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*Research*, part of a Special Feature on Long-term Vulnerability and Transformation

# Sustainable Small-Scale Agriculture in Semi-Arid Environments

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ABSTRACT. For at least the past 8000 years, small-scale farmers in semi-arid environments have had to mitigate shortfalls in crop production due to variation in precipitation and stream flow. To reduce their vulnerability to a shortfall in their food supply, small-scale farmers developed short-term strategies, including storage and community-scale sharing, to mitigate inter-annual variation in crop production, and long-term strategies, such as migration, to mitigate the effects of sustained droughts. We use the archaeological and paleoclimatic records from A.D. 900-1600 in two regions of the American Southwest to explore the nature of variation in the availability of water for crops, and the strategies that enhanced the resilience of prehistoric agricultural production to climatic variation. Drawing on information concerning contemporary small-scale farming in semi-arid environments, we then suggest that the risk coping and mitigation strategies that have endured for millennia are relevant to enhancing the resilience of contemporary farmers' livelihoods to environmental and economic perturbations.

Key Words: *adaptive strategy; archaeology; climate; risk; semi-arid environments; small-scale farming; U.S. Southwest*

## INTRODUCTION

In most rural areas of the developing world small-scale farmers who cultivate a few hectares of land, smallholders, are the basic units of agricultural production and are largely responsible for their own economic and social sustainability (Eakin 2006, Morton 2007, de Sherbinin et al. 2008). Regardless of state-level interests in larger-scale and more modern systems of production, small-scale farmers continue to comprise a substantial proportion of the population and are responsible for much of the crop production in many developing countries (Jones and Thornton 2003, Tiffen 2003, Morton 2007, Acosta-Michlik et al. 2008, Dhaliwal and Singh 2010). At the close of the first decade of the twenty-first century, therefore, it behooves us to consider that smallholder production has remained a viable, though at times challenged, livelihood since its inception roughly 8000 years ago. In addition to imagining ways to move these households into a new economic configuration, such as wage labor or cash crop production, it is also important to consider strategies to improve the conditions that enhance the long-term resilience of smallholder production.

In order to increase the resilience of smallholder farming, Mortimer and Adams (2001) have called for a long-term perspective on development that focuses on small-scale farmers' adaptive strategies. Archaeology's routine engagement with the long-term can help meet that challenge by considering vulnerabilities associated with small-scale crop production, and the long-term adaptations that have been successfully employed by prehistoric small-scale farmers for hundreds or even thousands of years. We use the archaeological, and to some extent the ethnographic, record of the American Southwest to identify the environmental risks that were faced by prehistoric Pueblo farmers of the Colorado Plateau, the Mogollon Rim, and Rio Grande regions across the four states forming the U.S. Southwest (Figure 1). We then draw on the archaeological record and conceptual models as sources of information concerning strategies that were used successfully to mitigate these risks at local and regional scales for centuries. Our analysis documents that there are three adaptive strategies, including household storage, inter-household food sharing, and migration, that have endured for millennia because they are robust in enhancing the resilience of small-scale farming in semi-arid

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environments. Long-term settlement of Pueblo villages and the tethering of farmers to particular locations on the landscape, which occurred late in prehistory, were only possible when farmers were able to select those portions of the Southwestern landscape that combined extensive agricultural land with a secure water supply that would mitigate the effects of long-term drought.

Although our main focus is on the archaeological data and analyses relevant to the Southwestern case study, the insights concerning resilience in small-scale agriculture that we derive from these analyses form the foundation of our concluding discussion on smallholder agriculture in the twenty-first century. In that discussion we address the applicability of prehistoric adaptive strategies to contemporary semi-arid smallholder farming.

Agricultural risk is by no means a new topic in the U.S. Southwest. For the past 25 years or so, Southwestern archaeologists have modeled, investigated, and published on this topic in entire volumes devoted to the issue (e.g., Gumerman 1988, Tainter and Tainter 1996) and in individual dissertations, books, and articles (e.g., Braun and Plog 1982, Burns 1983, Minnis 1985, Lebo 1991, Ford 1992, Rautman 1993, Anschuetz 2006). This literature, however, has largely aimed at a more accurate understanding of Southwestern prehistory. One of our points here is that the strategies used by Southwestern prehistoric farmers to avoid the risk of a shortfall in food or other resources could enhance the resilience of the food supply for contemporary smallholder farmers in semi-arid lands.

## VULNERABILITIES OF PREHISTORIC SOUTHWESTERN FARMING TO CLIMATE VARIABILITY

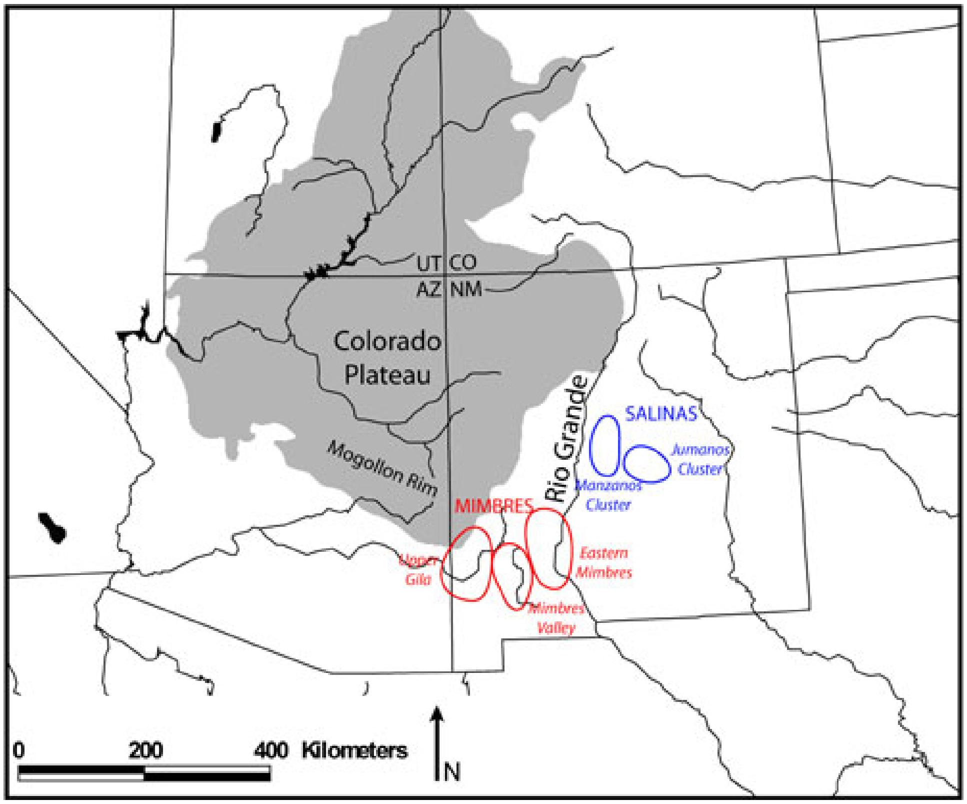
Prehistorically, once people began domesticating and cultivating plants, corn was the Southwestern dietary staple. Although beans and squash were grown and other plants encouraged, and while some wild plants, such as agave and pinyon, were important supplements, corn was the primary food eaten by all Southwestern agricultural populations. Bone chemistry data from several later prehistoric Southwestern peoples (e.g., Spielmann et al. 1990, Spielmann and Schoeninger 1992, Kellner et al. 2010) document that corn probably comprised 80-90% of Southwestern diets from A.D. 1000-1600, our main period of interest here. Today and in the past, corn is grown for subsistence, social, and ritual consumption at the household level. The area of the Southwest discussed here was not sufficiently productive for agriculture using the technologies of prehistoric farmers to provide sustained surplus beyond household needs.

There were no draft animals or domesticated stock in the Southwest prehistorically, and thus no plow for cultivation and no manure for fertilization. Soil fertility was replenished through deposits of silt from the flooding of fields adjacent to rivers and streams and the capture of sediment and nutrients by features such as rock alignments placed across modestly sloping agricultural fields. Nor were there beasts of burden to transport food and other commodities from place to place. The bulk of the diet was thus grown locally.

Given its arid climate and paucity of perennial streams, water is the limiting factor in corn production across the Southwest (e.g., Muenchrath and Salvador 1995). Prehistoric farmers were thus vulnerable to variations and changes in the timing and quantity of precipitation and stream flow. Much of the landscape modification across the Southwest, in fact, has to do with aspects of water control that reduce this vulnerability. Landscape modifications include check dams (Sandor 1990), terraces and waffle gardens (Anschuetz 1998, 2006), reservoirs and irrigation ditches (Herrington 1979), and extensive irrigation systems (Howard 2006). These constructions served to concentrate available water onto agricultural fields, reducing but not eliminating the impact of spatial and temporal variation in precipitation. Southwestern farmers had to cope not only with significant variation in precipitation within a growing season, but also with less frequent, sustained dry periods.

Southwest archaeologists are blessed with strong dendroclimatic (tree-ring) data that permit the reconstruction of annual variation in precipitation (Dean 2000). Identifying dry periods in the tree-ring record involves discerning relatively rare and prolonged periods of low moisture, and inferring adverse impacts on people during these periods. The substantial reliance on maize by prehistoric Southwest populations and the relatively low water availability for maize productivity in most areas of the Southwest provide reasonable support for the link between periods of low moisture and adverse impacts on people. Using dendroclimatic data, we

**Fig. 1**. Map of the Southwest.




document short and long-term variation in precipitation and then contrast a context in which dry periods result in an acute risk of shortfall with a context in which environmental conditions buffer against such shortfall. We conclude with a longitudinal analysis of changing trends in Southwestern agricultural settlement locations and discuss the implications of these prehistoric adaptations to the present.

## ADAPTATIONS FOR COPING WITH VARIABILITY IN PRECIPITATION

### Storage and pooling

Ancestral Pueblo farmers addressed the problem of variation in annual rainfall in part through the development of multi-year, household-scale storage capacity, as well as diversifying field locations and crop varieties (e.g., Ford 1992, Anschuetz 1998, 2006, Van West and Dean 2000), which we do not discuss here. The longevity of stored corn in this semi-arid environment matched the pattern of high frequency environmental variability in that an individual poor year or two could be ameliorated through the stored products of better years. Simulation of Pueblo household corn production and storage behavior has suggested that storage technology could have been used successfully to cope with inter-annual variation in rainfall (Slatter 1979, Burns 1983, Lebo 1991).

That storage was a critical strategy for coping with variability in crop production was recently documented archaeologically by Dean (2006) in his analysis of changes in household storage capacity in Ancestral Pueblo households in Tsegi Canyon, northeastern Arizona. In this case, Pueblo farmers used a coping strategy traditionally aimed at inter-annual variation in precipitation to address a novel, low frequency process: a marked decline in the water table and a prolonged dry period. Dean documented that in the mid-1200s, as conditions for agriculture worsened, household corn storage rooms (granaries) increased in number and living room space decreased (Figure 2). The fact that people chose to increase storage capacity suggests its central function in mitigating environmental perturbation in the Southwest. Ultimately, however, increasing storage proved unsuccessful under prolonged conditions of water deficit, and people left Tsegi Canyon. Migration, as we discuss below, was a persistent response to severe dry periods across the Southwest.

Even with a target of one additional year of corn in storage, not all households would be able to meet that target consistently enough to buffer all inter-annual variation. Southwestern ethnographic data suggest that community-scale sharing of food is an effective strategy for evening out imbalances in storage across households (e.g., Ford 1972). Michelle Hegmon (1991) evaluated this hypothesis through a simulation of Hopi agriculture. Her model demonstrated patterns of shortfall in storage; more than half the households did not survive without food sharing across households. When the model was run with restricted sharing, such that households met their own needs first and then shared any surplus they had available, over 80% of the households survived if living in communities of at least six to eight households. Further work by Hegmon (1996) as well as Kohler and Van West (1996) substantiates the importance of selective pooling of household food supplies to reduce the risk of shortfall.

In sum, at the local scale, household-based, multi-year storage and community-scale restricted sharing of stored food were common and robust adaptations for mitigating inter-annual variation in the availability of water for farming, and thus crop production. Archaeological evidence for increased storage capacity in times of extended dry periods supports the importance of this practice. In times when there were more than three or four consecutive years of drought, however, this strategy was insufficient for maintaining household food supplies.

## Migration

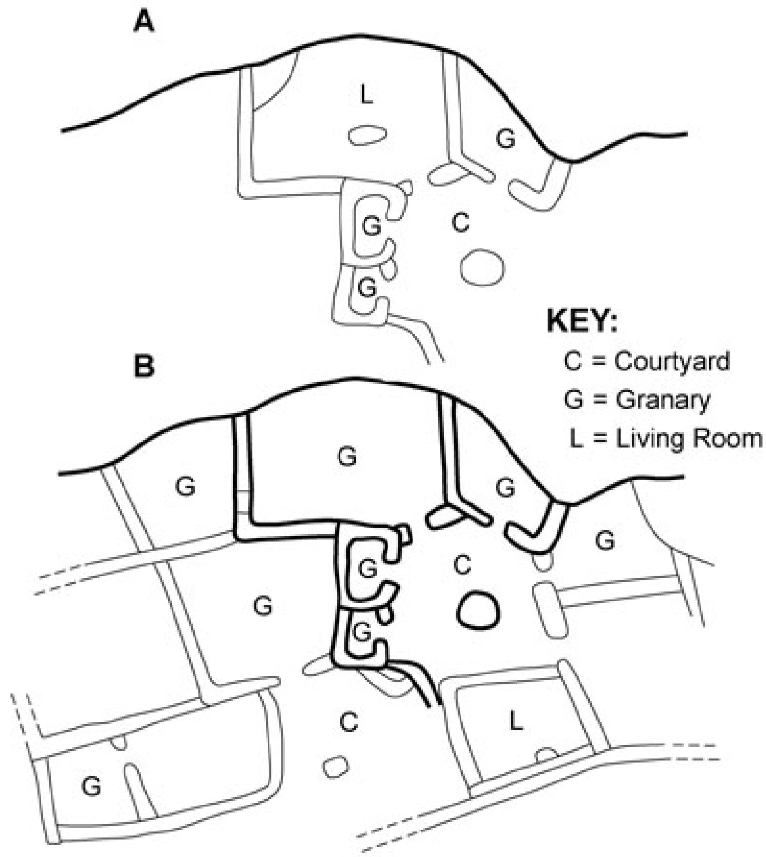
Severe dry periods presented novel though recurrent challenges throughout the prehistory of the U.S. Southwest. Severe droughts created landscapes of vulnerability that could not be addressed with storage and the use of diverse resources and farming strategies. The Pueblo farmers living in Tsegi Canyon, for example, permanently left their villages after experiencing several years of sharp and persistent reductions in precipitation and stream flow, which led to persistent famine conditions (Dean 1988, 1996).

Population movements and residential abandonments in the prehistoric U.S. Southwest have been closely examined and correlated at some places and times with changes in climate conditions, especially multi-year dry periods (e.g., Cordell 1975, Euler et al. 1979, Dean et al. 1985, Minnis 1985, Gumerman 1988, Schlanger 1988, Judge 1989, Lebo 1991, Orcutt 1991, Ahlstrom et al. 1995, Lipe 1995, Crown et al. 1996, Adams 1998, Van West and Dean 2000, Cordell et al. 2007). The importance of migration as an adaptation is highlighted by Cameron (1995:112), who argues that, “Movements of communities within a region, even when such movements have a lengthy periodicity, can be expected to be a normal part of a regional environmental adaptation that involves adjustment of a group’s home range.” Similarly, Dean and colleagues (1985) argue that mobility is the least costly strategy used to cope with environmental change when groups are not heavily invested in residential and agricultural facilities and when mobility is not restricted by population density.

In the following discussion we use two archaeological case studies, the Mimbres area of Southwestern New Mexico and the Salinas area of central New Mexico, to explore the conditions under which populations either emigrated or remained in place in the face of long-term drought. In the Mimbres case, reduced precipitation and stream flow in the context of aggregated populations are likely to have resulted in shortfalls in the food supply or certainly perceptions of bad conditions for farming. Many people permanently emigrated from the central Mimbres area, and this region never returned to pre-migration population levels. The Salinas case presents a much rarer situation in the Southwest in that high water tables allowed farming to continue through even the most severe dry periods. Long-term residential stability characterizes this area. The contrast between these two cases illustrates how stability of populations on the semi-arid Southwestern landscape was crucially linked to the reliability of the water available for crop production.

Migration was a strategy households used for much of Southwestern prehistory to mitigate sustained

**Fig. 2**. Room Cluster 2 at Kiet Siel, Tsegi Canyon, northeastern Arizona: (A) in A.D. 1271 with three fairly small granaries, and (B) in A.D. 1276 with eight granaries, note the living room turned into a granary. After Dean 2006, Figure 8.3.




shortfalls in the food supply. By the A.D. 1300s, however, the socio-political context in which households made decisions had changed. Pueblo people were increasingly choosing to live in aggregated, often nucleated settlements, perhaps due to warfare (LeBlanc 1999, Rice and LeBlanc 2001, Solometo 2006), the elaboration of ritual and economic systems (Upham 1982, Adams 1991), the development of sustained social institutions for managing land tenure (Adler 1996), and/or competitive escalation (Kintigh 1994). The increasing permanence of large communities required the selection of village locations that combined extensive arable land with a water supply that was reliable during periods of extended drought. As the Salinas case demonstrates, very long-term settlement stability in the Southwest is possible when there is a perennial water supply for agriculture. Thus, by the mid-1400s regional-scale migration was no longer a primary adaptive strategy, and communities did not choose to migrate again, if at all, until Spanish colonization in the early 1600s.

## THE CASE STUDIES

### The Long-Term Vulnerability and Transformation Project

The data were collected and analyzed over the course of the Long-term Vulnerability and Transformation project (NSF # 0508001). The goal of the project is the comparative analysis of resilience and vulnerability with respect to changing environmental circumstances across five case studies from the Southwestern U.S. and northern Mexico (Phoenix Basin Hohokam, Zuni, Mimbres, Salinas, and Malpaso Valley). One of several comparisons (Hegmon et al. 2008, Nelson et al. 2010, Nelson et al. 2011) that the project has made possible is presented here. The databases upon which we focus here are the dendroclimatic and demographic databases from the Mimbres and Salinas cases (Figure 1).

## Mimbres

The Mimbres case study presents an example of a common practice among prehistoric Southwestern farmers in which centuries of settlement within a region are followed by rapid emigration in the face of persistently poor climatic conditions and social stresses. We argue that such migration should not be considered a failure but is an effective adaptive strategy at the scale of the Southwest as a whole.

The Mimbres region is centered in southwest New Mexico, extending south into the Mexican state of Chihuahua and west into eastern Arizona. Our study focuses on the most densely occupied portion of the greater Mimbres region, which includes the upper watershed of the Gila River in the west, the Mimbres River at its center, and the Rio Grande and its western tributaries in southwest New Mexico at its eastern edge (Figure 1). The region has a Chihuahuan Desert, basin and range landscape cut by three major rivers. Primary field locations for farming were on the floodplains along these rivers and their tributaries (Minnis 1985, Nelson 1999). In addition, small upland alluvial fans and check dam fields were farmed (Sandor 1990).

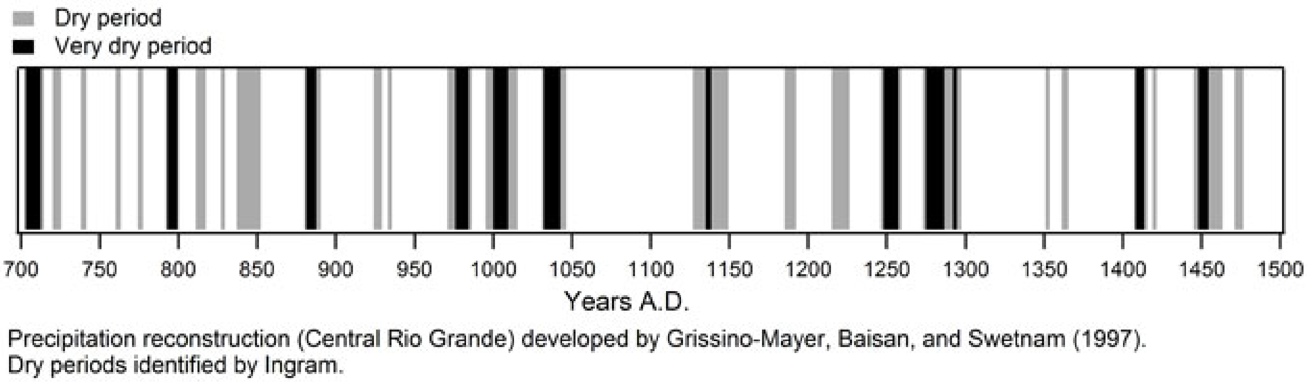
For well over a millennium, up until the late tenth century, people in the Mimbres region lived in diverse settings, and moved residence frequently (Anyon et al. 1981, Diehl 1994, Swanson 2009, Swanson et al. 2011). Over these centuries, farming became gradually more important to the diet, population grew steadily, and settlements became more focused on the major rivers and their tributaries (Diehl 1996). People appear to have addressed potential shortfalls in food supply by storing, using diverse field areas, and shifting settlement within the region. Near the start of the eleventh century, the beginning of the Classic Mimbres period, people in the Mimbres region aggregated into villages of up to a few hundred individuals. These villages were built primarily along the rivers and near sections of perennial streams (LeBlanc 1983, Minnis 1985, Blake et al. 1986).

The Mimbres archaeological sequence is marked by two major emigrations. The best known is a regional depopulation at the end of the Classic Mimbres period (A.D. 1130), on which we focus. The depopulation of all Mimbres villages around A.D. 1130 is associated with an extreme and prolonged dry period (Figure 3), although equally dry periods of equivalent length occurred before and after that event. As Nelson (1999, Nelson et al. 2011) and others (e.g., Leblanc 1983, Minnis 1985, Schollmeyer 2009) have argued, a coalescence of social and environmental conditions contributed to this region-wide depopulation. Although some people remained in the Mimbres region, especially in the eastern Mimbres area by dispersing into small hamlet settlements (Nelson 1999), the population of the region declined to about 25% of its Classic period maximum (Figure 4).

### *Precipitation and population in the Mimbres area*

The dendroclimatological data presented in Figure 3 document that the initial aggregation into the Classic Mimbres pueblos coincides with several very dry periods in the early 1000s. The village populations of the Late Pithouse and Early Classic periods were smaller than during the later Classic. In addition, the drought of the early 1000s was part of a pattern of frequent occurrences of low precipitation from A.D. 970 to 1040. The frequent shifting of residences that characterized the Pithouse period may have served to adjust to these conditions. Thus, risk of shortfall was different at the start of the Classic period, as compared to the end (Schollmeyer 2009). In contrast to the droughts at the start of the Classic period, the late Classic drought followed a long stretch of especially wet years. The eighty-five years from roughly A.D. 1040 to 1125, was an especially wet period (Minnis 1985; note long-term absence of dry periods in Figure 3), and the Mimbres population continued to grow and expand their villages. This moisture allowed people to farm upland alluvial fans and check dam fields and expand the extent of irrigation agriculture on floodplains (Minnis 1985). The continuous farming of floodplain fields resulted in the removal of much of the riparian vegetation in the Mimbres Valley (Minnis 1985), the richest and

**Fig. 3**. Mimbres climatic data.




most densely populated portion of the Mimbres region. In addition, the growing population depleted much of the large game, namely artiodactyls, from the main settlement areas (Cannon 2000, 2001, Nelson and Schollmeyer 2003, Schollmeyer 2009).

Storage became more formalized during the Classic Mimbres period, shifting from subfloor and extramural pits to rooms integrated into dwellings. All storage is associated with individual houses. A common house style includes one dwelling and one storage room, but many houses had multiple storage rooms (Shafer 1982, Hegmon et al. 2006).

After about A.D. 1125, an extreme dry period ensued, challenging the provisioning of the largest population ever to live in the region and increasing risk to village occupants. For over 80 years they had not experienced such dry conditions; as Schollmeyer (2009) has demonstrated, people could have remained in the region but their perceptions of the risk created by this extended dry period were probably influenced by their experience of the preceding long, wet period. Every large village in the Mimbres region was almost entirely depopulated and large numbers of people emigrated, especially from the Mimbres Valley (Figure 4). In the least densely populated eastern Mimbres area, about half the population remained and reorganized into the previously dispersed settlement pattern of the Pithouse period, continuing to farm floodplain and upland alluvial fan fields (Nelson 1999).

We do not know the destination of those who migrated from the region. At small hamlet sites in the eastern Mimbres area that immediately post-date the Classic period, we find the continued use of Classic period Mimbres Black-on-white pottery and its merging with new styles (Hegmon et al. 1998), but outside the area, the Mimbres Black-on-white tradition is rarely found in settlements dating after the Classic Mimbres period. Emigration from the Mimbres region was accomplished with rapid assimilation to new social contexts, perhaps in distant places; the social institutions that formed in the Classic Mimbres period did not continue beyond the middle of the 12$^{th}$ century.

## Salinas

The Salinas case study presents an instance of enduring economic, social, and settlement stability. The longevity of occupation of specific portions of the Salinas landscape is unusual in Southwestern prehistory, and we argue that it is due to the reliability of crop production in this area that was made possible by localized occurrences of a high water table. This condition offered long-term resilience of subsistence agriculture to precipitation variation and change.

The Salinas region is located in central New Mexico (Figure 1), east of the Rio Grande valley and the Manzanos and Los Pinos Mountains. The Manzanos Mountains, with pinyon-juniper woodland at the lower elevations and ponderosa pine and Gambel's

**Fig. 4**. Population trends in the Mimbres area. Source: Peeples 2010, *unpublished manuscript*.


oak on the upper slopes, supply water in the form of ephemeral streams. Chupadera and Jumanes Mesas lie to the south and east of these ranges. Pinyon-juniper woodland dominates the mesa tops and slopes, while sandy plains of rolling grasslands and sage extend to the east. There is now no permanent source of surface water in the vicinity of these mesas, although seasonal playas and springs were common prior to groundwater pumping.

Salinas sites occur in two areas, referred to as the Manzanos and Jumanos clusters. The Manzanos cluster lies in the eastern foothills of the Manzanos Mountains in the northwestern portion of the province. The Jumanos cluster lies to the south, on and east of Chupadera and Jumanes Mesas. Since our best data pertain to the Jumanos cluster, we focus our discussion on this portion of the region.

In the Jumanos cluster, although few are known, the earliest farming sites, which are pithouse villages and appear to be established before the A.D. 900s (Ice 1968, Rautman 1990, Rocek and Rautman 2007), lie at the same locations as later villages of above-ground wattle and daub, or jacal, residential structures, which are provisionally dated to the A. D. 1000s-1200s. Chamberlin (2008) has documented that in the late A.D. 1200s people living in jacal villages aggregated largely in place into plaza-oriented masonry pueblos. In the early 1400s, most of these early pueblos were abandoned, and the Jumanos cluster population nucleated into a few large villages built at the locations of some of the early pueblos (Spielmann 1996). This final nucleation of the regional population focused on lower-elevation, eastward-extending fingers of Chupadera Mesa and basins between these fingers.

Figure 5 documents this persistence of occupation across the region as a whole by displaying all recorded prehistoric architecture sites. As this map illustrates, the locations of pithouse, jacal, early pueblo and the later large village sites are fairly consistent through time. The lack of substantial numbers of early sites around Chilili, Tajique, and Quarai is likely due to a lack of systematic survey. Available information from general investigation around these large villages suggests that similar clusters of early pithouses, jacal structures, and pueblos were likely present. At the same time, within the shaded area between the large villages shown on this map, few structural sites have been recorded despite nearly 20,000 acres (> 80 sq km) of intensive survey. The few undated architectural sites that have been recorded within this area likely represent temporary use areas rather than year-round habitations. Overall, this suggests that habitation across the Salinas region was consistently concentrated in just a few locations during the agricultural occupation of the area.

*Precipitation and population in the Salinas area*

Figure 6 documents several very dry periods from the mid-1300s to the mid-1600s, yet as the demographic data in Figure 7 indicate, there were no marked population changes in the Salinas area. Thus, although the Salinas dendroclimatic data document widely spaced, dry periods of the sort that contributed to depopulation of the Mimbres region, there is no evidence that people left the Salinas area in significant numbers. Settlement reorganization within the Salinas area consisted solely of the reorganization of the local population into increasingly aggregated and finally nucleated villages, with no apparent immigration from elsewhere (Figure 7).

The tightly clustered and remarkably stable location of settlements in the Salinas area is likely due to the unique configuration of the water supply in this region. In the early twentieth century, before drilling for water had taken place, hydrogeological studies documented the presence of highly localized, perched water tables and artesian well conditions in the Quaternary alluvium east of Chupadera Mesa and the Manzanos Mountains (Meinzer 1911, Neel 1926, Spiegel 1955). Localized water tables at or near the ground surface would have sustained some crop production and domestic water supplies even through prolonged dry periods. For example, despite a severe drought in the area in the late 1890s-early 1900s, the water table in places remained at ground level and could be tapped for ditch irrigation. Likewise, the shallow water belt identified by Meinzer in 1910 was still in place during a drought from 1921-1925 (Neel 1926).

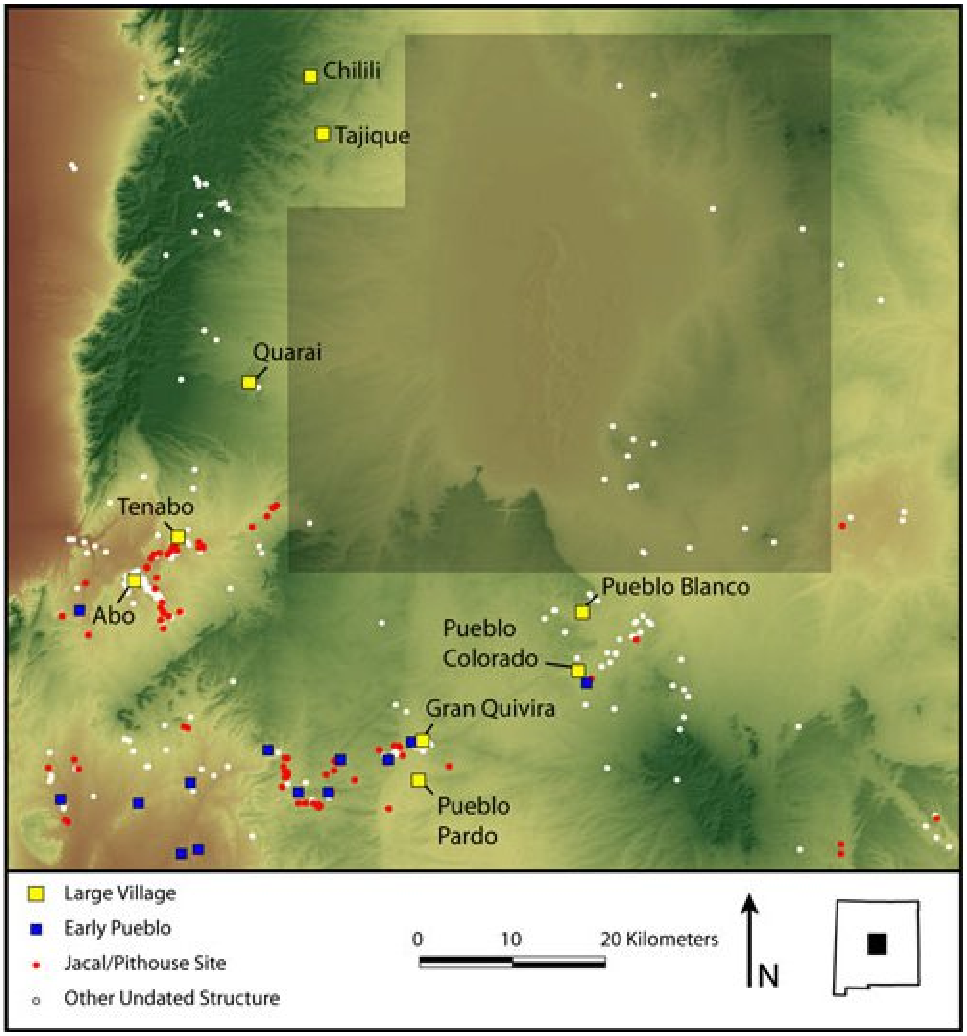
By creating highly localized, permanently productive places on the landscape, perched water tables also may have created conditions for inter-village violence, particularly during drought periods when people would have had to rely solely on those portions of the landscape that were best positioned to access the water table. The mid-1300s dry periods, for example, coincide with extensive and intense burning at two of the early pueblo sites (Rautman 1995, Rautman and Chamberlin 2008). Recurring dry conditions in the early 1400s may have in part been responsible for the final, large-scale aggregation and nucleation into Gran Quivira, Pueblo Pardo, Pueblo Colorado, and Pueblo Blanco on the lower fingers of the mesas, where water would have been more accessible.

Alternatively, this evidence of conflict may relate to defense on the part of Salinas peoples against immigrants who wished to have access to reliably watered fields. Despite the clearly favorable hydrological conditions of the Salinas area, the Jumanos population estimates reveal no marked increases from when our data begin (around the A. D. 1100s) to Spanish contact in the early 1600s (Figure 7; Peeples 2007). Thus even though large numbers of migrants moved into the Rio Grande valley, just west of the Salinas area, in the late A.D. 1200s, they either did not venture further east into the Salinas area, or were rebuffed.

## Migration’s end

Migration across the Southwestern landscape was a fairly common strategy throughout Pueblo prehistory into the 1300s, with households, village segments, and whole villages shifting settlement frequently and moving into new regions. The A.D. 1200s was a particularly active century for large-scale movements across the Southwest. Beginning in the A.D. 1300s, however, most people living in the northern Southwest limited their settlement location decisions to portions of the landscape that provided some of the most reliable sources of water for agricultural production; they then remained for centuries in those areas. Figures 8A and B document the reduction in the occupied area of the Southwest

**Fig. 5**. Jumanos sites in Salinas area. Note juxtaposition of pithouse, jacal, early pueblo and large village site locations. Source: Peeples 2009, *unpublished manuscript*.




between the AD 1100s and the 1400s. While not all well-watered portions of the Southwest were occupied by the fifteenth century, those that people selected did provide very reliable water for crop production. Having settled in areas in which food production was resilient to extremely dry periods, Pueblo farmers remained in these locations up to and through European colonization in the early 1600s. Thus, the stability of population that was possible in the Salinas area from the beginning of farming in the A.D. 800s, was achieved elsewhere by the early 1400s.

One illustration of this shift to stable water sources in the late prehistory of the Southwest comes from the Four Corners region. From A.D. 1270-1300, people living on the Colorado Plateau experienced an extended period of "*unfavorable convergences*" (Van West and Dean 2000:37; italics in original) characterized by declining water tables, entrenched stream channels, and a severe dry period. Agricultural productive capacity declined markedly. This 30-year period is situated within a longer period (A.D. 1239-1488) of unusual climate in which the dominant bimodal pattern of annual precipitation in the Four Corners area of the Colorado Plateau disintegrated (Van West and Dean 2000:35, Cordell et al. 2007). Such a dramatic change in rainfall patterns would have made decision making for many Colorado Plateau farmers

**Fig. 6**. Salinas climatic data.


extremely difficult. In part, as a consequence of these multiple challenges to agricultural production, thousands of people moved out of this area, primarily east into the Rio Grande valley. The Rio Grande valley is characterized by higher precipitation and its tributaries are more reliable perennial water sources than those in the Four Corners portion of the Colorado Plateau, and it did not experience any disruption in its precipitation regime (Ahlstrom et al. 1995, Van West and Dean 2000). Several of those immigrant Pueblo groups continue to live in the Rio Grande valley today.

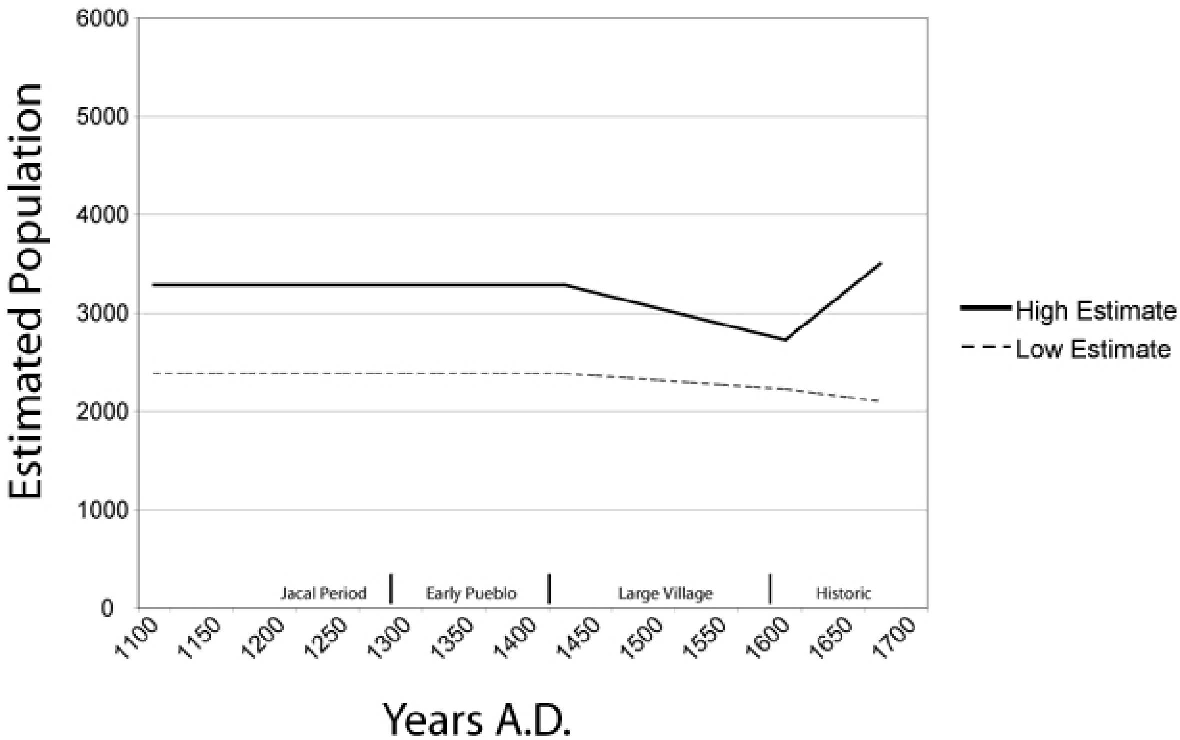
Perhaps due to the unprecedented challenges to farming on the Colorado Plateau beginning in the mid-1200s, those people who chose to remain on the Plateau selected two spring-fed and/or riverine locations with high water tables: the Hopi Mesas and Zuni. At the Hopi Mesas, dune sands lower runoff after rain and there are more permanent springs than in the surrounding areas (Brew 1979). At Zuni, farmers shifted settlement to the main drainages of the area, especially the Zuni River, with its extensive river bottomland and ready access to riverine water for irrigation (Kintigh 1985). Similarly, in the Rio Grande area, the shift to better watered locations also involved farmers moving from higher elevations to the broader, more arable floodplains of the river's tributaries (Orcutt 1991, Crown et al. 1996).

In sum, prior to A.D. 1400, Southwestern farming settlements were widely distributed across diverse environments, many of which were vulnerable to variability and change in precipitation. At the scale of the Southwestern region, however, it was generally possible to move to relatively better watered or otherwise more productive locations during a prolonged dry period. Widespread social networks (Spielmann 2000 and references therein) meant that Southwestern farmers had sufficient knowledge of the region and social relations that allowed them to move relatively freely across it, and the farming practices of Southwestern people appear to have been adaptable from one local setting to another (Orcutt 1991), making migration a viable adaptation. The Mimbres case illustrates how quickly Southwestern farmers could permanently leave a region in the face of persistently poor climate conditions.

By the early A.D. 1400s, however, for a diversity of reasons that Southwestern archaeologists continue to evaluate, Southwestern farmers chose to live in large, aggregated and often nucleated communities, frequently referred to as towns. Some have suggested this was also a period of heightened, region-wide conflict among communities (LeBlanc 1999, Rice and LeBlanc 2001, Solometo 2006). The social costs of dissolving such communities to migrate in response to a dry period would have been much greater than when farmers were more dispersed and conflict was less pervasive.

These communities selected some of the best-watered locations in the region and remained in these areas until, and after, Spanish colonization. These data thus suggest that social preferences were

**Fig. 7**. Population trends in the Salinas area. Source: Peeples 2009, *unpublished manuscript*.



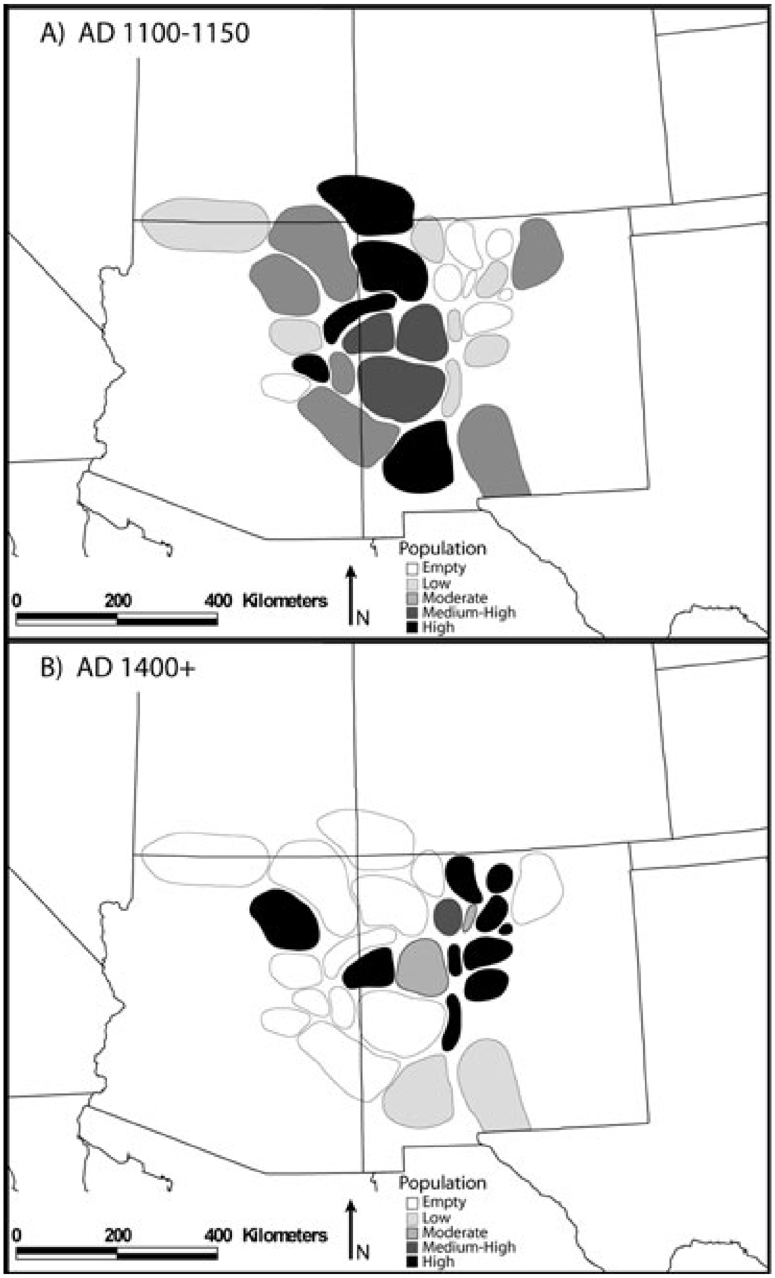

important drivers in economic decision making across Southwestern prehistory. The long-term history of migration as a Pueblo strategy for coping with dry periods was an adaptation developed by farmers who lived in villages and small hamlets and often maintained far-flung social networks. Town dwelling, however, required access to places on the landscape where vulnerability to dry periods and resource shortfall was markedly reduced and where soil fertility could be maintained. Not only were water for fields and additional labor readily available, allowing people to intensify farming in these areas through the construction of ditches for irrigation and a diversity of water control devices, but the nutrients carried by the streams that watered these fields would have replenished the soils at a scale that was not possible in upland locations. The Salinas area, being one of the few regions in which settlement location was stable well before 1400, illustrates some of the challenges to settlement stability, including inter-village conflict.

## DISCUSSION

As archaeologists, we work with data that are fragmentary, at a social scale that lies more at the community than the individual or household level, and with a temporal lens that is broad. As anthropologists, however, we seek to contribute our knowledge to address challenges that face the contemporary world. We suggest that prehistoric strategies deserve further consideration regarding their contribution to enhancing resilience in the present. Our analysis leaves us with the sense that a greater focus on household-scale storage and community-scale sharing, as well as an appreciation of the risk-managing role that subsistence agriculture continues to play, would enhance the economic security of contemporary small-scale farmers.

Storage and community sharing of resources are, in fact, adaptive strategies that contemporary small-scale farmers use to address inter-annual variability, but it appears these strategies have become very

**Fig. 8**. Population trends in the prehistoric Southwest. (A) Population concentrations A.D. 1100-1150. (B) Population concentrations after A.D. 1400. After Duff 1998; see Duff for data sources.




much secondary in risk management (e.g., Dupree and Rodel 1974, Hankins 1974, Heijnen and Kates 1974, Anyango et al. 1989, Kamau et al. 1989, Scoones 1996, Morton 2007). Back in the 1960s Allan (1965) noted that in Kenya, small-scale farming had what he referred to as a normal surplus in that by producing for what they needed in a below average year, farmers reaped a surplus for storage in better years. Today, however, there are two significant challenges to a reliance on storage: lack of surplus production and concerns over loss of stored resources.

Decreasing farm sizes (Eakin 2006, Acosta-Michlik et al. 2008) mean less land on which to produce a crop, and devoting some land to cash-cropping, which many small-scale farmers do, also moves land away from food production for family support. In a comparison of two smallholder farming communities in Mexico, for example, there is a direct correlation between the amount of land available to households, production of surplus for storage, and the use of stored corn to counteract poor harvests (Eakin 2006). Thus, one clear source of smallholder vulnerability is small land holdings (Eakin 2006).

Contemporary farmers in sub-Saharan Africa express concern about loss of stored food through insect and rodent pests, rot, and theft (Kamau et al. 1989, Morton 2007). In India, preventable post-harvest losses of food grains are estimated to be roughly 10% of the crop, a staggering amount of food in a country in which a significant proportion of the population is undernourished (Basavaraja et al. 2007). A recent survey focused on the level of post-harvest losses in wheat and rice among small-scale farmers in Karnataka implicates unsuitable storage as a factor in post-harvest grain loss. The study measured the extent of post-harvest losses at fifteen different stages from grain harvest on the farm to grain sale in retail establishments. Of these stages, the greatest loss occurred in the context of on-farm storage (Basavaraja et al. 2007), which accounted for about one-third of the farm-level loss and one-fifth to one-quarter of the total post-harvest loss. On-farm storage loss was attributed to insufficient storage capacity and poorly constructed storage containers that were susceptible to rodents, insects, and water damage. The authors of the African and the Indian studies note that more effort and resources spent by the farmer or development agencies in building more secure on-farm storage would ameliorate this problem. The fact that technological innovation has been focused almost exclusively on improvements in production rather than on storage has made a key buffering strategy that smallholder households could rely on too expensive. Small-scale farmers in some cases are now net buyers, rather than producers, of the food that they eat (Kamau et al. 1989).

In East and South Asia the nature of risk-bearing has shifted such that it is regions and states that manage storage, rather than households and communities. The Food Corporation of India, for example, is responsible for the centralized procurement, storage, and distribution of food grains, a practice that is coming under increasing scrutiny given its enormous cost and inefficiency (Kapila 2008), and the current concern as of September 2010 over the loss of large quantities of food grain due to lack of capacity in the state-level storage facilities (e.g., Devraj 2010). In response to this crisis, increasing storage capacity at multiple scales, including the household, has been advocated (Devraj 2010, Dhaliwal and Singh 2010). It would be worthwhile to analyze the relative success of more centralized organizations in comparison with household or community-scale storage at responding to the localized droughts that characterize semi-arid regions.

For small-scale agriculture to be successful in semi-arid environments farmers must adapt to both high inter-annual variability in rainfall and therefore crop production, and periodic severe, long-term drought. We infer from the analysis of centuries of agricultural production in the Pueblo Southwest that two adaptations provide resilience to the latter: migration and access to perennially watered portions of the landscape. We thus disagree with Acosta-Michlik and coauthors' (2008:540) characterization of migration as a response to "chronic adaptive failures." Tethering subsistence farmers to vulnerable places on a landscape is the adaptive failure (Nelson 1999, 2003).

Migration promotes the resilience of agricultural production at a regional scale when population densities are fairly low. In the contemporary world, however, migration from one farming location to another appears to be a viable strategy largely in frontier areas such as, for example, portions of the Amazon Basin. There is, however, global concern over the ecological impacts of rainforest clearing, which has resulted in an interest in discouraging this mobility (Barbieri and Carr 2005, de Sherbinin et al. 2008).

In the absence of new land to which to migrate, the quality of the existing land and its access to sufficient water become critical for the sustainability of smallholders. Their marginalized status, however, mitigates against such access, and land development policies can result in the conversion of fertile agricultural land to industrial use (Eakin 2006).

Without access to perennially fertile lands or to new lands through migration, farmers have developed a host of other adaptive strategies to mitigate shortfalls in crop production. This diversification of household income sources provides some resilience to perturbations in agricultural production. These strategies include part-time crafting and reliance on famine foods, strategies that were pursued in prehistory as well (e.g., Arnold 1987, Minnis 1996). The primary adaptation to variation in crop production, however, is a contemporary one: wages, from day labor jobs to remittances from wage-earning family members in urban centers. Several authors promote household diversification as a solution to the vulnerability of a farm-focused livelihood (e.g., Mortimer and Adams 2001, Tiffen 2003, Eakin 2006). In some cases, wage labor is a flexible strategy that can be increased or decreased in response to good or bad crop production cycles, in others, specialization within the household has developed such that some family members focus on farming while others, usually men, pursue wage labor.

Cash-cropping is another development that differentiates contemporary smallholders from those in prehistory. The growth in farmers' need for cash has become a driving force for change in small-scale agriculture (Raynaut 1997). Cash-cropping, however, carries its own risks including lack of access to markets, susceptibility to volatility in the market, and diminishing state support (Wisner and Mbithi 1974, Eakin 2006, Morton 2007, Acosta-Michlik and Espladon 2008, Acosta-Michlik et al. 2008, Aggarwal 2008, Eakin and Wehbe 2009). One strategy that smallholder farmers use successfully to manage the risk of cash crop failure and market fluctuations is to devote some land and labor to the production of subsistence crops for household consumption. Eakin (2006) notes, however, the disconnect between the adaptive value of this strategy among smallholders in Mexico and the Mexican government's perception that any engagement in subsistence agriculture is a sign of poverty and inefficiency. An understanding of the way in which households use subsistence production to manage risk in commercial production, and the importance of this practice for household economic stability, seems crucial.

Smallholders in the twenty-first century live in a far more politically, economically, and socially complex context than did the prehistoric farmers of the American Southwest. Nonetheless, given that a sustainable income for farmers in semi-arid areas is a challenge that was solved in the past, but one that goes unresolved in the present, the archaeological record from the Southwest can be helpful in identifying alternative strategies for adaptation. Those strategies that promoted food security in the past, namely, access to adequate and productive land, reliance on the local environmental information that farmers possess, appropriate storage technology, and diversification in income sources, including devoting some land to subsistence farming, can enhance the adaptive capacity of small-scale farmers today.

*Responses to this article can be read online at:*
*http://www.ecologyandsociety.org/vol16/iss1/art26/responses/*

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