

Past synchronies, asynchronies, and collations between naturally and anthropogenically driven changes in northern Chile

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How climate change influenced societies in the past is a key issue facing ongoing and future climate change. Past human society-environment relationships in northern Chile provide evidence of different ways to cope with climate change in extreme environments.

Either naturally or anthropogenically driven, climate changes could lead to large environmental changes and, hence, affect socio-economic activities at different temporal scales. Nowadays, as in the past, the world is facing these effects as climate changes occur, impacting human societies in different ways and forcing them to adapt, resist, or migrate.

Currently, in Chile, this situation is critical because of the scarcity of water following the decreasing precipitation trend. Its effects are quite clear, including the drying of high Andean wetlands and lakes, the lowest historical stands of water reserves, loss of vegetation cover, and the abandonment of productive land. However, northern Chile has experienced a series of climatic changes at millennial to centennial timescales. How did human societies cope with these past changes? Did some of them make adjustments in response to climatic changes? If yes, were those responses synchronous with the climatic changes? These and other questions can be answered through

interdisciplinary research using geosciences and archaeology across sites in northern Chile.

In this article, we focus on two main regions (Fig. 1): Pampa del Tamarugal, in the center of the Atacama Desert (21°S), which reveals a fascinating Late Holocene development of agricultural societies in the driest desert of the globe; and Los Vilos, located in the semi-arid coast of subtropical Chile (32°S), which was a region inhabited by hunter-gatherers specialized in exploiting marine resources throughout the Holocene.

Climatic setting

The Pampa del Tamarugal records near zero precipitation throughout the year, and surface runoff is only associated with extreme rainfall events in the highlands. Precipitation sourced from the east and associated with the South American summer monsoon falls in the Andean highlands (Altiplano) (Fig. 1) and infiltrates the land, becoming subterranean discharge. Once in the lowlands, the subterranean water table reaches the surface.

In contrast, on the semiarid coast of Chile (32°S), precipitation is around 200 mm/yr and represents a marked seasonality, with winter-centered rainfall controlled by the Southern Hemisphere Westerlies (SHW) (Fig. 1). River discharge shows a fluvio-nival pattern with increasing amounts in winter and spring.

Farmers in the arid Atacama Desert

The archaeological record of Pampa del Tamarugal shows abundant evidence of hunter-gatherer societies since 11 kyr BP (Fig. 2a). These groups settled along active springs, canyons, and wetlands in the center of the desert until 9.5 kyr BP, when conditions became so dry that only a few sites were occupied during the Mid-Holocene (Santoro et al. 2017). It was not until the Late Holocene (after 3 kyr BP) that these areas were again occupied, though showing quite different characteristics. A marked transitional period from exclusively hunter-gatherer societies to the development of agriculture, a sedentary lifestyle, and a high degree of social complexity occurred in the Pampa del Tamarugal at around ~2.5-1 kyr BP (the Formative Period; Fig. 2a). A vast array of diverse archaeological evidence recorded over hundreds of kilometers reveals the development of a network of multiscale settlements. These include villages with monumental public areas and intensive and extensive agriculture as shown not just by the cultivation plots, but by sophisticated technologies to manage surface water (Adán et al. 2013; Urbina et al. 2018; Fig. 2a). The development of such complex societies in the core of the desert (2000-1000 masl) cannot be explained unless this happened under completely different climatic conditions than those of today.

Pollen records from rodent middens collected at 3500 and 3750 masl at 21°S were used to reconstruct past environmental condition changes (Fig. 2a; Maldonado and Uribe 2015). The rodent midden pollen record at 3500 masl reflect drier conditions than present at around 3.7 kyr BP, and after 700 yr BP, while wetter conditions occurred between 2 kyr BP and 700 yr BP. On the other hand, the rodent midden pollen record at 3750 masl shows wetter than present conditions at around 10 kyr BP and 2.2-1 kyr BP, drier than present conditions at around 3.5 kyr BP and after 700 yr BP, and a transitional wet-to-dry phase between 1 kyr BP and 700 yr BP.

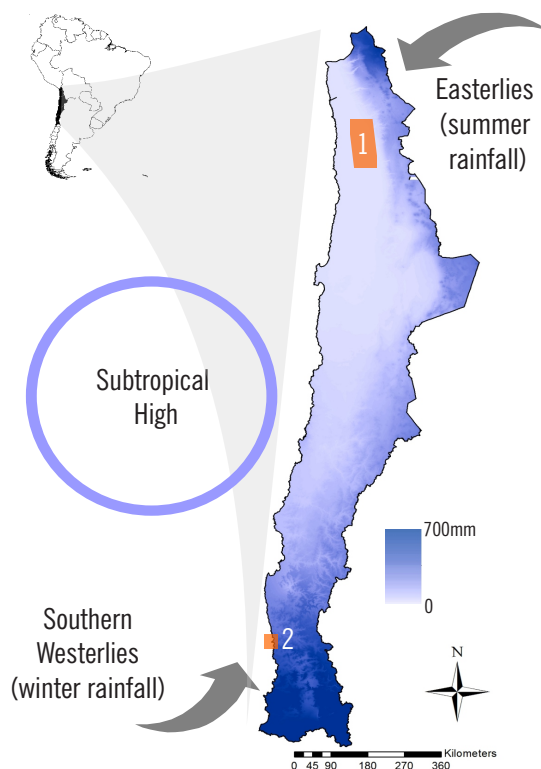


Figure 1: Map of the study area showing annual precipitation and the main climatic features of northern Chile. The orange rectangles show the study sites of Pampa del Tamarugal (1) and Los Vilos (2).

As for the archaeological record, central villages of the Formative Period started at around 2.3 kyr BP and were occupied until at least 1 kyr BP. By that time, villages of the Late Intermediate Period started growing in higher altitude canyons to the north, following the precipitation gradient. Thus, when integrating the environmental and archaeological evidence of Tarapacá, where water is extremely scarce and critical for survival, there is synchronicity between the occurrence of wetter-than-present conditions and the intensification of settlement and cultivation plots, accompanied by more social complexity during the Formative Period (Uribe et al. 2020). Besides, the development of villages at higher and more northern canyons occurred when conditions became transitional towards drier than present, during the Late Intermediate Period.

Coastal hunter-gatherers of semiarid Chile

In semiarid coastal Chile, the environment-human relationships are rather different to those in the Atacama Desert, and the key environmental archives for tracing past environmental and climate changes are sedimentary records in coastal swamp forests. Coastal swamps form diverse and densely vegetated hygrophilous small forests in a matrix of semidesert shrublands, and grow in areas where the water-table level

reaches the surface. The coastal water-table level is recharged by precipitation falling above 2000 masl that infiltrates and moves underground.

The swamp-forest pollen records show the occurrence of the two most contrasting periods corresponding to the driest interval between ~8–5 kyr BP, and the wettest period starting at 2 kyr BP (Fig. 2b; Maldonado et al. 2010; Maldonado and Villagrán 2006; Méndez et al. 2015). On the other hand, the archaeological record including more than 200 sites (mostly coastal and corresponding to shell middens) reveals an almost continuous presence of humans in the area for the last 13 kyr (Fig. 2b; Méndez and Nuevo-Delaunay 2021).

When integrating the environmental and anthropogenic trends (based on the sum of probabilities of radiocarbon dates, Méndez et al. 2018), both synchronous and asynchronous events are recorded. While people lived along the coast regardless of the environmental conditions, likely due to the permanent supply of marine resources, inland sites show a marked occupation only since 3 kyr BP, when the climate shifted towards wetter conditions, as shown by the pollen records of Laguna Grande (Fig. 2b). The archaeological evidence suggests different

mobility and occupation patterns of the coast over time. The initial human presence in the area was coeval with extinct megafauna under slightly wetter conditions than present. The first coastal adaptations at ca. 12 kyr BP reveal an almost permanent presence of settlers, with occasional incursions into the interior, under relatively humid but variable environmental conditions. During the Early Holocene (Huentelauquén Phase II) (Fig. 2), as the environment became drier, the once coastal hunter-gatherers turned their attention to ravine resources, and inland incursions increased. Interestingly, the driest spell of the sequence is associated with a decrease, and almost abandonment of, the coastal settlements between 8.3 and 7.6 kyr BP (Méndez and Nuevo-Delaunay 2021). After this extremely arid phase, settlements were again located along the coast. With the gradual return to wetter conditions, occupation density reached their maximum at 3 kyr BP, either in coastal or inland archaeological records. Finally, with the development of horticulture and pottery at 2 kyr BP (Early Ceramic Period), coastal occupations became less prominent, and groups increasingly occupied the inland under wetter than present conditions, at the expense of the use of coastal landscapes and their resources.

Final words

The case studies of human society–environment relationships in northern Chile show that people coped with past climate change at centennial timescales by either technological developments to manage the water, or by occupying sites where resources were independent of the environmental/climatic scenarios. The occupation of alternative sites (inland) or migration (highlands) occurred under the establishment of extremely wetter or drier conditions, respectively.

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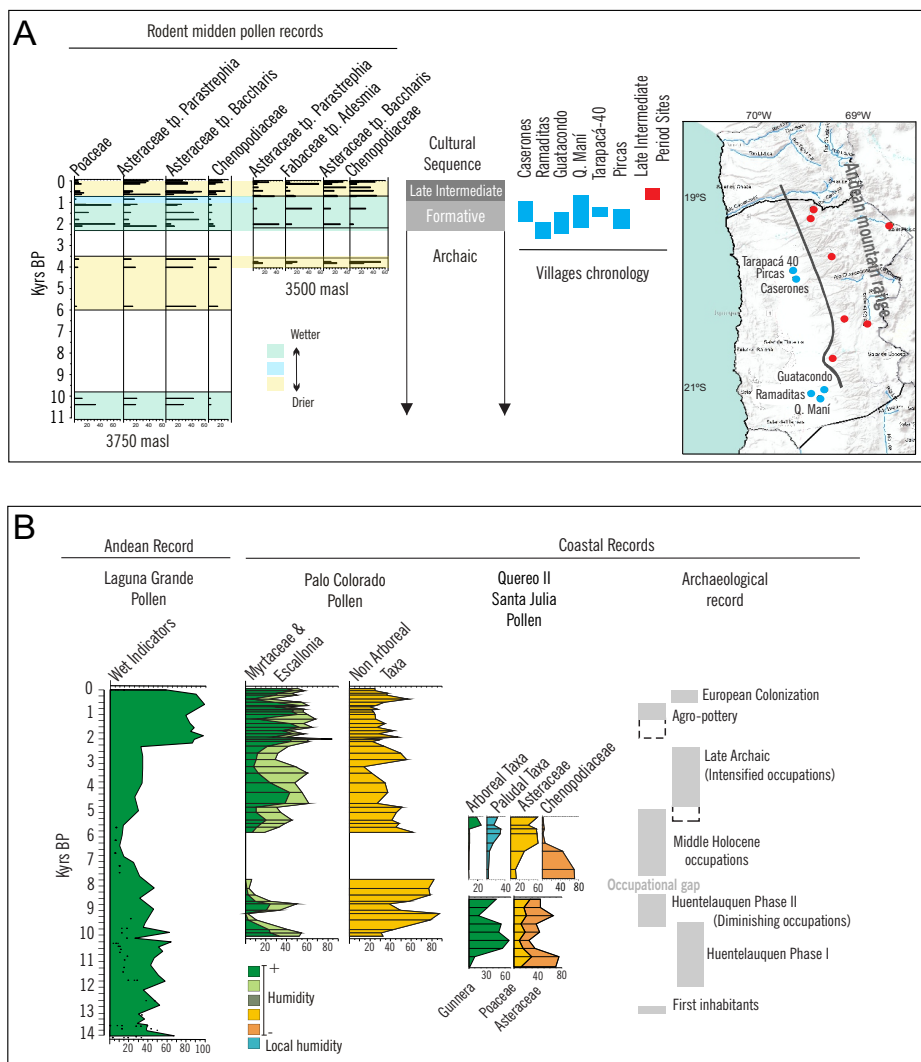


Figure 2: Comparison of paleoclimatic records and archaeological sequences in (A) the Pampa del Tamarugal (blue dots and rectangles correspond to Formative Period sites and red to Late Intermediate Period sites); and (B) Los Vilos areas.