EARLY AGRICULTURAL PERIOD SETTLEMENT STRATEGIES IN THE SOUTHERN SOUTHWEST

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ABSTRACT

In this chapter, Gregory, Nials, and Hill apply Geographic Information System technologies to geomorphological, topographic, and archaeological data to examine the settlement strategies of the Southwest’s first farmers between 2100 B.C. and A.D. 200. By applying the concept of naturally defined stream reaches, they identify reach boundaries as places with floodplain and hydrological characteristics that would have been particularly desirable for farmers. Their examination of settlement data from Early Agricultural sites in the Tucson Basin and southeast Arizona, and of data from more visible late prehistoric sites, shows preferential settlement of reach boundaries by farming communities throughout prehistory. Settlement data also suggests that Early Agricultural people had a secondary focus on upper piedmont slopes, perhaps in areas with productive springs and diverse wild plant resources. Furthermore, the stream reach method for examination of land use strategies is one that can be applied in arid lands settings globally.

The settlement strategies of the Early Agricultural period, that interval between the arrival of maize and the appearance of a fully developed ceramic container technology in the Southwest (circa 2100 B.C. and A.D. 200), are reviewed here. The task is daunting for a variety of reasons, not the least of which is the tremendous increase in data and new revelations about Early Agricultural period lifeways that have occurred over the last two decades.

The current, earliest dates for the arrival of maize have been continually pushed back in time to approximately 2100 B.C. (Figure 1; the data on which this figure are based are likely already incomplete), making the Early Agricultural period considerably longer than the subsequent and more completely understood Early Ceramic period (A.D. 50-500). Rudimentary irrigation was practiced by about 1500 B.C., and large floodplain settlements consisting of hundreds of pit structures and/or other features are characteristic of that interval in some areas. Finally, a remarkable uniformity in subsistence strategies over much of the interval is indicated by consistently high ubiquities in macrobotanical assemblages of not only maize but several wild plant species, as well as abundant and varied faunal assemblages in many cases.

Several interpretive frameworks have been proposed regarding the still expanding body of Early Agricultural period data. New theoretical developments have been focused on the complex set of problems relating to the spread of plant and animal domestication (and languages) on a global scale, and the domestication and spread of maize (and languages) in the New World, and the Southwest specifically (Bellwood 2005; Bellwood and Renfrew 2002; Benz 1999, 2006; Doolittle and Mabry 2006; Hard et al. 2006; Harris 1996; Hill 2001, 2002; Huckell 1995; Mabry 2005a; Minnis 1992; Renfrew 1998; Staller et al. 2006; Wills 1988, 1995). Models based on necessity, risk management, and opportunity or optimization, as well as interpretations emphasizing the role of migration, warfare, the biogeography of transmission, and environmental variation have all been offered (Carpenter et al. 2002; Diehl 2005a, 2005b, 2005c; Doolittle and Mabry 2006; Gregory and Nials 2005; Huckell et al. 2002; Hunter-Anderson 1986; LeBlanc 2002; Mabry 2002, 2005b; Matson 2002). Empirically and theoretically, there is better information than ever before about this critical and lengthy interval in Southwest prehistory.

Nonetheless, all interpretive frameworks suffer to varying degrees from several basic problems. The first of these is the paradoxically happy circumstance noted above: the rate of data accumulation has required constant reevaluation of interpretations to accommodate a rapidly expanding database. This is particularly true with respect to earlier and more widely distributed dates on maize, which demand
The Latest Research on the Earliest Farmers

reassessment of the temporal dimension of particular interpretations. Second, the current spatial distribution of relevant data represents a non-systematic sample of sites produced largely by cultural resource management research and geographically spotty excavations in rockshelters and caves. Unfortunately, many of the latter were excavated before the advent of AMS dating (or even before conventional radiocarbon dating), and before flotation sampling became standard practice. Finally, many interpretive frameworks have been developed primarily based on investigations at a single site or a closely spaced set of sites, and original research specifically designed to address these issues at a macro-scale has been largely lacking.

THE ENVIRONMENT AS A CONTEXT FOR SETTLEMENT STRATEGIES

A variety of factors may influence the set of decisions that culminate in settlement strategies. Perhaps the most important of these for arid lands farmers is the availability and reliability of water in combination with arable land. However, such factors may also include the distribution and density of natural plant and animal resources, technology, population size, and social relations, including warfare. This list could certainly be expanded, but the concentration here is on water and arable land.

Dean (1988) defines stable elements of the environment as: “climate type, topography, bedrock geology, elevational zonation of plant communities, and the distribution of mineral resources and raw materials” and suggests that “their present states are valid indicators of past conditions, and they need not be reconstructed” (Dean 1988:121). While reconstruction is not necessary, the spatial parameters of these environmental features must at least be identified and measured for purposes of settlement analysis.

The general frame of reference here for quantification is a division of the landscape into floodplains, piedmont slopes, and bedrock uplands (Gregory and Nials 2005). These divisions apply directly to all of the southern Basin and Range, and, with appropriate modification, to the Transition Zone and the Colorado Plateau as well. The focus here is on floodplains, particularly on stream reaches and reach boundaries. These aspects of the floodplain environment have been specifically identified and measured for large areas of the southern Southwest (Nials et al. 2007, 2011). The three major environmental divisions for the Tucson Basin, as well as the distribution of reach boundaries and springs, are illustrated in Figure 2.

Figure 2. Environmental divisions in the Tucson Basin.

The Stream Reach Concept

All arid lands streams are punctuated by locations where specific geological structures, hydrologic characteristics, and geomorphic processes combine to alter the nature of sediment load, characteristic surface flow, and/or groundwater availability. The influence of these variables has long been recognized and is well understood (Hendrickson and Minckley 1984; Hinderlider 1913; Lee 1905; Leopold et al. 1964; Meinzer 1942). Such locations are of two principal types: (1) those created by the presence of bedrock or relatively impermeable sediments in, beneath, or adjacent to the stream channel; and, (2) those created by tributary confluences. These locations are referred to as reach boundaries, and stream segments between such boundaries are defined as stream reaches, with the downstream boundary included as part of each stream reach for purposes of analysis (Gregory and Nials 2005; Nials et al. 2007).
Even casual perusal of topographic maps or aerial photographs reveals obvious indicators of reach boundaries such as (1) where a floodplain locally narrows or widens; (2) marked changes that occur in channel pattern and/or sinuosity; (3) erosion or deposition locally prevails; (4) local areas of high water tables are indicated by vegetation or springs; or, (5) streams become emergent or submersed. Thus, reach boundary locations and associated reaches may be readily identified using a variety of geologic and geomorphic criteria recognizable by remote means, primarily through examination of topographic and geologic maps, aerial photography, and satellite imagery. After reach boundaries are identified for any given stream, variables, including reach length, floodplain area, floodplain area per unit length, and floodplain gradient may be obtained via measurements from topographic maps. Additional quantification of reach properties is gained through the use of GIS analyses of digital elevation data and remote sensing imagery, including drainage area, number of tributaries, total flow of tributaries, average slope of drainage area, and so on. More than 2,500 linear kilometers of floodplains have been mapped and analyzed to date; some 300 previously identified and measured reaches within a large study area are shown in Figure 3. Measurement of remaining study area reaches is ongoing.

**Effects of Reach Boundaries**

Reach boundaries resulting from outcrops of bedrock or impermeable sediments create a barrier to groundwater flow, causing the water table to rise upstream from the barrier, and influence channel erosion (Figure 4) (Hinderlider 1913; Lee 1905; Leopold et al. 1964; Meinzer 1942). If the rise is sufficient, cienegas and springs form (Hendrickson and Minckley 1984), and the aquifer discharges into the surface channel, resulting in either a new segment

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**Figure 3.** Identified and measured stream reaches and reach boundaries in the study area.
of emergent stream or increased perennial flow. The consequent flow may be continuously emergent along the entire length of a reach, or it may eventually sink into valley-bottom sediments and the aquifer below. High water tables result in increased vegetation that enhances sediment deposition and leads to a wider, lower-gradient floodplain that allows flood waters to spread over a larger area and reduce floodwater depth and velocity. A short, oversteepened segment typically occurs immediately below the boundary, characterized by straighter, deeper, and more constricted channels. Excess sediments may be deposited downstream from the steeper segment, and the channel may shift positions more frequently (Graf 1982, 1983b, 1983c, 1988), causing the active floodplain to be wider below the boundary.

Tributaries have steeper gradients than mainstem streams and transport proportionally larger amounts of coarser sediment, much of which is ultimately deposited on the mainstem floodplain at and near their confluence. These deposits locally elevate and narrow the floodplain surface on the master stream, resulting in a flatter gradient above and an oversteepened segment immediately below the confluence. Groundwater contributions from large tributaries may also cause the water table in the mainstem alluvial aquifer to rise. The combination of additional groundwater and increased deposition of sediment on the mainstem floodplain at tributary confluences thus duplicates the effects of bedrock boundaries elsewhere. During the summer months in the Southwest, tributary floods are not necessarily coincident with mainstem floods, often leading to a prolonged runoff period below the confluence.

The effects exerted on groundwater and surface streams by reach boundaries depend, in part, on variables specific to a particular location and to a drainage basin. These include the type of boundary, nature and amount of runoff in the mainstem and tributaries, nature of valley bottom sediments, depth to water table, aquifer geometry, and rainfall distribution, among others. The particular combination of these variables at any given boundary may produce dramatically different conditions of surface runoff availability and water table depth.

**Temporal Variation in Boundary Effects**

Regional environmental variation is primarily related to climate, and floodplain conditions within a region at any given time are best understood in terms of repeated, climate-driven cycles of alluvial erosion and deposition. Although controversy over
Advantages of the Reach Concept

In addition to ease of identification and measurement, the stream reach concept offers several other advantages. The concept is universally applicable in all arid lands environments. Stream reaches and reach boundaries represent basic structural elements in the landscape, and may be considered as stable or constant aspects of the environment for at least the late Holocene (see Dean 1988), and thus, not only for the period of concern but for earlier and later intervals as well. For a given discharge regime and local variables, the nature of change associated with particular types of boundaries is predictable in terms of consequences for geomorphic processes and stream character. This fact allows modeling of reach characteristics for different climate patterns, and it provides a basis for assessing agricultural potential and the suitability of irrigation and other agricultural technologies under variable conditions.

Reach boundaries also have predictable effects on floodplain environments vis-à-vis aboriginal agriculture. Areas immediately upstream and downstream from boundaries typically represent the most risk-free settings for farming: emergent stream segments in such locations may be the only places along a drainage where surface water is present in times of drought or low flow, where runoff is concentrated, and/or where the water table is closest to the surface (see Doolittle and Mabry 2006; Evenari et al. 1971; Mabry 2002; Nabhan 1979; Nials et al. 2011). These conditions, in conjunction with engineering advantages created by oversteepened downstream segments, make reach boundaries some of the best places to construct intake structures for canal irrigation systems (Gregory and Nials 1985; Nials et al. 2007, 2011). Closely spaced reach boundaries create particularly attractive valley bottom conditions, because these features favor continuous perennial streamflow, foster subirrigation of relatively large areas, and allow irrigation of the maximum amount of floodplain via short, relatively efficient canals.

The significance of reach boundaries, in particular, the importance of emergent stream segments to irrigation agriculture, was identified long ago in the Greater Southwest (Hinderlider 1913; Lee 1905; Southworth 1919). Subsequent investigators have noted these connections and have described their relationships to prehistoric agriculture in specific locations (Gregory and Huckleberry 1994; Gregory and Nials 1985, 2005; Nials 2008; Nials and Gregory 1989; Waters 1988). With respect to current concerns, it is clear that reach boundaries and their characteristic effects were recognized and were consistently exploited by Early Agricultural period populations.

A Case Study

A recent study demonstrates the general utility of the reach concept beyond the anecdotal settings that inspired it (Nials et al. 2007, 2011). Analyses drawn from that study illustrate the broader significance of the concept. Local density analysis (LDA) (Johnson 1984; see Kintigh 1992) was used to evaluate the spatial correlation among reach boundaries...
The goal of LDA is to evaluate the degree of spatial association among points. The local density coefficient (LDC) is the mean density of points of a given type found within a specified radius of a second point type, divided by the global density of the first type of points. The density of points is calculated as the number of points divided by: (1) the area of the circle defined by a specified radius; and, (2) the area being analyzed. The LDC provides a measure of the association of point types at a designated scale fixed by the radius used, with values around 1.0 or less indicating random distribution and values greater than 1.0 indicating relative spatial association.

This statistic provides an easily interpreted indication of the degree to which prehistoric land use was actually focused in the vicinity of reach boundaries, as opposed to any other location on the landscape. Further, it does so at a behaviorally meaningful scale indicated by the specified radius. A key to understanding the significance of reach boundaries is in relation to other locations where agriculture might be practiced. Thus, the LDC was compared for sites and reach boundaries with LDCs for sites and two randomly distributed sets of the same number of points. One set was drawn from the universe of all points with a larger than 50 ha watershed, and one was from the universe of all points having a larger than 50 km² watershed. Analyses were conducted at radii of 1, 5, and 10 km to assess spatial association within distances that would be meaningful to farmers tending fields at varying distances from a given settlement, allowing for a comparison of the degree of association at increasing distance from a critical resource.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Comparison of valley bottom processes and characteristics during erosional and stabilization phases of alluvial cycles.</th>
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</thead>
<tbody>
<tr>
<td><strong>Erosional Phase</strong></td>
<td><strong>Stability Phase</strong></td>
</tr>
<tr>
<td><strong>Flood characteristics</strong></td>
<td>Frequent, large peak discharges, increased flood depths (stage), reduced flood durations as arroyo networks integrate, progressively smaller amounts of floodplain inundation; high erosive power discharges; minimum effectiveness of precipitation.</td>
</tr>
<tr>
<td><strong>Stream channel</strong></td>
<td>Initial stages: discontinuous channel (may have braided segments), vertical erosion dominates, continuous arroyo formed. Later stages: lateral erosion dominates, expanding arroyo gradually consumes former floodplain.</td>
</tr>
<tr>
<td><strong>Infiltration</strong></td>
<td>Minimal.</td>
</tr>
<tr>
<td><strong>Sediment load</strong></td>
<td>Progressively larger and coarser sediment load until near end of phase.</td>
</tr>
<tr>
<td><strong>Floodplain processes</strong></td>
<td>Degradation, floodplain desiccates, secondary arroyos may form, piping may be locally important in some drainages.</td>
</tr>
<tr>
<td><strong>Water table</strong></td>
<td>Progressively lowers as channel is incised; most existing cienegas destroyed.</td>
</tr>
<tr>
<td><strong>Surface flow (baseflow)</strong></td>
<td>May initially increase as groundwater drains, but eventually becomes minimal; baseflow reduced, some perennial streams become discontinuous.</td>
</tr>
<tr>
<td><strong>Vegetation</strong></td>
<td>Significantly decreased in quantity, more xeric in nature.</td>
</tr>
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</table>
Site data consist of two sets of points, those dating to the Early Agricultural period and those dating to late prehistoric times. Early Agricultural ($n = 89$) sites in the study area are from a database of all known Paleoindian and Archaic sites in Arizona (Mabry 1998; Mabry and Stevens 2000). This sample does not include contiguous areas in New Mexico, Sonora, or Chihuahua. The late prehistoric data ($n = 275$) sites in the study area are from the Coalescent Communities database (Wilcox et al. 2003), and include all known sites dating from A.D. 1200-1700, having more than 12 rooms. Within the Early Agricultural period data set, there is a bias toward the well-investigated Tucson Basin. For this reason, spatial analyses outside the Tucson Basin will not fully reveal the true relationship among Early Agricultural sites and reach boundaries. The late prehistoric data set probably represents a more complete record of settlement distribution for this time period in the Tucson Basin and beyond. Five analyses were performed using various subsets of the site data: Tucson Basin Early Agricultural sites ($n = 34$), southeastern Arizona Early Agricultural sites ($n = 89$), Tucson Basin late prehistoric sites ($n = 32$), southeastern Arizona late prehistoric sites ($n = 200$), and all study area late prehistoric sites ($n = 275$).

The overwhelming indication from these analyses is that reach boundaries have a higher density of archaeological sites within close proximity than do either set of random drainage locations. In contrast to the mean coefficient for reach boundaries of 3.84, the mean coefficients for 50-ha and 50-km² watersheds are 1.33 and 1.94, respectively. Thus, sites generally appear to be focused around locations with substantial watersheds, but they show the strongest spatial association with reach boundaries. These differences are shown clearly in Figure 6, which illustrates coefficients for the five site groups obtained at the 1-km radius.

The density of archaeological sites within 1 km of reach boundaries is greater at every level of analysis than their density around other watershed locations. Notably, the weakest differences are found with the Early Agricultural data outside the Tucson Basin. It remains to be demonstrated if this is due to differences in Early Agricultural land use in neighboring valleys or to incomplete knowledge of buried deposits or other sampling biases. The fact that better-known late prehistoric sites maintain their strong associations with reach boundaries at all levels of analysis suggests the potential for similarly strong associations with undocumented Early Agricultural sites and those of other intervals as well. The statistical trends demonstrated by these analyses strongly support the validity of the stream reach concept as a powerful structuring influence on ancient
land use in the southern Southwest, and as persistent places in the occupation and use of the environment. Further profitable research along these lines is suggested.

**Strategies for the Use of Piedmont Slopes and Bedrock Uplands**

Largely because measurement of these areas and subsequent analyses of site locations and types using GIS techniques have not yet been accomplished, less quantitative information about land-use strategies in piedmont slopes and bedrock upland regions is currently available (but see Fish et al. 1992; Roth 1992, 1996). Regardless, several potentially important observations for future consideration are in order.

Next to the floodplains themselves, the most abundant and reliable water sources are springs that occur consistently at, or near, the piedmont slope-bedrock outcrop interface. Thus, the upper portions of the piedmont slope generally have a greater abundance and variety of wild plant resources, such as dense stands of saguaro cacti on south-facing slopes, than the lower portions. The upper portions of the piedmont slope are virtually everywhere farther from floodplain settlements than could be reached and returned in a single day, requiring at least one overnight stay.

Except a few sites at the toe of the piedmont, immediately adjacent to the floodplain, there is little evidence on the piedmont slope for sites of the size and complexity found in the floodplain. Most of the sites are relatively small scatters with little apparent depth, and visual inspection of available site distri-

**CONCLUSIONS**

One far-reaching result of the last two decades of work has been recognition that Early Agricultural period populations made intensive and extensive use of floodplains for settlement, as well as for farming and other subsistence activities. Extant survey data indicate no other portion of the environment was exploited to this degree or in these particular ways. Unfortunately, empirical data and the inherently dynamic characteristics of arid lands floodplain environments indicate that sites of this interval may have been wholly or partially destroyed by erosional processes, and/or may be deeply buried and difficult to discover and sample. However, there is little question that the primary strategy of Early Agricultural period settlement and other activities focused on the floodplains of major streams and their tributaries, especially at or near reach boundaries.

One other aspect of floodplain use deserves mention. Although a wide variety of site size and composition is represented in investigated sites, the largest sites appear to be of two types. In the first case, the ratio of pit structures to extramural pits and other features is quite high (see Gregory, ed. 2001; Gregory et al. 2007; Mabry et al. 1997); in the other, the reverse is true, with many more pits and other extramural features than pit structures (see Ezzo and Deaver 1998; Freeman 1998). While the latter kinds of sites are earlier in some cases, dates overlap in others. This difference in storage capacity and its implications for land-use strategies deserves attention in future research.

Although additional research is necessary, another strategy appears to have been the use of...
logistical settlements to exploit resources of the upper piedmont slope and perhaps of bedrock uplands. For the moment, a basic duality in settlement strategies may be hypothesized, with a primary focus on floodplains and a secondary focus on upper piedmont slopes. As GIS techniques and other analyses are applied to additional floodplain areas, as well as to piedmont slope and bedrock uplands, it may be anticipated that a much clearer picture of Early Agricultural period settlement strategies will emerge.
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