Cultivated wetlands and emerging complexity in south-central Chile and long distance effects of climate change

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Lands in south-central Chile, long thought to have been marginal until the Spanish conquest, are here shown to have been developing complex societies between at least AD 1000 and 1500. Part of the motor was provided by coastland cultivation on raised platforms, here identified and surveyed for the first time. The authors date the field systems and suggest that they were introduced by farmers from the north seeking wetlands in the face of increasing aridity in the central Andes and southern Amazon.

Keywords: South America, Chile, Araucania, pre-Hispanic period, agriculture, raised fields, drainage, canalisation, complex societies, monumentality

Introduction

Archaeologists, geographers and historians have seen the grasslands and temperate forests of the southern cone of South America as backwater environments where only hunters and gatherers lived until AD 1550 to 1650 when the Spanish and other European cultures introduced new technologies. But new archaeological discoveries in the Amazon basin (Heckenberger *et al.* 2003) and mid-Atlantic region (Iriarte *et al.* 2004; Stahl 2004) have revealed unexpected cultural complexity in the form of monumental architecture, sedentary villages and social differentiation in cultural areas previously conceived as marginal. In this paper we focus on the region of Araucania, south-central Chile, where raised fields imply extensive artificial agricultural systems, associated with ceremonial mounds, in the cool, temperate rainforests between AD 1000 and 1500. From these landscape features we infer intense crop production in wetlands and correspondingly new principles of order and organisation and social differentiation.

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Although mounds in the study area have been investigated previously (Latcham 1928; Dillehay 1985; 1990a; 2007), raised and canalised fields and their association with mound complexes have only recently been identified and studied. Cultivated fields in the region reported here are located in the coastal drainage of Lake Budi, in the delta of the nearby Imperial River and in the floodplain of the Purén and Lumaco Valley (Figure 1). We go on to explore the possibility that the technology of these fields might have been introduced by central Andean or Amazonian populations moving into more humid southern environments in response to prolonged aridity between AD 1000 and 1300 in their homelands.

Mound complexes in Araucania

Archaeological mound complexes in the floodplains and riverine estuaries of south-central Chile are large and numerous, date prior to AD 1000, and have their origins in local traditions and probably in central Chile (Dillehay 1985; 1990a & b; 2007). In the Purén and Lumaco Valley, more than 350 ceremonial and burial mounds, or *kuel*, are built on artificial platforms that are associated with public plazas (Figure 2). Some Purén/Lumaco complexes comprise up to 40 mounds, but most are small sites consisting of five structures or fewer and usually associated with nearby agricultural settlements, later defensive sites and the agricultural features discussed below. Diagnostic ceramics recovered from the fields and from nearby mounds and habitation sites are of the late Pitren and polychrome El Vergel traditions which are radiocarbon dated between *c*. AD 1000 to 1500 (Menghin 1962; Dillehay 1990a; 2007; Adán & Mera 1997; Quiroz & Sánchez 1997). *Kuel* are also found in other valleys in the Araucanian region, including the Budi and Imperial areas, but are less numerous and appear to date after AD 1100. Although the period of concern here is between AD 1000 and 1300, these complexes range between 2 and 10ha in size and date from *c*. AD 900 to the present-day. Some complexes are still in ceremonial use today by a few Mapuche communities in the Purén and Lumaco Valley (Dillehay 1985; 2007).

Raised and canalised fields

Raised fields are platforms where the topsoil has been elevated to protect it from excessive water and they provide a highly productive and important economic base for several Old World and New World civilisations (Denevan 1970; 2001). The most extensive raised fields in the New World are located in the tropical lowlands of Latin America (Turner & Brush 1987; Denevan 2001; Balée & Erickson 2006). Canalised fields are sinuous ridges that follow the natural contours of levees in the floodplain wetlands. Channels are often cut artificially between levees to facilitate and manage the flow of water for cultivation of the flat surfaces. Raised and canalised fields have been documented in several areas of the northern and central Andes, but never before in the southern cone and Araucanian region of South America.

Raised fields in the Budi and Imperial River area

Studying the temperate forests and wetlands around the seasonally brackish deltas of the Lake Budi and Imperial River estuaries (Figures 1 and 3a-b), we found that the environment

Figure 1. Location of the three study areas in south-central Chile.

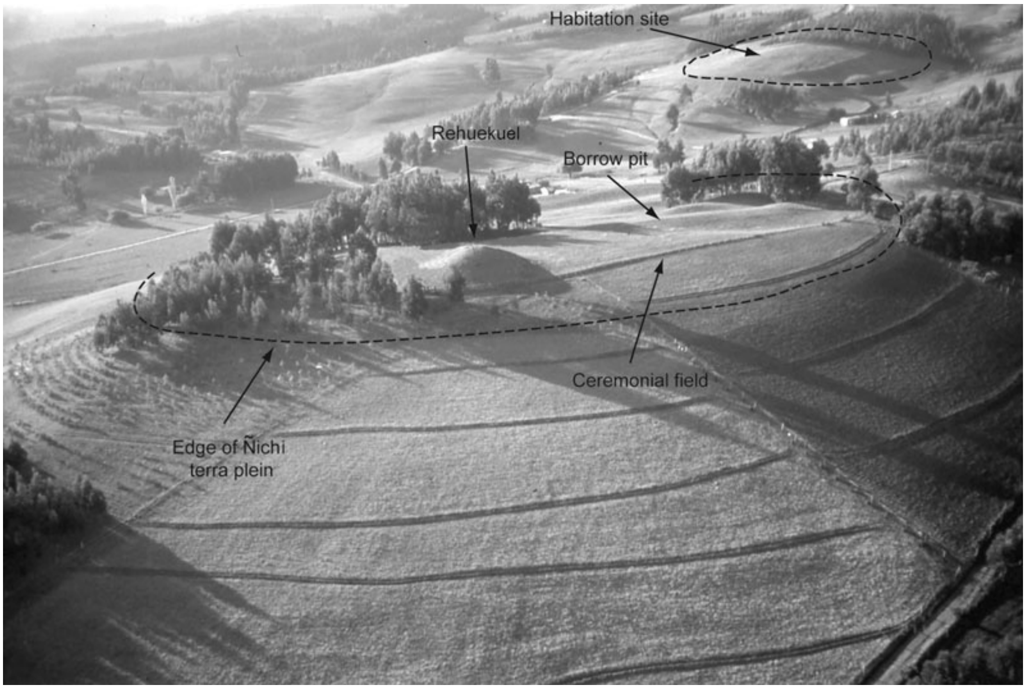

Figure 2. One of hundreds of prehistoric and historic ceremonial mounds and precincts associated with extensive habitation sites in the Purén Valley. Shown are the mound (rehuekuel)*, the platform on which it has been built* (ñichi)*, an active ceremonial field, the borrow pit from where the earth was removed to build the mound, and a distant prehistoric habitation site. This mound is still used today in public ceremony by the local Mapuche.*

had been widely transformed over the past 1000 years by a dense population of fishermen and farmers in a highly planned network of dense settlements and agricultural systems. The largest continuous block of raised fields lies in the mouth of Lake Budi, in a former linkage between the lake and the Pacific Ocean, which occupies long narrow backwater wetlands that were fed primarily by three lake outlets. Approximately 175ha in Lake Budi and 120ha in the delta of the Imperial River have been surveyed from the air and on the ground. The current coastline has been altered significantly by tectonic movements and glacio-eustatic sea level changes, most intensively since at least the middle Pleistocene period. As a result, some rivers have become lakes like Lake Budi and some areas have suffered from erosion and reactivated dunes. The major earthquake in 1960 significantly modified the outlets at the mouths of the Imperial River and Lake Budi and altered drainage patterns in the fields. Sediments in the study area include a wide variety of sand formations defined by beaches, dune fields and outer estuary deltas.

The Budi and Imperial fields are linear, parallel side-by-side arrangements of large elevated planting platforms located in estuaries protected by sand dunes and an artificial seawall on the seaward side (Figures 3a and 4). Although the fields have now been abandoned and partly destroyed by wind and tsunami erosion, we have documented several geomorphological details and technological functions. The raised platforms are constructed of sandy sediments taken from all of the local environments. The individual elevated platforms range from 18

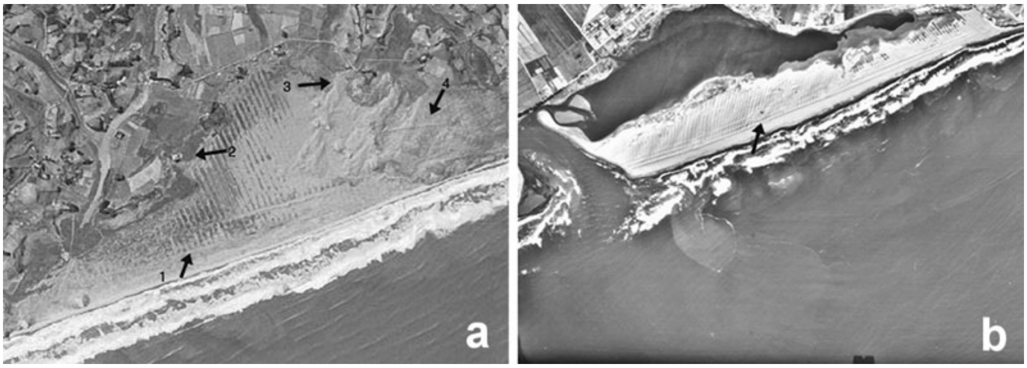

Figure 3. (a) Aerial photo of raised fields in the mouth of Lake Budi, showing (1) the prehistoric seawall protecting the fields, (2 and 3) locations of adjacent prehistoric domestic villages, and (4) a drainage canal extending to the south. Photo courtesy of the Instituto Geográfico Militar, Chile; (b) Aerial view of the raised fields in the mouth of the Imperial River. Photo courtesy of the Instituto Geográfico Militar, Chile. Arrow points to a prehistoric artificial seawall protecting the fields.

Figure 4. Close up of large raised platforms of the Budi system. Arrow to the far right points to the artificial seawall protecting the platforms. Arrows to the left and central point to individual raised food processing platforms.

to 20m wide, 1.2 to 1.7m high and up to 200m long. Approximately 80 per cent of the field systems is given to the platforms. The remaining portion is occupied by intervening canals that derive their water from local fluvial networks connected to the lake outlets, natural

Table 1. Concentrations of Ca, K, Mp, Mg, pH, and N from Various Raised Platforms and Control Samples at Lake Budi.^*

Platforms	Ca	Mk	P	Mg	pH	N	Organic[#]
1	06940	0390	0125	0270	7.61	0960	0.3
2	09910	0078	200+	0573	9.20	2680	0.2
3	11410	0314	0059	0905	8.10	0810	0.3
4	14400	0271	0061	0923	7.40	1240	0.2
5	15460	0099	0047	4230	8.55	3240	0.3
6	20570	500+	200+	4260	9.20	0930	0.3
7	28900	500+	0045	0914	8.93	0870	0.3
8	06860	500+	200+	0883	7.40	1950	0.1
Non-archaeological control samples							
1	04340	0080	0070	0440	8.40	0750	0.1
2	03800	0120	0110	0330	8.10	0680	0.0

^ Anonymous. Soil analysis of sediments from selected sites in south-central Chile. Report in possession of the authors (Vanderbilt University, Nashville, 2005).

* Extractable ppm

[#] Trace amounts of organic matter

springs, percolating ground water and seasonal rainfall and by levees and dikes, all of which were employed to impound, conserve and distribute water in the field complexes.

Between 25 and 60cm below the ground surface of the raised platforms is a proto-palaeosol that contains a moderate density of organic material, which sustains humidity and favours crop production. Sediment samples from tested platforms have produced significant differences in the organic matter, calcium, magnesium, potassium, manganese, phosphorus and nitrogen levels of the palaeosols in comparison with control samples taken from non-archaeological sediments in the area (Table 1). The higher presence of these elements suggests different plants grown on and the intense use of the platforms.

Preliminary phytolith, starch grain and macrobotanical flotation studies have been carried out but with no positive results. This is probably due to high pH levels (see Table 1) and to the destructive sedimentary mechanics of the coarse, sandy deposits of the platforms.

Oral tradition of local indigenous Mapuche today has it that maize, potatoes and beans were produced in the fields in the past. Locals refer to the Budi fields as *deume,* meaning large constructions. Today, the Mapuche open and close the ancient levees and dikes to drain Lake Budi as much as 1m during the spring months, which allows opportunistic potato and other crop cultivation along the wet lake shores and control of the amount of water flowing and draining through the raised fields. Every winter during the heavy rainy season the lake outlet is artificially reopened to prevent the inundation of adjacent lowland Mapuche communities. These water management techniques also were likely employed in the past to produce crops and to control flooding.

The Purén and Lumaco valleys

In the wetlands of the Purén Valley, located approximately 50km to the north-east of the Budi and Imperial areas, similar but smaller raised fields occupy small floodplain areas

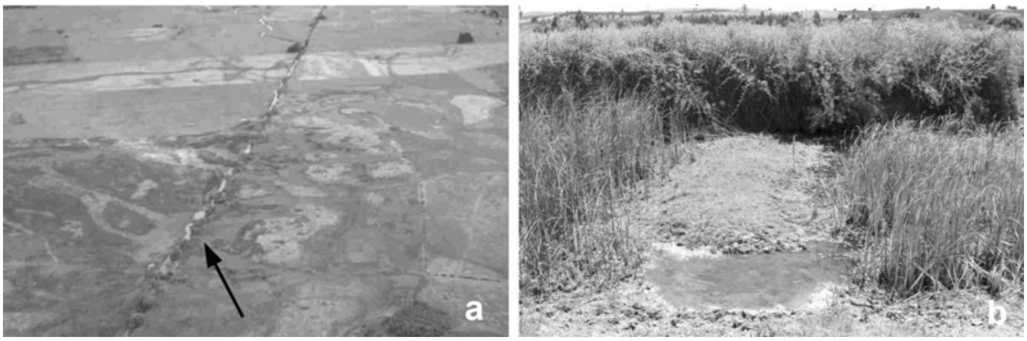

Figure 5. (a) Close-up of a section of canalised fields in the floor of the Purén Valley. Note the long canal (arrow) that traverses the amorphous-shaped canalised fields. (b) One of several small-scale raised platforms (c. 3m wide and 8m long) in the floodplain wetlands of the Purén Valley.

between 2 and 5ha that are characterised by 0.5 to 1m high and 8 to 15m long platforms (Figure 5a). Also located in the floodplain wetlands are canalised fields (Figure 5b). Several canals have been dug between many levees to regulate the flow of water for crop production on the levee surfaces. Today, the active Purén and Lumaco river carries large quantities of sediments eroded from surrounding uplands. During the rainy season, the river often breaches the natural levees that contain it, redepositing its sediment loads across the adjacent floodplain. Other sections have been effaced through erosion triggered by heavy seasonal rains and by modern activity. Some canalised and raised fields in the Purén Valley have recently been reclaimed and restored successfully by local Mapuche to produce potatoes.

Charred macro-plant remains of several cultigens, including maize (*Zea mays*), tarweed (*Madia sativa*), quinoa (*Chenopodium quinua*) and an unspecified fruit (Poaceae), have been recovered from raised platforms, canalised fields and nearby agricultural villages in the Purén and Lumaco Valley (Bonzani 2005; Silva 2005). Associated with the Purén and Lumaco fields are previously reported mound complexes, agricultural villages and defensive networks dating to the same period (Dillehay 1985; 2007).

Dates

Although it is difficult to date raised agricultural platforms due to the scarcity of organic materials, two radiometric dates were obtained from proto-palaeosol strata in two excavated platforms in the Budi fields. These are 670 ± 40 ^{14}C yr BP (*c*. 1210-1320 cal AD, Beta Analytic 167 596) and 860 ± 110 TL yr BP (*c*. 1145 ± 110 AD, UCTL 1759). Located in the low hills around the Budi and Imperial fields are numerous ancient settlements dating at least to the tenth century AD. A radiocarbon date from a raised platform in the Purén and Lumaco fields placed them at 660 ± 40 ^{14}C yr BP (*c*. 1220-1420 cal AD, AA64654).

The radiocarbon dates strongly agree with those processed from excavated domestic settlements and mound complexes associated with the fields and with diagnostic El Vergel ceramics. El Vergel ceramics recovered from the fields and associated mound and habitation sites have been dated by thermo-luminescence between *c*. AD 1050 and 1300 (Dillehay 2007).

Sources for Araucanian agriculture

The Araucanian raised fields discussed above fall technologically and typologically within the broad range of raised fields located between 3500 and 2500km further north along the coast of Peru (Denevan 2001), in the Llanos de Mojos lowlands of north-east Bolivia (Denevan 1970; 2001) and at Lake Titicaca in the altiplano of north-west Bolivia (Erickson 1987; 1995; Ortloff & Kolata 1993; Kolata *et al.* 1997; Kolata & Janusek 2004). Fields in these localities have been dated by radiocarbon means or associated diagnostic artefacts between *c*. AD 900 and 1400, AD 700 and 1300 (Erickson 1995; Balée & Erickson 2006) and *c*. AD 600 and 1000 (Erickson 1987; Kolata *et al.* 1997; Kolata & Janusek 2004), respectively. The Lake Titicaca fields are geographically closest to the Araucanian ones.

It is not known whether raised and canalised field technology in south-central Chile was developed independently by local populations or introduced by outsiders. No raised fields have been reported previously in the southern cone and there is no archaeological evidence of prototypes or trial and error experimentation with artificial agricultural systems in the region prior to AD 1000, which would be expected of a new technological invention (Schiffer 2005). The sudden appearance of field technologies in the Araucanian wetlands after AD 1000 therefore suggests they might have been introduced by outsiders, probably from the central Andean region.

There is mounting ceramic, linguistic and genetic evidence of contacts between late prehistoric Araucanian peoples and peoples in the central Andes and south Amazon basin. For instance, mound-building and the Pitrén and El Vergel ceramic traditions seem to have their technological roots in earlier central Chilean and possibly north-west Argentine cultures (e.g. Latcham 1924; 1928; Menghin 1962; Dillehay 1990b; 2007). There is also genetic and linguistic evidence to link late prehistoric (*c*. AD 1100-1500) and contemporary Mapuche with southern Amazonian groups, particularly the Arawak (Croese 1985), the Bolivian Tacanan (Acuna *et al.* 2003; Key 1978; 1979) and Guarani (Carnese 1996; Sans 2000). Preliminary studies suggest that the varieties of maize (*Zea mays*) and quinoa (*Chenopodium quinua*) recovered from excavated sites in the Purén and Lumaco Valley have probable morphological affinities with central Andean varieties (Bonzani 2005; Silva 2005; Dillehay 2007). Maize is of the 4 to 12 row Araucano variety grown in south-central Chile today and likely derived from varieties in Bolivia, Peru, or north and central Chile (cf. Sánchez *et al.* 2004). The origin of Araucanian quinoa also is not well understood but probably has its roots in the central Andes or central Chile (cf. Planella & Tagle 2004; 2005).

Discussion – why was agriculture introduced?

Not enough archaeological and palaeoecological data are currently available for these regions to determine the specific times and places of human movement and technological diffusion from one region to the other during this period, and the extent to which factors such as warfare, social collapse and economic change might have contributed to regional cultural disruptions and interregional contacts. However, important discontinuities in published archaeological sequences with sufficient radiocarbon dates at various sites imply simultaneous settlement abandonment, population dispersion and cultural instability in widely separated but culturally connected regions during this period.

It is significant that the development of agricultural technologies along with polychrome ceramics in the Araucanian region corresponds with major cultural and climatic events documented between AD 1050 and 1300 in Bolivia (Ortloff & Kolata 1993), northern and central Chile (Núnez & Dillehay 1979; Núnez 1993; Rothhammer & Santoro 2001; Berenguer 2004) and north-west Argentina (Nielsen 1996), where political fragmentation and excessive aridity apparently spurred a '*diaspora altiplanica*', resulting from the demise of some chiefdoms and states.

The overall pattern of these changes is consistent with supra-regional increases in aridity during this same period in Peru (Thompson *et al.* 1985; Shimada *et al.* 1991) and Bolivia (Kolata *et al.* 1997; Kolata & Janusek 2004: c.f. Erickson 1999), northern and central Chile (Maldonado & Villagran 2002) and northern Patagonia and central Argentina (Villalba 1990; 1994). This aridity apparently caused the simultaneous abandonment of extensive raised fields at Lake Titicaca and of the large nearby city of Tiwanaku and other population centres of the Tiwanaku state (Kolata *et al.* 1997; Kolata & Janusek 2004) and triggered population dispersion in the Bolivian altiplano. We can extrapolate from these records to hypothesise that dispersing populations in search of new suitable environments might have caused long-distance ripple effects of both migration and technological diffusion across the south-central and south Andes between *c*. AD 1100 and 1300 (cf. Berenguer 2004: 154-66; Nielsen 1996; Ortloff & Kolata 1993; Shimada *et al.* 1991 for north Peru).

The temperate environments of the southern cone and especially the wetlands of the Araucanian region are unique as one of a few continuous tracts of land south of Peru, Bolivia, northern Chile and north-west Argentina, where cultivated landscapes and moderate population densities could have been sustained. Today, the length of Chile is characterised by a marked gradient of annual precipitation, with the world's driest desert in the north (Atacama desert with 1mm of annual rainfall), to a Mediterranean environment in the central zone (325mm) to a cool temperate rainforest in the south-central Araucanian zone (2350mm). Proxy climatic records for the last millennium (Mann & Jones 2003) are scarce for the southern cone. However, temperature reconstructions from tree growth rings (e.g. *Fitzroya cupressoides*) in south-western South America show a warm, dry period between AD 1080 and 1250 (Villalba 1990). This time-span generally corresponds with the optimal medieval warm period registered in Europe (Villalba 1990) and with a warm period between AD 800 and 1400 in the northern hemisphere (Mann & Jones 2003) and between AD 800 and 1250 in the central Andes (Cook *et al.* 2004; cf. Schimmelmann *et al.* 2003) and in the northern half of Chile (Maldonado & Villagran 2002). The climate of the forested Araucanian region was generally cool and humid between AD 1000 and 1400 (Maldonado & Villagran 2002). The Lake Budi and Imperial study area is characteristic of a transition climate from Mediterranean to cool temperate rainforest and averages about 1400mm of rainfall a year. The Purén and Lumaco study area exhibits a semi-esclerofilia vegetation (di Castri & Hajek 1976; Donoso 1981) with seasonal Mediterranean aridity similar to climates located 200km farther north (1050mm annually; cf. Montecinos & Aceituno (2003) and Ortlieb (1994) for El Niño climatic impact). These regions were therefore potentially attractive to cultivators in the period AD 1000-1300.

We do not want to leave the impression that complexity suddenly developed in the Araucanian region when raised and canalised field technologies appeared, because this is not the case. Social differentiation, horticulture, incipient mound-building, settlement aggregation and a simple chiefdom society had begun by at least AD 800 to 1000 (Menghin 1962; Dillehay 1990a & b; 2007). Whether the fields were invented locally or adopted from outsiders, local populations would have had to understand how to build and maintain them and to grow crops on them in different wetland environments. Working the fields would have had the same effect of managing other large-scale public works, such as mounds, fortresses and roads, by learning new skills and new ways to invest resources and labour and by enhancing the administrative relations between elites and non-elites.

Conclusions

Over the past three decades archaeological and palaeoecological investigations in the Purén, Lumaco, Imperial and Budi areas have discovered, mapped and tested large-scale agricultural features, ceremonial mounds and permanent villages in and around prehistoric and historic settlements. These surveys have revealed advanced cultural patterns that developed in circumscribed wetlands and coastal estuaries in south-central Chile between at least AD 1000 and 1300. The large-scale transformations of the Budi and Purén landscapes reveal a late prehistoric complexity not documented before now in the southern cone of South America. Crops produced on raised platforms complemented cultivation in adjacent firm lands around the shores of the Budi, Imperial and Purén fields and in wetlands in the nearby hills, alongside fishing and shellfish gathering on the nearby coastline.

Not enough interdisciplinary data are presently available to account for the presence of these features in the south Andes and for contacts between these regions. At present, the most plausible explanation is cultural diffusion and perhaps long distance migration prompted by desiccation further north. The results of this study should encourage a broader consideration of the widespread climatic, demographic and cultural changes that occurred in other parts of South America.

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