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Tree-Ring Dates and Demographic Change in the Southern Colorado Plateau and Rio Grande Regions

Michael S. Berry and Larry V. Benson

In this chapter, tree-ring dates from the southern Colorado Plateau, Mogollon Highlands, and Rio Grande areas (fig. 3.1) (hereafter referred to as the study area) are used to estimate regional-scale timber-harvesting and construction activities between AD 600 and 1600 (the Basketmaker III through Pueblo IV periods). Within that time span, we focus our attention particularly on the AD 1045–1300 period, a time when anomalously wet periods alternated with megadroughts (fig. 3.2). Tree-ring-date distributions (histograms) for eight archaeological subregions within the study area have been created using a database of more than twenty-four thousand tree-ring dates from archaeological sites. These dates, in turn, are compared with the paleoclimatic record for the study area as a whole (fig. 3.2).

The Sample: Bias and Interpretation

More than twenty-five years ago, Berry (1982) used the then-available tree-ring data from the Quadrangle Series of the Laboratory of Tree-Ring Research to generate a histogram of contemporaneously occupied sites for each ten-year increment during the period from AD 600 to 1450. Berry argued that fluctuating southwestern tree-ring date distributions indicated changes in relative population size and consequent population movement. He inferred that these phenomena resulted from periodic droughts. He further argued that the stages of the Pecos classification system could be interpreted as temporally discrete episodes separated from one another by drought events. The modeling of paleoclimates for the Southwest has evolved significantly since then, but our current understanding lends support to Berry’s model of demographic shifts, especially during the mid-twelfth century and the thirteenth-century megadroughts.
Figure 3.1. The location of tree-ring dated sites in the southern Colorado Plateau and Rio Grande areas.

KAY Kayenta region
NSJ northeastern San Juan Basin
CSJ central San Juan Basin
SIN Sinagua region
HOP Hopi region
CAL Cibola-Acoma-Laguna region
RIO Rio Grande region
SAL Salt River region (Mogollon Highlands)

Large filled circles indicate location of PDSI nodes; open squares indicate locations of tree-ring sites; medium-sized filled circles indicate site clusters; small filled squares indicate single sites.

The rectangle encloses the Cortez rectangle, which ranges from 109° to 108° W and from 37° to 38° N.
Figure 3.2. (A) The mean of six normalized precipitation data sets from the Four Corners area. (B) The mean of nine PDSI data sets from the southern Colorado Plateau. (C) “Death” (grey rectangles) and “v” (black rectangles) date distributions for the southern Colorado Plateau. The tree-ring-based climate data sets were smoothed with an eleven-year running average. W1 and W2 refer to two wet periods (grey-shaded areas), and D1 and D2 refer to the mid-twelfth- and late-thirteenth-century megadroughts (black-shaded areas).

Criticisms of Berry’s model revolved around the issue of potential sampling bias. It was argued that such variables as differential preservation, archaeological interest, systematic neglect, a penchant for burning structures at various times, a penchant for not burning structures at other times, etc., had the combined potential of rendering meaningless the patterning of the tree-ring sample. As a consequence, the model, as well as the attendant notion of climatically induced demographic shifts, was largely ignored. Indeed, despite the focus of the current volume, none of our fellow contributors cited Berry’s 1982 work. We therefore anticipate that many archaeologists working in the Southwest today may similarly dismiss the representativity of the data we present herein. However, confronted with the very large sample of chronometric data currently available that suggests a punctuated set of temporally discrete
occupations, we have opted to consider the likelihood that these data are, in fact, representative of prehistoric reality and worthy of further inquiry, even as we acknowledge the occurrence of certain potential sources of bias.

A much more robust sample of more than twenty-four thousand tree-ring dates is now available from structures in the study area that fall between AD 500 and 1600, yet the fundamental temporal distribution presented by Berry (1982:105) has not significantly changed. Of the total number of dates, 8,515 are “death” or cutting dates and another 3,068 are “v” dates, which are accurate to within a few years of the timber-harvest date. During the time period of interest for the current analysis (AD 1045–1300), the tree-ring database contains 6,984 “death” and “v” dates collected from 413 archaeological sites. In the following sections, we rely solely on “death” and “v” dates (referred to collectively as tree-ring dates) for interpretation. We have eliminated from consideration “vv” dates, the temporal placements of which are earlier than the cutting event of interest by an unknown amount of time. We acknowledge that, in rare cases, a clustering of “vv” dates can inferentially indicate a probable construction event. Such cases are in the minority, and a site-by-site analysis is not the focus of the current chapter, since this is, after all, a regional analysis. As a result, we may overlook a few individual sites of possible interest. We have also excluded dates with a “++” modifier because they likely indicate the use of dead timbers. We point out, however, that histograms generated with “vv” or “++” dates are not markedly different from the temporal patterns we have constructed using only “death” and “v” dates. When the “too old” dates were included, high points remained high, and low points, as might be expected, were partially filled in (fig. 3.3D).

In the discussions that follow, we make no assertion of a direct correlation between tree-ring date fluctuations and population size. We do, however, interpret these fluctuations as a relative measure of construction activity. Diminished construction activity, as measured by the lack of cutting dates, most likely indicates declining populations, whereas increasing populations were likely accompanied by accelerated construction activities, with a concomitant increase in tree-ring dates. Of particular interest are those cases wherein diminished construction activity in one area is coupled with accelerated construction in an adjacent area,
Figure 3.3. Cutting-date histograms for study area demonstrating the effect of bin size and tree-ring date accuracy on tree-ring date distributions. A–C were created using “death” and “v” dates; D was created using “death,” “v,” and “vv” dates.
leading to the inference that this pattern probably reflects population movement (e.g., Ortman, this vol.). However, we make no attempt to quantify the populations involved. That would require a much more in-depth analysis incorporating room counts, room size, site-specific room contemporaneity, and a host of other variables. (Such population estimates have been undertaken, for example, for a subregion of the Southwest by the Village Ecodynamics Project [Ortman, Varien, and Gripp 2007; Varien, this vol.].) No quantitative population analyses have yet been conducted for the entire study area considered in the current chapter, and such an effort is clearly beyond the scope of this chapter.

Analytic Methods

To facilitate analysis, the senior author developed a computer application, TRGraph, that features data input, data querying, mapping, and histogram functions. The underlying database is Microsoft Access, but other formats can be imported. The user interface is written in Borland C++ Builder, Version 6.0. The mapping function allows the user to place a polygon around a geographic area of interest and generate a histogram of tree-ring dates from archaeological sites within that particular polygon. The Structured Query Language (SQL) interface allows the user to query the database on a wide variety of criteria and display the results in both map-distributional and histogram formats. The queried data can then be exported to a spreadsheet such as Microsoft Excel for further analyses.

Histogram Bin Size and the Inclusion of “vv” and “++” Dates

Figure 3.1 indicates the overall study area, with eight archeological subdivisions enclosed in polygons. Figure 3.3 illustrates the effects of both bin size and the inclusion of “vv” and “++” dates on the depiction of tree-ring dates from the study area. If the bin size is decreased to ten-year increments (compare figs. 3.3A–C), the fine structure in the distribution of tree-ring dates becomes visible. Inclusion of “vv” and “++” dates (fig. 3D) tends to blur the fine structure, with the “vv” dates filling in minima in the tree-ring date distributions (compare fig. 3.3C with 3.3D). The lesson here is that using too large a bin size (e.g., of twenty-five or fifty years) will tend to smooth substantial variability, masking significant
tree-ring minima of decadal duration. Given the effect of “vv” and “++” dates on the histograms, all plots that follow omit “vv” and “++” dates and display only tree-ring dates that fall within ten-year intervals.

Using intervals larger than ten years for plotting the number of tree-ring dates is quite similar to the problem of temporal interpretations that rely primarily on ceramic “dating,” which has an inferential accuracy of between twenty-five and two hundred years (Blinman 2000; Breternitz 1966). Consequently, ceramic dating will similarly mask decadal-scale occupational variations. Ceramic dating is based on the proposition that a given relative frequency of ceramic types at a tree-ring-dated site, if found in similar proportions at an undated site, implies contemporaneity. Such an inference, of course, represents a hypothesis to be tested, not an empirical fact. The pitfalls of reliance on ceramic dating when dealing with decadal change need no further elaboration.

**Tree-Ring-Based Reconstructions of Climate Change**

One of the questions we seek to answer is whether the distribution of tree-ring dates from archaeological sites bears a significant relationship to records of climate change in the study area. Tree-ring-based reconstructions of the Palmer Drought Severity Index (PDSI) (fig. 3.2B) averaged over nine nodes within the study area (fig. 3.1) are based on an expanded tree-ring data set (Edward Cook, Lamont-Doherty Earth Observatory, personal communication, 2007) that improves the accuracy of the grid-ded network of PDSI reconstructions originally created by Cook and colleagues (2004). The 2004 tree-ring network used for PDSI reconstruction over North America was originally composed of 835 annually resolved records. Cook’s 2007 revised network containing 1,825 records is now available and has been used in this chapter. PDSI data were calibrated using a point-by-point regression of prewhitened instrumental PDSI data against tree-ring records for the period 1928–1978 (see Cook et al. 2007 for a discussion of the calibration procedure).

Tree-ring-based reconstructions of precipitation (fig. 3.2A) used here are derived from data sets published by Grissino-Mayer (1996) and Dean and Funkhouser (2004), as well as recently published data sets from the University of Arizona Tree-Ring Laboratory (Benson, Peterson, and Stein 2007) (see fig. 3.1 for locations of the tree-ring sites). Each of
the climate-proxy records was normalized (Z-scored) before stacking (averaging of data sets), and the normalized records of the precipitation and PDSI data sets were plotted using an eleven-year running average, which is comparable to the ten-year increments used in the tree-ring-date histogram for the study area (fig. 3.3C).

In order to apply regional and overall tree-ring-date distributions to the estimation of timber harvesting, construction, and population changes over time, we made the following assumptions:

• Although regional sample sets of archaeological tree-ring dates used in this chapter clearly do not represent random selection, there is no reason to suspect intentional systemic bias. Moreover, the very large sample size lends confidence to the representativeness of the tree-ring-date distributions.

• Given that many, and perhaps most, pithouses and small sites were occupied from ten to forty years (Ahlstrom 1985; Cameron 1990; Cordell 1997; Crown 1991; Gilman 1987; Hantman 1983; Matson, Lipe, and Haase 1988; Nelson and LeBlanc 1986; Powell 1983; Schlanger 1987; Varien and Ortman 2005; Varien et al. 2007), timber harvesting and construction activities should have persisted even when populations were static or slightly decreasing. It follows, therefore, that tree-ring date minima indicate times when populations probably declined (either as people migrated from the region in question or as death rates exceeded birth rates).

• When maxima in tree-ring-date distributions are based on large samples, the maxima can be assumed to indicate times of intensified timber harvesting and construction. We assume that population increases were primarily responsible for increases in construction.

• Tree-ring dates used in this study are probably accurate within one to five years and serve to precisely define temporal changes in timber harvesting and construction activities. Thus, they have a significant advantage over ceramic dating or radiocarbon-based models of construction activity.

Results

In the following section, we show that tree-ring-date patterns from the eight archaeological regions that comprise the study area reflect demographic
change in response to climatic change. In general, when we speak of demo­
graphic change, we are referring—nonquantitatively—to fluctuations in
human populations, human aggregation in response to subsistence stress
and violence, and human immigration and emigration as reflected in the
tree-ring record of construction activity.

A Comparison of Tree-Ring Dates from the Study
Area with Tree-Ring-Based Reconstructions of
Climate Change

Figure 3.2 indicates two composite records of climate change for
the study area. Figure 3.2A shows the mean of six normalized (Z-scored)
records of precipitation from northwestern New Mexico and east-central
Arizona (fig. 3.1). The stacked (averaged) record of PDSI for nine nodal
sites (fig. 3.1, large filled circles) is shown in figure 2B. The PDSI value is
a measure of soil-moisture content and is a function of air temperature,
precipitation, and soil moisture (Palmer 1965). Negative PDSI values
indicate dry conditions, whereas positive values indicate wet condi­
tions. This index was specifically designed to evaluate drought impacts
on agriculture. PDSI values range from $-6$ (extreme drought) to $+6$
(extreme wet) and were calibrated using data for the period 1928–1978,
which was a wet period relative to the mean value for the past two thou­
sand years (Cook et al. 2004). Therefore, we have plotted the stacked
PDSI values relative to a PDSI value $(-0.5)$, which is the mean value for
the six site records during the past two thousand years. For the period in
which they overlap (AD 765 to 1600), the two stacked records are nearly
identical (figs. 3.2A, B). Therefore, in what follows, we have chosen to
use only the longer PDSI record.

A Comparison of the PDSI and
Tree-Ring-Date Records

Figure 3.2 (B, C) indicates that prior to AD 1000, when the tree­
ring datasets are relatively sparse, tree-ring date minima and maxima
are not always associated with a particular degree of wetness/dryness.
On the other hand, when a high density of tree-ring dates is achieved—
certainly between AD 1045 and 1300, when populations were at rel­
avtively high levels across the study area (Dean, Doelle, and Orcutt
1994:73)—the number of construction dates during minima and maxima
Figure 3.4. PDSI contour maps for (A) the AD 1045–1129 wet period, (B) the middle-twelfth-century drought, (C) the AD 1193–1269 wet period, and (D) the late-thirteenth-century drought. An average PDSI value of $-0.5$ (calculated for the period AD 1–2000) has been used to distinguish drought conditions ($\text{PDSI} < -0.5$) from relatively wet conditions ($\text{PDSI} > -0.5$). PDSI values are given in the scale to the right of each contour map.

frequently have a clear relation to climate change. For example, the very pronounced timber-cutting maxima between AD 1030 and 1130 and between AD 1190 and 1290 are associated with two of the wettest periods in the PDSI record (W1 and W2). In contrast, the timber-cutting
minimum between AD 1130 and 1200 and the rapid decline in tree-ring dates after AD 1290 were each prefaced by severe decadal-scale megadroughts, the middle-twelfth and late-thirteenth-century droughts, D1 and D2, which occurred between AD 1130 and 1177 and between AD 1273 and 1297, respectively (figs. 3.2B, C).

These megadroughts impacted much of the contiguous United States, with the southern Colorado Plateau being a region of severe drought during both periods (fig. 3.4B, D). For the most part, the southern Colorado Plateau was free of drought during the two wet periods (AD 1045–1129 and 1193–1269), although areas to the east and west of the
southern Colorado Plateau were mildly drought stricken (figs. 3.4A, C). Importantly, Cook et al. (2007) concluded that the twenty-three-year period from AD 1140 to 1162, which falls within the middle-twelfth-century drought, represents the single greatest megadrought experienced by North America since AD 1.

A Comparison of the Timing of Major Climate Oscillations with Regional Tree-Ring-Date Distributions

The eight archeological subregions delineated in figure 3.1 reflect generally accepted southwestern culture areas (Adler 1996a). Figures 3.5A–D and F–I display tree-ring date distributions for these archaeological subregions. Date distributions for the Cortez $1^\circ \times 1^\circ$ area (fig. 3.5E) are also included because of their relevance to interpretations generated by the Village Ecodynamics Project (Kohler et al. 2007)—interpretations that lead to different conclusions from those we reach in this chapter. The tree-ring data from each of these subregions are considered below. We shall discuss the relationship between the construction histories in each subregion and (1) the two wet periods, AD 1030–1130 and AD 1190–1290 (W1 and W2, respectively); and (2) the two megadroughts, AD 1130–1177 and AD 1273–1297 (D1 and D2, respectively). Where relevant, construction activity during the AD 1140–1162 segment of D1 will be examined. This period, as noted above, represents the single greatest megadrought experienced by North America since AD 1, and close examination of the contemporaneous construction activity yields insight into critical transitional events. We will, admittedly arbitrarily, set the analytical threshold at sites having more than two dates for this period as substantial evidence of construction.

The Northern San Juan Subregion. The tree-ring sample for the northern San Juan subregion consists of 3,601 dates from 234 archaeological sites. The archaeological record indicates that timber harvesting accelerated during the W1 wet period (AD 1045–1129) (fig. 3.5A). During the succeeding D1 megadrought (AD 1130–1177), timber harvesting decreased sharply. Only five sites evidence substantial construction during the most intensive period of D1 (AD 1140–1162). These include the Eagle's Nest ($n = 11$), Hoy House ($n = 11$), Lion House ($n = 24$), and
Figure 3.5. Tree-ring date distributions for eight archaeological regions and the Cortez $1^\circ \times 1^\circ$ rectangle. The two vertical hachured rectangles indicate two climatically wet periods (W1 and W2), and the two grey rectangles indicate two megadroughts (mid-twelfth- and late-thirteenth-century droughts, D1 and D2). The number of tree-ring dates incorporated into each histogram is shown on the vertical scales.
Morris' Site 5 \((n = 7)\) (all located in Johnson Canyon, immediately south of Mesa Verde National Park on the Ute Mountain Ute Reservation), as well as Knobby Knee Stockade \((n = 4)\) (located south of Ruin Canyon, in southwestern Colorado).

Accelerated timber harvesting appears in the archaeological record once again at the beginning of the W2 wet period (AD 1193), only to terminate during the late-thirteenth-century drought (fig. 3.5A). The late-thirteenth-century cessation of timber harvesting is consistent with Lipe's (1995) previous analysis of tree-ring dates from the northern San Juan drainage, which showed that tree-ring dates later than AD 1280 were absent from the subregion.

**The Central San Juan Basin Subregion.** The tree-ring sample for the central San Juan basin consists of 2,697 dates from 38 sites. The history of timber harvesting in this subregion (fig. 3.5B) is somewhat similar to that in the northern San Juan subregion, but with a few significant differences. Although both subregions show diminished construction during the Dr and D2 megadroughts, low levels of timber harvesting persisted during the D1 drought in the northern San Juan subregion, whereas harvesting all but ceased in the central San Juan basin. Indeed, no sites date convincingly to the AD 1140–1162 period of the D1 drought in the central San Juan basin.

However, tree-ring dates during the W1 wet period in the central San Juan basin (fig. 3.5B) are far more numerous than in the northern San Juan subregion (fig. 3.5A). This situation is reversed during the W2 wet period, with the northern San Juan evidencing much greater construction activity than that seen in the central San Juan basin. The termination of the Chaco phenomenon during the D1 drought is perhaps the event of greatest cultural significance in this subregion.

**The Cibola-Acoma-Laguna Subregion.** The tree-ring sample for the Cibola-Acoma-Laguna subregion consists of 686 dates from 39 sites. Some timber harvesting occurred prior to and during the first part of the W1 wet period (fig. 3.5C). During the succeeding D1 drought, minimal timber harvesting is indicated in the archaeological record for this subregion. Two sites on Cebolleta Mesa, each with a single date, yield weak evidence of construction during the AD 1140–1162 segment of the D1 drought.
Timber harvesting markedly increased during the W2 wet period, only to cease with the onset of the D2 megadrought. Timber harvesting again resumed between AD 1310 and 1370, after the D2 drought (fig. 3.5C).

The Mogollon Highlands Subregion. The tree-ring sample for the Mogollon Highlands (Salt River) consists of 322 dates from 17 sites. Timber harvesting in this subregion accelerated during the middle of the W1 wet period, only to decline during the D1 drought (fig. 3.5D). Construction during the AD 1140–1162 portion of D1 is evidenced at Carter Ranch (n = 3). During the later stage of the W2 wet period, timber harvesting increased in the Mogollon Highlands. During the D2 drought, construction occurred at the Pinedale Ruin (n = 3). Similar to the situation in the Cibolla-Acoma-Laguna subregion, timber harvesting in the Mogollon Highlands surged again after the D2 drought, beginning at AD 1330.

The Sinagua Subregion. A total of 466 dates from 45 sites comprises the sample from the Sinagua subregion. Timber harvesting in this subregion differed markedly from that documented for the central and northern San Juan subregions. As was the case for the central San Juan basin, harvesting increased in the Sinagua subregion during the W1 wet period. However, in contrast to the central San Juan basin, harvesting continued in the Sinagua subregion throughout the D1 and D2 droughts. For the AD 1140–1162 segment of the D1 drought, Wupatki (n = 35) is the only site evidencing construction. During the D2 drought, construction occurred at Kinnikinnick Pueblo (n = 17) and the Pollack site (n = 3) in the southern portion of the subregion. The continued construction in the Sinagua subregion strongly indicates that this subregion acted as a refugium during the two megadroughts (Berry 1982; Plog 1989).

The Hopi Subregion. The tree-ring sample for the Hopi subregion consists of 544 dates from 19 sites. Substantial increases in construction are not indicated by tree-ring dates in this subregion during the W1 wet period (fig. 3.5G). Instead, construction dates began to increase at about AD 1220, during the middle part of the W2 wet period. The number of construction dates increased sharply at about AD 1250, that is, toward
the end of the W2 wet period. Thereafter, the subregion witnessed a rapid decline in construction dates during the onset of the late-thirteenth-century megadrought. Construction activity does not reappear in the archaeological record until AD 1360. As a caveat, little timber exists in the Hopi subregion, and the dates from this area may reflect the use of recycled material in some instances. Thus, it is possible but not demonstrable that older timbers may have been used in construction that post-dates the D2 drought. However, it is just as feasible that the dating is representative of actual construction activity, thus casting doubt on the widely held notion that the Hopi mesas were continuously occupied from some time in the distant past through the modern era.

The Rio Grande Subregion. The tree-ring sample for the Rio Grande subregion consists of 722 dates from 53 sites. In this subregion, construction dates were sparse during the W1 wet period. A very small number of tree-ring construction dates are documented for the latter part of the D1 drought (fig. 3.5H). Construction dates during the AD 1140–1162 period of the D1 drought are from the Arroyo Negro site ($n = 20$). During the following W2 wet period, a large number of tree-ring construction dates are documented in the Rio Grande subregion. In contrast, there are few tree-ring construction dates for the D2 drought. The latter are from a group of sites in the Cochiti Dam pool area ($n = 44$) and at Pindi Pueblo ($n = 13$). Tree-ring construction dates increase markedly between AD 1300 and 1580. This latter phenomenon may indicate an expansion of an empirically underrepresented, preexisting Rio Grande population (Boyer et al., this vol.) or the impact of immigration from areas outside the Rio Grande (Lipe, this vol.; Ortman, this vol.).

The Kayenta Subregion. The tree-ring sample for this subregion consists of 885 tree-ring construction dates from 53 sites. Construction dates in the Kayenta subregion (fig. 3.5l) began with an increase in the latter part of the W2 wet period and peaked during the initial portion of the D2 drought, then abruptly terminated during the last phase of the late-thirteenth-century drought. This pattern is consistent with other data indicating that most of the Kayenta population was moving south during the latter part of the thirteenth century (Dean, Doelle, and Orcutt 1994; Dean 1996b; Dean, this vol.).
Tree-Ring Dates and Demographic Change

The Cortez Subregion. In addition to our eight cultural subareas, we have plotted the tree-ring construction date distribution for the general Cortez area (Cortez 1° × 1° rectangle). This area is congruent with that bounded by the Village Ecodynamics Project Study Area (Kohler et al. 2007), a region central to many studies presented in this book. The tree-ring sample for this subregion consists of 885 dates from 79 sites.

In a study of the occupation histories of 3,176 habitation sites in this area, Varien and others (2007) identified two population cycles, one peaking in the late AD 800s and the other peaking in the middle AD 1200s (Varien et al. 2007: fig. 4; table 1.1, this vol.). Varien and colleagues created “momentary” population estimates for 14 periods between AD 600 and 1280, each of which has a time span ranging from 20 to 125 years, with most of the time spans being 40 years or greater in duration. Varien and his colleagues concluded that “formation of aggregated settlements . . . is positively correlated with increasing population . . . but it does not correlate with climate variation averaged over periods” (Varien et al. 2007:273).

This conclusion is inconsistent with the distribution of tree-ring construction dates displayed in figure 3.5E. These data clearly indicate a construction minimum during the middle-twelfth-century drought (D1), implying a reduction in the population of the Cortez subregion. Kohler and colleagues (2007:83)—although acknowledging “that in general tree harvesting tended to decline during periods with a greater proportion of drought years and increase during periods with fewer drought years”—suggested that their study area “served as a potential refugium during drought.”

We suggest that the relatively large bin size used by Varien and colleagues (2007) when constructing their population estimates obscured decadal-scale variability in timber harvesting and construction, thereby essentially masking the substantial impacts of the D1 drought. Moreover, we submit that the minimum in tree-ring construction dates during the D1 drought indicates a significant reduction in population within the Cortez subregion.

As discussed in the northern San Juan subregion summary, the primary evidence for occupation during the D1 drought is from the Johnson Canyon area south of Mesa Verde National Park. Excavations in the Johnson Canyon area that produced evidence of occupation during
the DI drought were accomplished during the 1970s (Nickens 1975). Despite the subsequent energetic and highly productive efforts of the Crow Canyon Archaeological Center, no additional DI sites have been tree-ring dated to this period. Clearly, the tree-ring construction record from archaeological sites and the climatic data do not support the assertion that the northern San Juan subregion, as a whole, served as a drought refugium.

**Regional Construction Trends**

We are certainly not the first to suggest a relationship between droughts, population decline, and migration in the Southwest (see Berry 1982; Brown, Windes, and McKenna 2008; Clark 2001, 2007a; Crown, Orcutt, and Kohler 1996; Dean 1996b; Dean, Doelle, and Orcutt 1994; Douglass 1929; Fowler and Stein 1992; Gumerman and Dean 1989; Hill et al. 2004; Judge 1989; Kintigh et al. 2004; LeBlanc 1989; Lekson 1986; Matson, Lipe, and Haase 1988; Plog 1989; Reid 1989; Rose, Dean, and Robinson 1982; Stanislawski 1963; Stein and Fowler 1996; Varien et al. 1996; Varien et al. 2007). While there is merit in all the previous studies, the chronometric support for the various arguments is uneven. Some studies are, indeed, based on tree-ring data, but others rely on radiocarbon dating or assumptions based on ceramic temporal placement. In the current study, we have opted to restrict analyses to tree-ring-dated sites in a large but geographically bounded region of the Southwest in order to minimize reliance on imprecise absolute dating methods (radiocarbon, paleomagnetic dating, thermal luminescence, etc.) or conjectural inference (ceramic dating).

We have shown that tree-ring dates from eight archaeological subregions on the southern Colorado Plateau (fig. 3.1) provide a coherent history of timber harvesting and construction activities when their distributions over time are binned at ten-year intervals. The data indicate that

- A wet period between AD 1045 and 1129 (W1) was associated with an overall increase in tree-ring dates throughout most of the study area (figs. 3.2C, 3.5).
- The mid-twelfth-century megadrought (DI) was associated with tree-ring date minima in every archaeological subregion except the
Sinagua, which appears to have been a refugium for people abandoning other areas (fig. 3.5F). The Wupatki basin of the Sinagua subregion is an arid landscape, seemingly an unlikely refugium candidate. Stone and Downum (1999:113) provide the following explanation:

The ashfall left by the eruption of Sunset Crater Volcano in AD 1064 created a bonanza for the prehistoric inhabitants of the area around Wupatki National Monument in northern Arizona. . . . This natural mulch apparently improved soil conditions enough to attract more than 2,000 immigrants during the following century. . . . A recent survey recorded more than 2,000 small sites on the 55 km² monument, but the most striking feature of the cultural landscape are the numerous large pueblos that arose in the twelfth century. These include 10 pueblos of more than 20 rooms each, apparently organized into settlement districts or clusters centered on Wupatki Pueblo (150+ rooms) and the Citadel (50+ rooms).

As shown in figure 3.5F, increased construction activity followed immediately on the heels of the ashfall and continued through AD 1220. Given that the vast majority of Colorado Plateau sites experienced tree-ring minima during the D1 drought, the significance of the Wupatki basin as a drought refugium has yet to be fully recognized.

To a lesser extent, the early part (AD 1130–1150) of the D1 drought was accompanied by some timber harvesting in the Johnson Canyon area of the northern San Juan subregions, the Mogollon Highlands, and the Rio Grande (figs. 3.5A, D, H).

- A wet period between AD 1193 and 1269 (W2) was associated with a sharp increase in tree-ring dates in the northern San Juan, Cibola-Acoma-Laguna, Hopi, Rio Grande, and Kayenta subregions (figs. 3.5A, C, G, H, I). Increases in timber harvesting and construction also occurred during this period in the Mogollon highlands and Sinagua subregion (fig. 3.5D, F).
- The late thirteenth-century megadrought (D2) was associated with an apparent cessation of tree harvesting and construction activities in the northern San Juan subregion, the central San Juan basin, and the Cibola-Acoma-Laguna, Sinagua, Hopi, and Kayenta subregions (fig. 3.5A, B, C, F, G, I). Tree harvesting and construction in the
Cibola-Acoma-Laguna, Mogollon Highlands, Hopi, and Rio Grande subregions continued after AD 1300 (figs. 3.5C, D, G, and H). The Sinagua subregion witnessed construction activity during D2 for entirely different reasons from those behind its refugium status during D1. Sites in the southernmost portion of the Sinagua area occur at 7,000 ft in elevation on Anderson Mesa. Taking advantage of an extended growing season during warm droughts and orographic rainfall in high-elevation environments was a fairly common drought strategy in the Southwest (Berry 1982).

We invoke Occam’s razor in suggesting that tree-ring-date distributions in the southern Colorado Plateau reflect demographic responses to climate change after regional populations achieved a certain density. That is, at higher population densities than previously achieved, people were increasingly vulnerable to a combination of anthropogenic reduction of local resources (Duff et al., this vol.) and regional climate change. In addition, larger local populations provided more samples for the documentation of trends in construction. In terms of the data presented here, that population density was achieved in the study area on or before approximately AD 1100, at which time populations were expanding into areas that were marginal with respect to dryland production of maize under “normal” climatic conditions. Although tree-ring date distributions are not quantitative measures of population change, their minima and maxima are critically informative of major decreases and increases, respectively, in subregional populations.

**Concluding Remarks**

So, how best to interpret the rapid acceleration of tree-ring dates that followed major drought intervals? More than six decades ago, well before the existence of the sophisticated databases upon which the current analyses rely, famed geographer Carl O. Sauer (1954:553) may have said it best: “It seems to me most appropriate to re-examine the cultural scene of the Southwest, both vertically and horizontally, as a deep and wide zone of interpenetration of peoples and institutions, mainly originating elsewhere.” How else to explain the linguistic and cultural variation of the Southwest overlain upon the common factor of maize
dependence? We suggest that the rapid responses of building activity, following the two megadroughts, are not solely attributable to \textit{in situ} population increase on the part of residual populations that may have persisted during droughts in extant structures. In situ survival of remnant populations may well explain the observed continuity of certain classes of material culture (e.g., ceramics, textiles, lithics, etc.), but the accelerated building rates immediately following the return to favorable climatic circumstances may well reflect influxes from adjacent regions of populations—perhaps including hunter-gatherers attracted to a new lifeway—to regions that once again possessed robust agriculture potential. Each such influx would have contributed linguistic, cultural, and genetic variability to, in Sauer’s terms, the deep and wide southwestern cultural scene.

This leads to a consideration of “pushes” and “pulls” in the explanation of prehistoric migrations—a topic frequently raised in this volume. While we do not deny the possibility that environmental and cultural “pulls” exerted influence over the outcome of certain migrations, we have concentrated on the climatic “pushes” that instantiated population movement. We have taken this approach primarily because climatic variability and the corresponding maxima/minima are empirically attainable. Conversely, the “pulls” or attractors, especially the cultural variety, rely upon secondary or tertiary levels of abstraction that have little probability of empirical support or refutation. We are not saying that such conjectural modeling is a waste of time. Those engaging in such conjecture, however, are obliged to provide a possible roadmap to connect with the empirical world of archaeological data. For example, the scenario briefly suggested above of hunter-gatherers enjoining a maize-dependent lifeway is eminently testable through the use of $^{13}$C/$^{15}$C isotopic analyses in conjunction with chronometric data (Coltrain 1993, 1997; Coltrain and Leavitt 2002; Coltrain and Stafford 1999; Decker and Tieszen 1989; Ezzo 1993; Martin 1999; Matson and Chisholm 1991; Spielmann et al. 1990; Wolley 1988).

In conclusion, we have presented a geographical and temporal substrate for the understanding of southwestern prehistoric phenomena. Unless or until the patterns we have demonstrated are overturned through the recovery of additional data, we recommend that southwesternists involved in regional modeling at various levels of abstraction be
cognizant of, and account for, the constraints imposed by these geotem­poral patterns. To do otherwise will likely lead to dubious inferences.

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Note

1. Any use of trade, product, of firm names in this chapter is for descriptive purposes only and does not imply endorsement by the U.S. government.