years. It also proposes to monitor and nowcast extreme weather events (droughts, heatwaves and extreme rain) that are expected to increase in frequency as a result of the vulnerability of the area to climate change. The project is open-ended and can be amended by even more detailed chemical analysis of particulate matter that can adapt to changing standards and suggestions of the World Health Organization concerning the health effects related to air quality.

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