Why ecology needs archaeologists and archaeology needs ecologists

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Over the past five decades, ecologists and archaeologists have dismantled two longstanding theoretical constructs. Ecologists have rejected the "balance of nature" concept and archaeologists have dispelled the myth that indigenous people were "in harmony with nature". Rejection of these concepts poses critical challenges to both fields as current disciplinary approaches are inadequate to grapple effectively with real-world complexities of socioecological systems. In this review, we focus on the relationship between human action and ecosystem change by examining some of the long-term impacts of prehistoric agriculture. Using an interdisciplinary approach, we present results from two studies that suggest that even relatively non-intensive and short-term agriculture can transform ecological systems for a very long time. It is therefore imperative that ecologists and archaeologists work more closely together, creating a truly cross-disciplinary alliance that will help to advance the fields of archaeology and ecology.

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Over the past 50 years, ecologists, archaeologists, and other scientists have dismantled two deep-seated theoretical constructs. Ecologists have rejected the "balance of nature" concept and now view ecosystem development as an interaction between persistent ecological processes and possible historical events, including human action (Wu and Loucks 1995; Scheffer *et al*. 2001). Similarly, archaeologists have dispelled the myth that indigenous people were "in harmony with nature", based on an accumulation of evidence suggesting that humans substantially altered and often degraded their environments for millennia prior to European settlement (Bottema *et al*. 1990; Butzer 1996; Redman 1999; McIntosh *et al*. 2000; Mann 2005). The dismissal of these constructs presents challenges to both natural and social scientists as current disciplinary approaches are unable to handle real-world complexities of socioecological systems. We contend that strongly integrated interdisciplinary research is essential for understanding human–ecosystem interactions.

Collaborative research between ecologists and archaeologists can expand our understanding of ecology in a number of ways. First, archaeologists can provide ecologists with a long-term view of human land use. Although ecologists know that ecosystem structure and function may take decades or centuries to fully respond to disturbance, most ecological studies examine ecosystem dynamics over a few days to a few years. Rare, centennial-scale studies have suggested that some human impacts are enduring, but few integrative ecological studies of human land use cover time scales longer than 200 years (Turner 1985; Foster *et al*. 2003; Heckenberger *et al*. 2003). Deciphering the relationship between human land use and ecosystem structure and function requires the time depth accessible through the archaeological record. Second, a deeper understanding of coupled human–natural systems can show that "pristine" environments that provide the ecological baselines for studies of environmental change were partly structured by past anthropogenic alteration (Bayliss-Smith 2003; Heckenberger *et al*. 2003; Gilson and Willis 2004). Third, biologists have historically viewed "impact" as a straightforward product of human land use, without addressing the social dynamics that lead humans to alter the landscape in diverse ways. People make decisions not only in response to the physical environment, but also in relation to social conditions, such as kinship, ideology, and perceptions of threat and scarcity (Petterson 1988; Bollig and Schulte 1999). To better understand human–environmental relations, we must therefore document both the choices that people made and the factors that influenced those choices (van der Leeuw 1998; Collins *et al*. 2000). Finally, a long time scale combined with a sophisticated understanding of the economic, social, and political drivers of land use can provide ecologists with an unprecedented ability to model human–environment interactions as a complex, dynamic system.

Interdisciplinary research with ecologists is equally critical for anthropology. Since the 1950s, with Braidwood and Howe's (1960) and MacNeish's (1974) pioneering multidisciplinary research on the origins of agriculture in the Near East and Mesoamerica, respectively, archaeological use of environmental data has become commonplace. Archaeologists often work with natural scientists when

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attempting to reconstruct "the" prehistoric environment. However, these reconstructions are usually focused not on ecosystems but on factors that are of economic importance to humans. More recently, archaeologists have come to recognize that the environment is more than simply a stage upon which human action takes place, so that human impacts have become a focus of archaeological inquiry (Kohler and Matthews 1988; Sandor *et al.* 1990; Redman 1999; Fall *et al.* 2002; Hayashida 2005). However, these studies lack analyses of long-term, recursive human–environmental interaction and an ecological perspective on "impacts". Anthropogenic changes are assessed at the scale of human needs, rather than in terms of ecosystem structure and function.

Our project is situated within a growing, global research interest in the long-term ecological changes that have been wrought by human actions. To this point, most of this research has either looked from the present to the past, acknowledging historical change (eg Fairhead and Leach 1996; Head 2000) or, particularly in the Americas, has made the case that humans had substantially altered landscapes prior to European contact especially with regard to their agricultural practices (WebTable 1; Delcourt 1987; Doolittle 2000; Lentz 2000; Delcourt and Delcourt 2004). It is extremely rare, however, for the gap to be bridged between an ecological understanding of contemporary landscapes and archaeological knowledge of the long-term history of human use of those landscapes. Collaborative research between archaeologists and ecologists, with an explicit focus on documenting the long-term processes that led to the contemporary landscape, remains uncommon, although research in Amazonia is an important exception (eg Heckenberger *et al.* 2003; Mann 2005).

In the American Southwest, where our research is focused, there is a history of joint research between archaeologists and soil scientists in the context of archaeological projects. This work has revealed that prehistoric farming has had persistent effects on modern soils (Homburg and Sandor 1997; Homburg *et al.* 2004), and has shown (though not quantified) differences between the modern vegetation growing in former agricultural fields and off-field vegetation (eg Fish *et al.* 2004). The results of these studies are largely published in the archaeological reports on the project that produced them (eg Homburg and Ciolek-Torrello 1997; Doolittle and Neely 2004) or in other archaeological publications (eg Homburg *et al.* 2005), although some of this research does appear in agronomy journals (eg Sandor and Gersper 1988; Sandor and Esch 1991).

In this paper we combine vegetation and soil data to evaluate the persistence of agricultural legacies through a case study that examines long-term impacts of prehistoric agriculture on the modern-day landscape of southwestern North America. In the Southwest, prehistoric refers to the period prior to the Spanish invasion, ie before 1539. Our case study contributes to an emerging literature that promotes an interdisciplinary approach to ecology and archaeology (see Sanford and Horn 2000; Gillson and Willis 2004; Vitousek *et al.* 2004).

Our focus is on the long-term effects of prehistoric agriculture in two arid areas of the American Southwest: (1) Cave Creek, on the northern periphery of the Phoenix Basin in central Arizona, where the Hohokam people (see below) developed an extensive irrigation system, and (2) Perry Mesa, in the canyon and mesa country north of the Phoenix Basin, where only dry farming was possible. Our findings support the argument that, in both cases, the cumulative effect of prehistoric agriculture was a permanent transformation of local ecosystem structure and function. Additionally, in both cases these impacts on the ecosystem still exist today, in spite of historic cattle and sheep grazing.

The Hohokam of the Southwest

The Hohokam people of central and southern Arizona lived in the Phoenix Basin for a millennium or more, ending in the AD 1400s (Redman 1999; Bayman 2001). The centerpiece of Hohokam agriculture along the Salt and Gila Rivers was their extensive irrigation system, which included hundreds of kilometers of canals, some as long as 30 km. At our Cave Creek study site, we report on how Hohokam canal building along a small drainage unit of Cave Creek still impacts vegetation nearly 700 years later.

Cave Creek

The Cave Creek study area is within the northern Phoenix Basin of central Arizona. The Cave Creek watershed begins in the New River Mountains to the north and drains out of the mountains across the bajadas, finally merging with the Salt River. The region shows evidence of prehistoric agricultural fields, cultivated from about AD 800–1200 (Schaafsma and Briggs in press). Cotton, corn, beans, squash, tobacco, and numerous herbaceous plants were cultivated in a series of fields along Cave Creek. These fields were abandoned by the Hohokam some time between AD 1200 and 1250. They have not been farmed for approximately 750–800 years, although the area has been grazed during the past 150 years or so by domestic cattle and sheep. Agricultural features, including rock alignments, rock clusters, check-dams (small, temporary stone dams across natural or man-made channels), ditches, and canals define the fields. The rock alignments are the most prominent feature of the fields, ranging in length from 5–140 m (Schaafsma and Briggs in press; Figure 1).

Cave Creek methods

The vegetation and soils in Cave Creek are typical of the Lower Sonoran Desert. To assess the effects of Hohokam agriculture on present day vegetation, percent plant cover was measured in 150 0.25 m^2 quadrats in three agricultural fields (50 quadrats in each field). For comparison, an

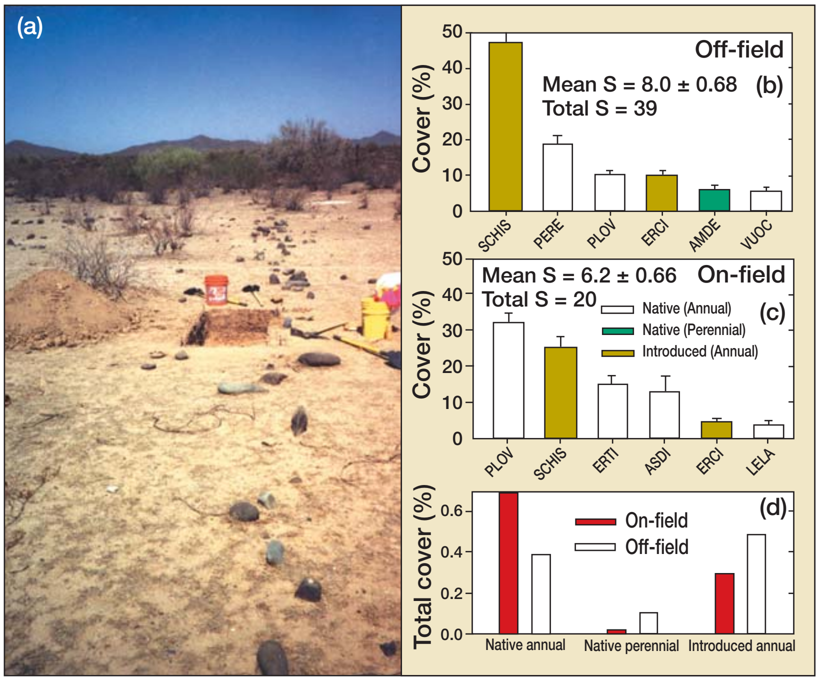

Figure 1. *(a) One of the prehistoric agricultural fields at Cave Creek during the dry season, showing rock alignments (the remnants of a Hohokam water control feature for an irrigation canal) and location of one of the soils pits dug for pollen extraction. (b, c) The average cover and standard error (vertical error bars) of the six dominant species composition in 0.25 m^2 quadrats located on and off prehistoric agricultural fields at Cave Creek. (d) The growth form and origin (native versus introduced) of the vegetation in 0.25 m^2 quadrats placed on and off prehistoric agricultural fields at Cave Creek, expressed as percentage of total cover. Note that while native annual vegetation on and off the fields are almost identical, the percentage of introduced annual vegetation was higher on the prehistoric fields than in adjacent off-field areas. (Mean S = mean species richness of 0.25 m^2 quadrats; Total S = total species richness. SCHI =* Schismus sp*, PERE =* Pectocarya recurvata*, PLOV =* Plantago ovata*, ERCI =* Erodium cicutarium*, AMDE =* Ambrosia deltoidea*, VUOC =* Festuca octoflora*, ERTE =* Erodium texanum*, ASDI =* Astragalus didymocarpus *and LELA =* Lepidium lasiocarpum*.)*

equal number of quadrats (150) were sampled off the fields, but within 100 m of them. The cover of woody vegetation and cacti was determined using the point-quarter measurement on the three agricultural fields and on three transects in topographically similar off-field locations.

We also collected soil samples from the field and off-field locations. Ten off-field samples were taken at a depth of 0–5 cm and two were collected from trench sidewalls, one each from 50–60 cm and 60–70 cm depth. Ten on-field samples were collected from 0–5 cm in depth and four were collected from trench sidewalls at depths of 5–15 cm, 20–30 cm, 50–-60 cm, and 60–70 cm. The hydrometer method was used to assess soil texture (Blake 1965). This method quantitatively determines the physical proportions of three sizes of primary soil particles as determined by their settling rates in an aqueous solution using a hydrometer device. Subsamples of finely ground, oven-dried soil (60° C) were analyzed for total organic carbon (C) and nitrogen (N) by coupled combustion-gas chromatography on a Carlo-Erba NA 1500 autoanalyzer (Calo-Erba Instruments, Milan, Italy), following pretreatment with 1molar hydrochloric acid to remove inorganic carbonates.

We collected pollen samples to determine the dominant vegetation that existed both prior to cultivation (ie earlier than AD 800) and during the time the fields were under cultivation. We were particularly interested in the presence of any domestic plants (eg maize). Pollen was collected from seven 1 x 2 m excavated trenches placed on and off the fields (Figure 1). Samples were sent to the Laboratory of Paleoecology, Northern Arizona University in Flagstaff, AZ, for pollen extraction and subsequently sent to Archaeological Consulting Services in Tempe, AZ for pollen identification.

Cave Creek results

At Cave Creek, we found almost twice as many plant species growing in the off-field sites (39) as in the on-fields sites (20), with an average of 8.0 (± 0.68) species found per quadrat on the off-field sites and 6.2 (± 0.66) species per quadrat in on-field sites. Additionally, the percent cover of introduced annuals and perennial plants was lower on the abandoned fields, and there were more native annuals on- as opposed to off-fields (Figure 1).

Woody and cacti vegetation communities were also noticeably different in Cave Creek abandoned agricultural fields. *Larrea tridentata* was the only woody or cactus species censused on the fields, while off-field locations had seven species, with the dominant species being *Ambrosia deltoidea*. The seven species consisted of three woody shrubs species (*A deltoidea*, *L tridentata*, and *Ziziphus obtusifolia*), and four cacti (*Opuntia acanthocarpa, Ferocatus wislizenii, O versicolor,* and *Mammillaria microcarpa;* Figure 2). There were also significant differences in the spatial configuration of *L tridentata* off and on the fields. Individual *L tridentata* shrubs off the fields were significantly larger than those on the fields (1.9 m ± 0.9 m vs 1.3 m ± 0.5 m, respectively; $t = 2.8$, $P = 0.005$). *L tridentata* individuals were also significantly further apart on the fields than off the fields, (4.9 m ± 2.8 m vs 2.0 m ± 1.8 m, respectively; $t = 5.1$, $P < 0.001$).

Cave Creek agriculture appears to have altered the soil texture as well. Soils on the abandoned prehistoric agricultural fields are on average 32% sand, 45% silt, and 23% clay, while the soils off the fields consist of an average of 69% sand and only 18% silt and 13% clay. The chemical composition of the soils was also different. The total percentage of N in the soils is significantly greater on-fields than off-fields (0.057% ± 0.003% and 0.048% ± 0.007%, respectively; Kruskal–Wallis test $x^2 = 5.7$, $P = 0.002$) as was the total percentage of C (0. 44% ± 0.033% and 0.34% ± 0.079%, respectively; Kruskal–Wallis test x^2 = 7.6, P = 0.006).

Thirty-six different genera were identified in the pollen record, but most could not be identified to the species level and some only to the family level. Here, we present only the 12 dominant types (Table 1). Pollen of *L tridentata* had the greatest difference in percentages between the on- and off-field locations, composing only 2.8% of the prehistoric abandoned agricultural field pollen, but making up 8.3% of the off-field pollen. The only true domesticated species recovered during this study, *Zea mays*, was found exclusively in the prehistoric abandoned agricultural field soils, with one exception being a sample from 10 cm below anthropogenic field soils. Plants that have been identified as "partially domesticated" by the Hohokam showed a trend towards an increase during the cultivation time period, but this was not statistically significant. However, these numbers, include both *Chenopodium* and *Amaranthus* genera, which are known to have widely dispersed pollen.

Perry Mesa

Our other research site, Perry Mesa, lies within Agua Fria National Monument (AFNM) about 80 km north of the Phoenix Basin (Figure 3a). This desert grassland and riparian ecosystem experienced a sizeable agricultural occupation sometime around AD 1300 (Wilcox *et al*. 2001). Livestock grazing has occurred on the site since the mid-1800s. Semiarid grassland covers most of the region at present, and soils are generally basalt and granite derived.

The primary prehistoric occupation of Perry Mesa probably lasted less than 100 years, and so overlapped the late end of the interval of Hohokam occupation further south. Our research area lies within the Perry Mesa Archaeological District, in which over 300 sites, including many large masonry pueblos with 30 to over 100 rooms, numerous dispersed 1–10 room hamlets, and petroglyph concentrations, are documented. Dryland agricultural features are extensive, and include linear soil and water control features (field borders and terraces; Figure 3c), rock piles for agave production, and field areas conspicuously cleared of rocks.

At one of these sites, Pueblo La Plata (circa 100 rooms), we have gathered data concerning the relationships between prehistoric farming and contemporary soil properties and plant distributions. Wall bonding and abutting data acquired from our team's recent mapping project indicate that the pueblo grew from a small core by the periodic addition of 4–6 room units (Mapes 2005).

To assess the impact of this occupation on the landscape, we assumed that the intensity of prehistoric human action would have decreased with increasing distance from the pueblo. Thus, we established a 500 m transect originating from the edge of the pueblo (pueblo transect). Another transect (control transect) was established with the same orientation, on a mesa approximately 1 km to the south, to provide complementary data from a similar

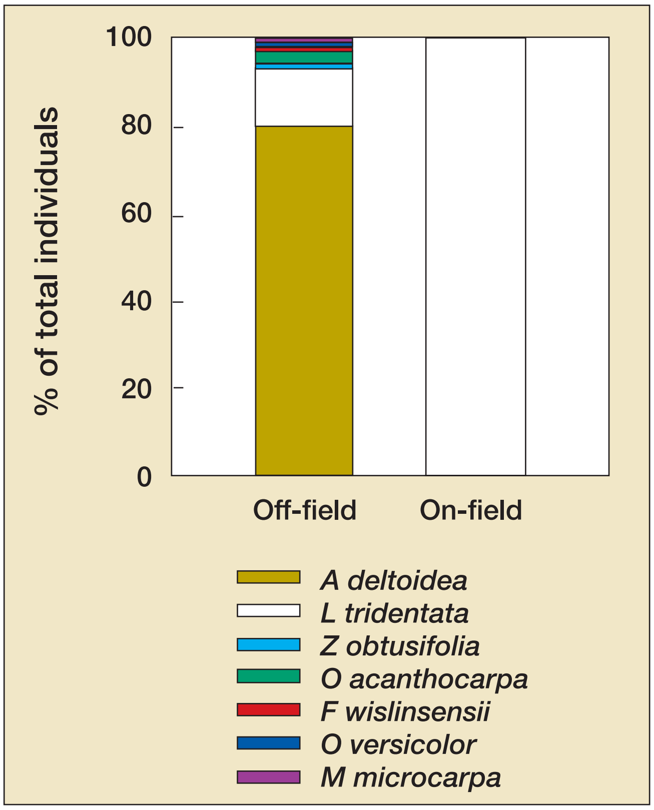

Figure 2. *The percentage of woody vegetation on and off prehistoric agricultural fields at Cave Creek, as measured using the point-quarter method. Note that on the fields only one species (*L tridentata*) was present, while in adjacent areas, seven species were found. (Species in order of mention:* Ambrosia deltoidea, L tridentate, Ziziphus obstusifolia, Opuntia acanthocarpa, Ferocatus wislizenii, O versicolor, Mammillaria microcarpa.*)*

environmental setting with less prehistoric human activity. Archaeological and ecological data collection was centered on points spaced at 50 m intervals along each of the transects. For each point we counted all artifacts (ceramics and chipped stone) and estimated the percentage of rock cover in three 1 m^2 quadrats (spaced 5 m apart on a line perpendicular to the transect). The size and number of all woody plants were recorded in a 10 x 15 m^2 area centered on each of the transect points.

Agricultural terraces were located and mapped near Pueblo La Plata and two other large pueblos. Herbaceous species composition of these fields was measured in the spring of 2005. Soil nutrient data (C and N) were obtained using identical methods described for Cave Creek. We also sampled herbaceous vegetation and soils in adjacent areas with similar soil types, slope, and aspect, but with no obvious agricultural features.

Perry Mesa results

As expected, nearly all archaeological artifacts were found on the pueblo transect; only five artifacts were found in the control transect 1 km distant (Figure 4).

Table 1. Pollen data from agricultural and natural soils at Cave Creek for the dominant 12 genera ordered by economic importance to prehistoric Hohokam farmers

		Mesic indicators			*Field weeds*			*Economically important native plants*			*Cultivar*		
Location	Depth in cm	*Typha* (+)	*Cyperaceae*	*Salix* (+)	*Populus* (+)	*Sphaeralcea* (–)	*Boerhaavia*	*Larrea* (–)	*Euphorbia* (+)	*Eriogonum* (+)	*Umbelliferae* (+)	*Solanaceae* (+)	*Zea*
Silt field	3–12	1.0		2.6					2.6	3.1	1.0		
Silt field	12–16	1.5			1.0				2.5	1.0	3.0		
Silt field	105–110	1.5	0.5	1.5	1.0			1.0	0.5	3.6	1.5	1.5	
Silt field	5–10			1.8					1.8	4.0	1.3	1.3	
Silt field	8–12	2.5		1.0					1.0	2.5	1.0	1.0	2.7
Silt field	25–30	1.0	0.5		1.5	3.4				3.4		1.5	
Silt field	72–75							1.7		0.6			8.7
Total on-field		**7.5**	**1.0**	**6.9**	**3.5**	**3.4**	**0**	**2.7**	**8.4**	**18.2**	**7.8**	**5.3**	**11.4**
Below-field	80–85	1.0				1.0	0.5	0.5	1.0	1.5			0.5
Below-field	84–89			0.5		1.0		1.5	1.5	1.0			
Below-field	87–92	1.0				0.5		4.0		1.5			
Below-field	140–145							2.1		1.6			
Off-field	0–10	1.0		1.0		2.0				1.5	1.0		
Off-field	20–30								1.4	1.0	1.4	1.4	
Off-field	40–50	0.5				1.0		0.5	1.0	1.5		0.5	
Total off-field		**3.5**	**0**	**1.5**	**0**	**5.5**	**0.5**	**8.6**	**4.9**	**9.6**	**2.4**	**1.9**	**0.5**

Notes: There is an increase in mesic trees and economically important natives and a decrease in weedy types on fields
(–) pollen type that decreased during the period of field cultivation
(+) pollen types that increased during field cultivation

This supports our assumption that the area traversed by the pueblo transect was more intensively used by prehistoric people. Furthermore, the percentage of rock cover on the landscape appeared to have been altered by prehistoric human activity. There was a significant relationship between distance from the pueblo and rock cover on the pueblo transect (Figure 5a). On the control transect there was no relationship between rock cover and distance from the start of the transect. Overall, there was a significant difference between the total rock cover on the pueblo and control transects (Figure 5a and inset).

This distribution of rocks had a significant impact on the woody plant cover. On the pueblo transect there was a significant relationship between the number of woody plants (>95% of all individuals were cat claw acacia, *Acacia greggii*) and total rock cover (Figure 5b). We believe the most plausible explanation for the relationship between rocks and woody vegetation is that the rock cover provides "safe sites" for the woody vegetation from fires that occasionally sweep across the landscape. We believe that the impact of ancient humans on the present woody vegetation is indirect. Through their activities (eg moving rocks to build a pueblo or to clear fields) they altered the landscape in a way that still affects the modern day distribution of plants, nearly 700 years after the pueblo was abandoned.

As shown in Figure 6a, scatter plots of principal component axes 2 and 3 of the herbaceous plant cover data suggest that the community compositions on and off terraced fields were different. Unlike Cave Creek, there were no differences in species richness, growth form (annual versus perennial), and origin (native versus introduced species) of the herbaceous vegetation on and off terraced fields at Pueblo La Plata. Finally, no differences were found between percentages of either total N or C of soils (5–15cm) at La Plata (Figure 6b). These results suggest that prehistoric human activity had a smaller impact on the terraced fields at La Plata as compared to the prehistoric agricultural fields at Cave Creek.

Legacies or pre-existing conditions?

Are these two case studies examples of prehistoric human legacies on the modern-day landscape or are the differences we found simply due to pre-existing conditions on the landscape? Prehistoric humans in the Southwest used landscape features, including soils, vegetation, and microtopography, to select agriculture field sites. Sandor *et al.* (2002) report that at least one extant Native American tribe (the Zuni) in the Southwest has valuable knowledge of agroecosystems. Although ethnopedological investigations specify relatively few Zuni terms for soils, each term holds rich meanings that extend beyond a description of material characteristics to provide insights into the origin of these materials and soil–geomorphic relationships and processes. It is likely that prehistoric humans knew exactly where to place their agricultural fields to maximize production.

Thus, pre-existing conditions explain some of the differences we found on and off the abandoned agriculture fields at Cave Creek. However, at Cave Creek, we also know that prehistoric agriculture did create a legacy on the landscape. The soils that comprise the agriculture fields (on which native Sonoran vegetation now grows) were deposited as a direct consequence of prehistoric irrigation (Figure 7). It is well known that the canals built by the Hohokam, in addition to bringing much needed water, also carried suspended sediment into the fields (especially during floods) that provided necessary nutrients and soil building material. This is extremely important in the Southwest because natural soil development processes are slow (Redman 1999).

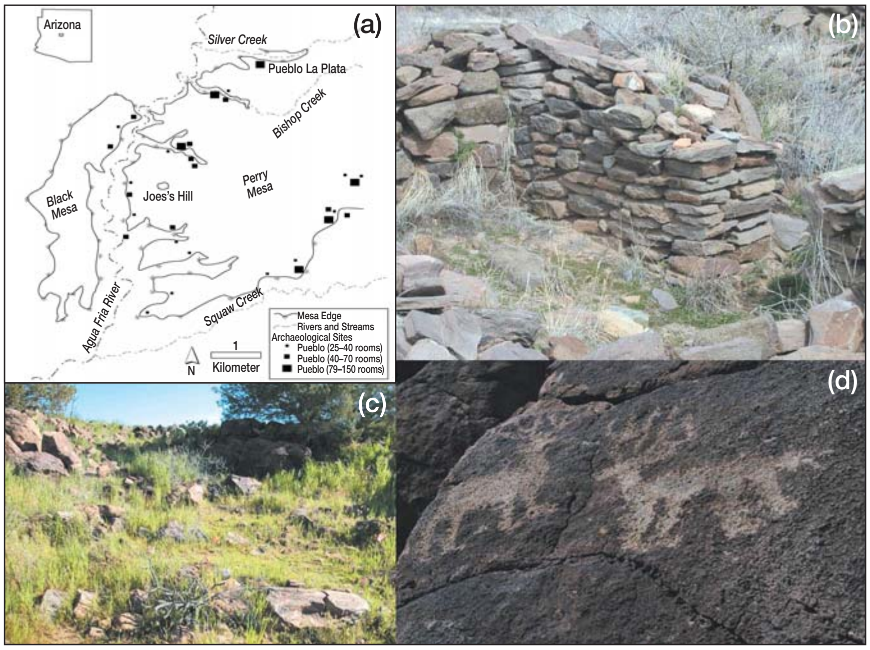

Figure 3. *(a) Location of Agua Fria National Monument with some of the major archaeological sites. (b) One of the doorways at Pueblo La Plata, illustrating the large number of rocks that were moved to build the circa 100 rooms. (c) One of the many terraced fields at Agua Fria National Monument. (d) Example of rock art panels present at Agua Fria National Monument.*

With regards to Perry Mesa, we suggest that by moving large amounts of rock around the landscape, prehistoric humans created an ecological legacy around Pueblo La Plata. The ancient inhabitants moved the rocks partly to accumulate construction stone (Figure 3) and perhaps to enhance plant production. However, based upon the data we have compiled at this time, we do not see an ecological legacy on the terraced fields around Pueblo La Plata. It may well be that the differences we find today with regard to species composition (Figure 6), are simply due to differences in the sites, regardless of past prehistoric human activities. More research (by archaeologists and ecologists collaborating together) is needed at these sites.

Lessons learned and future directions

So what did we learn from these two examples and how can they be used to further advance our knowledge of ecology and archaeology? Ecologists who conduct research in the vast areas in which prehistoric agriculture was practiced must, in their research designs, take into account the likelihood, or at least the possibility, that the ecosystem of their study site was, in part, structured by prehistoric humans. Ecologists should work more closely with archaeologists to assess the extent and impact of prehistoric agriculture in and around their study areas. Of course, this recommendation is not limited to North America. Some of the most dramatic effects of prehistoric human agricultural practices on ecosystems have recently emerged from studies in the tropics. For example, in the "pristine" rainforests of the Solomon Islands, recent archaeological studies have reported that the forests have regenerated in less than 150 years (Bayliss-Smith 2003).

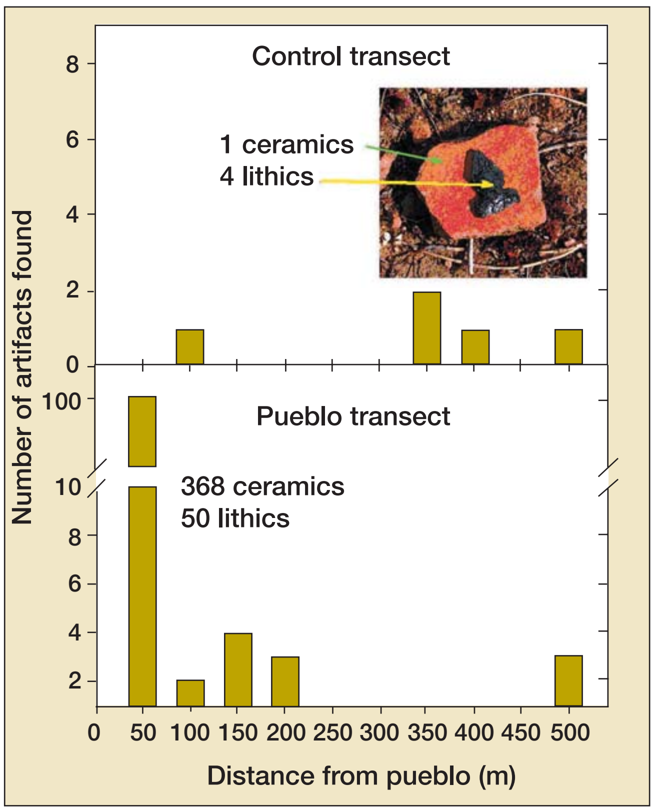

Figure 4. *Results of an archaeological artifact survey from the two transects. As expected, most artifacts found were concentrated near the pueblo. On the control transect, only a total of five artifacts were found.*

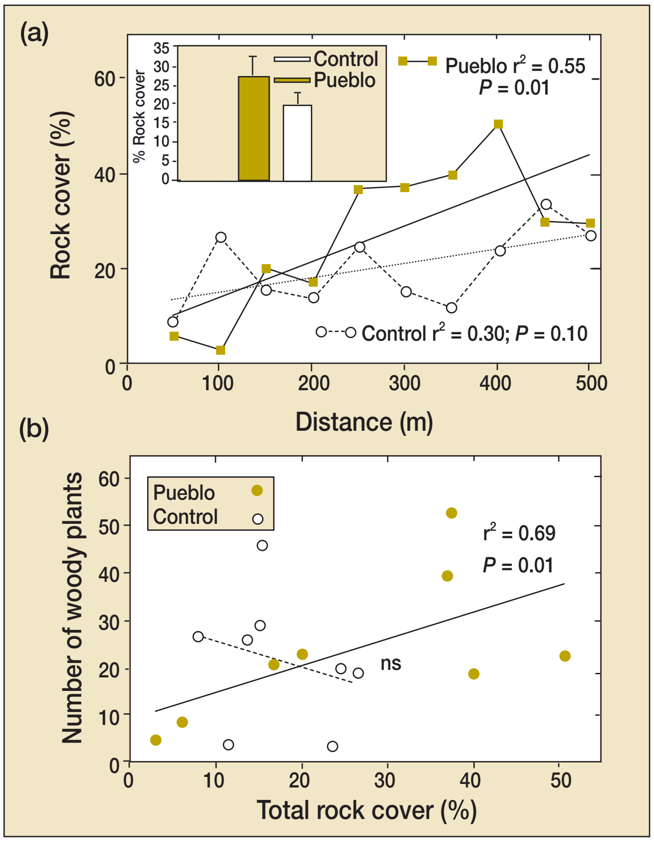

Figure 5. *(a) The percentage of rock cover plotted against the distance from the edge of the pueblo and the start of the control transect. There was a significant relationship between distance from the pueblo and rock cover (P = 0.01) while there was no significant relationship on the control transect. (a inset) The total amount of rock cover on the pueblo and control transect. Vertical bars represent one standard error of the mean. (b) The number of woody plants on the pueblo and control transect at each transect point. The relationship between the amount of rock cover on both transects and the number of woody individuals for the first 400 meters. There was a significant relationship (r^2 = 0.69, P = 0.01) between total rock cover and the number of woody plants on the pueblo transect but not for the control transect (ns = no significance).*

Similar studies have been reported in central African rainforests (van Gemerden *et al.* 2003) and from a dense rainforest in the upper Xingu region of Brazil (Heckenberger *et al.* 2003). Many other examples, including those from Europe, Asia, and Australia, are discussed by Gillson and Willis (2004).

Our results from Perry Mesa, where we found a lighter "footprint" of prehistoric use, suggest that even relatively non-intensive and short-term agriculture can transform an ecological system for a very long time. Finally, as mentioned at the beginning of this paper, ecologists can benefit from a longer-term view of human land use than they may have previously taken.

By the same token, archaeologists can benefit from working with ecologists. Through the use of contemporary ecological perspectives that focus on ecosystem processes, archaeologists can gain a better understanding and appreciation of the longer-term impacts of prehistoric human agriculture. By documenting these impacts in a wide variety of biomes, a better synthesis of the impact of humans on the environment should emerge, benefiting both disciplines. It is therefore imperative that ecologists and archaeologists work together to form truly cross-disciplinary collaborations, and that funding agencies be receptive to these activities.

We suggest that ecologists who conduct research in areas that were farmed prehistorically include discussion of relevant archaeological research in their descriptions of the study sites. Finally, it is essential that ecologists who work in the Americas abandon "prior to European settlement" as a temporal benchmark. Use of this dividing line is misguided and misleading because Native American use affected and transformed the biomes of the Americas for a very long time prior to 1492. As Delcourt and Delcourt (2004) state, "there is no such thing as a Holocene, 'presettlement' natural environment untouched by human hands in North

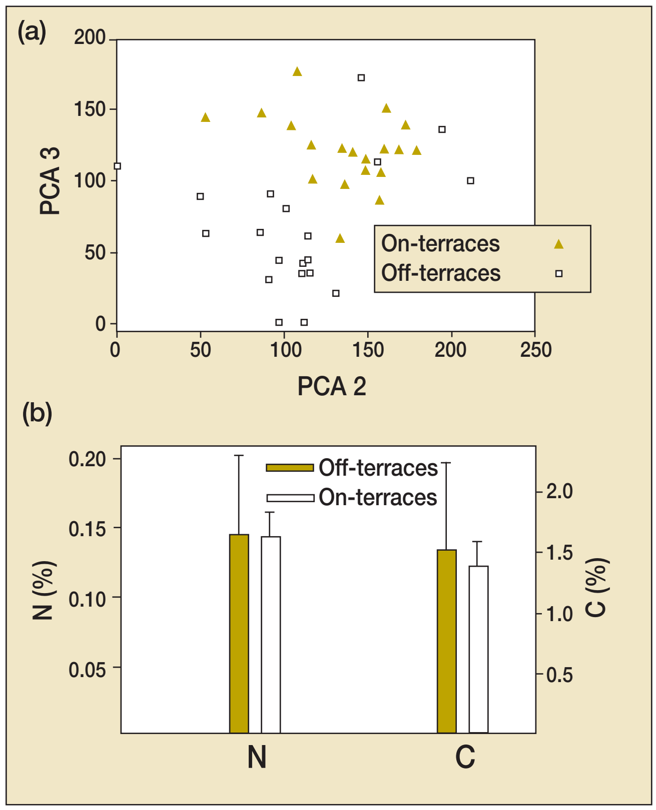

Figure 6. *(a) Scatter plot of quadrat scores on principal axes 2 and 3 from a principal components analysis (PCA) of herbaceous vegetation cover by species at Pueblo La Plata. Quadrats on terraced fields are represented by triangles and off the field by squares. The separation of the points suggests that although the numbers of species were similar on and off the terraced fields, the community composition is different. Unlike the fields at Cave Creek (Figure 1), no difference was found in the life form or the origin (native vs introduced) of the vegetation. (b) Total N content (%) and C (%) of soils (5–15cm) on terraced and off terraced fields at La Plata. No significant differences were found.*

America". Ecologists must recognize this truly long-term impact.

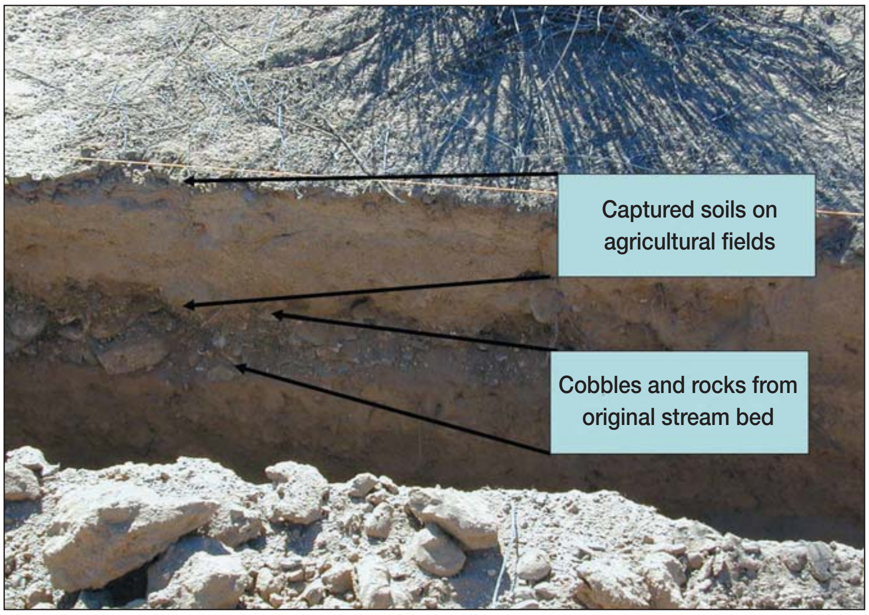

Figure 7. *Soil profile below one of the agricultural fields at Cave Creek. Note the cobbles and stone from the original stream channel with soil and silt layers that have been created overtop by irrigation practices of the Hohokam. Maize pollen was found in this layer (see Table 1). The creation of these agricultural fields has left an ecological legacy that affects the modern plant flora nearly 700 years later.*

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