

Accepted in *Quaternary Science Reviews* as an “Invited Review”

DOI 10.1016/j.quascirev.2016.08.015 (2016)

# **Natural and anthropogenic drivers of cultural change on Easter Island: review and new insights**

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## Abstract

Easter Island (Rapa Nui) is a remote Pacific island known for its megalithic statues, the *moai*, built by an ancient culture whose disappearance is still debated. Theories claiming for either self-destruction (ecocide) of this ancient culture or an eventual genocide after the European contact have been the most popular. Anthropogenic drivers have been traditionally preferred as causes of this major cultural shift, whereas climatic changes have been dismissed or underrated. However, the latest findings suggest that the topic is more complex than formerly thought and demand a more holistic perspective. This paper reviews the main paleoclimatic, paleoecological, archaeological and historical evidence of the major Rapanui cultural shift leading to the end of the *moai*-building civilization and uses an integrated approach to analyze its timing and potential causes. The disappearance of the ancient Eastern Island culture that erected the *moai* was a dramatic cultural shift with significant changes in lifestyle, socio-political organization, religious performance, art and also in the geographical settlement of the cultural core of the Rapanui society. The ancient society, represented by the so called Ancient Cult (or *moai* cult) was centered on the Rano Raraku crater, to the east of the island, whose soft volcanic rocks (tuff) were suitable for *moai* carving. This society was replaced by the Birdman-Cult society, based on Rano Kao, to the westernmost end of the island. The assumed date for such shift is uncertain ranging between mid-16<sup>th</sup> and late-18<sup>th</sup> centuries. It is suggested that such geographical change, as well as the associated societal transformations, may have been the result of a combination of climatic, ecological and cultural drivers and events. The latest paleoecological reconstructions show that the Rano Raraku catchment was deforested by AD 1450 and the lake inside dried out by AD 1550 owing to an intense climatic drought. This would have caused a landscape deterioration transforming the Raraku catchment into a wasteland devoid of freshwater and unsuitable for human life and the cultural flourishing that characterized the Ancient-Cult society. The drought lasted for about

a century and a half and would have forced the Rapanuis to look for alternative freshwater sources. The only feasible option was the freshwater lake inside the then forested Rano Kao crater, where the ceremonial village of Orongo, the center of the Birdman Cult, was founded by AD 1600. The Kao crater is made of hard volcanic rocks (basalts) unsuitable for *moai* carving by the Neolithic Rapanui culture, unaware of metals, which would have contributed to the end of the *moai*-building phase. Deforestation and drought would have led to a general demographic decline. The shift from the rigid socio-political organization of the Ancient Cult to the more flexible system characteristic of the Birdman Cult could be viewed as a cultural adaptation to changing environmental conditions. The occurrence of a further, rather catastrophic, genocide caused by slave trading and epidemic diseases, occurred shortly after the European contact (AD 1722), has been documented historically. Therefore, the Rapanui civilization has undergone at least two cultural crises caused by natural and anthropogenic drivers. A complex synergistic scenario like that proposed here can conciliate multidisciplinary lines of evidence formerly used to defend more simplistic and apparently contradictory hypotheses of cultural change.

**Keywords:** deforestation, collapse, cultural shift, paleoclimate, paleoenvironment, ecocide, genocide, Rapa Nui

## Introduction

A major enigma in the recent history of Easter Island (Rapa Nui) (Fig. 1) is the timing and causes of the disappearance of the ancient culture that built the iconic megalithic statues known as *moai* (Fig. 2). The most well-known explanation is the ecocidal hypothesis, according to which cultural collapse originated from the exhaustion of natural resources as a result of human overexploitation (Bahn & Flenley, 1992; Flenley & Bahn, 2003; Diamond, 2005).

Alternatively, the cultural shift could have been the result of a genocide of the Rapanui society caused by slave trading and the introduction of unknown diseases after European contact (Rainbird, 2002; Peiser, 2005; Hunt, 2006, 2007; Hunt & Lipo, 2011). A potential role for climate change has also been suggested (McCall, 1993; Hunter-Anderson, 1998; Nunn, 2000, 2007; Nunn & Britton, 2001), but this theory has received little attention as direct evidence of *in situ* environmental shifts on Easter Island has been elusive until the last decade. Recent studies have documented conspicuous climatic shifts that challenge the classical collapse theories and demand reconsideration of the island's history using a holistic approach that combines climatic, ecological and cultural factors and drivers of change (Rull et al., 2013, 2016).

This holistic approach is used here to address the disappearance of the ancient culture represented by the *moai*, also known as the Ancient Cult, and its replacement by a totally different social, political and religious organization, represented by the Birdman Cult. The paper begins with a brief review of the nature and main features of the cultural transformation and an account of the hypotheses currently available to explain it, most of which are anthropogenic. Then, the potential role of environmental shifts is considered, and the climatic changes of the last millennium recorded on the island are highlighted. The following section combines environmental and cultural evidence to propose a new comprehensive scenario,

using the holistic approach, for the occurrence of the cultural shift under study. Finally, the new scenario is analyzed in light of theoretical frameworks such as environmental determinism and collapse catastrophism. Ideas for further research are provided to assess the robustness of the new proposal.

### **From the Ancient Cult to the Birdman Cult**

Despite the different views on the timing and causes of the shift from the Ancient Cult to the Birdman Cult (abbreviated here as the ABS, Ancient-Birdman Shift), there are some features that are generally accepted. The ABS represented a profound change in the Rapanui social organization and religious practices, although the essential beliefs remained the same with *Makemake* as the supreme deity (Edwards & Edwards, 2013). Before the ABS, the *moai*, representing deified ancestors, were standard worship subjects to ensure land and sea fertility and, hence, social prosperity. The basic social unit was the clan and there was a hierarchical pyramidal organization with a maximum authority, the *Ariki Mau*, who was invariably the chief of the *Miru* clan, descending directly from the first Polynesian settlers, who arrived between AD 800 and AD 1200, depending on the study (Flenley & Bahn, 2003; Hunt & Lipo, 2006; Vargas et al., 2006; Wilmshurst et al., 2011). After the ABS, the symbols of fertility and prosperity were migratory birds, notably the sooty tern or *manutara* (*Onychoprion fuscatus*), which used to nest on the island's surrounding islets, especially the one called Motu Nui (Fig. 3). The higher political hierarchies disappeared and the power was held by the clan chiefs, who competed each year to become the Birdman (*tangata manu*), who represented *Makemake* and was the highest authority of the island. The Birdman was the chief of the clan whose representative won an athletic contest consisting of a climbing and swimming race to Motu Nui and back to carry the first intact egg of the sooty tern during its seasonal migratory passage by the islet.

The ABS also involved a radical geopolitical change as the center of the cultural life and activities shifted from east to west. During the *moai* phase, also known as *ahu moai*, the cultural core of the island was the quarry where the giant statues were carved, situated in the walls of the Rano Raraku crater, to the east (Figs. 1 and 4). This crater is formed mainly by tuff, a soft and porous volcanic rock more suitable for carving than basalt, the dominant rock of the island (Vezzoli & Acocella, 2009; Gioncada et al., 2010). In contrast, the center of the Birdman cult was situated above the cliffs of the Rano Kao caldera, in the ancient village of Orongo, at the westernmost end of the island (Figs. 1 and 4), just in front of the Motu Nui islet, where the sooty tern used to lay its eggs in the austral spring.

The first European visitors, from the Dutch expedition of Jacob Roggeveen in AD 1722 to the British cruise led by James Cook in 1774, described island's population as relatively small, barely a few thousand people, with poor social organization and technological skills. Such culture was considered to have been unable to develop the flourishing culture characterized by the *moai* cult and all its manifestations. For example, Cook wrote: "We could hardly conceive how these islanders, wholly unacquainted with any mechanical power, could raise such stupendous figures, and afterwards place the large cylindrical stones, upon their heads." (McLaughlin, 2007; p. 36). By that time, the Rapanuis lived hidden in caves formed by lava tubes, in contrast to the high number and variety of open dwellings associated with the *moai* culture whose remains are still preserved in the island (Vargas et al., 2006). The French La Pérouse, who visited the island in 1786, was the first to suggest the occurrence of a cultural collapse that eradicated the ancient *moai*-building culture (Heyerdahl, 1968; Middleton, 2012). This idea was taken up again a couple of centuries later by Mulloy (1979) and formed the embryo of the ecocidal hypothesis. However, regardless of the interpretation, the traits and

the lifestyle of the Rapanui people of the 18<sup>th</sup> century suggested the occurrence of a significant cultural change at some time before European contact.

The deep religious, geographical and socio-political transformation of the original Rapanui society has been acknowledged by the vast majority of ethnologists since Routledge (1919) or Métraux (1940). More controversial matters are the pace and chronology of these changes, the demographic trends involved and, especially, the causes of the ABS. A variety of hypotheses on these issues still survive due to the absence of conclusive evidence.

### **Current hypotheses**

The ecocidal view was based on palynological analyses of lake sediments showing a sudden and abrupt disappearance of palm forests and replacement by grasslands (Flenley & King, 1984; Flenley et al., 1991). This change was interpreted in terms of island-wide deforestation and a general exhaustion of natural resources by human overexploitation that would have led to a cultural collapse. The deforestation would have been completed by AD 1400 or, at the latest, by AD 1600 (Flenley & Bahn, 2003). The finding of burnt fragments of palm stumps and fruit endocarps in some soils suggested that anthropogenic fire was the more likely cause of forest clearing, which would have deforested the island by AD 1500 (Mieth & Bork, 2010). The ensuing social crisis and starvation would have led to conflicts and internal wars -as suggested by the finding of sharp obsidian objects interpreted as spear points (*mata'a*)- which resulted in the reduction of population and a significant change in lifestyle. One of the main manifestations of these changes would have been the end of the *moai* cult and the toppling of these giant statues (*huri moai*). The eventual superiority of the westernmost clans in such a conflicting scenario would have determined the change of cultural polarity from east to west (Flenley & Bahn, 2003).

The ecocidal hypothesis has dominated the field for decades, but recent findings have challenged its validity. One criticism is that this view is based on incomplete sedimentary records due to the occurrence of an extended sedimentary gap encompassing 3-4 millennia, which included the critical phase of replacement of forests by grasslands. Therefore, the apparent abruptness of this ecological shift would have been an artefact caused by the lack of a continuous record (Rull et al., 2013). Moreover, a detailed study of the *mata'a* revealed that these objects were general-purpose tools for peaceful tasks, such as ritual scarification, rather than warfare weapons (Lipo et al., 2016). In addition, a recent study of cranial injuries formerly interpreted as signs of island-wide warfare concluded that most of the scars and fractures studied could be attributed to localized and episodic violence events (Owsley et al., 2016). On the other hand, a recent exhaustive meta-analysis of radiocarbon dates from archaeological sites and objects across the island did not find consistent evidence for a cultural crash of the indigenous civilization before the European contact (Mulrooney, 2013). Archaeological evidence indicated heterogeneous patterns of land use with declines in some coastal and upland areas before European contact and increases and subsequent declines in other coastal locations (Stevenson & Haoa-Cardinali, 2008; Stevenson et al., 2015).

In other Polynesian areas, including small and remote islands and archipelagos, deforestation after human arrival was common, but it did not lead to resource exhaustion and cultural collapse. Instead, more or less efficient agricultural practices enabled human subsistence until European colonization, when greater landscape transformations began (e.g., Prebble & Dowe, 2008; Allen et al., 2011; Prebble et al., 2013). It could be asked why the situation was different on Easter Island, where deforested terrains were also occupied by crops and Polynesian agricultural practices likely increased soil fertility (Ladefoged et al., 2010). It has been tentatively suggested that soil degradation was more intense on Easter Island likely due to



increasing aridity (Ladefoged et al., 2005; Stevenson et al., 2006, 2007). In some Polynesian islands, native forests were removed and replaced by anthropogenic woodlands of economic importance, which contributed to protecting soil from eventual climatic extremes (Huebert & Allen, 2016). Similar silvicultural practices have not been documented on Easter Island.

According to the genocidal view, the ancestral Rapanui culture did not collapse until the arrival of Europeans. The genocide would have been due to direct violence, the introduction of epidemic diseases and slave trading. Hunt & Lipo (2011) proposed that the genocide would have initiated with the first Dutch (Roggeveen), Spanish (González de Haedo) and British (Cook) visitors, who arrived during the 18<sup>th</sup> century and likely killed people and introduced diseases of sexual transmission. Others believe that the social breakdown did not occur until the 19<sup>th</sup> century, when slave trading and epidemic diseases decimated the population of the island to unsustainable levels (McCall, 1980). The occurrence of such genocide has been confirmed by historical documents (Fischer, 2005) but this is not incompatible with the occurrence of significant cultural changes before European arrival, of which the change from the Ancient Cult to the Birdman Cult would be especially relevant. In other words, under the genocidal scenario, the ABS and the cultural collapse of the Rapanui society –which, under the ecocidal hypothesis are considered to be the same phenomenon- could be separate events occurring before and after, respectively, European contact. Another difference between the ecocidal and the genocidal theories is the pace and causes of deforestation. According to some defenders of the genocidal hypothesis, forest clearing was gradual, occurred between the arrival of the Polynesian settlers (ca. AD 1200) and ca. AD 1650, and was caused mainly by massive palm fruit consumption by Polynesian rats (Hunt, 2006, 2007; Hunt & Lipo, 2011). The evidence of this proposal is the frequent occurrence, in several archaeological sites, of palm fruit endocarps with evident signs of rat gnawing.

A date that is often mentioned for the pre-European demographic collapse is AD 1680 (Rainbird, 2002) but the evidence for this date is still unclear, and some researchers consider this proposal to be an unsupported myth (Mulrooney, 2009). Additionally, some authors believe that the Rapanui cultural breakdown would have occurred between the visit of Roggeveen (AD 1722) and that of Cook (AD 1774), as the first reported a relatively healthy Rapanui society still practicing the *moai* cult, whereas the second described a more depauperated island and reported, for the first time, the presence of toppled *moai* (Fischer, 2005). For example, the following passage from Roggeveen's expedition log: "The fields were full of growing crops, neatly planted, almost ready for harvesting... The island is very agreeable and it would be very pleasant to spend one's leisure on it...", contrasts with Cook's opinion, 52 years later: "No nation need to contend for the honour of the discovery of this island, as there can be few places which afford less convenience for shipping than it does. Here is no safe anchorage, no wood for fuel, nor any fresh water worth taking on board" (Hermann, 1958; p. 280-281). The Spanish expedition led by González de Haedo in AD 1770, only four years before Cook's visit, apparently found a healthy society, more similar to that reported by Roggeveen's logs. Some authors speculate that they may have been a catastrophic event, possibly a war, between AD 1770 and 1774 (Fischer, 2005; Hunt & Lipo, 2011).

Considering the ecocidal and the genocidal views together, the time of the purported collapse of the Rapanui society ranges between shortly before AD 1600 and the early 19<sup>th</sup> century. The first historical record of the Birdman cult dates from AD 1780 (Routledge, 1919) but many archaeologists believe that this ceremony began much earlier. For example, some consider that the Birdman games started near the dates of foundation of the Orongo village, which was the center of the Birdman Cult from where the athletes started and arrived after their race, by AD 1600-1630 (Ferdon, 1961; but see Golson, 1965). Others propose AD 1550 as the starting date of the Birdman Cult (Lee & Liller, 1987), but the evidence is still inconclusive. Therefore,

the chronological uncertainty for the occurrence of the ABS ranges from, roughly, the mid-16<sup>th</sup> to the late-18<sup>th</sup> centuries. The Birdman Cult was active, as a religious and political ceremony, until AD 1862, when it was prohibited by Christian missionaries, but continued until AD 1878 as a solely athletic competition (Routledge, 1919).

The demography of the ABS is equally uncertain owing to the lack of direct evidence. The first estimates were based on assumptions considering the archaeological evidence and the estimated carrying capacity of the island, as well as comparisons with other Pacific islands of similar size. These methods yielded maximum estimates of 6000-8000 inhabitants (range: 3000-20,000) by AD 1400-1600 (Flenley & Bahn, 2003; Diamond, 2005). Theoretical modelling constrained by paleoecological and archaeological evidence has been used to simulate the population dynamics since the Polynesian settling under different scenarios (Basener & Ross, 2005; Cole & Flenley, 2007, 2008; Brandt & Merico, 2015). The latest ecocidal-based simulations showed a nearly exponential population increase with a maximum of nearly 15,000 inhabitants by AD 1600 followed by a sharp decline to less than 2000 inhabitants at the time of European contact (Fig. 5). The genocidal model yielded maximum values of ca. 4000 inhabitants at AD 1300-1400, which remained unchanged until the end of the 18<sup>th</sup> century and then underwent a steady decline up to approximately 1000 inhabitants. A third model comprising aspects of both ecocide and genocide exhibited rapid growth until ca. 7000 inhabitants by AD 1400 followed by a gentle and maintained gradual decline until 2000 people by AD 1800 (Brandt & Merico, 2015).

### **Environmental change during the last millennium**

The first proposals of the potential influence of environmental changes on the ecology and society of Easter Island were based on theoretical assumptions. For example, McCall (1993)

argued that the climatic severity, especially eventual droughts, of the Little Ice Age (LIA) might have affected the island's culture and speculates on the ABS as a change towards a ceremonial focus that was "...more economical of time and centre around the state of climate, ie the annual austral spring arrival of a migratory sea bird." (p. 103). The weak point was that the occurrence of the LIA on Easter Island and the surrounding areas was still to be demonstrated. Nunn (2000) speculated about the occurrence a cool-wet climatic reversal –likely due to an El Niño-Southern Oscillation (ENSO) intensification (Haberle & Chepstow-Lusty, 2000; Stenseth & Voje, 2009)- known as the "1300 event" preceding the cool-dry LIA in East Polynesia and related this event to the ABS. During both the "1300 event" and the LIA, sea levels would have been lower than at present, which might have affected Easter Island's coastal resources, including migratory birds, as occurred in the Eastern Pacific islands, in general (Nunn, 2007). The occurrence of the "1300 event", however, has been questioned (Allen, 2006).

This situation contrasted with earlier times, notably the Medieval Climatic Anomaly (MCA), during which the climate was more stable and sea levels higher, which favored social prosperity and intensification of long-distance navigation across the Pacific Islands (Goodwin et al., 2014). According to Fischer (2005), Easter Islanders might have been in contact with their assumed place of origin –the island of Mangareva, in the Gambier Islands, situated to the west at approximately four weeks of navigation at those times- until AD 1500, when communication was interrupted due to a general climatic and societal crisis that halted transoceanic navigation. However, direct evidence on such climatic and sea-level shifts on Easter Island is still lacking and a number of authors believe that climate change would not have had as much influence as human activities on Easter Island (MacIntyre, 2001; Flenley & Bahn, 2003; Azizi & Flenley, 2008). Modern climatic observations reported that ENSO variability did not produce significant variability on island's precipitation during the second half of the 20<sup>th</sup> century (Genz & Hunt, 2003). Junk & Claussen (2011) modelled the past climatic

trends of Easter Island and concluded that the climate changes of the last millennium might have been too small to explain the strong ecological and cultural changes documented, in particular the deforestation and its assumed cultural consequences.

Further paleoecological records on peats and lake sediments confirmed the occurrence of relevant Pleistocene and Holocene climatic shifts on the island (Mann et al., 2008; Sáez et al., 2009; Cañellas-Boltà et al., 2012; Margalef et al., 2013). However, most of these records still have sedimentary gaps hiding the environmental history of the last millennia. Recent investigations of nearly continuous sedimentary sequences from lake sediments allowed reconstruction of the main climatic and ecological shifts occurred on Easter Island during the last millennia at multidecadal resolution. These studies demonstrated that the deforestation was not abrupt or synchronous across the whole island. Rather, total forest removal resulted from the accumulation of local deforestation events that occurred at different times and at different rates depending on the site (Rull et al., 2015). In addition, the occurrence of drier and wetter phases could be confirmed. Especially interesting was the finding of two drought phases between ~AD 880 and AD 1170 and between ~AD 1570 and AD 1720, with dating errors ranging between  $\pm 30$  and  $\pm 40$  years (Cañellas-Boltà et al., 2013; Rull et al., 2016) (Fig. 6). The later occurred during the LIA (Fig. 7) and matched with the chronological range of the ABS (16<sup>th</sup> to 18<sup>th</sup> centuries), which is in agreement with the earlier speculations of McCall (1993). This author considered that the LIA climatic severity forced humans to drastically change their life style, social organization and rituals, but the link between environmental and cultural shifts is not straightforward, and it is not clear how such a complex sociological process could have happened. The latest paleoclimatic and paleoecological findings may provide a relatively simple and parsimonious, although partial, explanation for the profound cultural change represented by the ABS.

## A new scenario

The LIA drought reported above (AD 1570 to AD 1720) was recorded in the sediments of Lake Raraku, the quarry of the *moai* and center of cultural life during the Ancient Cult phase. The main evidence for drought was the interruption of lake sedimentation, likely due to the total drying of the lake (Cañellas-Boltà et al., 2013), a situation that persisted for ~150 years. This means that the core of Rapanui culture became devoid of freshwater for a century and a half. The anthropogenic deforestation of the Raraku catchment was completed by ~AD 1450 (Cañellas-Boltà et al., 2013), roughly a century before the lake dried, and the last signs of cultivation dated from AD 1320-1440 (Horrocks et al., 2012a) (Fig. 7). The whole picture suggests that, until AD 1450, the Raraku catchment supported intense cultural activity where agriculture and *moai* carving coexisted in a forested landscape with favorable climatic and ecological conditions, including the presence of palm forests and a freshwater lake similar to that at present. After those dates, anthropogenic deforestation –possibly in combination with fruit consumption by rats, which might have prevented forest regeneration- and intense drought would have transformed the basin into a wasteland devoid of freshwater, which likely made human life and *moai* carving unsustainable leading to a social crisis and the downfall or cessation of the Ancient Cult.

Freshwater availability is a strong limiting factor in Easter Island, as the only permanent freshwater bodies of the island are the two lakes, Raraku and Kao, and the Aroi swamp (Fig. 4). Surface water currents are absent due to the high porosity of the volcanic rocks that form the island (Herrera & Custodio, 2008). A drought like that reported here, intense enough to cause the desiccation of Lake Raraku, would have forced the Rapanui society to find an alternative freshwater supply to survive and to adapt to the new climatic and ecological conditions. Such climatic reversal would also have prevented forest recovery.

In the Aroi swamp and its surroundings, there is no evidence of large-scale permanent human settlements during the LIA drought beginning at AD 1570. The site was deforested by AD 1650 (Rull et al., 2015) (Fig. 8) and human occupation lasted until, at least, AD 1670 (Horrocks et al., 2015) (Fig. 7), but it appears that the area was occupied intermittently and only by marginal populations. The Aroi catchment was also dry during the same period as Lake Raraku desiccation (Rull et al., 2015) (Fig. 8).

The other potential freshwater source was Lake Kao. There is sound evidence that the Kao contained freshwater during the LIA drought, as indicated by the presence of many lake sediment samples with ages ranging from AD 1570 to 1720 (Rull, 2016). Therefore, this lake was likely the only feasible alternative for a continuous freshwater supply to support the Rapanui society, which would have determined the migration of the cultural center from Raraku to the Kao region. Additional multidisciplinary evidence supports this idea. Indeed, as stated before, the ceremonial village of Orongo, the center of the Birdman Cult, was probably founded in the early 17<sup>th</sup> century (Ferdon, 1961), near the middle of the LIA drought that desiccated Lake Raraku and likely ended the Ancient Cult. In addition, the continuous and consistent records of microfossils from Polynesian cultigens in the Kao sediments indicate that agricultural activities were common in the lake-shores below Orongo since its foundation (Horrocks et al., 2012b, 2013). Unfortunately, local deforestation patterns and chronologies at Kao are more difficult to assess due to dating inconsistencies (Butler et al., 2004; Horrocks et al., 2013), but the more consistent record available to date suggests that some palm stands would have been present in this catchment until the end of 18<sup>th</sup> century (Butler & Flenley, 2010) (Fig. 9).

While the geographical migration of the Rapanui cultural center from Raraku to Kao for survival reasons seems to be the more plausible explanation of the existing evidence, the shift from the Ancient Cult to the Birdman Cult needs further clarification. First, it should be noted that the Rapanui culture was Neolithic and did not have metals. In the Raraku quarry, the *moai* were carved on tuff using tools made from harder rocks, mostly basalt, obtained in other island craters, the Kao among them. The Kao crater is made of basalt and, therefore, much more difficult to carve with the technology available at those times (Gioncada et al., 2010). Of the ~900 *moai* known today, only a dozen were carved on basalt (Van Tilburg, 1994). The most frequent rock art in the Kao area are petroglyphs with the mythic Birdman as a favorite motif. These petroglyphs are also modelled on basalt but carving them is much easier and feasible than making gigantic *moai* (Fig. 3).

Geological features could help explain the end of the *moai* carving and the associated cult after migration to the Kao region and the associated cult but not the origin of the Birdman Cult. Based on the existence of images similar to the Birdman in other Polynesian cultures, it has been suggested that the Birdman ceremony might have been present since the initial Polynesian settling of Easter Island, although it was not as relevant then as in later times (Edwards & Edwards, 2013). However, evidence for such a statement is still lacking, and most researchers believe that the *moai* cult and the Birdman Cult did not coincide. The onset of the Birdman Cult and the social context in which it was originated is a complex cultural phenomenon that cannot be addressed with the available evidence and needs further multidisciplinary research. Interestingly, the date suggested by Lee and Liller (1987) for the onset of this cult, AD 1550, coincides with the beginning of the LIA drought analyzed here but, once more, the link between environmental inferences and cultural developments is not straightforward and needs inputs from varied fields of research.



From a sociological perspective, climatic stress and the ensuing impact on wild ecosystems (e.g., palm forests and coastal resources), freshwater availability and agriculture would have favored hunger and social crisis possibly leading to a population decline and the increase of social insecurity, which might explain the demographic decline and reclusion in caves. When the first Europeans arrived on the island during the 18<sup>th</sup> century, the LIA drought was still in progress –although close to the end (AD 1720)- and the island society was still affected by the environmental and societal crisis, which might explain the precariousness observed by the alien visitors. It would be interesting to check written historical documents to determine whether these expeditions mention Lake Raraku which, according to the latest paleoclimatic reconstructions, should have been dry until AD 1720. If this is true, the lake should probably have been absent at the expedition of Jacob Roggeveen (AD 1722) but present afterwards, during the arrival of the Spaniard González de Haedo (AD 1770), the British James Cook (AD 1774) and the French La Pérouse (AD 1786). Cook emphasized on the absence of freshwater in the island, but this expedition landed on Hanga Roa (Fig. 1) and it is not clear whether they visited the lake catchments or not.

The societal crisis would also have led to changing socio-political relationships among clans. For example, the religious and political power of the eastern Miru clan, which dominated during the Ancient Cult phase, would have been downgraded by the disappearance of Lake Raraku in favor of the westernmost clans, notably those inhabiting the Kao area, where freshwater was still available for social development. This might have been the onset of a social reorganization leading to the end of the perennial dominance of the Miru dynasty-based “monarchy” and the origin of a more “democratic” political system in which all clans were entitled to compete for power through the athletic Birdman competition, in which physical abilities, rather than dynastic attributes, were decisive. The new social order differed from the rules of the ancient society in several ways, but the contrast between the former divine

immutability of the Ancient Cult and the yearly renewal of the dominant clan based on physical strength (Birdman Cult), a system that seems to be better suited for adaptation to eventual socio-economic changes driven by a changing environment, is especially remarkable.

## **Conclusions and discussion**

A new scenario for the major cultural change on Easter Island that occurred before European contact is proposed based on a combination of climatic, ecological and anthropogenic drivers and events acting together. The deep transformation of the Rapanui society expressed in the change from the Ancient *moai* Cult to the Birdman Cult, associated with a migration of the cultural center from Rano Raraku to Rano Kao, a significant demographic decline and a deep transformation of the political organization may be explained by the occurrence of an extreme LIA drought that caused a general economic and social crisis across the island and desiccated the lake inside the previously human-deforested Raraku crater. The combination of these natural and anthropogenic phenomena, occurring between AD 1570 and AD 1720, would have determined the end of the flourishing Rapanui culture that built the *moai* leading to the more declining society encountered by the first Europeans, who arrived starting in AD 1722.

The further genocide of the Rapanui people caused by slave trading and epidemic diseases introduced after European contact has been documented historically. Therefore, the Rapanui society underwent at least two episodes of cultural disruption, the first caused by the synergy of external climatic shifts and internal anthropogenic factors, and the second forced by external cultural drivers. There is potential for a third, still pending confirmation, societal crisis between the visits of Roggeveen and Cook. In spite of these repeated disruptions, the Rapanui culture may be considered unique as it was not totally eradicated and their identity, language,

practices, traditions and other manifestations, although significantly decimated, are still alive (Middleton, 2012; Edwards & Edwards, 2013).

This new approach to the understanding of Easter Island's history should be considered a working hypothesis because a number of relevant points remain to be validated with further research. First, it should be noted that the new proposal is based chiefly on paleoecological evidence coming from analysis of peats and lake sediments and, therefore, cultural inferences should be considered tentative until the appropriate archaeological and anthropological evidence is analyzed. For this to be accomplished, the existing cultural evidence should be reconsidered in light of the new holistic proposal and, eventually the search for new evidence to test the new scenario of cultural change proposed here should be encouraged.

The debate around the influence of environmental variability on human societies is a classical one, where environmental determinism opposes environmental neutrality, as the two more extreme positions. The compulsive search for proof of one or another governing hypothesis, *sensu* Chamberlin (1965), would lead to researchers overlooking or ignoring relevant evidence pointing towards new and more realistic interpretive approaches. A dual scenario based on *a priori* theoretical considerations does not seem to be the best framework to analyze the existing empirical evidence for environmental change and cultural shift on Easter Island. Long-standing controversies between early or late colonization, ecocide or genocide and human vs. rat deforestation, among others, have led to enthusiastic but mostly unproductive debates (e.g., Flenley & Bahn, 2007; Hunt & Lipo, 2007). The new holistic scenario presented here has the potential to reconcile most of the existing evidence and, hence, seems to be the more parsimonious scenario available to date to unify observations and measurements from varied fields of research.

The incorporation of climatic shifts and their influence on Easter Island's ecological and cultural change should not be viewed as a defense of environmental determinism but rather as an attempt to include all the internal and external factors that may have been relevant to the observed reality. The underlying question is not how societies respond to environmental changes but how climatic, ecological and cultural phenomena and drivers of change occur together and interact to produce the observed overall picture. For example, in the new scenario, both climate (i.e., drought) and internal human pressure (i.e. local deforestation, either with or without the help of rats) contributed to the transformation of the Raraku catchment from a suitable place for human life and *moai* carving into a bare landscape, which likely favored a migration of the Rapanui cultural center and the first documented cultural change of this society. Climatic amelioration, expressed as a wetter climate and the replenishment of Lake Raraku, arrived after European contact and shortly before the beginning of the second demographic and cultural shift, this time forced by anthropogenic causes. Therefore, the second transformation was, again, the result of the combination of natural and anthropogenic drivers but, in this case, external human factors were the more decisive.

In summary, Easter Island's history is not a matter of one driver or another causing the collapse of its entire civilization at a given time or not but a complex process in which climatic, ecological and anthropogenic factors interact in different ways and at different spatio-temporal scales. This theoretical framework fits with the belief of Haldon (2016), for whom links between environmental changes and societal developments are obvious but "simplistic one-to-one determinisms are, of course, entirely inadequate: human social organization is incredibly complex, and societal reaction to change can rarely be understood from a monocausal perspective" (p. 191). In this sense, the cultural transformation represented by the shift from the Ancient Cult to the Birdman Cult and the associated changes from a rigid and unchanging society to a more dynamic socio-political organization could be interpreted as a

strategy for a better adaptation to the new environmental context, rather than a civilization collapse. Terms such as “transition” or “transformation” are preferred to “collapse” or “catastrophe”, which tend to distort the message and create a narrative that can dominate the scene, leading to simplistic and unrealistic cause-effect scenarios (Middleton, 2012). The Rapanui society neither collapsed nor disappeared, it did not split into minor groups or cause massive departures from the island (at least voluntarily). Easter Islanders remained at their home despite the intense environmental and cultural pressure, and persist today showing an exceptional cultural resilience to external natural and anthropogenic pressures.

### **Further research**

As suggested above, archaeological, anthropological and historical evidence could be reconsidered under the light of the holistic scenario depicted here. As it regards paleoecology, the evidence is still far from being complete. Paleoecological records from Rano Raraku and Rano Aroi have been useful to delineate the new framework as they are nearly continuous for the last millennia (Cañella-Boltà et al., 2012, 2013; Rull et al., 2015). However, the Kao records still show significant chronological inconsistencies that hamper reliable historical reconstructions (Butler et al., 2004; Horrocks et al., 2012b, 2013). New coring campaigns should emphasize the recovery of better sequences from Rano Kao, without forgetting Raraku and Aroi sampling for consistency. To date, there are two initiatives to obtain these data. One is an almost continuous Kao record from ca. 3500 to 1200 cal y BP (KAO05-3A), whose paleoecological analysis is yet to be published (Gossen, 2007). The other is a short core (KAO-03) containing a continuous and consistent record of the last ca. 1200 years that is currently being analyzed for several proxies.

So far, most paleoecological reconstructions have emphasized climate and vegetation, hence, evidence for human activities is mostly indirect. The development of new analytical technologies to study molecular biomarkers in sedimentary sequences, as for example DNA and fecal lipids, should be incorporated in the study of Easter Island, as they can provide direct evidence of human presence and activities (Rull et al., 2010, 2013).

Studies on sea level variations are still lacking on Easter Island and are needed to test the hypothesis of the “1300 event” (Nunn, 2007). The occurrence of coral reefs around the island, although not as developed as in tropical Pacific islands (Glynn et al., 2003; Hubbard & Garcia, 2003), could be useful for this purpose, as well as for paleoclimatic reconstruction.

Radiocarbon ages obtained thus far indicate that these corals could be useful to record environmental changes of the last centuries (Mucciarone & Dunbar, 2003; Burr et al., 2009).

A constant in Easter Island research has been the isolation of different scientific disciplines, which has created a bias in the existing hypotheses according to the field of research in which they have emerged. Some authors have tried to integrate evidence from varied disciplines on their own, but the emergence of joint initiatives by multidisciplinary teams incorporating archaeological, paleoecological, anthropological and historical approaches, among others, has been rare if not nonexistent. Given the nature of the problem and of the evidence required for a solution, a truly multidisciplinary approach is imperative (Rull et al., 2013).

## **Acknowledgments**

The ideas of this paper emerged during the writing of a popular book to be published this year by Editorial CSIC and Catarata Books (Madrid, Spain). I am very grateful to Beatriz Hernández (CSIC) and Arantza Chivite (Catarata) for their support and encouragement. I also acknowledge the comments and suggestions of Núria Cañellas-Boltà, Santiago Giralt, Encarni Montoya, Sergi Pla-Rabes, Joandomènec Ros, Alberto Sáez and Teresa Vegas-Vilarrúbia.

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## Figure captions

1. Topographic sketch map of Easter Island showing the sites mentioned in the text. The position of the island in the world map is indicated by a star. Lakes and marshes are in blue. The location of the ancient village of Orongo (Og) and the Motu Nui islet (MN) are highlighted by red dots. Green dots represent the distribution of present-day *moai* (Van Tilburg, 1994). Tk indicates the location of the Ahu Tongariki *moai* complex depicted in Figure 2.

2. The *moai* complex of Ahu Tongariki (Photo: N. Cañellas). Statues are up to 9 m high and 86 tons of weight. See Figure 1 for location.

3. General view of the three islets (Motu Nui, Motu Iti and Motu Kau Kau) situated at the SW of Orongo, where the athletes should obtain the eggs of the sooty tern (Photo: V. Rull). Note the petroglyphs modelled on basalt rocks in the foreground. See Figure 1 for location.

4. The Kao and Raraku lakes and the Aroi peat bog, the only freshwater bodies of the island (Photos: V. Rull).

5. Simulated demographic evolution of the Rapanui population according to three hypothetical situations, namely ecocidal, genocidal and mixed. Redrawn from Brandt & Merico (2015).

6. Summary multiproxy diagram of Lake Raraku (core RAR-08), adapted by Rull et al. (2013) from original data by Cañellas-Boltà et al. (2013). The shaded area is the interval missing in former surveys, which data were used to support the ecocidal hypothesis (Flenley et al., 1991; Dumont et al., 1998; Mann et al.). The two phases of lake drying (AD 880-1170 and AD 1570-1720) are represented by zig-zag red lines. The red dot indicates the vegetation change



characterized by the onset of palm decrease and the increase of grasses and *Verbena litoralis*, coinciding with the increase of fires.

**7.** Summary of the climatic, ecological and cultural trends of Easter Island over the last three millennia (simplified from Rull et al., 2016). Drought phases are shaded. Horizontal bars represent the age range for the occurrence of the indicated cultural and environmental events according to the available literature (details in the text). Abbreviations: RWP = Roman Warm Period, DACP = Dark Ages Cold Period, MCA = Medieval Climate Anomaly, 1300 = “1300 event”, LIA = Little Ice Age, Am = Americans, cu = first evidence of local cultivation, dgt = drought, pd = partial deforestation, td = total deforestation, wtr = wetter.

**8.** Summary multiproxy diagram of Rano Aroi (core ARO-08 02) from original data by Rull et al. (2015). The dry phases, corresponding to phases of landscape opening (LO1, LO2 and LO3), are shaded.

**9.** Summary pollen diagram of Lake Kao (core RK2) redrawn from Butler & Flenley (2010). Dating information as provided in the original reference. The date of the total deforestation has been estimated assuming a linear sedimentation rate between the last dating point (435-350 cal yr BP) and the present (AD 1950).

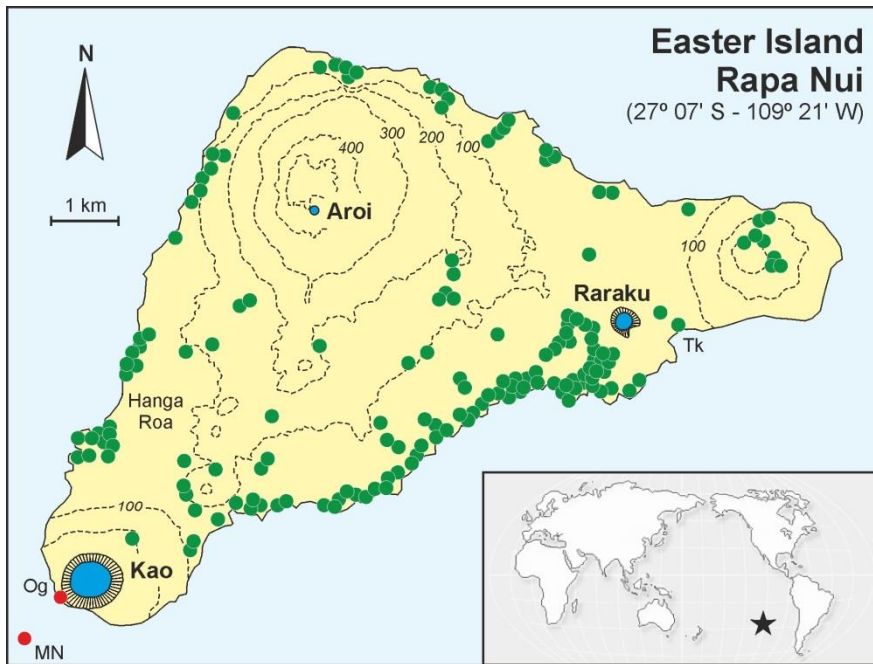


Figure 1



Figure 2



Figure 3



Figure 4

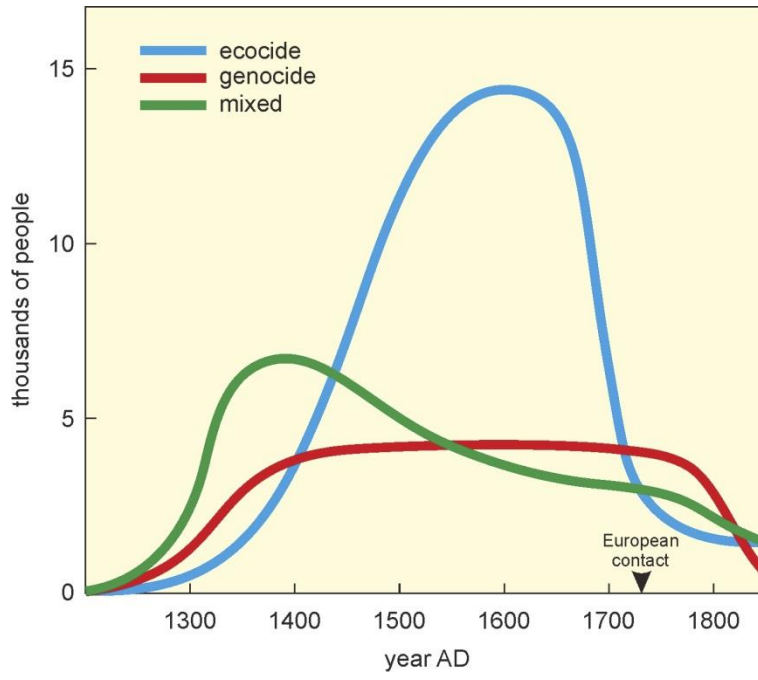


Figure 5

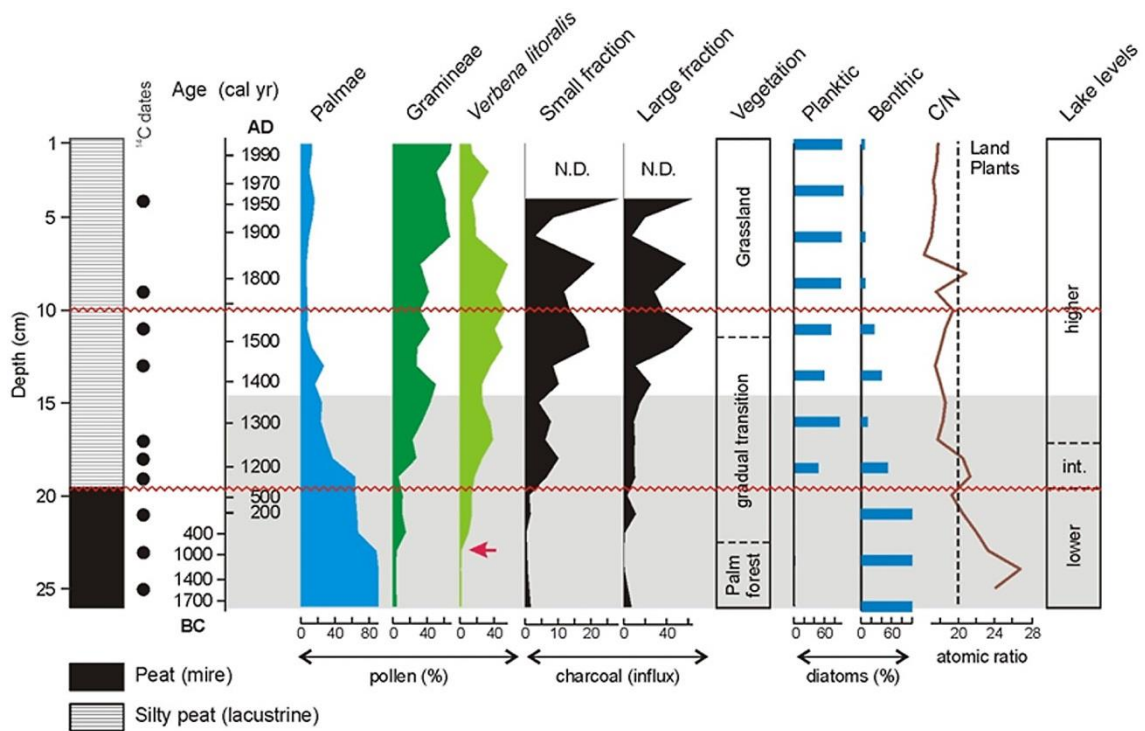


Figure 6



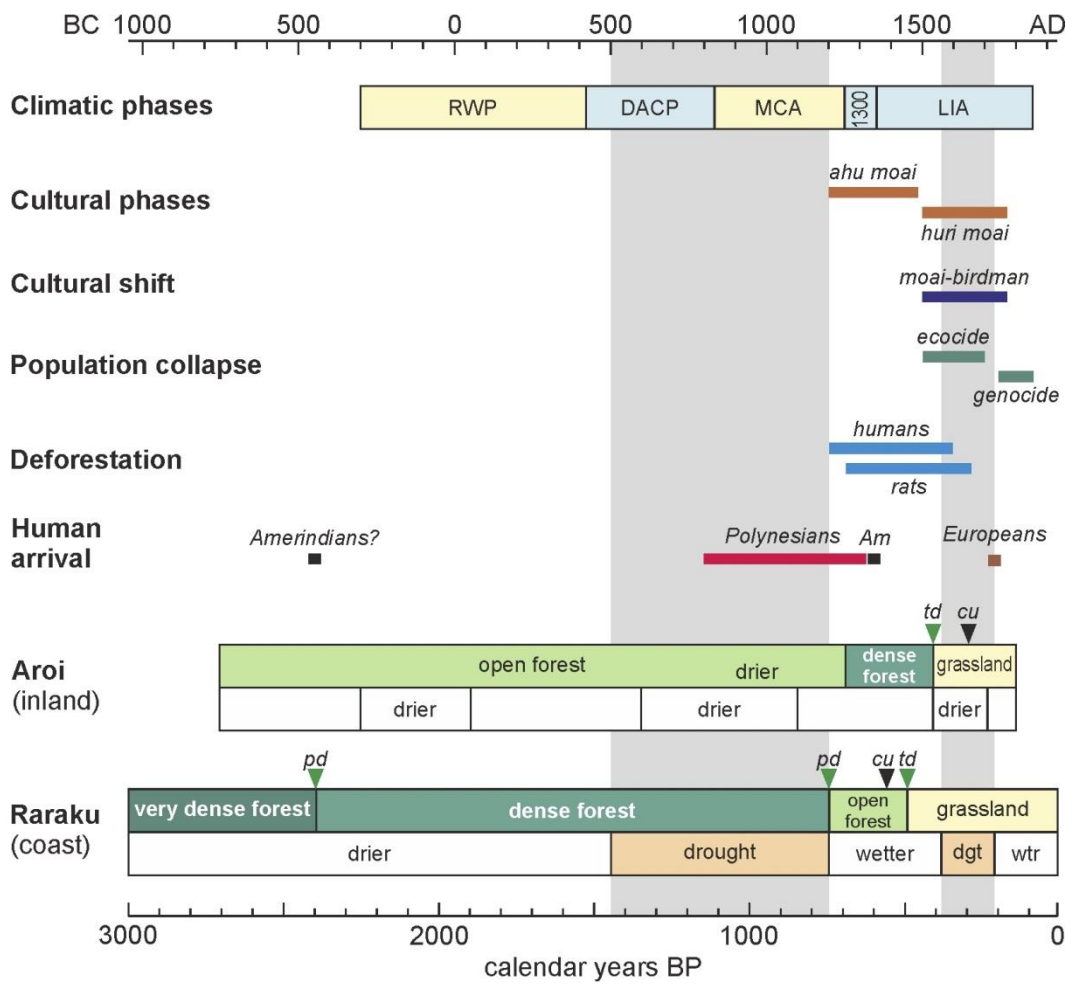


Figure 7

Rano Aroi - core ARO-08 02

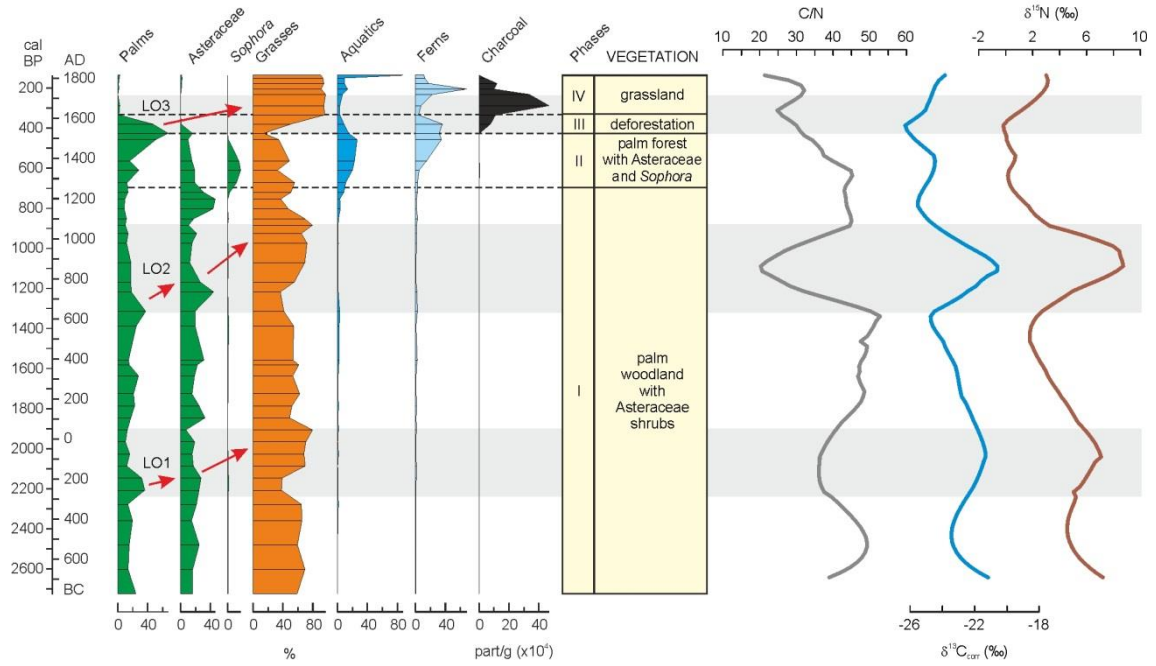


Figure 8

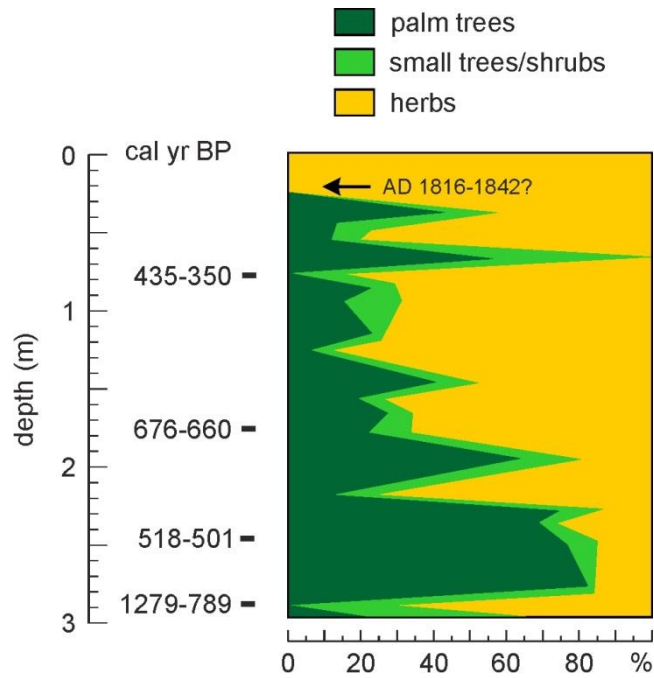


Figure 9