CLIMATE CHANGE IMPACT IN THE RIVER NABAO WATER RESOURCES

Tomé, Sara Baudoin

Abstract

The hydrological resources are of fundamental importance in evaluating the impact of climate change in the human activity.

This is primarily due to the direct impact of climate change on the availability of the hydrological resources and its impact on a number of social and economical activities.

This article will try to illustrate the impact of climate change on the availability of surface water and ground water resources of the River Nabao basin (being also part of the River Tejo's basin).

The shaping of this river basin and the study of the potential impact of climate changes in the quantity and quality of its hydrological resources, both at surface and ground level, will provide understanding and influence the future planning of the water resources management strategies and policies.

One of the main conclusions of this article refers to the variations in the annual water flows, namely, the potential disappearance of runoff in spring and the decrease in aquifer seasonal recharge.

Keywords

Climate change, climate scenarios, vulnerability, hydrological model

Introduction

Climate change constitutes a threat without precedence to the Humanity and Nature. Climate is changing due to the emission of gases into the atmosphere (the greenhouse effect) and because of profound alterations in agriculture practices, both of these as a result of human activities.

Therefore, there is a need to create future climate scenarios that enable us to model the changes imposed by the climate in order for societies to be conscious of the imperative need to stop and act, minimizing and adapting to the changes that they impose.

The water resources are imperative for life and for integrity of ecosystems.

Water has a fundamental role to play in all human activity: domestic, agricultural and industrial use.

This dissertation sets out to evaluate the effects of climate change on the hydrological resources of the River Nabao basin within the time horizon of 2050 and 2100 based on Hydrological and hydro geological models.

Climate change

The average Earth temperature results from a balance between the direct solar radiation absorbed (surface radiation) and the outflow of solar radiation (infrared radiation released into space). It is this natural greenhouse effect that allows life on Earth as it increases the average surface atmospheric temperature from 18ºC to 14ºC.

Therefore, when the concentration of greenhouse effects increases (largely due to the emit ions resulting from Human activity), a large part of infrared radiation emitted from the Earth and by the Troposphere is absorbed, altering the natural equilibrium and causing a temperature rise.

Since the Industrial Revolution, there has been a great increase of the concentration of greenhouse gases (figure 1), mainly due to human activities.

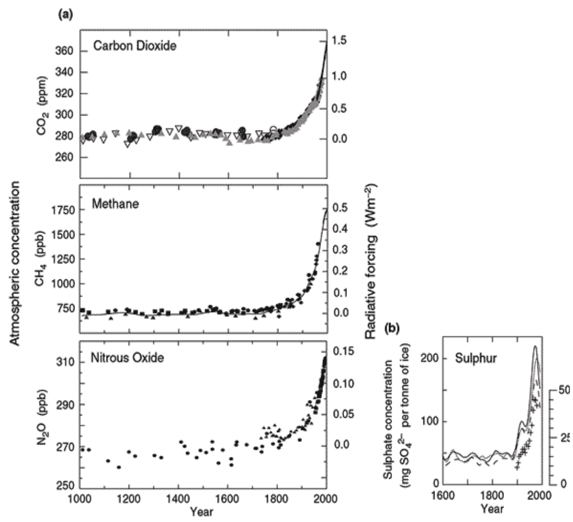

Figure 1 - Evolution of greenhouse gases since the Industrial revolution

(source: IPCC)

In the pre-industrial period, accordingly to the analyses made in the Poles, the concentration of CO_2 in the terrestrial atmosphere it was around 280ppmv. At the end of the 1950s, this concentration was already around 315ppmv, and in the middle of the 80's it had risen to 343ppmv. Currently the CO_2 concentration is the alarming level of 379ppmv.

The IPCC (Intergovernmental Panel on Climate Change) formed in 1988, looks at, in an objective and transparent way, the relevant information to understand the scientific basis of the risk of Climate Change anthropogenic, as well as its impacts and the options for mitigation and adaptation.

In the IPCC fourth report, there is a general consensus that global warming is intimately related with the change of Human activity since 1750, following the arrival of the Industrial Era. A large part of the increase observed of the averages temperatures since the middle of the 20th Century is most likely due to the increases of anthropogenic greenhouse effects.

Global warming is unmistakable and evident in the studies made; the rise in average temperature of the air and the oceans, as well as on the increase of the ice melting and of the sea level.

The enlargement of the oceans is due to the increase in temperature, which tends to cause a rise in sea level.

The layers of snow in the mountains and in the Glaciers are decreasing in both the hemispheres; such as the rapid defrosting of the Greenland, which also contributes to the increase of sea level that has reached the highest value in the period of 1993-2003, over that of 1961-2003.

In relation to the future projections of climate change, the 4th report from the IPCC suggests that in the case of duplication of CO_2 concentration it is very likely that global warming of the surface will settle at between 2 and 4,5ºC.

The warming tends to reduce the ground and the oceans capacity to capture CO_2, which results in a greater fraction of anthropogenic emissions remaining in the atmosphere. The rise in temperatures forecasted for the 21st century takes in place in geographic patterns: a greater warming of the continents and of the highest latitudes at North and a lower warming of the oceans of the Southern Hemisphere and parts of the North Atlantic.

The impact of global warming will be evidenced on the decrease of the sea-ice and of the Glacier ice seas possibly leading to the complete disappearance of the Arctic during the summer months. The extreme hot temperatures, heat waves and phenomenon of intense precipitation have a strong probability to continue and to become more frequent, as well as tropical cyclones (hurricanes, tsunamis, monsoons) and more powerful and stronger winds and intense rains.
The storms movement in direction to the Polar Regions, with consequences in the winds patterns, precipitation and temperature.
Variation in rain distribution is expected, being heavier rainfall in higher latitudes and less in the equatorial zones.

The anthropogenic CO_2 emissions, past and future, continue to contribute to the heating and increase of the sea level, for more than a thousand years due to time scale of CO_2 removal.

Portugal

Portugal has adopted the politics followed by the UE, implementing some measures such as the National Strategy for Climatic Change and the National Program for Climatic Change (NPCC).

The NPCC forecasts, for the Iberian Peninsula, an increase of the temperature between 4 and 7ºC, a decrease of the precipitation (with a bigger incidence in the zones centre and south) and an alteration of the monthly distribution pattern with a substantial decrease in the spring and an increase in the winter.

Associated to this forecast there is a set of variables as follows:

- the increment of the planning problems and management of the water resources associated with the reduction of water availability, the increase of the seasonal draining variation, the increase of the water necessities for the agricultural sector and aggravation of flood problems and quality of the water.
- the rise of the sea level in the Portuguese coastal area;
- the reduction of the precipitation in the Spring and the Summer that will increase the need of water for irrigation;
- at the human health level, the climatic changes lead to an increase of the number of deaths due to longer periods of high temperatures;
- on an energy consumption level, the increase of cooling needs will exceed the gains of lower heating need for air and waters;
- the increase of the surface temperature of the sea and the changes in the wind patterns will modify the distribution and the abundance of the marine organisms and its food in the Portuguese coast. (PNAC, 2001)

The Project "Climatic Alterations in Portugal. Scenarios, Impacts and Measures of Adaptation – SIAM", had as an objective the integrated evaluation of the vulnerability and adaptability of the natural and social systems, as well as the impacts derived from the AC.

The book SIAM classifies four main scenarios: A1 as "Global Economy" and A2 as "Regional Self-sufficiency"; B1 is called "Global" and B2 finally known as "Agricultural Sustainability". In general the scenarios families A1 and A2 (with more economical motivations) projects a bigger amount of greenhouse emissions up to the year 2100 and subsequently they lead to a greater increase of global average temperature than that of the scenarios families B1 and B2 (with more environmental motivations). In the horizontal axle, the families A1 and B1 are guided for towards a higher global coordination and A2 and B2 for an emphasis in the local effort.

All the models, in all the scenarios, forecast a significant increase of the average temperature in all the regions of Portugal until the end of 21st century. As for precipitation, there is a greater uncertainty in the future climate.

However, almost all the models forecast a reduction of precipitation in continental Portugal during the spring, summer and autumn, which could reach values between 20 and 40% of the annual precipitation, with the biggest deficits occurring in the South. For the winter, the majority of the models predict an increase of precipitation, mainly in the northern region.

Impact of the Climate Change in Portuguese Water Resources

In Portugal the average precipitation is about 960mm. However, its distribution is extremely irregular, as well as its seasonal frequency being very anti-symmetrical, with December and January being the wettest months and July and August registering the minimums of rainfall.

The average temperature is about 14ºC and is regulated by the altitude, latitude and proximity to the sea.

Temperatures also clearly indicate a seasonal pattern, with the lowest occurring during the months of January and February and the highest in July and August. In relation to the possible evapotranspiration, the projection is of an average of 1100mm, with the lowest values in December and January and the highest in the peak of the summer.

Stream flow is affected by regional and seasonal climate variations, and therefore the draining in Portugal is irregular with an annual average of 385mm, reaching maximum values in February, two months after the heaviest precipitation occurs.

Water uses are mainly related to the domestic, agricultural and tourism demand. On average, only 70% of the water needs for irrigation is satisfied.

The climatic scenarios presented by the models show a small increase in the annual precipitation for the northern zone of continental Portugal and a decrease for the south. The models also project an increase in seasonal asymmetry with a noticeable decrease in precipitation during the summer months. The average annual temperature will probably increase, especially in the south of the country.

The results obtained in this study indicate a gradual reduction in the annual draining of the rivers. During the 21st century, this reduction seems less apparent in the northern region, but it increases gradually for the southern region of continental Portugal. If confirmed, this trend would accentuate the current spatial asymmetry in the availability of water resources in Portugal.

It also appears there will be a tendency to concentrate the draining in the winter period, induced by a period of similar pattern in the distribution of the precipitation that would accentuate the asymmetry in seasonal distribution of the water availability. The concentration of rain in the winter months and the forecasted increase of periods of heavy rain will probably lead to an increase in the frequency and magnitude of floods, particularly in the northern part of the country.

With regards to the impact of climate change on the demand for water, it is unlikely that these will condition the water requirements for domestic and industrial uses. Nevertheless, the demand of water for irrigation could be significantly affected. It is, however, difficult to forecast the increase in water demand for agricultural use, as it not only depends on climate change but also on crop yield and the increase in areas of cultivation; aspects that are not only conditioned by climatic factors.

Regarding the impact of climate change on the ecosystem, we must highlight the diminished water quality as well as the rise of its temperature. The ecosystems of the coastal area will tend to be the most affected by the saline intrusion that can occur due to the probable rise of the sea level.

As a result of the before mentioned, we are forced to recognise that climate change will affect the management of water resources.

The River Nabao Drainage Basin

The basin of the river Nabao is located in centre of the country, in the area of the Tejo valley, about 40km off the Atlantic coast. This basin is cut according to the limits of the river Nabao and its tributaries (figure 2).

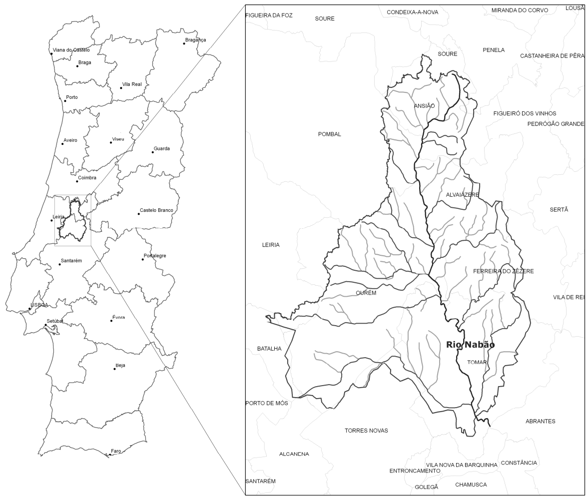

Figure 2 - The river Nabao drainage basin in Portugal

The basin of the river Nabao is part of the basin of the river Tejo and occupies approximately an area of approximately 1025 km^2.

The area the course of the river Nabao runs through belongs to the districts of Leiria and Santarem.

The study of past data shows a tendency for an increase of the precipitation in the summer months, as compared to a great reduction during the winter and spring months. In the case of the temperature, it is possible to conclude that it a trend exists for the average temperature to increase during winter and autumn and a decrease during the months of spring.

The basin of the river Nabao includes five aquifer systems Liasico Penela-Tomar, Sico-Alvaiazere, Ourem, Maciço Calcario Estremenho e Tejo-Sado right bank.

The fractured areas allow circulation of water with underground streams surfacing close to the edges W and E do Maciço Calcario Estremenho aquifer.

Model

After characterizing all the relevant components of the river Nabao basin for the modelling of the stream flow, one proceeds to the modelling of the draining process.

The applicable model to the basin is called "Temez", and it is a hydrological precipitation-draining model presented by R. Oliveira (1998). Figure 3 shows how the model is being applied.

It is a continuous, aggregated and deterministic model that forecasts monthly values.

This model simulates the transformation phenomenon of the precipitation into draining; basing itself on four parameters: The coefficient of excess (C), the capacity of the land field (H), the maximum infiltration levels (I_{MAX}) and the rate of exhaustion of the underground aquifer (A).

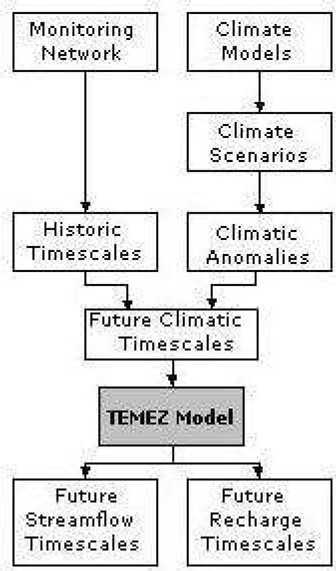

Figure 3 – Methodology

The data imputed into the model corresponds to that of the monthly precipitation levels, and of the potential evapotranspiration of the drainage basin. The latter can be forecasted by using the Penman-Monteith method and is based on the air temperature, levels of humidity, solar radiation and the speed of the wind.

Precipitation

The rain regime is characterised based on the identification of the influential meteorological stations in the area of the basin by the method of the Thiessen polygons and the research and analysis of the precipitation records in the SNIRH (Portuguese system of water resources data) of the selected meteorological stations. After that, a monthly precipitation series is produced based on the evaluation of the records from the relevant stations, with data from October 1976 to September 2006.

Temperature

To characterise the air temperature, data records available from the SNIRH of the relevant meteorological stations of the Nabao area are used; monthly average temperatures are calculated for the period in observation (Oct 76 to Sep 06).

Relative Humidity

For the relative humidity levels, daily data is collected from the SNIRH of the relevant meteorological stations of the river Nabao basin and are calculated for the period in reference (from Oct 76 to Sep 06).

Solar Radiation

With regards to the solar radiation, there is only data available from the year 2000. Therefore, it was opted to calculate an average year, using the data from the daily radiation of the relevant stations of the basin of the river Nabao.

Wind Speed

With regards to the wind speed, there is only data available from 2000, from the relevant stations in the study area. Therefore it was opted to calculate an annual average using daily records.

After treating the relevant data one proceeded to the calibration of the model. The calibration takes place in order to diminish uncertainties related to the conceptual formularization of the model. In this study, the calibration is a subjective process, based in adjustments in the parameters of the model, within the value range, in order to obtain real values. The model was conceived to calibrate itself according to the introduction of the observed superficial draining values.

Susceptibility Index (SI)

This is calculated by addition of five parameters: depth of the water level (D), recharge (R), material of the aquifer (A), topography (T) and land use (LU).

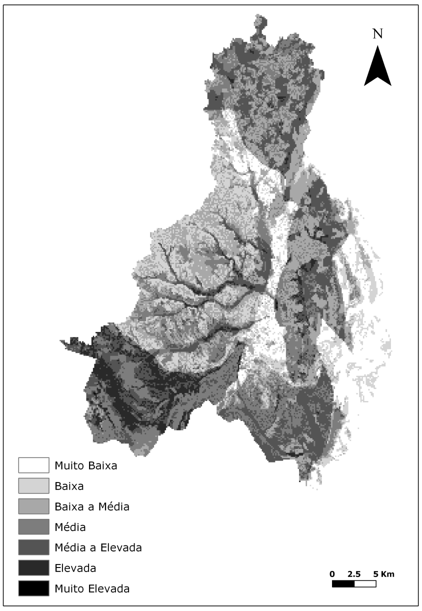

Figure 4 - Susceptibility Index in Nabao drainage basin

The SI is applied to the basin of the Nabao shows that there are, practically, no zones of high vulnerability.

According to this index, only some zones present a high index, not only due to the use of the ground, but also because of the high recharge that it is processed in a calcareous rock zone, making the system vulnerable to contamination.

Whilst in general the level of vulnerability is not high, we have to consider all the irrigated land areas; the agricultural areas as well as the type of fertilizers used. This means that in order to analyze, all sources of pollution must be considered, as well as the risk they present.

Impacts of Climate Change

Forecast for 2050

The socio-economic scenario B2, of the climatic model; HadCM, foresees increases in draining levels by volume, mainly during Autumn and Winter months in line with the forecasted increase in precipitation for the same months. For the summer months there is a decrease of the superficial draining. Scenario A2, a more pessimistic one, forecasts a reduction in the precipitation levels by 14% in winter and 30% in the summer, showing lower draining levels than that of the period of control.

This study takes a first look on the impact of the climatic change in the recharge through the results of the TEMEZ model. Although this model is not precise for the calculation of the recharge, its values have been considered after doing a calibration that takes in consideration the infiltration of the shaped basins. In figure 5 we can see the variation (%) of recharge comparing with the values of present time.

Forecast for 2100

For 2100, the social-economic scenario B2 highlights smaller increases in the draining levels, for winter months, and a reduction of the same for the remaining months. With regards to A2 scenario of the same HadCM model, the forecast points to a significant reduction in the superficial draining of the basin of the Nabao. Once again, these conclusions are supported by the reduction in precipitation levels; in the order of the 14% in winter and 30% in the summer, forecasted by the model. On the other hand, the regional model, HadRM, presents a more optimistic forecast for draining levels, as in spite of a reduction in the summer, the results suggest a significant increase in draining levels for the remaining months of the year.

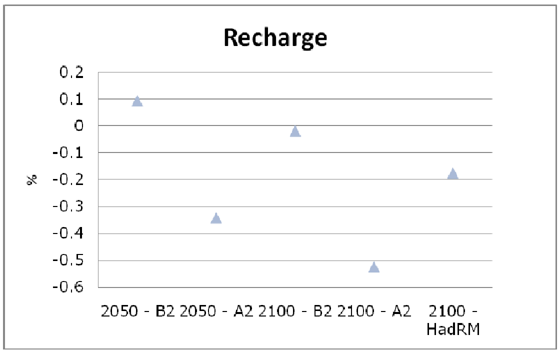

Figure 5 - Variation of recharge when compared to reference recharge values

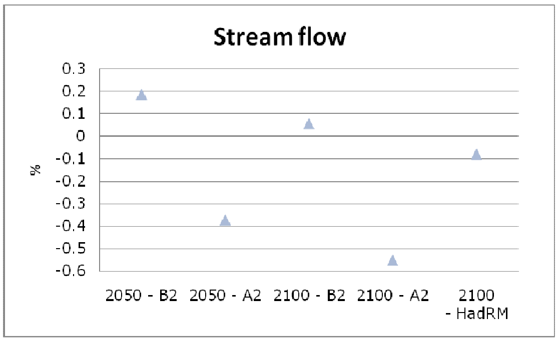

Figure 6 - Variation of stream flow when compared to reference stream flow values

Figure 6 shows the variation of stream flow within different scenarios.

It is included within the scope of this dissertation, the forecast of the variation of the SI, caused by the change in precipitation levels and, subsequently, the recharge and the possible change in the use of the ground. An alteration in soil usage caused by a change in agricultural practices as an answer to climatic changes will have an indirect impact in the quality of the underground water. Given the nature of the parameters of this method, for the calculation of the future scenarios only variations in the values of underground recharge and use of the ground have been considered.

The SI appears to be majorly influenced by the changes in land use. Therefore, if the agricultural practices are intensified, the aquifers are more vulnerable than when agriculture practices are attenuated.

Conclusions

There are many proofs that climatic change is happening on Earth, and that it is directly linked to gas emissions and the green house effect all over the world.

This study intends to aware that the forecast of climate change will make more difficult the planning and managing the water resources in Portugal, that will come from the reduction in the availability of water, the increase of the seasonal variation of the draining, the probable increase in water requirement for the agricultural sector, the maintenance and probable increase of floods and also of the probable decrease in water quality.

The challenge that climate change presents will demand increasing attention when setting out water resources management strategies.

In river Nabao drainage basin is expected, following predictions for all Portuguese territory, a reduction in superficial runoff and recharge.

The non consideration of climate change in the management process of the Portuguese water resources will lead to more difficult and complex management.

The potential reduction of water availabilities and the increase of the seasonal asymmetries, together with the occurrence of more restrictive conditions in terms of the quality of water and risk of floods, only highlight the importance in adopting water resources management and policies based on a solid and deep knowledge of the reality of the Portuguese water resources. This highlights the need to further extend the studies of evaluation of the water resources and to carry out additional investigation on the climate change in order that the information on the climate change can influence directly the management practices of water resources.

References

ALMEIDA, C.; MENDONÇA, J.; DUARTE, R.; QUINA, A.; NEVES, J. (2000), *Glossário de Termos Hidrogeológicos*, Centro de Geologia e Instituto da Água, Portugal

Comissão para as Alterações Climáticas (2001), *Programa Nacional para as Alterações Climáticas*, versão 2001 para discussão pública

CUNHA, L. V.; OLIVEIRA, R. P.; NASCIMENTO, J.; RIBEIRO, L.(2006); *Impacts of Climate Change on Water Resources: A Case Study on Portugal*, artigo

European Environment Agency, *Climate change and water adaptation issues,* Copenhagen, 2007

IPCC (2007), Summary for Policymakers in: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report, Cambridge University Press, UK and NY

NASCIMENTO, J.; RIBEIRO, L.; CUNHA, L. V.; OLIVEIRA, R. (2006); Efeitos das Alterações Climáticas na Disponibilidade Hídrica e na Qualidade da Água Subterrânea da Região Alentejo, Lisboa, artigo

OLIVEIRA, R. (1998), XLWAT: um add-in para Excell, Modelo de Precipitação-Escoamento, Chiron, Monte da Caparica

RIBEIRO, L. (2004); Recursos Hídricos subterrâneos de Portugal Continental, Instituto da Água, Lisboa

RIBEIRO, L.; CUNHA, L. V.; OLIVEIRA, R. (2006); Efeitos das Alterações Climáticas na Disponibilidade Hídrica e na Qualidade da Água Subterrânea da Região Alentejo, Lisboa, artigo

SANTOS, F. D. & MOITA, P. (editores) (2001), Climate Change in Portugal. Scenarios, Impacts and Adaptation Measures – SIAM, Gradiva, Lisboa

SANTOS, F. D. & MIRANDA, P. (editores) (2006), Alterações Climáticas em Portugal. Cenários, Impactos e Medidas de Adaptação – Projecto SIAM II, Gradiva, Lisboa