

Visualizing the Anthropocene: Human Land Use History and Environmental Management

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Abstract—The term “Anthropocene” defines the current, human-dominated, geological epoch of human-caused environmental influences. Some researchers believe that the beginning of this epoch coincides with the inception of the Industrial Revolution (Crutzen and Stoermer 2000). Research is revealing that humans have affected environments on global and local scales for millennia. Contention over land management often hinges on disparate beliefs about the environment and the ways in which policy makers and the public visualize the past. There is a need to communicate the complexities of anthropogenic environmental change, on a local scale, through a medium that transcends different disciplines and cultural backgrounds. This paper discusses ongoing research of long-term human land use, and the ways human-environmental interactions have shaped the landscapes we encounter today. Environmentally based landscape visualizations are crucial forms of communication, which can be used to establish benchmarks for ecosystem restoration, future land management planning, and as a venue for better communication with the public. A picture may be worth more than a thousand words in bridging conflicting visions of nature, past, present, and future, in environmental disputes.

Introduction

The Anthropocene: Climate Change Linked to Humans

The Anthropocene epoch has been described as the period in which past human effects have altered the global environment. Just as geological phenomena take place on global, as well as regional and local levels, anthropogenic environmental change also has occurred across geographic scales. Initially, the Anthropocene was defined as beginning with the Industrial Revolution, in the latter part of the eighteenth century. Crutzen and Stoermer (2000) argue that greenhouse warming began with the Industrial Revolution, based on their analysis of aerosols trapped in glacial ice. Yet, by defining the beginning of the Anthropocene as a geological epoch beginning only 200 years ago, Crutzen and Stoermer truncate thousands of years of human interactions with the global environment.

Examination of older glacial ice levels shows intriguing evidence of human-caused climate change, beginning nearly 8,000 years ago. The initiation and intensification of human impacts coincide with the divergence of Holocene Greenland ice core CO² (carbon dioxide) and CH⁴ (methane) concentrations from levels predicted by previous interglacial patterns. The

anomalous variations in CO² and CH⁴ concentrations in the middle and late Holocene are well outside levels that prevailed over the previous 300,000 years (Ruddiman 2003:263). Late Holocene ice core evidence suggests that increased levels of greenhouse gasses coincide with the development of agriculture and other technologies (Ruddiman 2003). Paleoenvironmental research around the globe indicates that human societies have cumulatively influenced a wide variety of ecosystems. Around 5000 B.C., CH⁴ levels began a slow increase, culminating in completely anomalous levels by the beginning of the Industrial Revolution. By then, methane levels were already as high as they had been at the end of the Pleistocene, 14,000 to 12,000 years ago. Carbon dioxide output also grew with increasing human populations and technological advances. Small-scale deforestation and the use of fire for clearing land dumped carbon directly into the atmosphere. Landscapes across the world were cleared of forests to produce grazing lands for domesticated livestock (Zolitschka and others 2003). Deforestation increased as wood was cut for household use, firing pottery and bricks, metal production, and for use as building material. Fewer trees led to likely resulted in less carbon sequestration (Ruddiman 2003:274). This trend in anthropogenic change grew larger with the development of metallurgy and other fuel-intensive technologies.

Metal production added CO², as well as heavy metals to the atmosphere. Scientists have discovered correlations between elevated atmospheric lead levels in peat bog deposits in Switzerland, and the development of European silver mining and smelting. Beginning around 400 B.C., European peat bogs exhibit increased levels of lead isotope around 400 B.C. These deposits show a steady increase in lead levels through the second century A.D., which corresponds to increased European silver smelting (Shotyk and others 1998:1637). This lead isotope signal also appears in ice cores from Greenland glacial deposits, perhaps indicating the world-wide effects of Roman era pollution (Hong and others 1996). Cumulative environmental change, at local and regional scales, when viewed over thousands of years, may add up to significant shaping of the global environment.

The Anthropocene at Regional and Local Scales

At local and regional scales cumulative environmental change, when viewed over thousands of years, may add up to significant shaping of the global environment. Researchers have found a range of evidence indicating long-term, human-induced change at regional and local levels in environments around the globe (Baker and Biger 1992, Cotton 1996, Norton 1989, Pearsall 2000). Pollen and charcoal studies from Western Europe, Africa, Asia, Australia, and North and South America show that humans have been changing Earth's ecosystems for millennia (Walker and Singh 1993:108). Increases in microscopic charcoal, changes in fossil pollen assemblages, and faunal extinctions may be used as proxy indicators of human-induced ecological change (Burney 1993 and 1997; Chambers 1993; Walker and Singh 1993).

Since the end of the Pleistocene, people in Europe have altered, manipulated, and domesticated ecosystems, transforming the continent into a system of interconnecting and overlying cultural landscapes (Caseldine and Hatton 1993, Hope and Golson 1995, Simmons 1989). Archaeological investigations provide ample evidence of human impacts on long-term soil formation, at local and regional scales (Acotte 1998:74-75, French and others 2003).

The first New World settlers first arrived more than 12,000 years ago. Their technology, including the use of fire, initiated a slow and cumulative process of broad-scale environmental change (Brown and Hebda 2001). As populations expanded, groups of people spread throughout North and South America. Native peoples increasingly modified and managed landscapes to heighten the production of vital resources. By 4000 B.C., Andean landscapes were already being cleared by local societies

for agriculture (Chepstow-Lusty and others 1998). In the southern region of the United States, during the late-Holocene, Appalachian Oak-Chestnut communities were the product of landscape management by Native Americans. Pollen and charcoal-particle analyses indicate that for thousands of years, Native Americans influenced biological diversity and maintained a heterogeneous landscape mosaic using fire (Delcourt and Delcourt 1997). Prior to the arrival of Europeans, Native Californians altered thousands of hectares of forests, grasslands, wetlands, and river valleys, through intensive land management (Blackburn and Anderson 1993). Native peoples lived in settlements that ranged from villages, with small family units, to cities housing tens of thousands of individuals. In the Southwestern United States, native cultures affected soil development, erosion, and hydrology, as demonstrated in the remains of water control features, irrigation canals, and specialized agricultural technology (Deneven 1992:370, Periman 2001).

Current Geoarchaeological Research

My research focuses on human-environmental change in New Mexico's desert landscapes and in the forests of western Montana. A main objective of this research is to develop an integrated, interdisciplinary approach for reconstructing extended landscape history, and identifying cumulative anthropogenic effects on landscapes through time. I use archaeological data, as well as paleoenvironmental data collected from alluvium, bogs, and wood rat middens, to produce visual models of how different landscapes may have appeared during various periods. Computer-generated visualizations create representations of past environments that enhance understanding of the dynamics of landscape changes. Such visualization technology mediates challenges in resource management, by providing models of landscapes during specific periods and under a variety reference conditions (Appleton and Lovett 2003).

In the Rio del Oso study, located on the Santa Fe National Forest in New Mexico (fig. 1), I use a wide variety of scientific techniques to construct three-dimensional representations of past landscapes. These temporal and spatial visualizations, based on paleoenvironmental and archaeological data, help tie conceptualizations of past human land use to existing landscapes. First, I created archaeological site area, vegetation, and soil data layers using a digital elevation model and the geographical information system (GIS) software ArcInfo and ArcView. Using these GIS map layers, and vegetation density data derived from fossil pollen and phytolith analyses, I then

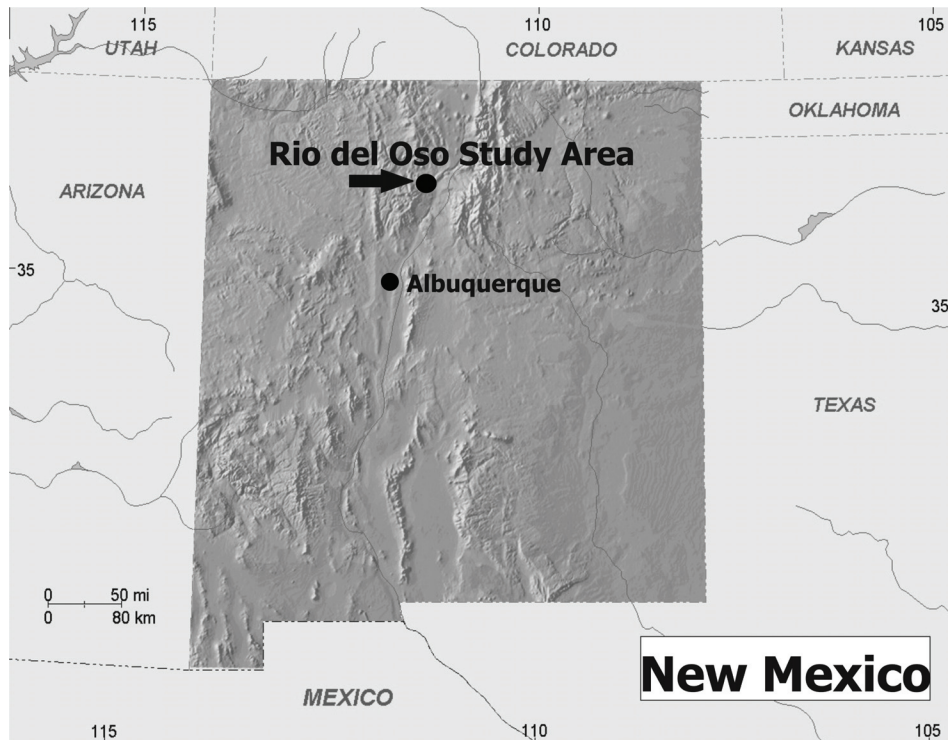


Figure 1. Rio del Oso study area, northwest of Santa Fe, New Mexico.

produced the landscape models using Visual Nature Studio (3DNature). The landscape models are organized by economic strategy, i.e., hunting and gathering, Puebloan horticulture, Spanish colonial and Mexican era subsistence ranching, and post 1850 commercial grazing. I construct the landscape models taking into account the ways in which each strategy may have affected the landscape through time. During the Archaic period (5500 B.C. to A.D. 600), vegetational change in the Rio del Oso was likely driven by a combination of climatic conditions, lightening fires, and human activity including burning to increase desired resource production. Fire and disturbance-related vegetation was common. This past landscape was dominated by grassland, with juniper densities ranging from approximately 0.5 tph (trees per hectare), to less than 2 tph, with less per-hectare density of pine in the lower drainage. During this period, the sedimentation rate was between 4.5 and 8 centimeters per century. The high incidence of late Archaic period microscopic charcoal, consisting of a high percentage of 10 to 25 micron particles, suggests the burning of grassland on a landscape scale (Periman 2001). These smaller particles represent airborne particulate from landscape-level fires; while large particles indicate localized fires (Clark and Royall 1996, Delcourt and Delcourt 1996). Interestingly, there is a lack of archaeological evidence for the period from A.D. 600 to 1200.

During the Puebloan period (A.D. 1200 to 1600), the Rio del Oso floodplain was at least 5 to 8 meters higher than current levels, and the frequency of Puebloan

archaeological sites in the valley is the highest of any period. Archaeologists have recorded 237 sites with a total site area of approximately 196 hectares. The fossil pollen record shows high levels of disturbance-related vegetation, and sedimentation rates increased to >14 centimeters per century. This increase in floodplain accumulation represents more than a doubling of the sedimentation rate from the Archaic period rate of 6.25 centimeters per century. From A.D. 1400 to 1765, the sedimentation rate increased to 16.42 centimeters per century (Periman 2001).

Landscape level fire in the Rio del Oso appears to have diminished between approximately A.D. 400 and 1600. Pine and juniper densities were within the same range as they were during the Archaic period. The Puebloan landscape consisted of open grassland, dominated visually by a central village, with fields dispersed in the floodplain, and supplementary agricultural features on Pleistocene terraces (fig. 2). As the population of the centralized villages and surrounding areas grew, the creation of fields and frequently used trails increased the exposure of soil to wind and water erosion, and likely resulted in greater sediment deposition in the floodplain.

The Spanish period and subsequent Mexican period landscape, A.D. 1700 to 1848, differed greatly from its predecessors. Colonial documents from the eighteenth century reveal that by the 1730s, Spanish settlers lived in the upper portion of the Rio del Oso canyon (Periman 2001). Archaeological sites recorded from this period cover an area of 63 hectares. These communities imposed



Figure 2. Visual model of the Rio del Oso landscape during Puebloan period (ca.1400). The Landscape was dominated by grassland, with juniper densities ranging from approximately five trees per hectare, to two trees-per-hectare. The light patches in the middle ground are Anasazi agricultural fields.

an Old World model of subsistence farming and livestock grazing upon the Puebloan landscape. By doing so, the Spanish helped to create a composite landscape upon the ruins of the older, Puebloan land use systems.

Floodplain erosion began with the intensification of Spanish era ranching in the eighteenth and early nineteenth centuries. In the Rio del Oso valley, fire levels fell sharply and Spanish period juniper density increased to >10 tph, while disturbance vegetation, once utilized by Puebloan peoples, declined to levels below any period of the past 6,000 years. The alluvial record in the lower portion of the valley ceased aggrading, terminating after A.D. 1765. Although the valley floor had been stable for nearly 7,000 years, Spanish period erosion dramatically altered the Rio del Oso ecosystem. The meandering stream and riparian area became a hydrological system of braided channels. The remnants of the former floodplain are now arid, supporting mostly juniper and cholla cacti.

With the expansion of the cattle industry in the 1870s, severe erosion occurred in the Rio del Oso. Overgrazing caused massive decreases in vegetation cover, plant vigor, and the suppression of natural fires (Wozniak and others 1992). The floodplain, stripped of vegetation by grazing, became a labyrinth of arroyos when seasonal rains returned, following prolonged drought during the latter part of the nineteenth century. Presently, the Rio

del Oso landscape has juniper densities of >50 tph, and pine densities of 15 tph (fig. 3).

My research of human land use and fire in riparian ecosystems has expanded to other areas in New Mexico, and the mountainous, forested landscapes of western Montana. The Rio Puerco study area, in New Mexico, was occupied for at least 10 millennia, as indicated by numerous archaeological sites. Soil thin section microscopy of samples collected from the Rio Puerco show that successive fires within riparian ecosystems, over approximately 7,000 years, have helped shape geomorphology and ecology through time. Thin section analysis of in situ burned sediments show that intensive fires, with high fuel loading, have changed soil structure in what was once a rich riparian habitat. I have found riparian fire events preserved in stratified sediments, which show periodic fire over thousands of years. In June 2004, I discovered a hearth in sediments upstream from one sampling area. Charcoal from this feature was dated to a conventional radiocarbon age of 2170 BP (Beta – 196423). Although not directly associated with individual, large-scale riparian fire events, this type of archaeological evidence places humans in the area, using fire, during a period with frequent riparian fires (Billmoro 1993).

My research focuses on the local, landscape scale. Such studies can illuminate understanding of large, global



Figure 3. Today, the Rio del Oso landscape has juniper densities of >50 trees per hectare, and pine densities of >15 trees per hectare. The valley bottom has eroded 6 to 8 meters below the level attained at the end of Puebloan occupation.

scale, human-caused environmental change. Preindustrial burning of vegetation within watersheds added carbon to the atmosphere. Geoarchaeological analysis indicates that fire was one of the main tools that shaped vegetation patterns and soils. Regions are made up of such landscapes. The Anthropocene begins to emerge when we consider human-environmental activity at a local level, compounded by thousands of years, affecting vast areas of interlocking landscapes. Such change would have a lasting geological effect on a given area.

The physiographic alteration of soil and geomorphology, through successive land use, creates a human defined landscape. The cumulative and geographic expansion of such physically changed areas instigated the Anthropocene.

Human Perceptions and Communicating the Past

Although humans have had an effect on greenhouse gases for thousands of years, human-induced environmental change continues to take place on a local, landscape level. Localized activities, such as burning a landscape to provide better grazing for livestock, inject carbon into the atmosphere; clearing land to grow wetland rice produces methane. Cumulative land use, the repeated application of fire for example, can potentially change the physical structure of soils and their biochemistry (DeBano and others 1998:78). Over time, this type

of influence would affect ecosystems at a landscape level. The local landscape may be the common scale at which humans change the Earth. In a sense, we can see the Anthropocene at the scale of human experience, the scale of landscape.

Within the ideology of ecological restoration is the goal of returning natural ecosystems to conditions resembling those of the past (Society for Ecological Restoration 1993). Ultimately, an understanding of a landscape's historical processes and changing ecological dynamics applies to present management of environments. Ecological cycles, although of central importance in landscape dynamics, represent only one dimension of understanding. Human influences tend to change the developmental trajectory of ecosystems (Winterhalder 1994:29-30).

A holistic understanding of human-environmental interactions is applicable to natural resource management, planning future conservation, and economic development. Environmental archaeology can describe ecological conditions that existed before people "overgrazed the land, put out all the fires, and liquidated most of the old-growth trees" (Covington and Moore 1994:45). The accumulation of excellent archaeological data can provide a way to visualize how layers of a cultural landscape fit within the ecological matrix of the floodplains, terraces, and mesas of a specific area.

Monitoring the environment implies visualizing; conflict over environmental issues often forms over how we see the past. There is a growing need for effective ways

to communicate environmental planning and information to non-expert participants, and improving the quality of land management (Bishop 1994:61; Orland and others 2001). Groups often hold disparate beliefs about the environment, how it should look, and be used or managed. This extends to how we may envision an ecosystem's history, its present condition, and thus, its future. People often imagine past landscapes as idealized, preindustrial, pristine, and uninhabited. This view is contradicted by the complex archaeological record of thousands of years of human-environmental interactions throughout the globe (Baker and Biger 1992). The computer-generated visualizations of past landscapes, as depicted in the Rio del Oso study, create a common reference at the local scale. Using such methods to communicate past environmental conditions provides managers a greater range of choices for management.

Monitoring the Anthropocene

We can identify extensive and cumulative changes at local and regional scales, regardless of when humans began to affect the global atmosphere. Although we may be witnessing accelerated anthropogenic climate change today, humans have altered and managed landscapes through millennia. Successful management implementation, with the goal of sustained ecological health and resource production, is simply part of the continuum of human interactions with environments. Effective management decisions need to be depicted and implemented at the same landscape scale that our ancestors encountered when they were hunters and gatherers. Although large-scale industries significantly affect greenhouse gasses, carbon sequestration, habitat rehabilitation, and resource production can only be implemented on a given number of hectares at a time. Management decisions may be made on national, or even continental, levels, but making positive change begins with localized activity. Computer-aided visualization techniques help us view and monitor the Anthropocene. Studying how people have interacted with, altered, and created landscapes through time enhances our understanding of the Anthropocene's complex dynamics.

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