ACADEMIA | Letters

Climate Change and the Aveiro's Lagoon (R)evolution (Portugal)

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Abstract

As we retreat into historical time, the attempt to reconstruct past climates and their impact in the ecosystems becomes increasingly complex. This study makes a correlation between solar radiation and the growth of a sandy spit that allowed the formation of the Aveiro's lagoon. Knowing the controversy surrounding the use of a single proxy for the definition of phenomena as complex as climate fluctuations, whenever possible, a link is established between the average rates of annual progression of the sandy spit with the known data of the NAO (North Atlantic Oscillation) and the great climatic periods. A more intense pace of development is found during the Medieval Warm Period, that is fallen to a speed of about half during the Little Ice Age.

Keywords: climate; solar radiation; north coast Portuguese; coastal morph dynamics

Introduction

This short paper correlates climate change from the medieval period until the modern day with the formation and development of the Aveiro´s lagoon (fig. 1). This is significant because

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the geomorphologic evolution of this Northwestern Portuguese littoral is one of the quickest known developments in the evolution of European coastal zones and one of the fastest in the world.

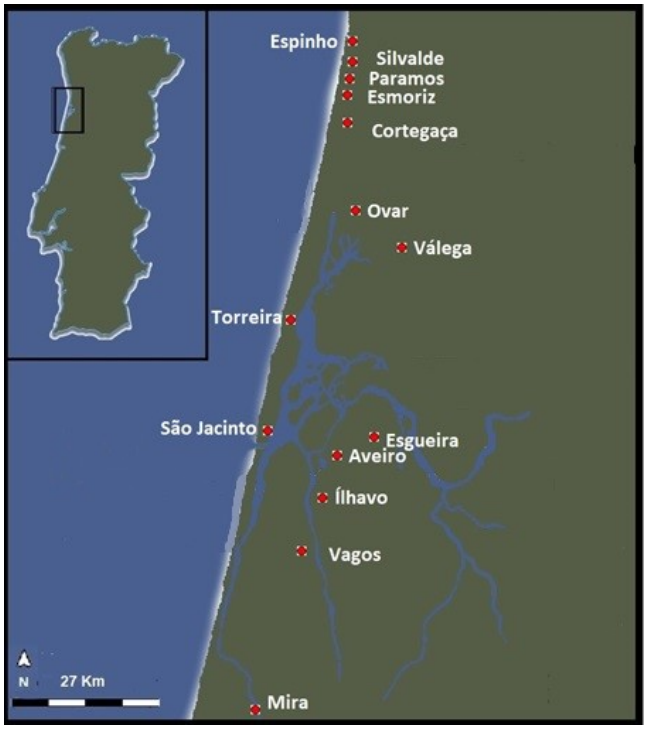

Fig.1 - The case study of the coastal zone.

It is interesting to highlight that the beginning of the Aveiro's lagoon formation and the Portuguese Kingdom's independence from the Iberian Kingdoms of León and Castile (to which it was attached) took place at the same time (Oliveira, 1988). In the 12th century, overpopulation between the Minho and Douro rivers (in the north of Portugal) encouraged migration into this coastal area that had been recently pacified in the face of conflict with Muslim powers in the region: the so-called Christian Reconquest of the Iberian Peninsula (Mattoso, 1991), namely after Lisbon's definitive conquestto the Islamic world in 1147. Meanwhile, the coastal evolution of the Aveiro's zone allowed the formation of a sheltered coast from maritime agitation, but where salt water arrived and, thus, allowed an intense salt production (Rau, 1984; Bastos, 2015). More than any other resource from the sea, salt was, at the time, a valuable product for seasoning and more importantly the conservation of food. In the words of historian Michel Mollat du Jordin, salt was the "white gold of the Middle Ages" (Mollat,

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1995). It is therefore not surprising that the intensive occupation and exploitation of this coast was forming and evolving.

How does all this relate to the climate and, more specifically, the sunspots? In the next section, we will explore this issue in more detail.

Material and Methods

To get to the heart of the issue, we resorted to an interdisciplinary approach. Therefore, it was developed as an analysis with historical, geomorphologic and paleo meteorological components. This approach's methodology is common in Environmental History; a branch of knowledge that frames this work. This has been attempted a scientific "cross-fertilization" between the historical written data, found in various Portuguese archives at a national, district and local level (Bastos, 2015), as well as data remains in coastal geomorphological studies (Abecasis, 1955; Dias *et al*. 1994, 2000, 2012). This is in order to better understand the impact of the North Atlantic Oscillation (NAO) and the sunspots in the growing of the Aveiro´s lagoon sandy spit on both a historical and geomorphological basis. Data concerning climate changes, recorded in the chronological period under analysis, was gathered from studies on climate indices (mainly related to sunspots) and NAO influences in the study area addressed (Cunha, 1959; Dias *et al*., 1994; Mann & Jones, 2003;Muscheler *et al*., 2009; Mann *et al*., 2009; Trouet *et al*., 2009; Liu *et al*. 2011; Diaz *et al*., 2011; Moreno *et al*., 2012; Ortega *et al*., 2015; Oliva *et al*., 2018). Unfortunately, as far as we know, there are not yet any studies that conduct an analysis with a historical, geomorphologic and paleo meteorological component for this coastal zone (or even the wider area of the coastal Iberian Peninsula). Therefore: a) it is impossible to refer similar papers approach; b) there are a great number of references in Portuguese language.

Results and Discussion

As we go back through the centuries, attempts to reconstruct past climates and their impact in ecosystems become increasingly complex. This study makes a correlation between solar radiation and the growth of a sandy spit that allowed Aveiro's lagoon formation. Knowing the controversy surrounding the use of a single proxy for the definition of a phenomena as complex as climate fluctuations, a link is established, whenever possible, between the average rates of annual progression of the sandy spit with the known data of the NAO and the great climatic periods. A more intense pace of development is found during the Medieval Warm

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Period that falls to a speed of about half during the Little Ice Age, which can be observed in figure 2.

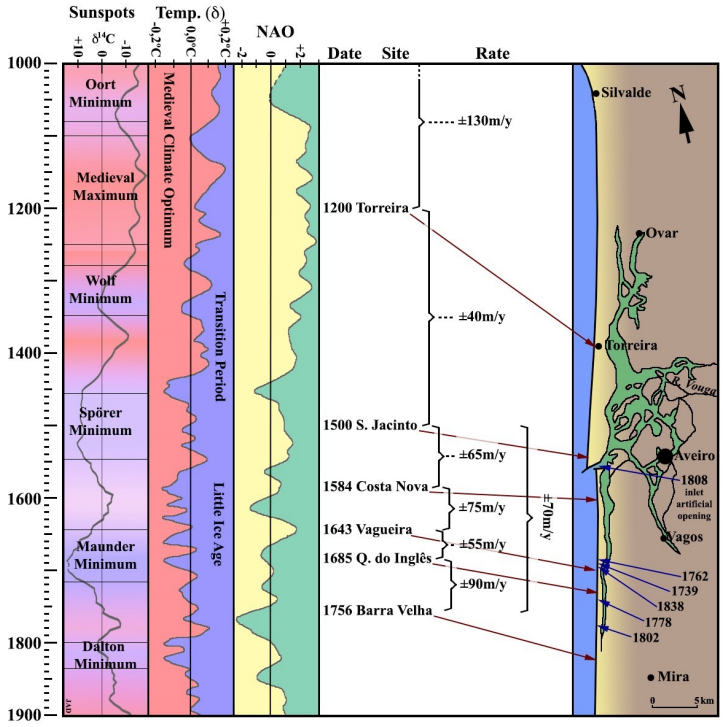

Fig. 2 – Evolution of Aveiro's lagoon sandy spit as an indicator (proxy) of the climatic oscillations during the Medieval Warm Period and the Little Ice Age in the Northwest of Portugal.

NOTE: The Figure above was mostly based in data collected in the following Authors/Papers: Cunha, 1959; Oliveira, 1988; Dias *et al*., 1994; Mann *et al*., 2009; Trouet *et al*., 2009; Liu *et al*. 2011; Muscheler *et al*., 2009; Ortega *et al*., 2015; Bastos, 2015.

From the analysis of the figure above, it seems possible to conclude that the migration rates of the tip of sandy spit were higher in periods of warmer climate (Bastos, 2015), reducing when climate degraded (Araújo, 2003). Thus, the rates seem to indicate that the sandy spit progressed at an extremely high rate (in the order of 130m/year, during the Medieval Warm Period, reducing substantially during the transition phase which we consider demarcated by Wolf and Spörer minimums), with rates as high as 40m/years. Subsequently the pace of migration of the bar increased again during the Little Ice Age, to values of about 70m/year (Pereira *et al*, 2021). In this last period, the presence of islands in the lagoon's environment is attested,

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resulting from an intense silting process that was already coming from its antecedent (Bastos, 2015 & Pereira *et al*, 2021). In the 18th century the sandy spit totally enclosed the lagoon, and an artificial inlet was opened in 1808 (Abecasis, 1955).

Conclusion

It can therefore be proved that in the Aveiro's lagoon and its *hinterland* natural and anthropic actions are almost always linked throughout History. Most of the time, it is difficult to distinguish what is human interaction and what is physiography in landscape construction. However, there are some chronological and geographic contexts that seem to provide evidence of joint humankind and environmental influence. It seemed to happen in the case study of this analysis because the Christian Reconquest and the quick geological evolution of the coast, allowed the settlement and exploitation of the resources of this new littoral. This was in the Medieval Warm Period and most of the Little Ice Age. At the end of the latter, the worsening of weather conditions, with extremely cold and rainy winters, coincided with the closing of the natural inlet, sometimes getting the lagoon communication with the Atlantic Ocean cut out. That meant that the eutrophication of the lagoon required a strong anthropic intervention that consisted of the opening of an artificial bar. At times, ephemeral natural bars were opened, which occasionally continued to occur even after the current artificial inlet was opened in the beginning of 19th century.

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