The vertiginous and unquestionable climate change could alter the delicate balance that exists between human beings and nature. Countries struggle to reach international agreements to set mitigation measures or adaptation to changing climatic condition; otherwise, autochthonous population in certain vulnerable regions could be forced to search better life conditions. They are poorest communities settled on ecologically fragile areas with a lack of livelihood alternatives, low income and their greater reliance on climate-sensitive sectors like agriculture that is relied on low technology. The loss of hydrology resources decreases the agricultural productivity due to climate change. Several coupled systems, briefly mentioned climatology, livelihood resources and the individual dignity concern are studied in the MEDCHANGe project. In this context, this paper only tries the methodology to tackle one of the echelons of this complex causality chain. The connection between climatology and hydrology and consequently agriculture has been well studied in the literature. Some methods have been applied in numerous areas of the world where exogenous and endogenous variables have different weights according to the particular circumstances, which are determined by the soil, local climate, market economy involvement, among other factors. The objective is to advance in this causality chain, to connect with the social researching, by integrating the results in a mixed method (qualitative and quantitative). This is in order to find a more suitable model that could best reveal the causality or correlation between climate change and agriculture in the Marrakesh region. Agriculture is in fact the basis of the economy and the population welfare and, consequently, it can determine the proper conditions and hence evaluate the life dignity threshold that forces people to the exodus. The findings will be useful in the MEDCHANGe context, to confirm the hypothesis of a possible relationship between climate change and the people movement in the Mediterranean area. Therefore, among the factors intervening in the decision to emigrate, climate change phenomena should be considered in some measure. By isolating the factor impact, the method to mitigate the effects would be encouraging under this approach.

1. Introduction

Climate change will eventually be the most important concern that can interfere the development of this century. Effects of climate change are already noticed in many populations in the world. The livelihood of those populations is severely harmed, especially in the case of minorities immersed in poverty. The effects of climate change on different economic sectors involved in the migration process could not completely be identified. Therefore, the concept of environmental migration has often been rejected or not sufficiently considered, because of the complexity of factors contributing to migration (Renaud et al. 2011).

The intervention of different aspects with more or less influence, depending, for example, on geopolitical situations makes that “the environmental migration is understood as a multi causal phenomenon, in which environmental drivers play a significant and increasingly determinative role. These drivers can be in the form of natural disasters or environmental degradation and these
may or may not be related to climate change” (IOM 2011, 2). Since the term ‘climate migration’ could suggest ambiguous concepts, in this work it, we assume to express an environmentally induced migration closely linked to the climate change in spite of other meanings. Faist and Schade (2013) simplified the multi causal phenomenon with their two key elements: the migration as a process of cumulative causation connected with environmental phenomena and the capabilities ‘development. This paper investigates the causality chain that starts at the climate change in revealed hints, going through primary resources availability—such as agriculture—and the economical budget to keep a dignified welfare, and finally reaches a critical state when the individual is forced to emigrate for the development of capabilities.

The causation chain can be observed, from the social and economic development that depends on the availability and the sustainable management of water resources at a given place and time, and this availability is strongly affected by climatic conditions (Hammer et al., 2001). Among the researches that have attempted to investigate the consequences of climate change on water availability and social livelihoods, Gohar and Cashman (2016) propose a dynamic nonlinear model to optimize the economy of irrigation and food security under the extreme events of climatic assumptions.

The variability of the precipitation patterns, regarding intensity, duration and frequency of rainfall, will alter the surface water and groundwater availability. Consequently, in some way, agriculture profits and crops are affected. A new approach of the Ricardian theory (Ricardo, 1817), was the cross method to assess the long-term impact of climate on agriculture by correlating the net revenues per hectare with a set of meteorological variables (Mendelsohn et al., 1994). Another application of Ricardian proposal comes from Salvo et al., (2013) to measure the impact of climate change on permanent crops in an Alpine region. Even more, Darwin (1999) explicitly includes the irrigation to improve the Ricardian analysis.

Climatic variability establishes the hydrological cycle. So any alteration in the climate pattern for a given region will signify an alteration in the availability of water and therefore in the entire dependent ecosystem. Water is considered the primary resource and agriculture as the essential economic support of the emigrant potential in the study of the original areas. The objective of this paper is to propose an advance in the causality chain defined from the climate change phenomena to the availability of critical resources, which could force a population to emigrate. That means setting up a methodology to connect the functional analysis of meteorological data with the social researching, i.e. mixed methods (qualitative and quantitative) are carried out from a multidisciplinary study.

2. Methods
   a) Organisational Method

The connection between climatology and hydrology and consequently agriculture has been deeply considered in the literature. Some methods have been applied in numerous areas of the world where exogenous and endogenous variables have different weights according to the particular circumstances, determined by the soil, local climate, and market economy involvement, among others.

The chained causation is categorized in three levels (Fig. 1): the revelation level, the impacts level and the consequences level. Each one of these constitutes a subsystem domain and all of those levels are with are coupled each other by mutual influence.

- The first level shows the climate change evidence through indicators as hydrological cycle alteration or thermal trending. Analysis techniques can locally reveal periodicities and trending. In this level, some nonlinear analysis techniques are tried out to show the
trend of time series, which represent historical variations of certain meteorological parameters concerned to the geographical area under study.

- In the second level, the study of correlations and high statistics methods can help to reveal the human activities affected by the impact factors identified in the first level. The list of these activities can be too broad, not well defined and roughly assessed, due to multiple factors incidents, and to the rate of interleaving among activities. Therefore, as a lead idea and prototype guidance we focus the study of the weather conditions (specially temperature and precipitation) on agriculture, assuming that it is the essential economical sustenance for the inhabitants in the origin countries.

- The third level assesses disparate impacts on environmental migration, climate refugees, life mode restructuring, loss of homes, medical facilities and other essential services.

- The fourth level represents the social groups that suffer from the greater consequences of climate change: special minorities, victimized women, unprotected children, uprooted native people, low-income populations, and inhabitants of areas with weak health infrastructure.

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**Fig. 1. Methodology based on a chained causation categorized in three levels. Red circles mark the issues treated in current study.**

**b) Trend analysis methods**

Different techniques can be used to identify the permanent and periodic components in a non-stationary time series. The permanent component can be interpreted as a trend, whereas the transitory component may be the stochastic cycle. “The essential idea of trend is that it shall be smooth” (Kendall, 1973). Trend statistical techniques are useful aid to interpret historical data and describe the behavior of the observed data, such as when rainfall time series exhibits an increasing or decreasing trend. Among the variety of functions to depict a trend, the most common is a least-squares fit, to get the representation of a simple linear regression. A standard function, such as least-squares, can fit a polynomial to a set of discrete data points $p(x)^{\text{th}}$. The polynomial $p(x)$ of degree $n$ represents a vector of coefficients in the monomial basis. The
algorithm uses the x values to form Vandermonde matrix. Since the columns in this matrix are powers of the vector x, the condition number can be considerable for high-order fits, resulting in a singular coefficient matrix. In these cases, the operation of centering and scaling has been applied to get a more reliable fit.

c) Wavelet techniques for trend and correlation.

When the time series presents a vanishing autocorrelation, different techniques based on wavelet transform should be applied to get a nonlinear trend. Using the fractionally differenced process, Craigmille et al. (2004) proved the discrete wavelet transform at extracting a polynomial trend in this type of time series.

Wavelet transform provides the frequencies contained in the signal and sheds light on the moment at which each frequency is present (Mallat, 1999). Wavelets are well appropriated for analysing signals that hold local nonlinearities and singularities. The continuous wavelet transform (CWT) $f(t)_{s,\tau}$ of a function $f(t)$, on the base of the wavelet mother $\psi_{s,\tau}$ is defined as the inner product $\langle f(t), \psi_{s,\tau} \rangle$ in the measurable and square integral spaces (Daubechies, 1990) as is set out in Eq. 1:

$$W_{\psi, f}(s, \tau) = \int_{-\infty}^{\infty} f(t) \psi_{s,\tau}^*(t) \, dt \quad (1)$$

$$\psi_{s,\tau}(t) = \frac{1}{\sqrt{s}} \psi(\frac{t-\tau}{s}) \quad (2)$$

Where $\psi^*$ is the complex conjugate and $\psi(t)$ is normalized mother wavelet. All wavelet functions used in the transformation are derived from the mother wavelet through translation (shifting) and scaling (dilation or compression), modifying $s$ and $\tau$ in $\psi_{s,\tau}$.

The cross wavelet spectrum, introduced by Hudgins (Hudgins et al., 1993) to study the atmosphere turbulence, reveals how regions in the time frequency space with large common power have a consistent relationship. This fact suggests causality between both time series. The cross wavelet spectrum (XWS) between $f(t)$ and $g(t)$ signals around time $t$ and scale $s$, is defined by (5) as the convolution of the CWT of both signals:

$$X_{w, \psi}[f(t), g(t)]_{s,\tau} = [W_{\psi, f}(s, \tau) \otimes W_{\psi, g}(s, \tau)]_{s,\tau} \quad (3)$$

Coherence in signal processing consists of a measure of the correlation between two signals. The cross wavelet coherence function introduced to assess the intensity coherence of turbulent signals (Sello & Bellazzini, 2000) and can be applied to estimate the correlation between climate variability and hydrological system or agriculture production.

d) Agriculture production models.

System engineering is defined broadly as the art and science of creating whole solutions to complex problems. It provides methods to find the right model adapted to the peculiarities of the system in study. Identification techniques, developed to represent typical engineering artificial systems through linear and nonlinear models, can be applied in the study of natural systems. The
technique also called data-driven modeling is based on the analysis of data from one system, seeking in particular connections between the system state variables (input and output variables).

The Ricardian method is a classical cross-sectional approach to studying agricultural production. It was named after David Ricardo (Ricardo, 1817) because of his original observation that the value of land would reflect its net productivity. This principle is captured in a function with different parameters: the market price, the output of the crop, a vector comprising all purchased inputs, water flow, a vector containing soil variables, a vector of economic variables, and finally—the focus of the issue—a vector of climate variables (see Mendelsohn et al., 1994). This empirical formula is the basis of a model to assess the impact of the climate change on the agriculture activity. Nevertheless, a grey box in the context of system engineering is the proper way to model the interaction of weather processes and agriculture production. A grey box modeling is an intermediate technique when peculiarities of internal laws are not entirely known, so it is based on both insight into the system and on experimental data analysis” (Chinarro, 2014).

e) Social study by qualitative methods

According to McClung (1970), participant observation is the door to the details and problems of the right social knowledge. Under Nussbaum’s theoretical Capabilities Approach framework, the participant observation and the in-depth ethnographic interviews of migrants are used to interpret the meaning of the results from the interactional model between climate system and population welfare expectations. At the same time, we have also found awareness to understand the ways in which people experience, perceive, feel, value, and interpret their world (Jax 1984; Van Manen 1990). Qualitative research has performed with the objective of which is to describe, decode and analyze natural phenomena such as the impact of climate change as one of the causes that forced people to migrate (Wolcott 2008).

Qualitative research methods include participant observation, document analysis, focus groups and personal interviews. These methods provide descriptions and information of phenomena that would be unknown if other method are used (Weiss 1994). When discussing the methodology that would be the most appropriate, we really wanted to hear the voices of migrants and their perspectives about their migration process.

3. Data and area of study

The study of regional climatic variability has been chosen in a way that encompasses with the migratory flow paths from the rural areas to Marrakesh and that is coincident with the same geographic area in which the qualitative study is focused, which is the official demarcation of the Marrakech-Safi region.

Marrakech-Safi region presents a wide diversity of climates according to Köppen–Geiger climate classification system (Kottek et al. 2006) (Fig. 2). History already demonstrates since ancient times an exceptional adaptation of the settled or transit population to these abrupt changes.
The diversity of landscapes of this region, the variability of climate and weather, the geological features, expose this region to many natural events, sometimes devastating the common life of inhabitants with notable effects. The latter can involve landslides, tsunamis and earthquakes. In addition, other more frequent events are included, such as persistent droughts, large floods, intensive wind, forest fires, heat waves, and strong storms. A significant amount of the rural population is particularly vulnerable to these threats.

We look at the hydrological basin of the Tensift (Fig. 3) as a relevant geographic element that is, on the one hand, very sensitive to climatic variations and, on the other, a fundamental support of agriculture and rural activity in the Marrakesh-Safi region. The Tensift basin is located inside latitudes 32°10’ and 30°50’ North and longitudes 9°25’ and 7°12’ west, enclosing the city of Marrakesh, in the western center of Morocco. The Tensift River, which flows from east to west for over 260 km, drained it. The basin extends over 19400 km2. Its vegetation is generally poor and depends on the nature of soils. The climate is semi-arid determined by Atlantic influence and the changes of altitudes from zero in the coast to 4167m in the High Atlas.
Fig. 3  Tensift watersheds map, in the Marrakesh-Safi region (source: riversnetwork.org site)

Meteorological time series were analyzed from 1957 to September 2016 with daily samples of maximum, average and minimum temperature, as well as daily rainfall. Before performing the analysis of the time series, some issues should be addressed on the form of achieving raw data, checking the integrity and reliability of preparing procedures. The raw time series have some data lost or unexpected values in some short periods mostly by the decades of the fifties and the sixties. These deficiencies are discordant values that can appear in a time series, also named outliers and Hawkins (1980) defined as “the observation that deviates so much from other observations as to arouse suspicion that was generated by a different mechanism”. Under assumption that an excessive deviation of the expected spectrum of a signal is interpreted as the possible presence of outliers, to recovery data in short gaps Wavelet-Rosner test, as an extension of Rosner test in the frequency domain, has been applied (Chinarro et al., 2011).

One of the first challenges of developing the research and fieldwork was the difficulty in narrowing the participants for our interviews. When developing the document analysis, we found there is a great diversity in concepts and definitions such as “environmental refugee”, “environmental migrant” and “climate change migrant” (Solà 2012, 46-57). In this study, the term ‘environmental migrant’ is defined by the IOM (2009, 43) as “persons or groups of persons who, for compelling reasons of sudden or progressive changes in the environment, their lives or living conditions are affected. They are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and they move either within their country or abroad”. The use of a unique concept is useful to have a global vision of this phenomenon. It would also help with the data, as there is a great limitation of sources, such as the poor or scarce data, the population census and migrants in different countries, and the complex mission of quantifying irregular migration.
4. Result analysis

a) Evident trends in the Marrakesh-Safi area

The meteorological data considered as highlighted impacts on agriculture have been temperature and precipitation. In the first approach of analysis of the time series of daily temperatures, we have computed the least-squares fit for a straight line (or composite line for piecewise linear trends) to obtain the straight-line trend slope (red line of Fig.4). This simplification is a comparison of begin-end values, with a significant slope of 2.04553 degrees from January 1957 to September 2016. Because we wanted to be more precise, we propose methods of adjustment for the nonlinear tendency that could reveal the evolution of time series and especially the effect in the final part. Testing with both polynomial fitting (magenta line) and wavelet filter (green line) methods; the result is that by 2000 the trend clearly starts the steep, although there was a slight decay in the decade of the sixties.

![Figure 4: Average temperature trend in Marrakesh-Safi, calculated by two methods, period: 1957-2016](image)

A well-known climate indicator is the DTR (“Diurnal Temperature Range”), defined as the difference between the highest and the lowest temperature during 24 hours (Braganza et al., 2014). Despite its strong precision, the DTR indicator was defined as the number of days for which the DTR is unusually higher than a reference value (i.e. the DTR of 1973) plus a vulnerability threshold. We call that the DTRI (Diurnal Temperature Range Improved) and was calculated in study the area from 1973 up to now (Fig.5). The result in Fig. 5 is a linear trend marked by a red line with negative slope.
The time series of daily rainfall (Fig. 6) comprises the period from June 1973 to September 2016, due to data before 1973 are not available with sufficient quality. The red line represents the linear trend which indicates a slight descent of the precipitation trend.

The nonlinear trend computed by wavelet filter presents some peaks in years (1975, 1982, 1990, 1996, 2009, and 2015), but the last decades the peaks are smoothed. Other way to observe the precipitation value decays along time is by spectral analysis using wavelet transforms (Fig. 7).
Then, hue color and represents the rainfall intensity in different bands of frequency. The most of bands of frequency is fading along the time. One of them, the annual cycle marked with 362 in the Fig. 6 as the central frequency presents dark red spots, which stand for a high power of wavelet transform, or relative significant precipitation. However, as you progress through the timeline toward nowadays, the red spots are going to discoloring and even vanishing. This means a scarcely precipitation over the Marrakesh-Safi region in the last decades.

![Fig.7 Daily precipitation wavelet spectrum. 1973-2016 period, in Marrakesh-Safi](image)

b) Impact on the agriculture

Within the scope of the MEDCHANGe project, previous studies related to the measurement of climatic impacts on agriculture have been reviewed. After the two meteorological variables affecting the study area, the temperature is apparently predominant. This corroborates the empirical results presented by Gbetibouo & Hassan, (2005) to prove that South African field crops are so sensitive to changes in temperature that there is a narrow margin of tolerance to increase temperature compared to changes in precipitation.

Heuristic procedures of local farmer provide hints to increase the net revenue, acting mainly on the geographical distribution and the type of crops and taking in account that this region is highly depending on the climate variations, besides other physical factors such as topography, vegetation and soil. This suggests that the Ricardian approach could also be applied to the Marrakesh-Safi region.
Participant Observation

During our first fieldwork experience in Marrakesh we developed a participant observation tool (Table 1). During our field observation, or direct observation (Lofland & Lofland, 1995) we worked on a tool that would help us frame our fieldwork experiences. We started and established a relationship with the case under study or the subjects in their natural environment (Fetterman 1989) in the process. We established contact with associations and climate/weather centers, completing our participant observation experience from the conversation with NGO directors and project managers in Marrakesh.

The questionnaire was designed in a specific way, avoiding direct questions to migrants on the main reasons for leaving their community of origin. We meant to make the response so simple as to reveal other deep causes wrapped by a general idea of improving their lives and searching to live peacefully. Those variable causes are indeed changing and evolving over time; therefore, we need to keep approaching people and continue listening to their stories and to what they have to tell us in order to understand at least a little bit their lives and realities. The use of qualitative research gives the researcher the opportunity to look into the detailed personal aspects of a phenomenon, which, with other research methods, would be very difficult to do (Kvale 2007). This includes differences that are “ideologically, epistemologically, methodologically and most importantly, humanly” (Merriam 2009, 52). Using it allows the researcher to look into details, personal aspects, interpretations and perceptions that quantitative research would not allow.

Conducting oral interviews gave us the chance to listen to migrants’ stories mainly women and minors, but also merchants. We also discovered how they see themselves in the general picture of the society they are living in right now. We interviewed 50 people including omen, non-accompanied minors, 4th and 5th generation of rural migrants and directors and/or NGO managers who work with migrants. Through dialogue and observation, we were able to collect interviewees’ views of reality, as well as the importance of events, and feelings (Goetz and LeCompte 1984; Fetterman 1989; Wolcott 1999).
There were two different sets of interview questions prepared: one for migrants and another one for NGO directors and/or project managers. Both interviews had 10 open-ended questions about the participants’ current situation and their past lives as well as the aims and challenges of their work with migrants. We considered Nussbaum’s theory as the base and conducting theme for all the questions. We considered those interviews as the most important data collecting technique (Fetterman 1989). Through them, we learned about places we have never been to and the way cities have changed over the years. Interviews provided us with information about different cultures, the challenges that people face in their daily lives in Morocco, and in the previous countries, where they have lived before.

5. Conclusion

- This research activity has helped us to meet the special meteorological, geographical and social circumstances in the Marrakesh-Safi region to set up full causality factors of emigration.
- Marrakesh city plays simultaneously the three types of roles given in migration as origin, destination and transition place
- An international or a multidisciplinary team should study deeply the migration drives, and especially the climate change impact.
- The study also indicates that knowledge about the economic impact of climate change on agriculture in Marrakesh-Safi is limited in the context of Medchange project and requires more extensive research and detailed analyses.
- Climate change will have serious effects on the availability of water for agriculture. If the temperature increases and precipitation decreases, soon a leading to water shortage will strangle the habituated crops in the region.
- Some qualitative research methods carried out by in-depth semi-structured personal interviews have provided rich information of migration phenomena.
- The methodology approach facilitates a guidance to find the more suitable model that could best reveal the causality or correlation between climate change and agriculture in the Marrakesh region. We take for granted that agriculture is the basis of the economy and the welfare of the population and, therefore, it can determine the proper conditions to estimate the life dignity threshold that forces people to the exodus.
- Interviewing is the most appropriate technique to hear the unheard voices of migrants in Morocco and to see the connection between climate change and migration. Dialogue is a necessary tool to make such a social knowledge emerge.
- This could mean a preamble of a broader study that necessarily should be carried out in a more ambitious context for research, such as European H2020 call
- We have posed a methodology, and we are going to put it into practice.
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2. Bibliography