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Chapter Seven: Hierarchical method using ethnographic data sets to guide archaeological research: Testing models of plant intensification and maize use in Central Western Argentina

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ABSTRACT

Ethnographic and environmental data sets developed by Lewis Binford are used to test models about the relationship between forager plant intensification and maize adoption in Central Western Argentina. By examining large suites of cases to identify regular patterns of association, the models describe regular interactions that are apparent in the patterning across known groups. To the extent that people in the past adapted in similar ways to environmental and demographic conditions as people recorded ethnographically, they may be expected to fall within the bounds of general ecological relationships.

1. Introduction

Archaeological interest in prehistoric farming in the Americas has focused primarily on questions surrounding the wild origin, domestication, spread, and cultivation of maize (*Zea mays*). Through such research, we have learned that maize was prehistorically domesticated in south central Mesoamerica (Benz, 2006; Benz and Staller, 2006; Blake, 2006; Pearsall, 2008; Ranere et al., 2009; Staller, 2010) and that from there, maize cultivation spread across many parts of North and South America. While the mechanisms that drove the prehistoric dispersal of maize cultivation are hotly debated, the fact that prehistoric maize spread over thousands of kilometers and into diverse environmental zones in both North and South America is remarkable (Merrill et al., 2009; Staller et al., 2006; Pearsall, 2008). Given the phenomenal spread of prehistoric maize, the absence of maize in many areas is often overlooked. However, equally remarkable is the fact that maize cultivation was not adopted prehistorically in many parts of both South and North America which are adjacent to areas where it was used. Prehistoric evidence of maize cultivation, and farming practice in general, is conspicuously absent from much of modern day Argentina, the Western United States, the South Central United States and Northern Mexico (Bettinger and Wohlgemuth, 2006; Johnson and Hard, 2008; Politis, 2008; Simms, 2008).

Both the initial cultivation of maize and the large-scale adoption of horticultural strategies are processes through which hunter–gatherer subsistence is transformed into horticultural subsistence. To fully explain why hunter–gatherers begin to practice horticulture in some places, we must also be able to explain why they do not adopt this strategy in other places. We do not argue that horticulturalists never migrated, taking horticulture with them; just that much of the process of the adoption of agriculture depends on choices made by hunter–gatherers. Nor do we argue all American horticulture was like maize horticulture. Focusing on maize provides a convenient control on the domesticates while exploring the utility of global scale macroecological models. Since each plant that is domesticated (e.g. maize, beans, squash, potatoes, quinoa) may be limited by a different set of ecological conditions this simplification of reality gives the model it's value. Where our model is too simple, there will be variation left unexplained that will drive future research. Here we explore a hierarchical method (following Johnson, 2013) for using ethnographic data on hunter–gatherer and horticultural subsistence to guide archaeological research on the variation in maize use in Central Western Argentina. This contribution is one small step toward the challenge of explaining and testing explanations of prehistory identified by Kelly (this issue) as the remaining challenge for 21st C archaeologists inspired by Childe and Binford.

Central Western Argentina, (30–40°S, 67–70°W) provides rich opportunities to investigate the prehistoric presence and absence of maize cultivation. The archaeological and ethnohistoric records from this region indicate that maize use over the last 2000 years varied from an integral dietary component to virtually absent all within a 400 km radius (Gil et al., 2010, 2011). Though quinoa,

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squash, and beans are also present, maize is clearly the most abundant and frequent cultivar found in archaeological remains in this region, and its consumption can be measured by stable isotope analysis.

The earliest European descriptions of Central Western Argentina identified two different ethnic groups: the Huarpes, in the northern part of the region and the Puelches in the southern part (Durán, 2000; Michieli, 1983; Prieto, 1997–1998). It is a simplification of the probably more complex ethic panorama (Durán, 2000; Michieli, 1983; Prieto, 1997–1998) but useful for the topic here addressed. The Huarpes were characterized as sedentary farming groups, with a medium population density. The Puelches were characterized as mobile hunter–gatherers with low population density (Michieli, 1983; Prieto, 1997–1998). Given this historical panorama it has been proposed that the South American boundary of farming, primarily (but not exclusively) maize production, is 30–32°S (Gil, 2003; Gil et al., 2006, 2010, 2011; Lagiglia, 2001). This variation in the dietary dependence on maize within a relatively small geographic area provides an ideal place to evaluate the utility of macroecological models designed to explain patterns of subsistence variability at a global scale.

As a first attempt to explain the distribution of prehistoric maize farming in Central Western Argentina, we derive expectations from a model of environmental constraints on hunter–gatherer plant intensification (Johnson and Hard, 2008) and combine these expectations with basic environmental constraints that should partly determine the labor costs of and risk associated with growing maize. The results presented here build upon Binford's (2001) global hunter–gatherer[1] and environmental data sets. We specifically evaluate the proposition that the presence and absence of maize in Central Western Argentina is systematically related to two dimensions of environmental variability [effective temperature (ET) and the availability of aquatic resources (following Johnson and Hard, 2008)] which have been shown to condition different paths of intensification both among contemporary hunter–gatherers (Binford, 2001) and among archaeological sequences (Johnson, 2004, 2008a) and that maize agriculture is also constrained by the season of rainfall. Given the difficulty of measuring prehistoric population density, here we follow Binford's (1983, 2001) logic that the process of intensification is driven by population growth and the subsequent packing of foraging groups on a landscape. To model intensification, we assume that populations grew in the past. This does not mean we expect every place in the world to follow a linear intensification pattern, just that where population densities do grow over time, we expect to see a regular pattern of intensification. Where this is the case, we should be able to predict the different paths that intensification took given three environmental constraints that are associated with modern hunter–gatherer and horticultural subsistence strategies: dependence on fishing, ET, and season of rainfall. While these static models are relatively successful at anticipating the presence and absence of maize cultivation across the archaeological areas examined here, significant opportunities to improve our understanding of subsistence change are highlighted by limitations of the models. Using our hierarchical method the limitations of our general, static models point to and provide a guide for determining the important variables at a regional scale of analysis.

2. Population packing and Intensification

Over the past 20,000 years, at both regional and global scales, the dominant pattern of subsistence change indicated by the archaeological record is that of intensification. With respect to subsistence economies, intensification is generally defined as a process by which more energy is extracted or produced per unit area through a shift in subsistence strategy or technology (Binford, 2001: 221, 357; Boserup, 1965: 43; Brookfield, 1972; Morrison, 1994, 1996; Netting, 1968, 1993: 262). This process describes a pattern of behavior in which groups of people shift their temporal and spatial scale of land use to produce more food from smaller segments of a landscape. Given that intensification appears to be the dominant pattern of subsistence change throughout prehistory and that maize cultivation is one strategy useful for boosting the productivity of a resource patch on a landscape, background knowledge of the important variables that partly determine alternative patterns of intensification is integral for explaining both the prehistoric presence and absence of maize cultivation.

From an ecological perspective, the adoption of domesticated plants by foragers is one outcome of processes that, more generally, drive changes in forager subsistence systems (Binford, 1983; Flannery, 1986). Foragers respond to dynamic changes in their environment. Whether the environmental changes are demographic, social, or physical, the organization of foraging systems fluctuates to control and dampen uncertainties inherent in environmental variation. Binford's (1999, 2001) cross-cultural examination of foraging societies cogently argues that the process of population packing is one demographic factor that dramatically conditions differences in the organization of foraging groups and, under some environmental and demographic scenarios can lead to farming.

Binford (2001:375) has identified a specific value of population density, a hunter–gatherer packing threshold, which marks the population density (about 9 persons/100 sq km) at which there is one minimal group (about 21 people) per foraging area (about 225 sq km) on a landscape meaning that there are no empty foraging areas into which hunter–gatherers can move to exploit fresh resources. At this density, there are pronounced differences in the organization of modern hunter–gatherer subsistence strategies. There are almost no modern hunter–gatherers above this density who are dominantly dependent on hunting terrestrial animals (Binford, 2001:381). At higher values of population density, ethnographically recorded hunter–gatherers are either dominantly dependent on terrestrial plants [primarily where it is warm effective temperature [ET] $\geqslant$ 12.75 °C] or dominantly dependent on aquatic resources [primarily along coasts, rivers and streams (cf. Keeley, 1995)] as shown in Table 7.1.

While the process of intensification must begin before a region becomes packed, once this density is reached, residential mobility options are severely limited (Binford, 2001: 380–387). Thus, many changes in subsistence strategies, related aspects of social organization and settlement, are expected to be density-dependent. As Binford (1999:11) postulates, "Other things being equal, the packing threshold should appear across geographic space at different times depending on the length of time that populations had been increasing in a region and the dynamics responsible for different rates of population growth. One would therefore anticipate culture change to be both chronologically and geographically patterned".

Archaeologically the specific timing of changes in subsistence and social organization are expected to vary based on the relative timing of a region's initial occupation, size of initial populations, rates of population growth, and migration rates. To the extent that these changes are part of a regular intensification process, it should be possible to predict the dates at which they would occur in regions where the date and approximate size of initial occupation are known and rates of population growth could be estimated. It should also be possible to recognize regions that do not follow a regular pattern of intensification.

[1] Binford (2001) organized data on 339 ethnographically documented hunter–gatherers from diverse environmental settings around the world for use as a frame of reference for archaeological research.

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Table 7.1
Crosstabulation showing relationship between population packing, effective temperature zone, drainage setting, and subsistence specialty.

ET zone	Setting	Subsistence specialty		
		Hunting **(63.2%)**	Gathering (2.3%)	Fishing *(34.5%)*
Unpacked hunter–gatherers [density < 9.1 people per 100 sq km]				
ET < 12.75	Coastal	1	0	**18**
	Lake	**12**	0	*2*
	River/stream	**41**	1	*10*
	Internal drainage	1	1	0
ET ⩾ 12.75		Hunting *(21.6%)*	Gathering **(77%)**	Fishing (1.4%)
	Coastal	0	1	0
	Lake	0	1	1
	River/stream	*14*	**22**	0
	Internal drainage	*2*	**33**	0
Packed hunter–gatherers [density ⩾ 9.1 people per 100 sq km]				
		Hunting (2%)	Gathering *(10.2%)*	Fishing **(87.8%)**
ET < 12.75	Coastal	0	0	**27**
	Lake	0	1	1
	River/stream	1	1	**15**
	Internal drainage	0	**3**	0
ET ⩾ 12.75		Hunting (3.9%)	Gathering **(60.5%)**	Fishing *(35.6%)*
	Coastal	0	*11*	**28**
	Lake	0	**3**	0
	River/stream	3	**53**	*18*
	Internal drainage	2	**11**	0

Bold marks the primary subsistence specialty associated with each ET & Setting combination. *Italics* marks the secondary subsistence specialty associated with each ET/setting combination where values seem noteworthy.

The interaction between the demographic variation in timing and scale of initial populations and their growth rates and the environmental variation structuring viable subsistence options sets the stage for the fascinating patterns of variation in the pace and pattern of change over time in the archaeological record. Johnson has demonstrated both that changes in basic hunter–gatherer subsistence strategies are more likely to result from changes in population density than climate change in most regions of the Americas during the late Pleistocene–Holocene (Johnson, 2008b) and that the environmental variables, such as effective temperature and dependence on aquatic resources, argued by Binford to affect the adaptations of hunter–gatherer groups, also correlate with patterns of material culture change among well documented archaeological sequences (Johnson, 2004, 2008a).

3. Empirical basis of the models

Three primary data sets are used in this analysis to develop expectations of prehistoric hunter–gatherer intensification patterns in Central Western Argentina. The first is Binford's (2001): Chapter Four; (Binford and Johnson, 2006) environmental frames of reference. These data are standardized calculations of environmental properties that start from basic inputs of simple geographic and climatic variables (e.g. mean monthly rainfall, temperature, and soil classification). This data set provides a basis for standardized comparisons of environmental properties around the globe. These variables can be calculated for any location for which the input variables are available or can be estimated. Data used here were calculated using the JAVA version of the Environmental Calculations program [ENVCALC2] (Binford and Johnson, 2006). Second, the hunter–gatherer frame of reference, which is based on data recorded from 339 ethnographically-documented hunter–gatherer cases distributed around the globe (Binford, 2001: Chapters 5–8), relates basic attributes of hunter–gatherer societies to environmental variables. This linkage facilitates the projections of modern hunter–gatherer attributes to anywhere in the world where sufficient basic geographic and climatic data are recorded. The third data set includes 44 ethnographically recorded societies which cultivate maize (Johnson, 1997; Freeman, 2007: Table 3.1) which are tied to the environmental frame of reference and have been analyzed in conjunction with a subset of Binford's hunter–gatherer data.

4. Theoretical model projecting subsistence intensification patterns

Differences in the timing and strategies of intensification are expected to pattern with respect to variables that control population density as well as the availability and distribution of food in local habitats. Binford's (2001) analysis of modern hunter–gatherer adaptations indicates that in most settings, terrestrial animal dependence is only possible at low (unpacked) population densities, which are settings where residential mobility is relatively unrestricted. When people live at population densities higher than the hunter–gatherer packing threshold, residential mobility is severely constrained, which is associated with intensified subsistence tactics. For modern hunter–gatherers living at densities higher than hunter–gatherer packing, plants and aquatic resources are the primary subsistence domains exploited. Thus, we can expect that hunter–gatherers who were forced to intensify by population growth in the past would focus their efforts on plants and/or aquatic resources.

Modern hunter–gatherers mostly dependent on plants only live in habitats where effective temperature [ET] is warmer than 12.75 °C, while significant aquatic resource dependence (i.e. dependence of fishing for food >30% of the total diet) is geographically limited to coastlines, rivers and streams (Table 7.1). This pattern suggests that plant based intensification strategies are primarily limited by the length of the growing season. Where modern hunter–gatherers live in habitats that are too cool to support significant plant based intensification, intensification is primarily focused on aquatic resources. Thus, whether prehistoric hunter–gatherer intensification strategies in any particular region focused on aquatic resources or plants should be related to effective temperature and the availability of aquatic resources.

In addition to these environmental factors which constrain the primary focus of intensification strategies, variation in the particular adaptations of hunter–gatherer groups is also conditioned by

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whether or not there is a need to store foods long-term. Modern hunter–gatherers living at ET ⩾ 15.25 exhibit no significant food storage, while those living in regions with ET < 15.25 have at least minimal food storage, as ET decreases (and latitude increases) the quantity of food stored increases (Binford, 2001: 266–267). It is expected that both the specific resources exploited and the organizational strategies involved in exploiting them may be different on either side of this storage threshold.

The most basic projections of the intensification model (following Johnson and Hard, 2008) can be stated as follows. (1) Archaeological evidence for intensification should occur earliest across geographic space where human growth rates in the past are suspected to have been highest. (2) All other things equal, increased investment into aquatic resources should be evidenced where they are available, especially in habitats with effective temperature values less than 12.75 °C. (3) Finally, evidence of increased plant consumption should occur where plants grow well and aquatic resources are constrained.

Of these, it is most difficult to project and evaluate expectations for population density and growth rates. Other parameters are simple to map using the calculated environmental frame of reference. The geographic resolution depends only on the availability of weather station data (particularly for calculating effective temperature).

5. Anticipating the presence and absence of maize

In the Americas maize cultivation is such a widespread component of plant based economies by the late prehistoric period that absence of maize from regions such as southern California, central Texas, and parts of Central Western Argentina has long puzzled archaeologists. Given that maize productivity is closely tied to both the length of the growing season and the availability of soil moisture during the growing season (Benson, 2010a, 2010b), the labor, social costs, and/or risk of cultivating maize should correlate with the climate variables that primarily determine the length of the growing season and the availability of soil moisture.

This idea was first considered in the early work of American anthropology by Kroeber (1939) following the suggestion of Carl Sauer. Kroeber (1939, p. 212) has surmised that the absolute amount of rain that falls during the summer in temperate North America limited the geographic distribution of maize. To test this hypothesis, Kroeber collected data on the ratio of summer to winter rainfall as a proxy for the absolute amount of rain that falls during the summer. He found that maize is generally grown in Western North America where summer rainfall is dominant and was not grown where winter rainfall was dominant (Kroeber, 1939: 210–214). Though the ratio of summer rainfall to winter rainfall may not actually be relevant for measuring the amount of soil moisture that maize requires during the growing season and thus not a direct test of his hypothesis, the correlation between winter dominant rainfall and the absence of maize is potentially useful for understanding the absence of maize in Central Western Argentina.

Empirical patterning among a sample of farming societies (Freeman, 2007; Johnson, 1997) and Binford's (2001) hunter–gatherer data is consistent with the idea that winter rainfall may induce constraints on maize productivity and labor costs to partly determine the presence and absence of maize. In general we expect maize agriculture in temperate environments results from the interaction of population density and patterns of rainfall. Specifically, if hunter–gatherer groups experience population packing, they will not adopt maize in environments where winter rainfall is dominant, but they might or might not adopt maize in environments where summer rainfall is dominant.

6. Model expectations for Central Western Argentina

Using standardized calculated variables from the environmental frame of reference allows us to map a combination of model parameters for modern weather station locations and distinguish areas of interest where we would expect similar or different patterns of intensification and/or maize use. The region of Central Western Argentina lies between 30–40°S and roughly 68–70°W (Figs. 7.1 and 7.2). As shown in Fig. 7.1, this entire region has ET ⩾ 12.75, such that hunter–gatherers *could* have been primarily dependent on plants (light gray and white regions) and almost none of the study area has an expected commitment to fishing of >30% (medium gray), such that hunter–gatherers *would not* have had good access to aquatic resources. Thus, it is expected that plant intensification is the most likely option for hunter–gatherers experiencing demographic packing across this region.

However, all parts of this region are *not* equally likely to support maize cultivation. The line distinguishing summer and winter rainfall patterns cross-cuts the region of interest (Fig. 7.2, dark gray shading). To the east of this line, spring/summer rainfall is expected to support maize agriculture where the growing season is long enough, while to the west of this line fall/winter rainfall would constrain the successful adoption of maize crops, without the added investment of irrigation. Zone C in the South is dominated by winter rainfall, Zone B in the Center has some summer rainfall, while Zone A in the North is dominated by summer rainfall. Thus, only Zone A is very favorable for maize agriculture, with

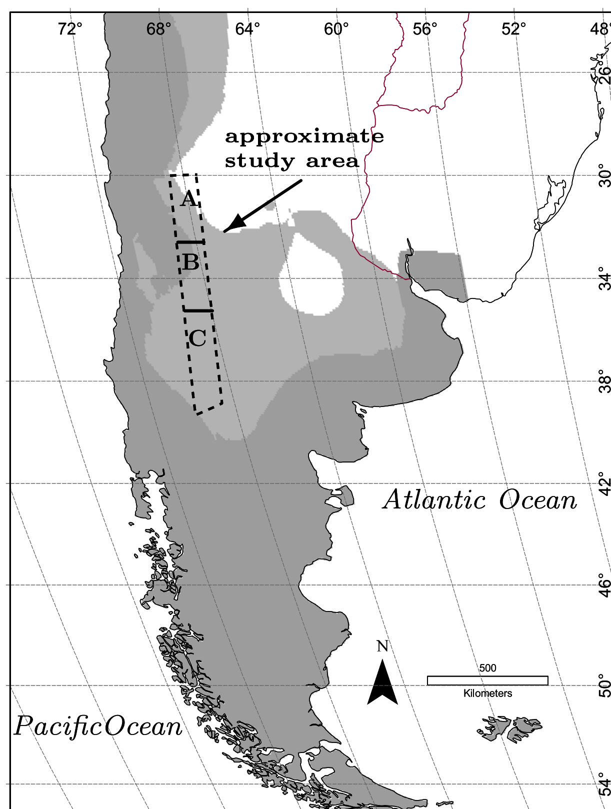

Fig. 7.1. Effective temperature (ET) and projected aquatic resource dependence (WFISHP). Dark gray = ET < 12.75 & WFISHP >30% where hunter–gatherers cannot be mostly dependent on plants, aquatic resources are an option, storage would be necessary; light gray = ET 12.75–15.25 & WFISHP <30% where hunter–gatherers could be mostly dependent on plants, aquatic resources are not a good option, and storage would be necessary; white = ET > 15.25 and WFISHP <30% where hunter–gatherers could be mostly dependent on plants, aquatic resources are not a good option, and storage would not be necessary.

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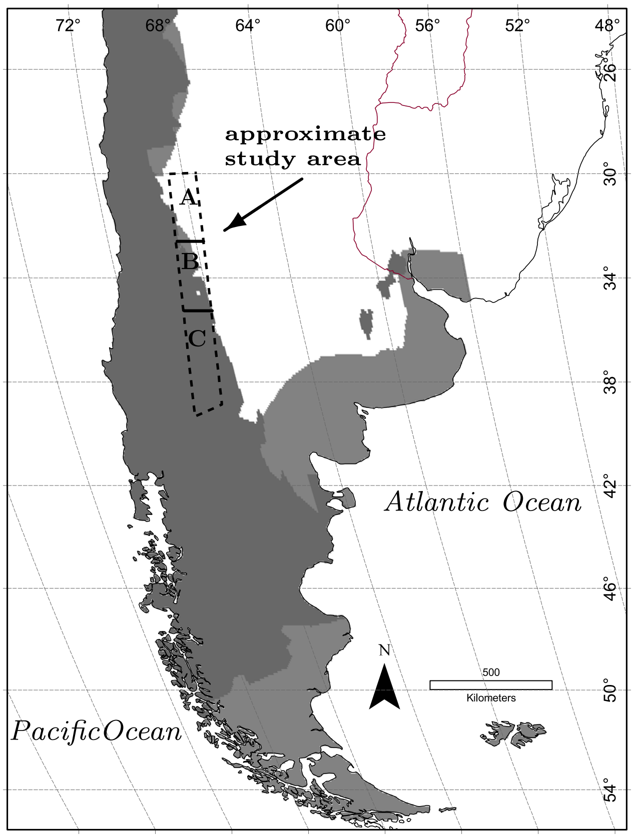

Fig. 7.2. Map of effective temperature, projected aquatic resource dependence (>30%) and fall/winter rainfall zone for Argentina and Chile (projections are most accurate in the west due to distribution of weather station locations used in interpolation). Dark gray = winter rainfall region where maize agriculture is not expected because rain falls in the wrong season, Lighter gray = ET < 12.75 & WFISHP >30% where plant intensification is not expected among hunter–gatherers; white = ET ⩾ 12.75 & WFISHP <30% & summer rainfall where hunter–gatherers are expected to intensify on plants and maize would be a viable option.

some possibility of its development in Zone B (particularly to the east) and little likelihood it is ever a major contribution to the diet in Zone C. Variation in the timing of intensification and degree of dependence upon maize could be related to variation in population densities across the region which we cannot currently model for particular time periods in the past.

7. Testing model projections against the archaeological record in Central Western Argentina

Recent studies of human stable isotopes from 30° to 40°S in Central Western Argentina and dated to the last 6000 years (Gil et al., 2010, 2011) indicates that maize was significant in the human diet during the last 1000–1500 years, primarily in the northern part of the region (Zone A: ⩽33°S). However, even in this region there is significant variation in the δ^{13}C values between samples, including recent remains from the same site. The stable isotope results (Fig. 7.3) reject the gradual dispersal in time and space of maize (and farming strategies) and show a highly heterogeneous pattern in the significance of this domesticate in the center (Zone B: 35–33°S) and probably null or scarce significance south of 35°S (Zone C). Thus, archaeological data indicate strong maize dependence in the northern area (Zone A: 30–33°S), maize presence but not ever strong dependence in the center (Zone B: 33–35°S), and no maize use at all just a little further south (Zone C: 35–40°S).

Consistent with the model of intensification proposed here, there is evidence for plant-based intensification and agriculture in Central Western Argentina. However, there is not sufficient resolution in the Intensification Model alone to predict regional variation in where maize agriculture does or does not become important. Including winter and summer rainfall constraints in the intensification model successfully differentiates the areas of Central Western Argentina where people prehistorically used maize from the areas where maize was apparently not cultivated and consumed. Given the distribution of modern rainfall criterion indicated in Fig. 7.2, we would expect the farming of maize to be possible in Zone A and parts of Zone B from 30° to 35°S, but highly unlikely beyond 35°S where winter rainfall is more dominant. These model expectations are consistent with variability in human isotopes values from the region (Fig. 7.3).

Although the modeling exercise we have demonstrated here successfully accounts for the presence and absence of maize in Central Western Argentina, the Intensification Model itself does not contain enough information to understand why the importance of maize in the diet of prehistoric populations was highly variable where the crop was adopted. Following the existing logic of the model, the difference in prehistoric maize use between

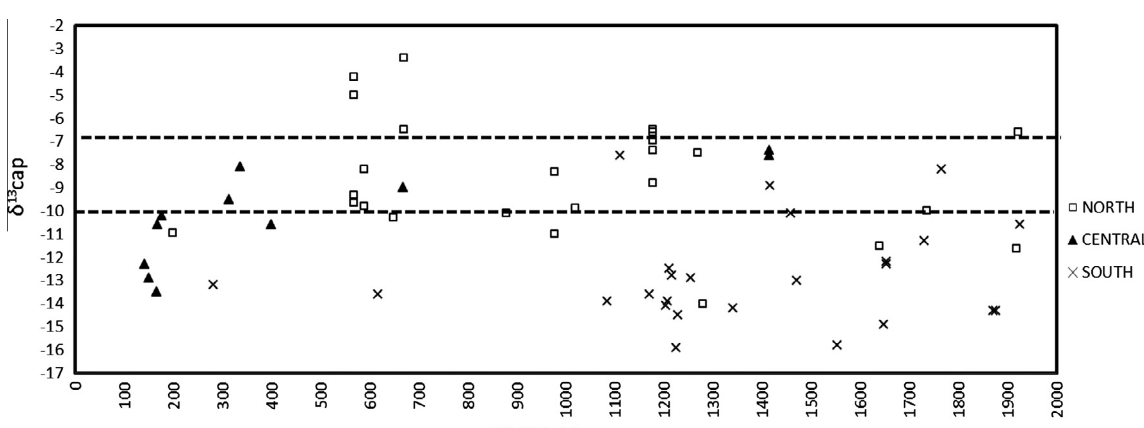

Fig. 7.3. δ^{13}C on bone apatite from human samples dated within the last 2000 years of occupation across this region and its temporal trends in the three areas under comparison. Values above −7 could be interpreted as individuals with high C_4 energy intake (most likely maize). Values between −7 and −10 indicate moderate C_4 energy intake. The patterns indicate high variation in C_4 resource use with more significant dietary contributions of C_4 plants in the North (30–33°S) with highest values around 1000–500 years BP (Gil et al., 2011).

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locations in Central Western Argentina could be related to any of the following three factors:

1. There were lower population densities in the center than in the north, thus less pressure to intensify.
2. There are/were more wild food options in the center compared with the north such that at equal population densities there was variable dependence on cultigens.
3. There were differences in the predictability of spring/summer rainfall. Since the center is closer to the fall/winter line – if the location of this boundary was shifted slightly to the east in the past or if the timing/quantity of spring/summer rain is less certain in this portion of the region maize might be a less-reliable intensification option.

These dimensions of potential variation require further archaeological investigation and the development of region-specific frames of reference. Careful development of strategies for measuring prehistoric population density, resource characteristics, and climatic shifts would not only contribute to knowledge of the archaeological record of this region, but would also serve as models for archaeological work elsewhere in the world. Of course, there are likely to be other important dimensions we have not yet identified. For example, it is likely that in some habitats a difference in "unearned water" for natural or controlled irrigation of fields (e.g. streams, springs, etc.) could impact the percent dependence on any single resource like maize, which is a crop sensitive to both amount and timing of water during the growing season. In their turn, these newly discovered dimensions provide new opportunities for the development of measuring strategies. The more relevant dimensions we can reliably measure, the greater the potential knowledge growth and the closer we come to the goal of testing explanations of patterns in prehistory.

8. Discussion and conclusion

Contrary to many archaeological uses of ethnographic material, the model presented here do not depend upon picking one or a few cases which are thought to be similar in setting and social organization with some past society to use as a direct analogy for patterns of subsistence, mobility, group size, or kinship organization. Rather, by examining large suites of cases to identify regular patterns of association, the models describe regular interactions which are apparent in the patterning across known groups. To the extent that people in the past adapted in similar ways to environmental and demographic conditions as people recorded ethnographically, we may expect them to fall within the bounds of general ecological relationships. Where expectations are met, existing theory contains sufficient intellectual content to anticipate large scale archaeological patterns. However, in those settings where the propositions are *not* supported by archaeological evidence, significant learning opportunities are likely to exist!

Developing explanatory theory that can be tested relies upon rigorous use of existing knowledge, in this case of ethnographically documented variation, to discover regular patterns of association between and among measurable aspects of demographic, subsistence, geographic, environmental and social phenomena. Testing explanations using the archaeological record requires additional development of strategies for measuring the ethnographically-recognized relevant dimensions of variation using archaeologically-recoverable data. The great advantage of working with theoretical models is that they dictate the logic of research.

Given patterns developed from knowledge of hunter–gatherer variation, we needed to measure effective temperature and probable hunter–gatherer dependence on aquatic resources to develop expectations for Argentina. Testing these expectations required using archaeological evidence for the presence of agricultural strategies and a measure of dependence on maize agriculture derived from stable carbon isotope studies. Through the use of this research strategy, we were able to learn that we did not yet know enough to account for the variation across the region of Central Western Argentina that is the focus of this study. This knowledge sent us back to explore patterns among an extended range of ethnographic cases – this time focusing on terrestrial dependent hunter–gatherers and horticultural groups. With new knowledge of limits on the incidence of maize agriculture conditioned by both population density and seasonality of rainfall, we asked new questions about the locations in our comparison. The resulting knowledge growth does help explain why maize agriculture is not evident 35–40°S, but does not yet explain the variation in measured dependence on maize between sites in the neighborhood of 33–35°S and those closer to 30–33°S.

Nevertheless, because we are working with a theoretical model, avenues for further research are clearly indicated. A self-perpetuating strategy which lends itself both to the systematic growth of knowledge about the study region and to the further testing of model expectations has been initiated. While the theoretical model does indicate what dimensions of variation are important to measure, the resulting patterns have the potential to surprise us. We are, therefore, in a strong learning posture to pursue future research.

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