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Legacies on the Landscape

The Enduring Effects of Long-Term Human-Ecosystem Interactions

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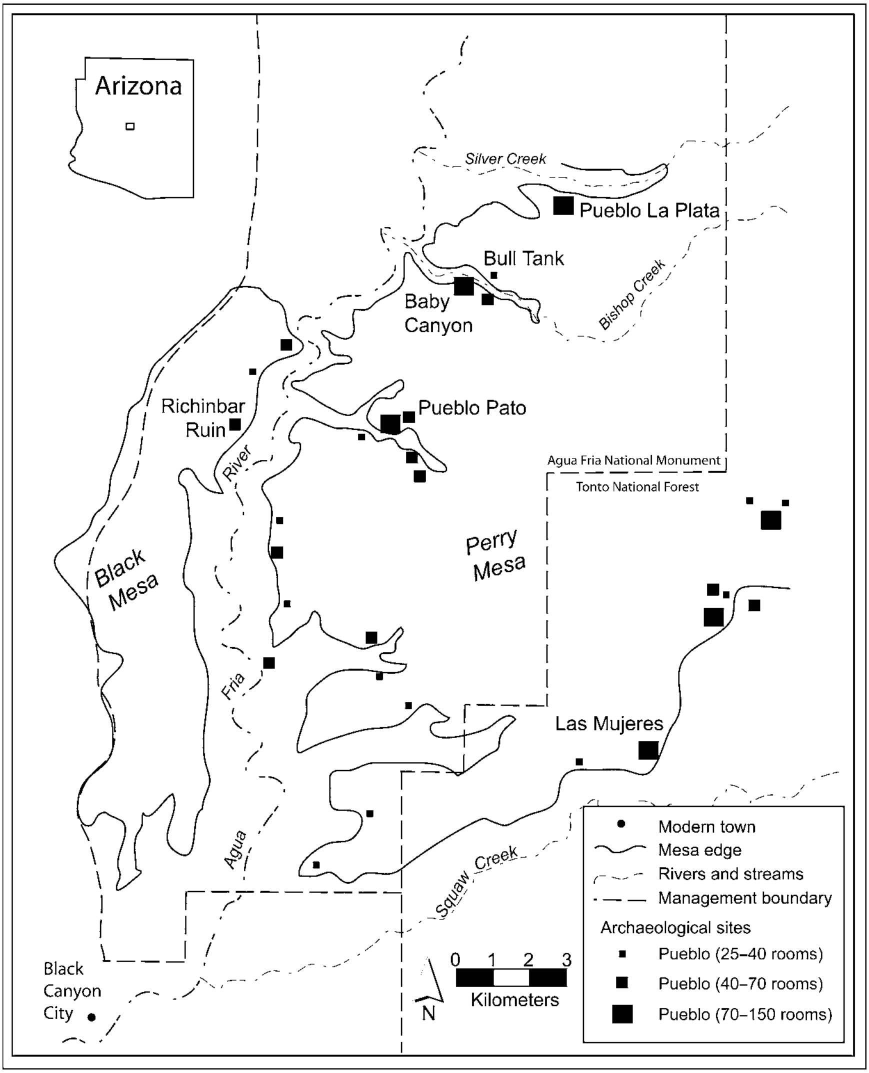
The Legacies on the Landscape Project is an ongoing collaboration between ecology and archaeology faculty, graduate, and undergraduate students at Arizona State University. The project was born out of the recognition that strongly integrated interdisciplinary research was essential for understanding human-ecosystem interactions. Our particular case study is focused on understanding the long-term legacy of prehistoric human land use on the ecology of semi-desert grasslands in the Southwestern United States.

The Legacies project is situated on Perry Mesa, primarily within Agua Fria National Monument (AFNM), fifty miles north of the Phoenix Basin in central Arizona (Figure 13.1). Semi-desert grassland covers most of the region and generally occurs on soils derived from granite, basalt, or wind-transported material. At this latitude (34° N) and altitude (3,400–3,700 feet) in Arizona, the gradient in elevation includes the southern and lower edge of the range for juniper (*Juniperus monosperma* (Engelm.) Sarg.) in the north and the northern and upper edge of the range for mesquite (*Prosopus velutina* Woot.) in the south. Cat claw acacia *(Acacia greggii* A. Gray) is also common on the mesa.

Perry Mesa is an ideal location for studying the ecological consequences of specific human actions because the landscape is characterized by a single, roughly century-long occupation of farmers in approximately the AD 1300s. Intense human impact did not



13.1. *Location of the Legacies on the Landscape Project*

recur on Perry Mesa until Anglo ranchers arrived in the mid-1870s, after the U.S. Army moved local Yavapai and Apache tribes to reservations and opened their lands to ranchers. Cattle have grazed the entire area since that time. Basque immigrants introduced sheep ranching to the area in the 1930s but have not herded sheep in the area in the past several decades. The Bureau of Land Management and the U.S. Forest Service administer the Perry Mesa landscape and regulate cattle grazing there.

Using data from Perry Mesa, we are addressing an essential question concerning the ecological implications of human action: what are the ecological and social conditions under which human land use results in long-lasting transformations of ecosystem structure and function?

IMPETUS FOR ARCHAEOLOGICAL-ECOLOGICAL RESEARCH

Interdisciplinary research that unites archaeologists and ecologists provides both fields with greater understanding concerning coupled human-natural systems. Interdisciplinary research with ecologists is critical for anthropology. Since Robert Braidwood's pioneering multidisciplinary studies in the 1950s (Braidwood and Howe 1960), archaeologists have used environmental data and, in some cases, worked with natural scientists to help to define "the environment" in terms of opportunities and constraints for adaptation. More recently, archaeologists have come to recognize that the environment is more than simply a stage upon which human action takes place, and human impacts have become a focus of archaeological inquiry (e.g., Fall, Falconer, and Lines 2002; Kohler and Matthews 1988; Lentz 2000; Leveau et al. 1999; Redman 1999; Sandor, Gersper, and Hawley 1990). Human-impact research, however, has generally lacked analyses of long-term, *recursive* human-environmental interaction and an *ecological* perspective on "impact." Anthropogenic changes are assessed at the scale of *human* needs rather than in terms of *ecosystem* structure and function.

In ecology, understanding coupled human-natural systems is critical because many landscapes that provide baseline ecological data for evaluating environmental change were structured in part by prehistoric occupations and agricultural practices. To make sense out of the observed ecological patterns on a landscape, it is imperative that we know something of the history of the processes acting to shape those patterns (Swetnam, Allen, and Betancourt 1999). An important, and often under-evaluated, aspect of virtually all landscapes is the fact that humans have been an active element of the biota (Ruddiman 2003). The global consequences of human activity are not just with us now (Vitousek et al. 1997); they have been present throughout the Holocene.

As recently as the mid-1980s, people were still treating human-landscape interactions as separate non-ecological interactions that disturbed natural ecological processes (O'Neill et al. 1986), in effect separating humans from ecosystems. In the last fifteen years, however, ecologists and archaeologists have begun to incorporate long-term interactions between human actions and ecological processes in collaborative research (Briggs et al. 2006; Bush and Colinvaux 1994; Dambrine et al. 2007; Dupouey et al. 2002; Foster et al. 2003; Heckenberger et al. 2003; Huntly et al. 2006; Sandor et al. 2007; Vitousek et al. 1997; Willis, Gillson, and Bruncic 2004; Wu and Loucks 1995). Expanding the focus of ecology to include humans as elements and often drivers of landscape processes, rather than as outside disturbers of ecological processes, has led to fundamental changes in the field of ecology (Foster et al. 2003). Some ecologists have gone so far as to assert that human influence throughout the Holocene has been so profound that this epoch should be renamed the "Anthropocene" (Ruddiman 2003).

The anthropogenic legacies that have been documented throughout the globe have shown that even relatively small changes to the environment can persist through centuries and even millennia in soils and plant communities (Bahre 1999; Caneva et al. 2003;

Dambrine et al. 2007; Delcourt and Delcourt 2004; Dupouey et al. 2002; Gomez-Pompa, Flores, and Fernandez 1990; Heckenberger et al. 2003; Myster and Pickett 1992, 1994; Sandor, Gersper, and Hawley 1990; Schaafsma and Briggs 2007; Willis, Gillson, and Bruncic 2004). Deciphering the relationship between human land use and ecosystem structure and function thus requires the time depth accessible through the archaeological record.

LEGACIES PROJECT

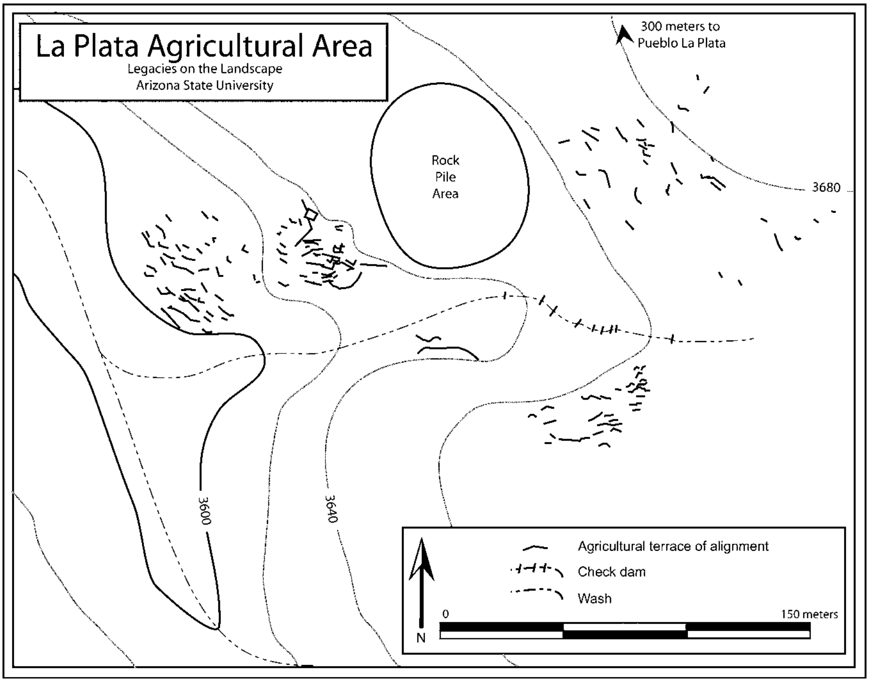
The Legacies project is designed to overcome this long history of examining landscapes from dichotomous natural or social science perspectives (Fairhead and Leach 1996; Head 2000) by focusing on the recursive relationship between human action and ecosystem-scale change. In 2003 a group of archaeologists and ecologists came together to collaborate on research concerning the long-term legacies of prehistoric farming at AFNM.

The Legacies project has focused on the Perry Mesa Archaeological District (National Register of Historic Places). A single fluorescence in population and land modification characterizes the district's prehistory. Ephemeral occupation before about AD 1280 (Ahlstrom et al. 1992:4; Wilcox and Holmlund 2007) contrasts with the subsequent fourteenth-century Perry Mesa Tradition (Stone 2000), for which over 300 archaeological sites have been recorded. These sites include many masonry pueblos of 30 to 100+ rooms, a large number of dispersed 1- to 10-room habitation sites, and petroglyph concentrations. Agricultural features are extensive and include linear soil and water control features (field borders and terraces), rock piles for agave production, as well as field areas conspicuously cleared of rocks (Fish, Moberly, and Pilles 1975; Gumerman, Weed, and Hanson 1975; Heuett and Long 1996; North 2002). Subsistence during this period focused on maize agriculture supplemented with cultivated squash and agave, and a range of wild animal species (Bohrer 1984; Douglas 1975; Fiero et al. 1980; Fish 1980; Heuett and Long 1996).

Our research is quantifying the relationship between human actions 700 years ago and ecological patterns and processes present today. As we discuss later, prehistoric activities that altered soil structure and surface rock density created persistent and measurable responses within modern plant communities. Ongoing research is evaluating the degree to which these actions resulted in long-lasting legacies in soil fertility that are still measurable in the twenty-first century (Trujillo in prep). Ongoing research by Kruse-Peeples is evaluating the degree to which these actions altered soil fertility to the point that habitation by prehistoric farmers was no longer tenable.

Agricultural Legacies

On Perry Mesa, given the relatively small size of the villages (generally $\leq$ 100 rooms), the most land-extensive human action was farming. The Legacies project thus has focused especially on the agricultural fields that are indicated by terrace systems. We began our agricultural investigations by creating a GIS database on the nature and

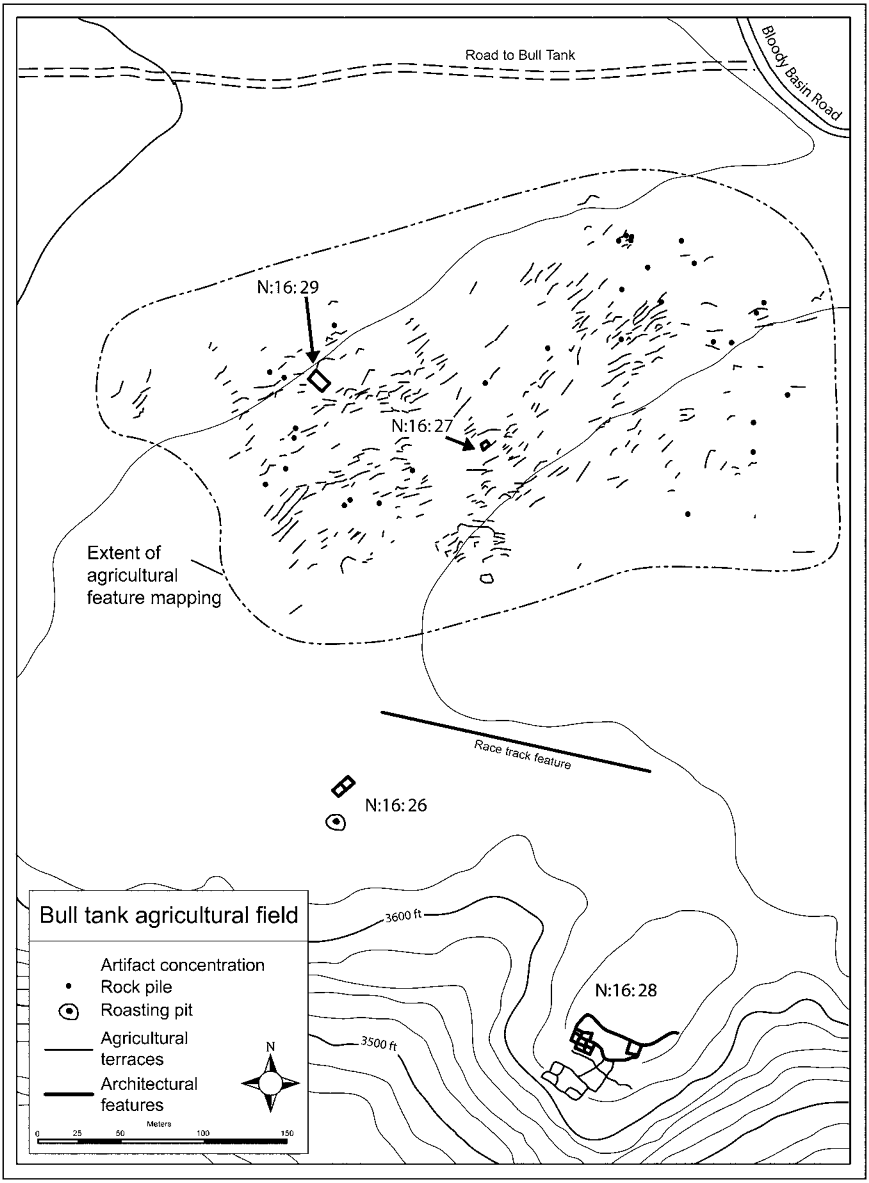


13.2. *La Plata agricultural area*

distribution of agricultural features and water management strategies on Perry Mesa. To date, this database consists of the fire history of the mesa, present and past grazing allotments, range improvements (stock ponds, water tanks, and similar improvements), soil type, elevation (DEM), prehistoric residential sites, and prehistoric agriculture features. Our work in the spring of 2005 focused on terraces near La Plata and Richinbar pueblos. In the spring and summer of 2007, we substantially increased our knowledge of the spatial scale of agricultural production on Perry Mesa through pedestrian survey and site recording around Pueblo La Plata, Pueblo Pato, and the Bull Tank area (Kruse-Peeples et al. 2009).

We surveyed an 85-hectare (210-acre) area near Pueblo La Plata (NA 11648). The largest agricultural complex we identified, called the La Plata Agricultural Area, is approximately 7 ha (17.5 acres) in size and is located 300 meters south of the main pueblo (Figure 13.2). It contains over 100 linear alignments, several check dams, and a rock pile area with a remnant agave colony. Ecological sampling was conducted in spring and summer of 2007, and analyses of these data are currently under way (Trujillo in prep).

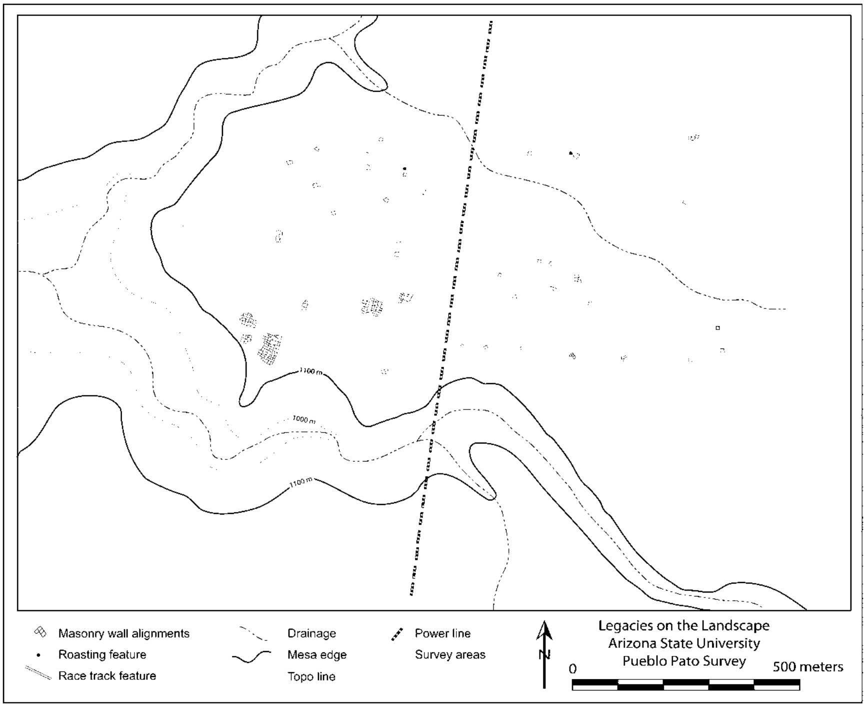
The Bull Tank Agricultural Area contains an extensive agricultural complex (Figure 13.3). Bull Tank is located across the canyon north of the 90-room Baby Canyon Pueblo (AZ N:16:45 [ASM]) and immediately northwest of (AZ N:16:28 [ASM]), a smaller roomblock overlooking Baby Canyon. To date, we have documented a field system over



13.3. *Bull Tank agricultural area*

10 ha (24.6 acres) in size, which contains over 300 agricultural features, four 1- and 2-room architectural mounds, a 12-room structure, one race track, and three roasting pits.

Finally, we surveyed a 91-hectare (225-acre) parcel around Pueblo Pato (Figure

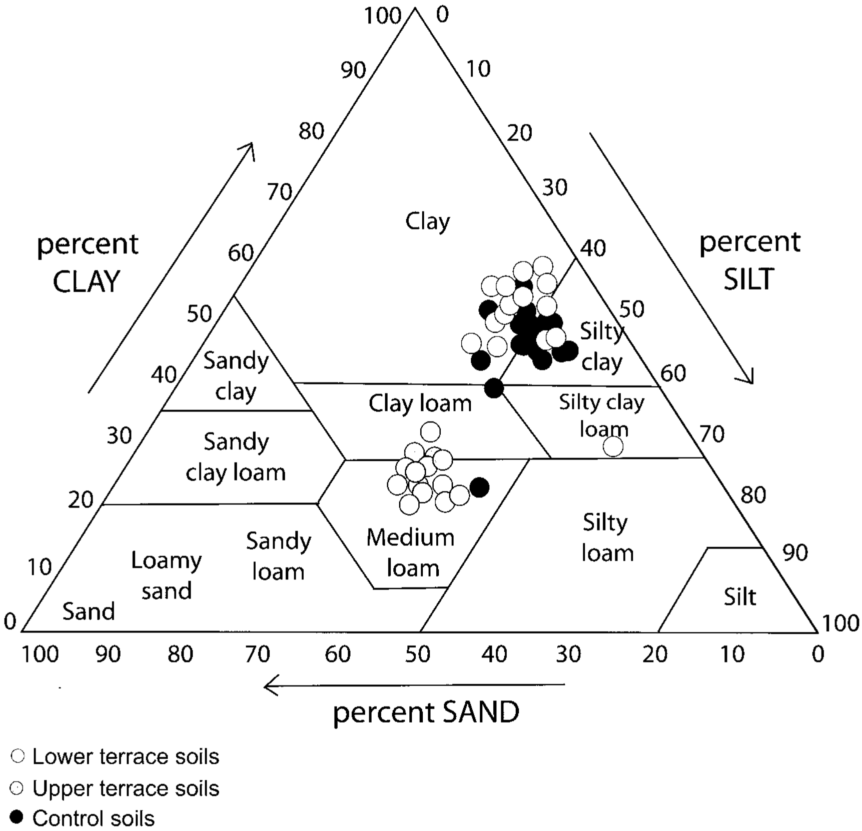


13.4. *Pato Mesa survey area*

13.4). Pato is a large village with five separate architectural mounds estimated to include at least 150 rooms. The survey identified thirty-seven separate architectural units and a nearly continuous distribution of agricultural features including terraces, check dams, and rock pile clusters throughout the survey area. We are currently preparing complete documentation of the agricultural landscape and architectural features near Pueblo Pato.

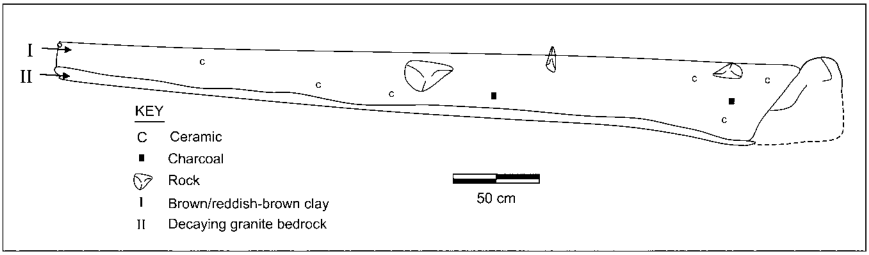
We have focused our ecological measurements on the agricultural fields we have mapped across the mesa. Much of the soil covering the surface of Perry Mesa is derived from wind-blown dust or basalt and thus contains a high silt and clay fraction. The secondary soils on the mesa are derived from granite and are high in the sand fraction. An agriculturalist in the agriculturally marginal environment of Perry Mesa would need to select the best soils possible for successful gardening. Soil texture influences the capacity of soils to retain water, the primary limiting resource to ecological processes in arid and semiarid landscapes. Soil classified as loam (containing about 50 percent sand, 30 percent silt, and 20 percent clay) in the U.S. Department of Agriculture soil classification schema is considered more desirable for agriculture than clay or sand (Figure 13.5).

The 2005 pilot study on the terrace soils at Richinbar Ruin and La Plata found that the soil textures on terraces, in most cases, are loamier than the surrounding soils regardless of the parent materials (Kruse-Peeples et al. 2010). To evaluate the degree to which



13.5. *Soil texture from Bull Tank terraces and off-field (non-terrace) "control" areas*

soil texture enhancement characterizes an entire field, in 2007 we collected soil texture data from well-constructed terraces near the top of the slope within the Bull Tank field system and from minimally constructed terraces near the bottom of the slope. For example, lower terraces in a field would receive water but perhaps not as great an influx of new sediments compared with terraces near the slope shoulder. It is also possible that the lower, less carefully constructed alignments were added later; thus farmers would have had less time to manipulate soil characteristics. We found that the upper terraces within the Bull Tank agricultural field are loamier in texture than the control, off-terrace soils, similar to patterns found at La Plata and Richinbar terraces (Figure 13.5). The lower terrace soils, however, are indistinguishable in texture from "off-field" non-terraced controls. These data suggest that soils on upper terraces were better places for growing maize than lower terraces and that modern ecological legacies left from this textural modification may be related to water retention and availability. Kruse-Peeples and colleagues (2010) speculate that the primary method prehistoric farmers used to change the textures of the soil in agricultural fields consisted of regulating the flow of



13.6. *Profile of trench excavated in a Richinbar terrace showing midden fill*

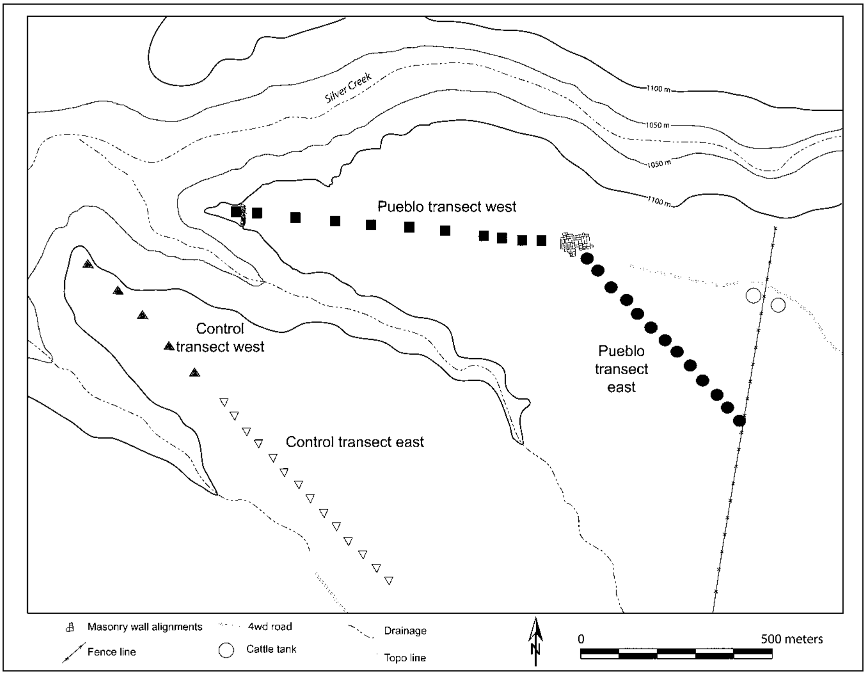
water across terraces such that sandier or clayier sediments would be deposited, depending on what was necessary to increase the loaminess of the soil. How all this might have been accomplished, however, is still unknown.

A second method of preparing terrace soils was discovered on the terraces at Richinbar Pueblo. There, terraces constructed close to the top of the slope had little chance of collecting sediments washed in from above the terraces. People living at Richinbar thus filled the terraces with thirty cm of dark midden deposits on top of bedrock capped by a thin A horizon (Figure 13.6). While it is not likely that many terraces were amended in this way, it is notable that these soils had to have been carried there specifically to fill the area behind the terrace wall.

Architectural Legacies

Although the most spatially extensive ecological transformations to the Perry Mesa landscape involve agricultural production, the construction of a series of relatively large masonry pueblos also had an effect on ecosystem structure. During our first field season in 2004, we examined a suite of ecological and archaeological variables at 100-meter intervals along two transects radiating out from Pueblo La Plata and a third "control" transect on an adjacent finger of Perry Mesa where far less evidence of residential occupation is present (Figure 13.7). These data document a rock-depleted "donut" around the pueblo, probably because of room building, and a significant correlation between density of rocks and woody vegetation (Briggs et al. 2006). Specifically, areas cleared of stones support lower densities of woody plants on the landscape, but areas where stones were concentrated, such as within the rubble mounds of the pueblos, support higher densities of woody individuals. Variability in woody plant cover appears to be a long-term biotic response to this anthropogenic alteration. We speculate that the lower density of woody plants near the pueblo is a result of increased fire exposure in rock-cleared areas of the landscape. Fires may burn more thoroughly in areas where rocks were removed uniformly, whereas areas that still have many rocks may create a patchy fire mosaic that will not burn as hot (Briggs et al. 2006).

We also collected data on the density and community composition of herbaceous plants along the transects at Pueblo La Plata. Ordination analysis shows that the herbaceous communities differ from each other in composition (Figure 13.8). Species

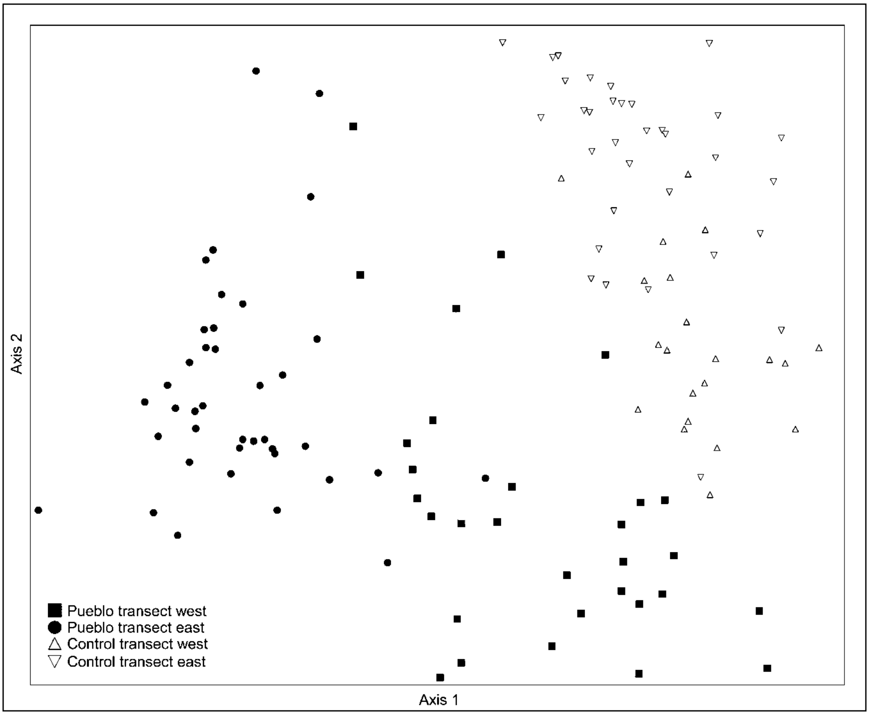


13.7. *2004 data collection transects from Pueblo La Plata and on the "control" mesa*

richness and diversity near the pueblo are lower than in the "control" area (twenty-one species near the pueblo compared with twenty-nine species in the control area), and areas near the pueblo have a lower Shannon-Weaver diversity index score compared with control areas (1.5 versus 2.2, respectively). These numbers suggest that, as found elsewhere in the Southwest (Schaafsma and Briggs 2007), areas containing prehistoric legacies of human actions tend to support lower species diversity. These data parallel prior studies of plant communities on and off the agricultural terraces at La Plata and Richinbar pueblos (Kruse-Peeples et al. 2010), where herbaceous communities on the terraces were more similar to each other and had fewer species than the communities in off-terrace locations.

Legacies of Plant Introduction, Manipulation, or Both

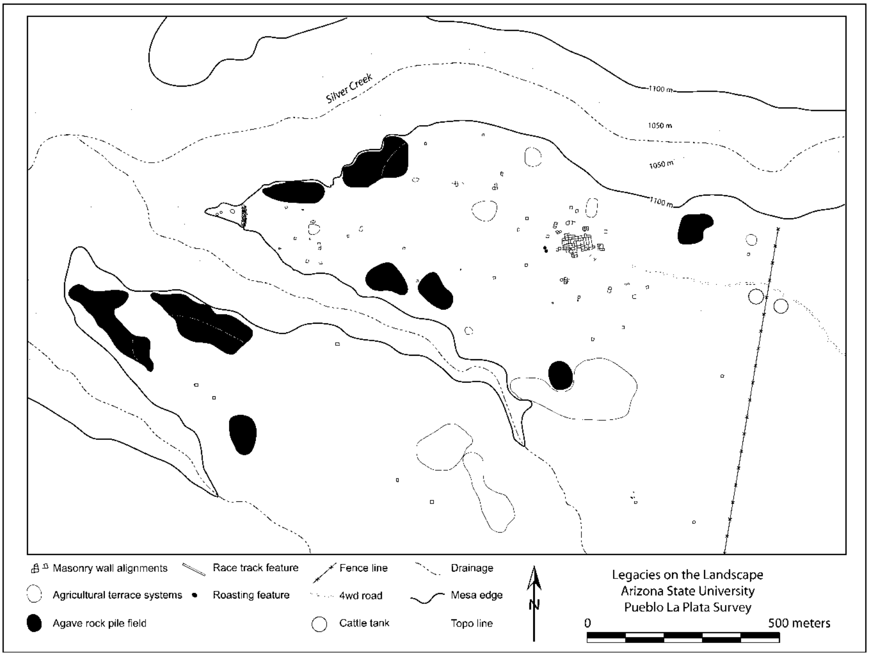
A third form of legacy we have documented on Perry Mesa is the contemporary presence of agave in former agave fields near Pueblo La Plata (Figure 13.9). Agave are also concentrated around Richinbar and Pato pueblos, although they are growing in naturally broken rock along the edge of the mesa rather than in association with anthropogenic rock pile fields, as is the case at La Plata. To explore the genetics and morphology of agave associated with the pueblos on Perry Mesa, we measured leaf attributes of agave plants at all three pueblos. Preliminary data from Wendy Hodgson at the Desert



13.8. *Ordination plot of 2005 herbaceous communities on the pueblo and "control" transects. Ordination plot shows a difference between the herbaceous plant communities on the pueblo and control transects*

Botanical Garden and colleagues of hers at the University of Georgia suggest that these plants are hybrids, a cross between *Agave chrysantha* and *Agave parryi*. We are continuing to map agave on the mesa to determine whether the correlation between agave distribution and large habitation sites is as strong as it currently appears, as well as to evaluate if and how prehistoric peoples manipulated the genetics of agaves in the area. It is possible that the hybrid varieties observable today are a direct result of prehistoric manipulation of agaves for improved palatability, productivity, or other economic uses.

Kathleen Parker and colleagues (2007) recently reported that the modern-day pattern of genetic variation in Southwestern agaves is in keeping with farming practices aimed at maintaining diverse genotypes within fields. Southwestern agave still exhibit less genetic variation, however, than is expected from natural agave populations. They infer from this level of variation that prehistoric people in the Southwest were moving agave varieties around the landscape, thereby homogenizing the distribution to some extent. Parker and colleagues (2007) also report that a modern population of two different agave cultigens reflects the dynamics of prehistoric human population movements and exchange, which have contributed to a fine-scale mosaic of genetic variation rather than a pattern of clear regional differentiation—a mosaic still evident many centuries



13.9. *Agave fields near Pueblo La Plata*

later. It is hoped that with more data from the agaves on Perry Mesa, we can determine if human actions hundreds of years ago directly influenced the agaves currently growing on the landscape.

CONCLUSIONS

Through a diversity of analyses, the Legacies project is engaging the question of whether humans were drivers of landscape processes on Perry Mesa 700 years ago. The people who began moving onto Perry Mesa in the late 1200s were corn farmers. However, Perry Mesa's arid climate and clayey soils would have presented challenges to people whose diet depended on corn. In response to these challenges, Perry Mesa farmers constructed rock alignments and terraces that captured both precipitation and sediment. These sediments may have transformed the soils from clayey to more loamy textures over time. Ongoing studies by Kruse-Peeples will determine whether these textures resulted from the prehistoric use of the terraces or through centuries of sediment capture since the terraces were abandoned.

Agricultural terraces are distributed widely across the Perry Mesa landscape, possibly a function of both ecological and social conditions. For example, land with sufficient slope to capture runoff but not steep enough to erode fields is distributed patchily across the mesa (Kruse 2007). In addition, the large villages of Perry Mesa are spaced evenly around the edge of the mesa rather than concentrated in one place. Whether this configuration of settlements is a result of social divisions, conflict, a balance between village size and the amount of locally available arable land, or some combination is not known. However, Kruse (2007) demonstrated that the locations of the largest villages coincide with the largest patches of arable land on the mesa. Given the accretional growth of these pueblos (Hoogendyk 2009; Mapes 2005; Schollmeyer 2004, 2005), people may have initially lived in small villages, some of which grew as new immigrants joined those villages that had sufficient land to absorb them. Improving our knowledge of Perry Mesa settlement growth will require more fine-grained chronological control than is currently available. As it stands now, it is not possible to divide the Perry Mesa occupation of the fourteenth century into smaller temporal divisions.

In the absence of suitable building materials other than rock, these larger villages required the accumulation of a fair number of rocks to construct residences. The fact that the rocks were taken from directly around the pueblos resulted in large, cleared areas, which we hypothesize created a different fire regime than most of the rocky mesa and thus affected the distribution of woody plants on the landscape. Similarly, we found a strong correlation between the abundance of agave stands and human habitation, implying an anthropogenic driver of agave distribution on Perry Mesa. However, we have not yet addressed the larger-scale ecological implications of these patterns in woody plant and agave cover, nor do we fully understand their social drivers. Was corn insufficiently productive that another, reliable carbohydrate resource was necessary to supplement it (Spielmann 1998), or was agave a fundamental part of the cuisine of the people who migrated to Perry Mesa? Or were both the case? Finally, the durability of rock and the effects of rocks on soil texture and water retention in this arid ecosystem suggest that rock movement by humans has resulted in long-lasting ecological legacies that have continued since the first construction of terraces and villages several centuries ago.

The likely landscape-scale result of the human actions that took place 700 years ago is a more fragmented and therefore patchier landscape, with patch dynamics that differ from what would have been the case in the absence of people farming. This altered patchiness persists and affects the landscape today. Overall ecosystem production is higher in a heterogeneous (patchier) system compared with that in a homogeneous system, especially in water-limited ecosystems (Aguiar and Sala 1999). The differences, albeit subtle, have implications for ecosystem structure (patchiness) and function (productivity and soil processes).

The farmers who migrated to Perry Mesa did not stay more than a few generations. What led them to leave remains a matter of debate. The causes may have been social, including external or internal conflict, or the mesa's relative isolation from more populated parts of the Southwest. However, they may also have been ecological. Was corn farming sustainable based on available nutrients in soil and sediments captured by the terraces, and did the climate remain suitable for farming? These topics are currently under investigation (Ingram 2009; Trujillo in prep).

Perry Mesa is one research location within a larger comparative study of enduring agricultural legacies in the southwestern United States that also includes the Cave Creek area in the northern Phoenix Basin (Schaafsma and Briggs 2007). The shorter-term dry farming practiced on Perry Mesa stands in contrast to the longer-term irrigation agriculture evident in the Cave Creek area. Such comparative studies are important because we know from research on modern agricultural systems that the type of agricultural practice and even the timing and amendments within a farming method result in significantly different ecological outcomes (Gregory, Shea, and Bakko 2005; Robertson, Paul, and Harwood 2000). Furthermore, the effects of current agricultural practices differ depending on climatic and soil factors that influence ecosystem dynamics (Ogle, Breidt, and Paustian 2005). Given this understanding, we cannot expect prehistoric land-use activities to be equal in their long-term impacts. Some landscapes may be more resilient to perturbation than others, and the ecosystem effects of human actions may effectively "disappear" from the ecological canvas over time, while in other contexts or other land uses, human-induced ecological transformations may endure for millennia.

To conclude, while the ecological literature clearly shows that the legacies of disturbance likely differ depending on vegetation type, population dynamics, and speed of nutrient cycling through ecosystems, only a few studies have focused on the long-term ecological legacies of human action in slow-growing, arid land systems that take centuries or more to develop (Briggs et al. 2006). The Southwest thus provides an ideal context to undertake interdisciplinary research that contributes to an emerging literature on long-term human legacies (Gilson and Willis 2004; Sanford and Horn 2000; Vitousek et al. 2004).

ACKNOWLEDGMENTS

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