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3.9. PROCESSES OF PREHISTORIC CROP DIVERSIFICATION IN THE LAKE TITICACA BASIN OF THE SOUTH AMERICAN ANDES

Maria C. Bruno

Introduction

The Lake Titicaca basin has long been recognised as an area of crop diversity in the Andes of South America (Beck and García 1991; Cardenas 1989; La Barre 1947; Weberbauer 1945). People began to farm this region as early as 1500 BCE and communities of indigenous Aymara and Quechua subsistence farmers continue today. The lake is located in the altiplano, a high (3500–4000 m asl) plain that extends between 15° and 22° S between the eastern and western Andean mountain ranges (Allmendinger et al. 1997; Clapperton 1993). The altiplano is one of the driest and coldest inhabited zones of the Andes with an annual rainfall of approximately 200–800 mm per year (Vuille et al. 2000) and a mean annual temperature of between 7° C–10° C (Montes de Oca 1995). The Lake Titicaca basin, however, is an oasis within the altiplano. The immense body of water (approximately 8562 km²) absorbs solar radiation making the water temperature warmer (10–14° C) than the surrounding land and air (Wirrmann 1992). This radiation of warmth generates ‘thermal effects’ (Boulange and Aguize 1981) that create warmer yearly temperatures and more rainfall. This temperate micro-climate supports very productive agricultural systems around the lake (Vacher et al. 1992).

Although its cool, dry climate prevents cultivation of Andean species such as chili peppers (*Capsicum baccatum* Jacq.), squash (*Cucurbita maxima* Duchesne, *C. moschata* Duchesne ex Poir.) and coca (*Erythroxylon coca* Lam.), the region has a great varietal diversity of
crop species that can be grown: quinoa (Chenopodium quinoa Willd.), kañawa (Chenopodium pallidicaule Aellen), potatoes (Solanum tuberosum L., Solanum stenotomum Juz.), and the Andean tubers oca (Oxalis tuberosa Molina), isañi (Tropaeolum tuberosum Ruiz and Pavón), and ullucu (Ullucus tuberosus Caldas). Farmers here also cultivate unique varieties of maize (Zea mays L.), tarwi (Lupinus mutabilis Sweet), and several Eurasian crops, principally fava beans (Vicia faba L.) and barley (Hordeum vulgare L.).

The goal of this paper is to explore some of the processes by which this diversity arose. I examine archaeobotanical data from the southern Lake Titicaca Basin to evaluate three models: 1) diversification due to the domestication of a crop in a particular area (a Vavilovian model); 2) diversification of crop species as a strategy of risk reduction and agricultural intensification; and 3) diversification as the result of a political-economic strategy.

The Andean region as a whole was home to several pre-Columbian civilisations (Fig. 3.27, Fig. 3.28).
In the Lake Titicaca Basin, complex societies first developed during the Formative Period, approximately 1500 BCE to CE 300 (Hastorf 2008; Janusek 2004a). This gave rise to one of the first Andean states, Tiwanaku, between CE 300 and 1100 (Fig. 3.27, Fig. 3.29) (Kolata 1993; Ponce Sangines 1977). Its monumental, ceremonial, and urban centre was located approximately 20 km from the southern lakeshore in modern-day Bolivia. Its influence, however, spread to southern Peru and northern Chile. After the fall of the Tiwanaku state, the population split into small, independent groups, often called señoríos or kingdoms (CE 1150-1450). By 1475, the Inca Empire conquered these groups and dominated the region until the arrival of the Spanish in 1532. In this discussion, I focus primarily on the first two periods of Titicaca Basin prehistory, the Formative and Tiwanaku periods, and their roles in producing the diversity of crop varieties found in the region today.

Based on recent genetic and archaeobotanical studies, I argue that the lake basin was likely not the centre of domestication for several of the crops, but that their diversity emerged out of dynamic productive, environmental, and cultural processes throughout its prehistory. First, I examine patterns in quinoa and tuber remains during the Formative period (1500 BCE-CE 300) and discuss how early farmers may have increased crop diversity as a strategy of risk reduction and agricultural intensification. Second, I examine how political factors during the Tiwanaku period (CE 300-1100) may have lead to the development of new maize varieties specifically adapted to the lake basin.

Domestication as an Explanation of Diversity

Following concepts developed by evolutionary biologist and botanist de Candolle (1884), the Russian agronomist N. I. Vavilov (1992) proposed that the place where a crop was domesticated could be located by identifying the area with greatest diversity of crop varieties. Vavilov (1992), following Cook (1925), proposed that the Andean region of South America was one of the world's primary centres of crop domestication. Subsequent researchers documented great diversity in varieties of Chenopodium quinoa grains have been found in two Archaic sites in the western Lake Titicaca Basin, Quelcatani Cave and Jiskairumoko, Peru. Although Phyllisa Eisentraut (1998) identified domesticated quinoa grains in Archaic levels at Quelcatani Cave, direct AMS\(^6\) dating of these seeds showed they derived from the Formative period approximately 900 cal. BCE (2740±50 bp). Radiocarbon dates were calibrated using OxCal 4.1, IntCal 04 (Reimer et al. 2004). Andrea Murray (2005) identified quinoa grains from Jiskairumoko and the site directors (Dr. Nathan Craig and Mark Aldenderfer) are currently waiting for the results of direct AMS dates in order to determine their age. Quinoa seeds occur in sites in the central Peruvian highlands and Chilean coast but have not been directly dated. They derive from contexts ranging from 5000 to 3000 BCE (Aldenderfer 1999; Iriarte 2007; Kuznar 1993; Nordstrom 1990; Pearsall 1992; 2008; Planella et al. 2005). Currently, the earliest direct date for domesticated quinoa in the lake basin is from the Formative period site of Chiripa, Bolivia, and is approximately 1500 cal. BCE (3200±60 bp) (Bruno and Whitehead 2003; Whitehead 1999) (Fig. 3.29).

Unlike some of the other primary centres of domestication (Near East, Mexico, eastern North America, tropical South America), there has been relatively little archaeological and archaeobotanical research focused on the origin and spread of Andean highland crops. Although limited, available archaeobotanical data do provide some insight into the early history of the domesticated pseudocereal quinoa, potatoes, and the Andean tuber oca in the Lake Titicaca Basin. Current data show that fully agricultural societies were established by the Formative period (Browman 1989; Bruno and Whitehead 2003; Eisentraut 1998; Whitehead 2006), thus many researchers suggest that the process of plant domestication must have begun in the Late Archaic period (approximately 4000–1500 BCE) (Aldenderfer 1989; Bruno 2006; Pearsall 1992) (Fig. 3.27).

Chenopodium quinoa grains have been found in two Archaic sites in the western Lake Titicaca Basin, Quelcatani Cave and Jiskairumoko, Peru. Although Phyllisa Eisentraut (1998) identified domesticated quinoa grains in Archaic levels at Quelcatani Cave, direct AMS\(^6\) dating of these seeds showed they derived from the Formative period approximately 900 cal. BCE (2740±50 bp). Radiocarbon dates were calibrated using OxCal 4.1, IntCal 04 (Reimer et al. 2004). Andrea Murray (2005) identified quinoa grains from Jiskairumoko and the site directors (Dr. Nathan Craig and Mark Aldenderfer) are currently waiting for the results of direct AMS dates in order to determine their age. Quinoa seeds occur in sites in the central Peruvian highlands and Chilean coast but have not been directly dated. They derive from contexts ranging from 5000 to 3000 BCE (Aldenderfer 1999; Iriarte 2007; Kuznar 1993; Nordstrom 1990; Pearsall 1992; 2008; Planella et al. 2005). Currently, the earliest direct date for domesticated quinoa in the lake basin is from the Formative period site of Chiripa, Bolivia, and is approximately 1500 cal. BCE (3200±60 bp) (Bruno and Whitehead 2003; Whitehead 1999) (Fig. 3.29).

Tuber remains are generally scarce in the archaeological record because they do not preserve well due to their high water content and thin-celled
walls (Wright et al. 2003). In the Lake Titicaca basin, it is rare to find large diagnostic specimens, but fragments of parenchyma tissue derived from tubers are common (Browman 1989; Erickson 1976; Whitehead 2006; Wright et al. 2003). To date, no tuber or parenchyma remains have been identified in Archaic period sites in the Lake Titicaca Basin; however, Claudia Rumold (2010) has identified Solanum spp. starch grains from Late Archaic (approximately 3200–2300 BCE) ground stone at the site of Jiskairumoko. She also identified Solanum spp. starch grains from Early Formative ground stone (Rumold 2010).

Like quinoa, the earliest tuber macroremains appear in Formative period sites, although none have been directly dated. At Chiripa, archaeologists have found whole charred potatoes, perhaps even chuño (freeze-dried potatoes), oca, and ullucu (Browman 1989; Towle 1961; Towle, pers. comm.). Midori Lee (1997) identified remains of chuño and oca at Ch’isi on the Copacabana Peninsula, Bolivia. Both of these sites pertain to the Middle Formative period (800–250 BCE), and are much later than the earliest identified potato or Andean tuber remains encountered in the central highlands or coast (earliest approximately 2000 BCE) (Pearsall 2008).

Given the fragmentary nature of the archaeological record, molecular genetic studies of crop populations can provide a better manner with which to identify where plants were domesticated (Pickersgill 2007; Zeder et al. 2006). To date, molecular studies have placed the domestication of two of these aforementioned crops outside of the Lake Titicaca Basin: quinoa in the eastern Andean slopes or plains of Argentina, Uruguay, and Paraguay (Wilson 1990) and oca on the eastern slopes of the Andes (Emshwiller 2006). Molecular studies of the potato suggest a single origin in southern Peru, which could include the Titicaca Basin (Spooner 2005).

Future excavations, archaeobotanical analyses, and molecular studies will improve our understanding of early plant use in the Lake Titicaca Basin. Current data, however, suggests that initial domestication may have occurred outside of the basin, requiring us to look beyond a Vavilovian explanation for diversity here (Brush et al. 1995; Harris 1990; Hawkes 1983). These data do show us, however, that farmers have been cultivating these crops in the lake basin for over 2000 years. I now explore how factors such as risk reduction, agricultural intensification, environmental characteristics, and socio-political processes may have contributed to the high crop diversity in the region.

Crop Diversification as a Strategy of Risk Reduction and Agricultural Intensification

Unlike modern, industrial monocrop agriculture, traditional farming systems strategically incorporate a diversity of crops and varieties. Increasing crop diversity not only decreases the risk of crop failure, but may also contribute to greater overall productivity (Hawkes 1983; Netting 1993). For example, many of the crop varieties cultivated in the lake basin today reflect the different risks present in various micro-environments within the region. There are sturdy frost- and drought-resistant varieties of potatoes, ullucu, quinoa, and kañawa that are grown at higher elevations and in the open plains. They also have varieties of oca, isaiiu, and potatoes that thrive in more temperate settings on the lakeshore and in protected valleys. Farmers plant each of these varieties across the landscape each year. This diversity usually guarantees that some of the crops will be successful despite poor conditions (frosts, drought, flood), and, in the best-case scenario, result in a successful harvest (Bruno 2011; Carter and Mamani 1982; Ochoa 1990). Thus, strategies of risk reduction and agricultural intensification provide another possible explanation for the diversity of crop varieties seen in the Lake Titicaca Basin.

I evaluate this scenario using results from my study of Formative period macrobotanical remains from the Taraco Peninsula, Bolivia. I analysed charred plant remains from three sites: Kala Uyuní, Sonaji, and Kumi Kipa (Fig. 3.30). The Taraco Archaeological Project, directed by Drs. Christine Hastorf and Matthew Bandy, excavated these sites between 2003 and 2005. Here, I consider 198 samples in total, 61 samples from the Middle Formative (MF) period and 137 samples from the Late Formative (LF) period.

Quinoa is one of the most common and abundant seeds recovered from macrobotanical samples in the Lake Titicaca Basin (Browman 1989, 147; Eisenbraut 1998, 171, 187; Whitehead 2006, 268; Wright et al.
2003, 387). In my study, quinoa seeds were present in 90% of the MF samples and 97% of the LF samples (see Bruno 2008 for full description of data) (Fig. 3.31). Its prevalence is due in part to the plant’s production of thousands of small, sturdy seeds that preserve very well when charred. It was also likely a very important crop early in farming history because it does not require much effort to cultivate. The soil does not need to be heavily tilled before planting, and the seed can be broadcast sown. To harvest quinoa, the stalk is simply pulled out of the ground by hand.

Assessing the role of tubers is more difficult given poor preservation, but tentative trends are emerging based on patterns in tuber/parenchyma fragments, as well as seeds derived from these species. Tuber and parenchyma tissue fragments are common in the samples I studied, occurring in 92% of the MF samples and 88% of the LF samples (Fig. 3.31). Although there were no diagnostic fragments, there are seeds of potentially two domesticated species, Oxalis spp. and Solanum spp., in the samples. Humans do not consume the seeds of these crops, but the plant is often fed to livestock before the tubers are harvested. Grazing herds also feed on wild populations (Bruno 2008). Thus, these seeds likely entered the archaeological record through the burning of domesticated camelid dung, a practice still common today (Hastorf and Wright 1998; Miller and Smart 1984; Winterhalder et al. 1974). Wild and domesticated species of Oxalis spp. and Solanum spp. have similar seeds; therefore, it is not possible to determine if the archaeological specimens are from crops or natural populations. Despite these difficulties, there is a notable change in their presence through time: the ubiquity of Oxalis spp. seeds increases from 8% in the MF to 17% in the LF and Solanum spp. increases from 17% to 28% (Fig. 3.31). The increase in their ubiquity suggests that both Oxalis and Solanum became more common on the landscape through time. Wild and domesticated...
species of these crops do have a close relationship (Brush et al. 1981; Emshwiller 2002; Johns and Keen 1986). It is common to find wild species growing in cultivated fields and studies show that the great diversity of potatoes, in particular, is due in part, to high introgression between wild and domesticated populations (Brush et al. 1995; Ochoa 1990).

These patterns suggest that during the Late Formative period tuber crops increased in importance on the Taraco Peninsula. The slower adoption of tuber crops may be due to the labour needed to cultivate them. Unlike quinoa, the soil must be excavated to plant and harvest tubers. Interestingly, we do find an increase in the density of stone agricultural tools during the Late Formative period (Miller et al. 2008), supporting the hypothesis that tuber production increased at this time. Increasing the cultivation of tubers would have increased the overall diversity of crop species produced on the Taraco Peninsula. Although these additional species would provide greater protection against crop failure from frost, pests, droughts or flooding, they would also increase overall food production. Based on survey (Bandy 2006) and excavations (Bandy 2007), we know that Late Formative populations were larger and more complex than previous Taraco inhabitants. It is, therefore, possible that crop diversification as a strategy of both risk reduction and agricultural intensification in this region has its roots in the Formative period (Bruno 2008, Chapter 12).

Political Economy and the Diversification of Altiplano Maize

While farmers must meet the needs of their household and village, there are certain circumstances when they must also meet demands of a larger political entity (Brookfield 1972; Sahlins 1972, 101–102). For example, the importance of maize (Zea mays L.) production for the political economy of the Inca Empire has been well-documented for the central Andes (Hastorf 1990; Hastorf and Johannessen 1993). Thus, the demands of an influential leader or a state apparatus may also motivate farmers to develop new varieties or adopt new crops.

This may have been the impetus for the development of maize varieties that can grow in the Lake Titicaca basin. Genetic data verify that maize was domesticated in Mexico and was introduced into the Andes and the Lake Titicaca basin (Matsuoka et al. 2002). Andean farmers adopted this tropical crop and developed dozens of new varieties, several of which are adapted to the more temperate areas of the Lake Titicaca basin (Confite Puñeno, Altiplano, Patillo and Kulli) (Cutler 1946; Ramírez et al. 1960). A growing body of data on maize from archaeological sites in the Titicaca basin permits us to track when it was introduced into the basin and began to be cultivated (Logan et al. 2012).

The earliest evidence of maize in the Titicaca Basin is from microbotanical remains. Amanda Logan (2006) identified maize phytoliths and starch grains from the sites Chiripa, Kala Uyuni, and Kumi Kipa on the Taraco Peninsula. She encountered them in a variety of contexts, including public, special-use buildings (sunken courts), domestic middens, and ground stone. Robert Thompson identified maize phytoliths from sites at Ch’isí on the Copacabana Peninsula, Bolivia (Chávez and Thompson 2006) (Fig. 3.28). None of these remains have been directly dated but derive from contexts dating to the Middle and Late Formative periods. There is little macrobotanical evidence for maize in the Formative period. Midori Lee (1997) identified one maize kernel and one maize glume from the Middle Formative period site of Qhot’a-Pata on the Copacabana Peninsula. I found two fragmented maize kernels at the Late Formative period site Kala Uyuni (Bruno 2008).

The scant evidence of maize throughout the Formative period suggests that it was not cultivated in the basin during this time. There is excellent preservation of charred seeds and even parenchyma tissue in these sites, thus the lack of maize macrobotanical remains should not be attributed to poor preservation. Instead, it may have been traded or brought in from temperate zones to the east and west. While maize may have been consumed as a food, the kernels boiled and eaten, as is common today, it may have been fermented to produce an alcoholic beverage known as chicha (Cutler and Cárdenas 1947; La Barre 1938). Recent studies of carbon isotopes from human remains suggests that maize was only consumed in significant quantities by individuals associated with Late Formative ceremonial architecture at sites such as Tiwanaku, Khonkho Wankane, and Kala Uyuni (Berryman 2010; Miller et al. 2008). Given the available data,
Maize was probably obtained from other regions as a special-use plant, not a food crop, during the Formative period.

Maize took on a much greater role in the Tiwanaku period. Analysis of macrobotanical remains from the site of Tiwanaku show that maize (cupules, grains and cobs) occurs in approximately 20% of all samples (Hastorf et al. 2006; Wright et al. 2003). An increase in maize consumption during the Tiwanaku period is also evident in human stable isotopes. Tiwanaku period individuals from sites in the lake basin have higher C4 signatures than those from the Formative period, particularly among people associated with monumental architectural spaces in the Tiwanaku urban core (Berryman 2010).

The increase in maize during the Tiwanaku period could be the result of it becoming a common food or that the consumption of chicha increased. Evidence for the latter can be found in the Tiwanaku ceramic assemblage, which includes specialised drinking mugs, known as keros, and large jars possibly used in fermenting great quantities of alcohol (Alconini Mujica 1995; Janusek 2003). Scholars believe that an important part of Tiwanaku's political strategy was to host large feasts and celebrations for people who travelled to and lived in the ceremonial centre (Janusek 2002; 2004b). There is also evidence for many of these practices in the Tiwanaku colonies in Moquegua and Cochabamba (Goldstein 2003).

A study of morphological variability in grain and cupules demonstrates that the Tiwanaku had access to a wide range of maize varieties (Hastorf et al. 2006). Morphological comparisons of maize from the Moquegua Valley in Peru and Cochabamba Valley in Bolivia suggests that these were two source regions, but there are other morphological variants whose geographical origins have not been identified (Hastorf et al. 2006). It is possible that some of these unidentified varieties could have been cultivated in the lake basin. Although more research is needed, I suggest that the cultural and political importance of maize for the Tiwanaku state may have instigated the development of varieties that could be grown in the basin. After the state fell, this variety would still have been available to local farmers, and may have been integrated into the household farming system alongside varieties of quinoa and tubers, as it is today.

Conclusions

The Lake Titicaca Basin is a locus of great crop diversity within the Andean region of South America. While some of this diversity could be attributed to it being a centre of crop domestication, the reasons why farmers integrated and developed new crops and varieties lie in the dynamic interactions of production, environment, culture, and politics. While it is possible that potatoes may have been domesticated in the Lake Titicaca Basin, other crops such as quinoa, oca, and maize were not, thus their presence and varietal diversity might be explained using other models, such as those addressing risk reduction, agricultural intensification, and political economy.

Archaeobotanical data from the southern Lake Titicaca Basin, particularly the Taraco Peninsula, Bolivia, suggests that crop diversification began as early as the Formative period with increasing integration of tuber crops, such as potatoes and oca, to systems primarily based on quinoa cultivation. The data also indicate that maize was not part of the Titicaca Basin farming systems until the Tiwanaku period. Given its important role in the politics of the Tiwanaku state, it is possible that farmers were encouraged to develop varieties that could also be grown locally. These are presented as a hypothesis to be tested, for much more research is needed to truly understand the character of crop domestication and diversification in the region. In addition to tracking the introduction of new crops, another important avenue of research for the future is the study of morphological changes within particular crops such as quinoa and kafiawa. With these data, we might be able to document the appearance of new crop varieties. We have begun to do this with maize, but more work is needed. An advantage to conducting such research in this region is that indigenous farmers continue to cultivate many of these crops and are conserving this great diversity in their fields. Collaborations between farmers, agronomists, and archaeologists promise to reveal more information regarding the origins of the diversity in the Lake Titicaca Basin of the Andes and preserving it for the future.
3.10. CONCLUSIONS

Elena Marinova

The current chapter took up a specific focus on looking at crop diversity through time and to seeking out a better understanding of the processes involved in this diachronic perspective. The various contributions illustrate the way different communities have maintained, enlarged or decreased diversity according to the changing natural and social environments they were part of. The studies presented have shown that the link between crop diversity and culture is unmistakable and that their interaction is often an extremely dynamic process. Crop diversity appears, therefore, as one of the multiple results of the dynamic nature of human decisions and natural resources.
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Chapter Notes

1. With four sets of chromosomes.
2. With six sets of chromosomes.
3. The central stalk of the cereal ear.
4. Spherical crystalline aggregations of calcium oxalate.

5. Bundles of needle-shaped calcium oxalate crystals.
6. Accelerator Mass Spectrometry, a high-resolution variant of radiocarbon dating.

Chapter Bibliography


CHAPTER 3: BIBLIOGRAPHY


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