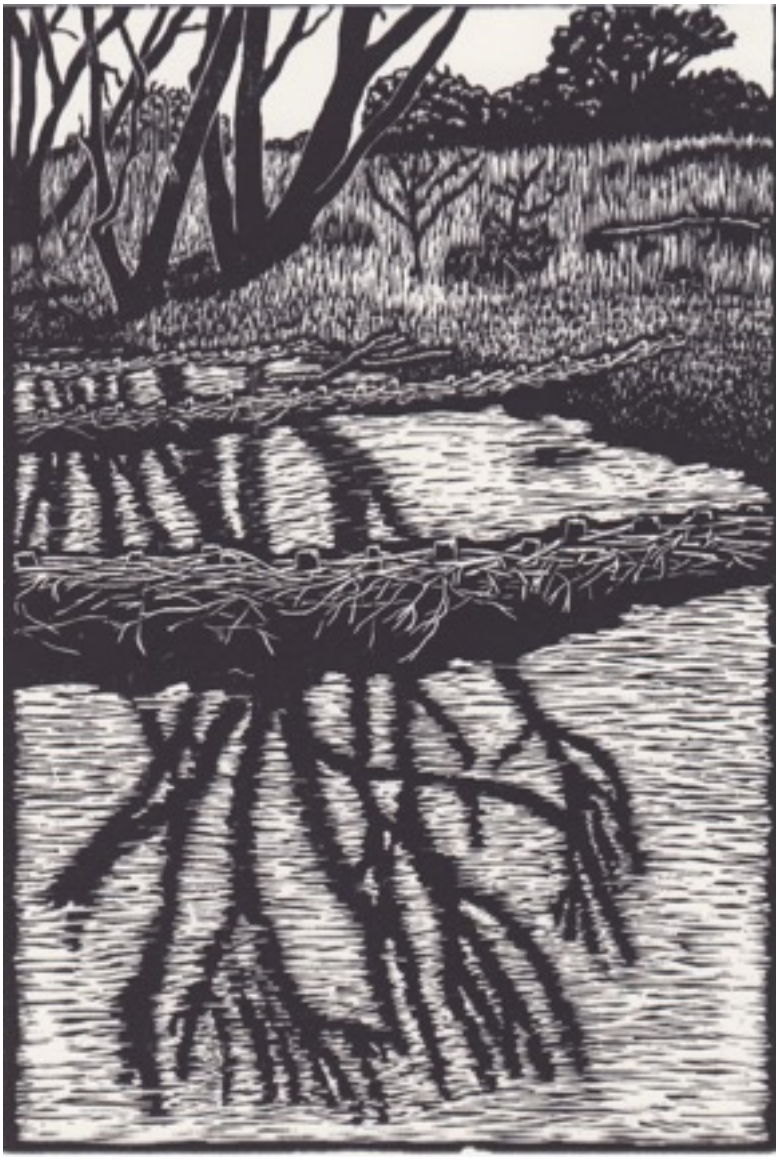
The Biotic Ethic:

Land Restoration and Carbon Sequestration in an Era of Climate Change



When my wife, Lucinda, and I retired in 2004 and took our leave from the classrooms and courtrooms of Arizona, we moved as close to wilderness as possible in a world burdened with nearly 7.5 billion people. Southwest New

Mexico, at 5,000 feet, is sparsely occupied and blanketed in night skies with stars seemingly within reach. Our closest neighbor is six miles distant. Outside, unwinding under the night sky, I can watch the flickering lights of airliners loaded with bustling travelers headed east to El Paso and beyond. Always in a hurry, living on clock time in a carbon-fueled world of accelerating technological progress, most people are inattentive, some don't care and many are ideologically oblivious to our current climate crisis. I think about their lives and families, their agendas and their futures. Our world is warming, hotter this year than last, year after year. Too many of those passengers remain skeptical about climate change and unsure they can do anything about it anyway.

These are worrisome times with complex problems. I agree with Wes Jackson, who said, "We live in the most important moment in human history." This is a period of pressing questions and a short fuse. Yet I also believe that each of us can make a difference, and, while our service alone may seem unimportant or even trivial, together we can redirect the trajectory of humankind toward a more just and livable world. Toward that end, we have settled in for the long haul, restoring a special and important place and its forgotten waters. The place is the Pitchfork Ranch south of Silver City, New Mexico, and the water is a ciénaga.

Ciénaga is a Spanish term derived from the word silt, *cieno*. Ciénagas are desert marshes, a wetland system unique to the American Southwest. They are alkaline, freshwater, spongy, wet meadows with shallow-gradient, permanently saturated soils in otherwise arid landscapes that 200 years ago occupied the entire widths of valley bottoms. They often occur because the underground structure forces water to the surface. This description explains historic, pre-damaged ciénagas, although few can be described that way now. Dead, non-restorable or severely incised ciénagas prevail today.

Ciénaga soils are squishy, permanently saturated, highly organic, silty, black in color and anaerobic. Highly adapted sedges, rushes and reeds are the dominant plants, with succession plants — Gooding's willow, Fremont cottonwoods and scattered Arizona walnuts — found on drier margins, down-valley in healthy ciénagas where water goes underground or along the banks of incised ciénagas. Although trees drown in historic ciénagas — which is why "swamp" is a common mistaken description, swamps have trees — these woody plants now occupy many damaged or drained ciénagas.

The ongoing, region-wide erosion that followed the arrival of Europeans in the American Southwest and the subsequent misuse of the land by settlers created ever-worsening incisions, firmly entrenching concentrated water flow between vertical walls, resulting in a drawdown of local water

tables, the drying up of most marshland environments, leaving behind scarcely few undamaged ciénagas. Many that remain today look and function like a creek: narrow, incised and continuing to degrade. Since the 1870s, natural wetlands in the arid and semi-arid desert grasslands of the American Southwest and northern Mexico have largely disappeared.

Although scarcely recognized, ciénagas have had played an important role in the American Southwest for eons. Many prehistoric agricultural settlements were located near ciénaga*s* or on the floodplains of the major perennial streams where irrigated agriculture could be practiced. But most Europeans saw little value in ciénagas. In his famous essay, "The Land Ethic," in *A Sand County Almanac*, Aldo Leopold wrote that early settlers even cut ditches to drain the ciénagas. It was not until 1985 that a college professor and one of his ichthyology students wrote a paper and alerted the academic community in the American Southwest to the importance of its overlooked ciénagas. So-called "progress" in the United States often led to thinking that the only good wetland was a drained wetland, to be emptied, improved and developed. Despite the loss of 95 percent of ciénaga habitat, efforts to catalogue, understand and restore ciénagas has gradually gained prominence over the last four decades.

The importance of ciénagas is difficult to overstate. They are critical for birds and a variety of other animals. More than 70 percent of land animals use riparian areas. Wetlands in the American Southwest occupy under two percent — some argue under one percent, but whatever the number, the percentage is shrinking — of the land area and have an exorbitant impact on the region. Wetlands are critical habitat for species that are at risk, and at least 19 percent of Arizona's endangered, threatened or candidate species for protection are dependent on wetland environments. Providing wetland habitat in otherwise arid regions, desert ciénegas and riparian corridors have the potential to increase regional biodiversity by up to 50 percent.

Abundant archeology surrounds ciénagas. They hold data about Native American land use; they contain fossil remains of prehistoric animals now extinct; they preserve proxy data such as pollen, charcoal and isotopes preserved in ciénaga sediment that is now cored and studied. Coring ciénagas appears to be one of the best ways to uncover the history of the American Southwest; as "keystone ecosystems," they have a vastly disproportionate relevance to their surroundings; and, not unimportantly, there is their beauty.

Ciénagas are also the source for "ecosystem services," an emerging restoration notion in which market value is attributed to various environmental functions provided by landowners for the public good and for which they have historically not been compensated, such as: filtering rain and snowmelt; slowing seasonal flood pulses to reduce stream channel degradation and to otherwise slow soil erosion; promoting groundwater recharge; and delivering clean, safe drinking water at a far lower cost than it would take to build infrastructure to replace these services.

A long-forgotten indication that there used to be far more water in the American Southwest, suggesting there were more ciénagas here than we'll ever know, is the *sumidero*. The word in standard Spanish means a sewer, drain or gutter, but to early settlers and ranchers it meant a mask well or sinkhole. They were dangerous, 10 to 20 feet across, deep traps that showed up unexpectedly on plains or alkali-covered flats with too much mud to flow and too much water to dry up. The thin, upper mud surface of a *sumidero* was baked dry, offering nothing to distinguish it from nearby safer ground. If a man, horse or cattle stepped onto the treacherous surface of a *sumidero*, like in quicksand, they could perish without ever being recovered. Old tales persist of cowboys and animals being sucked into the mud under the crisp surface of *sumideros*. These dangerous features of an arid American

Southwest are long gone but offer insight into the future of ciénagas, unless there is a concerted effort to save these few remaining forgotten waters.

There are two ways to think about the history of ciénagas: either how they were degraded after the arrival of Europeans in the American Southwest or how ciénagas developed — how they aggraded and how they were established during the 10,000 years before Anglo-European arrival on the continent. The task of uncovering the natural processes that established ciénagas is ongoing, although the reasons for their losses are settled.

In less than 200 years, a series of mostly human-caused events conspired to transform the American Southwest from a depositional environment to an erosional one, severely lowering groundwater tables, drying the land and resulting in a bewilderingly high number of ciénaga losses. This period can be thought of as "The Great Ciénaga Disappearance." What nature painstakingly assembled over a period of some 10,000 years, we humans nearly destroyed in less than 200 years. Most ciénaga habitat has simply disappeared, leaving only a “skeleton” or thin stream of water that is at risk of blinking out.

There are those who maintain that the main impact on the ecology of the American Southwest during the Spanish, Mexican and American occupation was the introduction of large-scale cattle ranching in the 1820s,

but the disappearance of ciénagas and general drying out of the American Southwest is far more complicated than simply the overstocking of cattle. Overgrazing was insignificant in the 1820s and 1830s. Between the 1846 Mexican-American War and the Gadsden Purchase in 1853, there were accounts of wild cattle in the region, but the boom in cattle ranching began when the Southern Pacific Railroad arrived, along with the windmill, the capture of Geronimo and the end of the Apache threat.

Ciénaga disappearance did begin with the arrival of Spanish livestock, but, initially, the dominate animals were sheep, not cattle. The search for the Seven Cities of Gold failed convincingly, but Spain's hunt for wealth persisted as sheep — trampling ciénaga banks, disrupting the habitat and over-using water — became the dominant domestic animal in Spain's northern frontier in the Americas. By the 1820s, as many as two million sheep covered New Mexico, and, by 1865, the numbers of sheep more than doubled with a ratio of sheep to cattle ballooning to 37 to 1 or 4,600,000 sheep to only 125,000 head of cattle.

Ciénaga dewatering continued with the over-trapping of beavers in the 1820s and '30s. In a surprisingly short period, beavers were virtually eradicated from the American Southwest. Beaver dams soon failed from neglect, and channels began to form in the soft sediments trapped behind

these barriers. Over time, the channels became increasingly connected and the process of channeling, down-cutting and dewatering of ciénagas worsened.

Shallow, flatland watercourses and adjacent riparian zones shifted from complex systems dominated by ponds, multiple channels, ciénagas, marshes and otherwise wide wetlands plentiful in fish and wildlife into simple, incised, single-thread channels with narrow strips of riparian vegetation. Beavers — "landscape-shaping creatures," an indispensable creator of ecosystems that foster entire ecological communities — are capable of building as many as twenty dams per mile of stream, smearing the water across the landscape, creating a series of broad pools and mucky wetlands linked by shallow, multiply branched channels.

In 1901, D. A. Griffiths, chief botanist in charge of grass and forage investigations for the Arizona Experiment Station in Tucson, Arizona, realized that rangelands in southern Arizona were more degraded than others he had seen in the United States. In an effort to understand the change, he sent out a questionnaire to pioneer ranchers asking what they saw as the causes. What he learned from the proprietor and owner of two large ranches was that, in 1870, the San Pedro Valley — near the town of Oracle in the southern part of Pinal County — had an abundance of willow, cottonwood,

sycamore and mesquite timber, as well as large beds of sacaton and grama grasses along a shallow, grassy riverbed with beautiful banks luxuriant in vegetation.

By the turn of the century, the river was deep, its banks were washed out and the trees and underbrush were gone. The valley had initially consisted of a narrow strip of sub-irrigated and very fertile lands. Beaver dams checked the flow of water and prevented channel cutting. Subsequently, however, trappers exterminated the beavers and grazing left little grass on the hillsides, permitting greater erosion. Within four or five years, a channel varying in depth from 3 to 20 feet was cut almost the whole length of the river. By the turn of the century, the river was deep, its barren banks were void of grass, trees and underbrush and the hillsides had been eaten off, with great sheets of water washing away topsoil and ever greater currents cutting and deepening the channels.

The demise of the beaver severely altered the Western landscape. With their engineering skills and sociability, beavers are the only animals, other than humans, that can significantly reshape their environment. The eradication of the beaver population was a major step in converting dynamic and complex stream and river ecosystems into the relatively static and simplified water delivery systems that dominate today's American

Southwest.

Populated by beavers, the American Southwest was far different from the arid lands we see today. At the intersection of Interstate 10 and the Gila River south of Phoenix, Arizona, hundreds of beavers were trapped out, where today only barren desert remains. A person could walk in the shade from the headwaters of the Gila River in New Mexico all the way to Yuma, Arizona, where the formerly perennial river emptied into the Colorado River. In 1891, two Silver City, New Mexico, men floated on the Gila River from its headwaters to Yuma. The American Southwest of today is unrecognizable compared to what it was 150 years ago. These changes are hars to see because they occur on a scale considerably larger than a human lifespan.

Many ciénagas also suffered damage when early settlers recontoured the broad ciénaga canyon flats in a misguided attempt to prevent the flooding of their agricultural fields. The resulting channelization and concentrated water flow reduced these historic wetlands to a fraction of their original size and inadvertently created deep, high-walled incisions that have progressively worsened — though most farming has long-since ceased — and exacerbated the region-wide lowering of the groundwater table, further dewatering formerly wetted ciénagas.

The damage to ciénagas was then exacerbated with the overstocking of cattle and the explosion in the number of cattle herds by the 1880s. Ciénagas were trampled and dewatered, stream banks caved, grasslands were neutered and erosion was accelerated. While the ratio of sheep to cattle was 37 to 1 a mere 25 years earlier, by 1890, cattle numbers had spiked and the ratio narrowed to nearly 2 to 1 and ultimately flipped in favor of cattle, 15 to 1.

Then the severe weather and drought of the late 1880s and early 1890s compounded the degradation of the re-contoured and overstocked landscape that had already seen grass and wetlands severely damaged. In the San Pedro Valley of Arizona, Griffiths learned that cattle and horses going to and from feed and water made many trails to the mountains; browse on the hillsides had been eaten off, giving the winds and rains full sweep to carry away the earth loosened by the feet of the animals; and waterways were cut from the hills to the riverbed, leaving little to stop the great currents of water reaching the reverbed with such force as to cut large channels and destroy much of the land under cultivation. Suddenly, the river was 10 to 40 feet below its former banks.

Lucinda and I moved to the town Casa Grande, located midway between Phoenix and Tucson, in 1972. Casa Grande and the San Pedro

Valley are both located in Pinal County, where the San Pedro River once flowed through a rich riparian corridor. I often traveled through Oracle, a short distance from the town of Mammoth, where I served as town attorney. The habitat I saw was not anything like that described to Griffiths by those two long-time ranchers when they responded to his questionnaire. It was an eye-opener to read the answers to Griffiths's circular; the world those ranchers watched disappear before the turn of the century was far removed from how I experienced the region one day each month for a good many years.

Near the century's end, the weather had worsened as mild winter rains and unusually dry summers peaked with two years of drought in 1891-3 and brought disaster with livestock mortalities reaching 75 percent. Springs and ciénagas long thought to be permanently wetted went completely dry. House-high piles of cattle bones and a severely damaged landscape scarred the American Southwest and foretold the desertification to be endured by future generations. The persistence of drought and uneven rains has continued, and now accelerating, human-caused global climate change and disruption has been added to the stresses on the already arid American Southwest.

Compounding the over-trapping of beaver, the overstocking of sheep and cattle, the draining and conversion of land for agriculture, and drought, fire suppression by Spanish settlers may have caused as much harm as these others combined. Caused by lightning originating in monsoon thunderstorms and by purposeful ignition by Native Americans, fire was a significant influence in the evolution of southwestern ecosystems in which many plant species became fire-adapted. But since the arrival of Europeans, fire has been suppressed to such an extent — previously appearing, on average, every 8 to 10 years compared to today, occurring almost never, except for forest fires — that woody plants have outcompeted grasses and transformed historic grasslands into a landscape dominated by trees and shrubs.

The majority of grass biomass consists of roots that lie beneath the surface, while trees and other woody plants are just the opposite, their biomass being above ground. Before the arrival of Europeans, American Southwest grassland fires occurred so often that they killed many woody plant species, yet merely topped off and strengthened the health of grasses. This frequent fire regime had been a long-time, natural intervention allowing grasses to outcompete woody plants. The subsequent transition from grasslands to woodlands, caused largely by fire suppression, helped finish off many ciénagas and severely reduced the size of those remaining.

Ciénagas not only provided a rich habitat for plant and animal life, but the combination of lateral spreading of flood pulses and abundant above-ground vegetation lessened the erosive potential of floods and protected the softer surface sediments. Broad ciénaga flats dispersed seasonal flood pulses into sheet flows and prevented the channelization fostered by the combination of insults outlined above. Ciénagas and grasslands formerly captured large amounts of sediment suspended in sheet flows, but, over the last 200 years, these concentrated flows have eroded barren soils and become gully-washers, flowing through rampant, ever-deepening incisions — or arroyos — and entrenched streams throughout the American Southwest. The result is heightened flash flooding and exaggerated channel discharge that has reduced water tables and further exacerbated the already severe dewatering of ciénagas.

The combination of these wounds transformed the entire American Southwest as this desertification reduced the ciénaga area to a mere fraction — five percent — of its historic expanse. The dominant land surface process in the American Southwest today is stream scour, the opposite of sheet flow or slow-moving water that was the norm just 200 years ago. Absent coordinated intervention to preserve these dwindling habitats, the future of ciénagas is bleak.

The mechanisms underlying ciénaga development — natural and long evolving, as opposed to those of their destruction which are extreme and abrupt — began as the earth cooled and the last ice age came to a close 11,500 years ago. Diverse and ongoing scholarship is slowly uncovering the evolution of these unique, aridland, fresh water habitats. These studies are teasing out answers by investigating the record of sediment build-up; by studying the profile of ciénaga-drawn core samples containing stable sedimentary isotopes, pollen, microscopic charcoal or fire remnants and elemental fractions of organic materials; and by identifying the sources of the organic matter buried within the sediments.

The story is complex and difficult to summarize but generally unfolded thusly. The period of the last glacial maximum, the Pleistocene or Ice Age, was a period when sea levels were at their lowest and glaciers were at their thickest. Ice sheets throughout the globe were at their maximum extension 21,000 years before present (BP). The planet then began to thaw, and water started to flow. Early in the Holocene — 11,500 BP — stream flow was still too strong for the establishment of ciénagas, but surface runoff slowed around 7,300 BP, fine grain sediment began to accumulate and wetlands started forming. Fire was infrequent, and woody plants dominated the uplands. The transition from woodlands to grasslands began around

5,300 BP when fire frequency increased from 1 every 200 years to 1.3 every hundred years. The runoff slowed. The period between 4,100 and 1,300 BP was a time dominated by grasses; far wetter, upland vegetation was stable; ponding occurred; ciénaga surfaces were well established; and fire frequency increased, on average, to 1 fire every 38 years and eventually to 1 every 8 to 10 years. This process ended abruptly with the arrival of the Spanish, and fire frequency decreased with the displacement of native agriculture by Anglo settlement, triggering the accelerated post-settlement transformation of wetland vegetation back to woody species that persists today.

There you have an abbreviated history of ciénaga development and the details of their demise. Absent serious intervention, the future of ciénagas is bleak and they will likely become extinct. Although there were likely hundreds and possibly even thousands of ciénagas before European arrival, today, there are but 155 identified ciénagas, and only 71 remain that are either functional or restorable. It is important to note that this numerical analysis is deceptive: by count, 46 percent of known ciénagas remain viable; but, in actuality, by area, 95 percent of ciénaga habitat is lost. Most surviving ciénagas are but slivers of their former selves.

On the Pitchfork Ranch, one of the 71 remaining ciénagas persists and that's where we enter this picture. The restoration efforts here demonstrate

how each of us can do something to restore our damaged planet and help turn the crushing tide of human-caused climate change. Recently I had an exchange with my dental hygienist, who expressed doubt about climate change and dismissed the issue by asking, "What can we do about it anyway?" With my mouth propped open and her tools at work, I was disadvantaged, silent and let it go. It's inexcusable and maddening that so many people remain oblivious. We're not helpless. The kind of restoration tools we are utilizing to restore this ciénaga can be replicated anywhere by anybody on property of any size. No property is too small.

Climate change has civilization in its crosshairs, and restoration is neither a cure-all nor a silver bullet. Yet it is one of five core tactics needed to slow the juggernaut of global warming that threatens civilization as we know it. Despite being ensnared in an atmosphere that is being radicalized by climate change, "The Great Transition" from a high-carbon world to sustainable progress can be accomplished by addressing five basic elements: (1) zero-carbon sources of renewables, (2) weatherization, (3) elimination of our consumptive lifeway, (4) mass transit and (5) habitat restoration. All five are necessary. Because the forgotten waters of ciénagas are critical to supporting life in the desert and are dwindling and because one of the few remaining ciénagas' waters pass by our home, our efforts to slow global

warming are focused on the fifth element — habitat restoration. And I am using our work on the ciénaga to describe how each of us can pursue restoration and draw down or sequester the legacy load of atmospheric carbon heating up the planet. What we are experiencing is no longer the slow-moving warming so many of us have long been ignoring. This is no longer *adaptation;* while too few recognize it, we are already in the era of *damage control.*

The scientists, marketers and other consultants — now revealed as the defrauding "merchants of doubt," first hired by the tobacco trade and re-cycled by the fossil fuel industry — have had their profitable day in the sun. Yet there are still remnants of fossil fuel-funded, science manipulators remaining entrenched in the halls of the American Enterprise Institute, Americans for Prosperity, Cato Institute, Heartland Institute, Heritage Foundation and now deeply embedded in EPA with the appointment of denialist Scott Pruitt to head the agency.

There is not a single scientific organization in the world that has taken the stand against the consensus position that climate change is real and that it is human-caused. Twenty-six scientific organizations — among them: the American Association of the Advancement of Science, the Environmental Protection Agency, the Geological Societies of America and London, and

the National Center for Atmospheric Research — as well as the Pentagon, the Center for Naval Analyses, the Central Intelligence Agency, the United States Department of Defense (climate change is the "mother of all risks") and eighty other national academies of science worldwide have taken formal positions that climate change is real and human-caused.

Multiple surveys covering thousands of peer-reviewed abstracts on the subject of climate change or global warming found that more than 97 percent of climate scientists agreed with the consensus position that humans are causing global warming. Although there are rare papers that take no position, as pointed out by www.theconsensusproject.com, not a single paper rejected the consensus position that global warming is caused by humans. The existence, causes and solutions are now well known and are thoroughly described in Naomi Klein's *This Changes Everything*. The consequences for life on the planet — the rate of extinction of species and races is conservatively estimated at 877 times above that prevailing before the origin of humanity — are detailed in Elizabeth Kolbert's Pulitzer Prize winning *The Sixth Extinction.*

For more than four billion years, astronomical and geological forces — such as solar heat output and volcanic eruptions — were the dominating influences on the Earth's climate, but this is no longer true, as humans are

changing the climate 170 times faster than natural forces. This catastrophic rate of change of the Earth system over the last six decades is purely a function of industrial societies.

The rapid rise in CO_2 was the driver in more than 10 mass extinctions of the deep past — "greenhouse mass extinctions" — and calls to mind American editor and writer Norman Cousins' Saturday Review editorial of nearly 40-years ago, "History is a vast early warning system." Greenhouse gasses have been the cause of the vast majority of past species extinction, and the history of atmospheric carbon increasing from 275 parts per million (PPM) to 400 PPM during the 260 years from the start of the Industrial Revolution until 2014, when contrasted to an increase of only 15 PPM during the 8,000 years previous to the industrial age, is telling. The year of 2016 was the hottest year on record, 2.3 degrees Fahrenheit above pre-industrial times and January of 2017 was 3.5 degrees Fahrenheit above the 20th century average. Of course, the warnings of history are often ignored, but never has humankind ignored such a consequential alarm.

The recent presidential election illustrates Cousins' caution as well as the implications of ignoring science. There is a frightening parallel between the southern slaveholders' refusal to recognize Charles Darwin's science in the *Origin of Species* in 1860 and climate change denialists ideological-

based rejection of scientist's warnings about today's threat of a warming planet. The current risk to the Republic is the most serious since the Civil War. President Trump's cabinet appointments are openly hostile to the agencies they were chosen to direct. White House chief strategist Steve Bannon has made clear that President Trump's cabinet picks are aimed at the "deconstruction of the administrative state," the bane of free market devotees. The term "deconstruct" is a euphemism for elimination. "I'm a Leninist [and] Lenin wanted to destroy the state, and that's my goal too. I want to bring everything crashing down, and destroy all of today's establishment." Soon after taking office, Trump's EPA head, Scott Pruitt, said that those who want to eliminate the agency are "justified." Trump has made his position on the EPA clear, calling the agency a "disgrace" and vowing to reduce it to "tidbits." The blowback has begun and will likely be fierce.

The Pitchfork Ranch Ciénaga Restoration Project is more broadly an undertaking to reclaim the health of the entire ranch with a comprehensive approach using a variety of grade-control structures, improved fencing, reduction of roads, introduction of at-risk species, fewer cattle and science. We have received 14 restoration grants from the Natural Resources Conservation Service, the United States Fish and Wildlife Service, the state

of New Mexico, The Nature Conservancy, The Peregrine Fund and others, meaning that 84 percent of the cost of restoration has been publically funded.

Using a dozen different designs of grade-control structures, the results thus far include capturing more that 50,000 tons of sediment — thereby raising the floor of the incised ciénaga toward its return to its historic condition — increasing vegetation, elevating the water table and surface level, expanding grasslands, establishing habitat for nine at-risk species and even the surprise of discovering a plant previously unknown to science. It turns out that the Pitchfork Ranch is currently the only known location on the planet for the Euphorbia *rayturneri.*

It turns out that ciénagas — like all other vegetated wetlands, as well as forests, jungles, swamps and similar habitats — serve as carbon sinks where atmospheric carbon is drawn back into the soil by the process we all learned about as kids, photosynthesis. There is an emerging awareness of the potential to use this natural process in the fight to save our warming planet. From a restoration perspective, each new blade of grass serves two important functions: acting as a dam, it blocks and captures sediment suspended in flowing water; and, acting as a straw, it siphons carbon from the atmosphere into the ground, where it will remain for thousands of years.

I have long subscribed to the notion that each of us can identify a handful of events that shaped our lives. This is not a reference to our developing loyalty to a sports team or even a political party. These are the two or three occurrences that influenced our life trajectory. I stood quietly beside my freshman college basketball coach and another professor talking about lawyers and the law. I never said a word, but my law career followed. Another incident that shaped my life and led to our retirement world of habitat restoration was our series of two-week Sierra Club volunteer service trips where Lucinda and I gathered with like-minded people and engaged in menial, but important, labor. Some of the work was archaeological surveying, simply walking along and looking down; there were also trail repair, fence and invasive plant removal and other aspects of habitat restoration. Our purchase of the Pitchfork Ranch and our habitat restoration work came as a result of that volunteer service, and, in turn, this work has led to an awareness of the seriousness of climate change and the need and opportunity to do something about it.

There is a general consensus that Aldo Leopold is the father of wildlife conservation in America. Leopold's *A Sand County Almanac* is the book that laid out the core principles for modern conservation ethics. Published in 1949, one year after he died of a heart attack while helping his

neighbors fight a grass fire at the age of only 61, it remains in print. Although he was a prolific writer of more than 300 papers and articles, he neither saw his crown jewel in print nor realized that his proposed land ethic would become so firmly ensconced in the modern American mind.

Leopold's thinking about his land ethic evolved at a time when conservation of land and natural resources was struggling for recognition among a majority of Americans, most of whom thought of land almost exclusively in terms of consumer resources: minerals, lumber and food. In his essay, "The Land Ethic," in *Sand County,* Leopold proposed an extension of ethics beyond the traditional Golden Rule that endeavored to integrate the individual into a co-operative human community. He argued that the proposed extension of ethics to the land was actually a process of ecological evolution, an evolutionary possibility that he saw as an ecological necessity.

Believing that the free-for-all competition of the marketplace had been replaced, in part, by co-operative mechanisms with an ethical content, Leopold understood the expansion of the Golden Rule beyond humans as two dimensions of the same thing: ecologically, as a limitation on the freedom of human action in the struggle for existence; and, philosophically, recognizing the difference between social and anti-social conduct. His land

ethic enlarged the boundaries of the community to include soils, waters, plants and animals — or, collectively, what he simply thought of as "the land." Leopold envisioned an ethical obligation of responsible citizenship, with contributing members of the human community in harmony between themselves and the land, treating the land as they would treat themselves and their loved ones.

Leopold would not accept the notion of "worthless" species; rather he thought in terms of "biotic right," irrespective of the presence of economic benefit to humans. He did not see land merely as soil; rather, Leopold characterized land as a fountain of energy flowing through a circuit of soils, plants and land — a sustained circuit, a slowly augmented revolving fund of life. He thought in terms of fertility, the flow of energy through plants and animals and its return to the soil by way of photosynthesis — that process that allows plants and the sun to convert carbon dioxide into oxygen for humans to breath and into carbon food for plants and all manner of subsurface organisms.

Leopold's seminal land-ethic essay mentions air only once and atmosphere, never. He wrote the essay almost 70 years ago. It's now known that Exxon was aware that carbon emissions from fossil-fuel products were warming the planet and would eventually threaten civilization, apparently

became aware of the risk and began to study it in the 1950s, shortly after Leopold died. If climate change was on Leopold's radar at all, there is no mention of it in his essays. The atmosphere was not specifically mentioned as a part of the "energy circuit" he hoped to protect by enlarging ethics to include biota, the total collection of organisms on, under and above the land that make up the biosphere, the global sum of all ecosystems.

The biosphere is the global ecological system that embraces all of life, including the atmosphere, and Leopold surely was aware of this. Although there is no explicit reference to the atmosphere in the essay that called for a land ethic, it's unthinkable to read it as having been excluded. If Leopold were alive and writing today, the atmosphere doubtless would have been explicit and central to his proposal to expand the reach of ethics. In light of his use of the terms "biotic citizen," "biotic right," and other "biotic" derivatives, he was thinking inclusively and that surely implied the atmosphere.

E. O. Wilson's 2016 writing parallels Leopold's of three-quarters of a century past: "The biosphere does not belong to us; we belong to it." He and a score of others have warned that the solution to the modern environmental crisis requires nothing less than a fundamental shift in human consciousness. The living world is in desperate condition as demonstrated by: the massive

loss of biological diversity, the scale of species extinction, the multifaceted degradation and warming of the atmosphere, the far-reaching depletion of diverse natural resources and the widespread toxification of various food chains.

Because so much of the destructive changes on the planet are not noticed as we go about our daily lives, they are ignored, despite extreme and measurable damage to both the land and atmosphere. David R. Montgomery, professor of Earth and Space Science at the University of Washington, writes in his 2007 *Dirt, The Erosion of Civilization*, "An estimated twenty-four billion tons of soil are lost annually around the world — several tons for each person on the planet. Despite such global losses, soil erodes slowly enough to go largely unnoticed in anyone's lifetime." Referring to these losses as "ecological suicide," Montgomery warns, "Legacies of ancient soil degradation continue to consign whole regions to the crushing poverty that comes from wasted land."

This point is so critical that it bears repeating: since the beginning of human civilization and up until about 200 years ago with the arrival of the industrial revolution, industrial agriculture and the burning of fossil fuels, the atmosphere contained around 275 PPM carbon dioxide content. Climate scientists warn we are already well above the safe CO_2 level for our current

form of civilization at the current 400-plus PPM; and, unless this number is rapidly returned below 350 PPM, a tipping point — abrupt climate disruption — will be reached beyond which irreversible impacts will set in motion events that will end civilization as we know it.

Living in the most important moment in human history, we must be aware that the climate crisis warrants the inclusion of atmosphere in the expansion of the human-centered Golden Rule. Atmosphere is unavoidably an element of Leopold's land ethic of soils and inhabitants, and, without it, the land ethic is incomplete. The solution to the climate crisis is an essential part of the "biotic ethic" that comprises the entire life circuit that Leopold yearned to protect.

Leopold's land ethic is couched in terms of ecological and evolutionary theory, and, for me, his thinking reflects a fundamental moral sensibility and civic virtue. This is an ethos for members of a community in which all affiliates are entitled to exercise their "biotic right" to exist free of exploitation. It's in "The Land Ethic" essay where Leopold wrote these famous lines in hopes of addressing land-use issues in terms beyond narrow economic interests:

> Examine each question in terms of what is ethically and esthetically right, as well as what is economically expedient. A

> thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.

Expanding the notions of doing what is ethically and esthetically right and calling for nothing less than a fundamental reform in our relationship with the land — as well as the atmosphere — and making an explicit summons to restore habitat, he emphasized,

> The only progress that counts is that on the actual landscape of the back forty…The government cannot buy 'everywhere'...The private landowner *must* enter the picture...The basic problem is *to induce the private landowner to conserve his own land*, and no conceivable millions or billions for public land purchase can alter that fact, nor the fact that so far he hasn't done it. (Emphasis and quotes in original)

This is where the reader joins us in this picture of ethical action in service of the biosphere by way of habitat restoration. What can we do? All we can do is do all we can. Everyone, anywhere and with any size property can pursue habitat restoration, and in turn sequester carbon.

Three-fifths of the United States population were growing victory gardens during World War II. Why not "climate gardens"? In 1941, 75 percent of the 137 million people in the United States had access to victory gardens, and 42 percent of fresh vegetables came from backyards. The government-recommended garden size was 7,000 square feet (50 feet by 140 feet). There were over 19 million gardens. If the same three-fifths of

today's 310 million United States inhabitants had access to climate gardens, the count of 19 million victory gardens would more than double to 50 million climate gardens. This nationwide, wartime program demonstrates that social mobilization of individuals and families on a massive scale is possible. Fifty million climate gardens would produce a great deal of local food and a large number of biodegradable straws to draw heat-trapping carbon out of the fossil-fuel infested atmosphere and return it to the soil where it belongs.

There are a number of people pursuing an agenda of habitat restoration that began with and remains focused on repair and rehabilitation of the land, yet are also helping stem the tide of climate change by removing carbon from the atmosphere. Journalist Kristin Ohlson's recent book, *The Soil Will Save Us,* is one of a growing number of writings that surveys scientists and practitioners who believe we can reverse climate change by restoring soil. According to one calculation:

> Ohio has lost 50 percent of its soil carbon in the last 200 years. But in some areas of the world where cultivation has been going on for millennia, soil carbon depletion is much higher — up to 80 percent or more. Altogether, the world's soils have lost up to 80 billion tons of carbon.
>
> For eons, this carbon was underfoot, but now it's floating in the ever

more warming atmosphere. The increasing number of soil enthusiasts — calling themselves soil farmers, microbe farmers, carbon farmers and soil or carbon ranchers and various supporters of these soil loyalists — sees themselves near the trailhead on the path to restore the land, air and water and to help arrest climate change. They are focused on the interaction between soil and climate, soil carbon and global warming. Rattan Lal, director of the Carbon Management and Sequestration Center at Ohio State University, maintains that responsible soil management can recapture most of the misplaced carbon by bringing soil back to health and simply allowing plants to do what they have always done: use sunlight to convert carbon dioxide to the materials that service life through photosynthesis. There are a number of sound strategies — the transition from fossil fuels to renewable energy being the most important among them — that avoid further uploading of carbon into the atmosphere, but these programs do not address the legacy load of carbon that began to stack up at the start of the Industrial Revolution. Therein lies the great green hope, the carbon drawdown that returns carbon to the soil.

Growing numbers of farmers, ranchers and others are pursuing new approaches to food production and land stewardship — dubbed "regenerative agriculture" — as a way not only to grow food, but also build

soil, store carbon and reverse the atmospheric warming that is overwhelming the atmosphere. Individuals can help, too. Climate gardens are one way to help, and habitat restoration is another. In the region surrounding the Pitchfork Ranch, there are a variety of restoration efforts being pursued by people with dissimilar life styles, varying incomes and differing property sizes that are improving land and drawing down atmospheric carbon.

A young renter in Silver City, New Mexico, has a .02-acre city lot where he is both restoring land and sequestering carbon as a result of gardening and selling plants. In the same town, a retired college professor purchased a historic home on .36 acres or eight city lots where she has begun a community garden and has replaced non-native vegetation with local plants, both restoring land and sequestering carbon. Another woman lives in a rural home on 11 acres, 20 miles from our ranch, and she has installed some of the same grade-control structures we use in our habitat restoration efforts. In the Burro Mountains, south of Silver City and up watershed about 30 miles from the Pitchfork, a couple have an 83-acre ecological preserve where they are gardening and using the same kinds of grade-control structures that we and the woman with 11 acres' use. Our place is a bit under 12,000 acres. We have friends with a 200-thousand-acre restoration project on the Arizona-New Mexico-Mexico border that takes advantage of similar

tactics in restoring a 40-square-mile, long overused habitat and coincidently sequestering carbon as a byproduct of their restoration activities.

Land restoration does not satisfy any one-size-fits-all silver bullet for solving all of the concerns that worried Leopold, so additions to and adjustments of basic tools are always necessary. Yet, the ongoing restoration on the 200-thousand-acre ranch uses the same basic model that is working on the other five properties and can be replicated on a global scale by almost everyone and on any property, large or small.

Although details of the efforts to restore the San Pedro River, studied so thoroughly by D. A. Griffiths in 1901, are beyond the scope of this material, it is instructive to recognize that the approach used to increase water flows in the 143-mile waterway that runs northward from Sonora, Mexico, to the Gila River in Arizona — the last major free-flowing, undammed river in the American Southwest — is conceptually the same as the techniques being used on the six properties just mentioned. After a decade of studies, planning and a multi-million-dollar commitment, three groups — The Nature Conservancy, the United States Army and Cochise County, Arizona — are building grade-control structures that will catch summer monsoon rain and filter it into the aquifer to supplement the San Pedro's already overdrawn waters.

In the spring of 2014, heavy loaders and earth haulers constructed a new storm-water basin that will hold up to 17 million gallons of monsoon rainwater and drain them through a series of recharge pools, trenches and wells about one-half mile from the river. Berms surrounding the basin will steer the water into a 120-foot-wide channel where it will pool behind and spill over four-foot-high walls, slowing the flow so that the water can seep into and replenish the aquifer. Slowing the flow not only allows the water to seep down and wick laterally, but also prevents incisions and captures sediment. The plan for the San Pedro mimics those for the afore-mentioned restoration projects — or vice versa — that can be accomplished by almost anyone, almost anywhere.

Consistent with the notion that "there is nothing new under the sun," in the summer of 2016, students and staff from the Archaeology Southwest and University of Arizona 2016 Upper Gila Preservation Archaeology Field School performed an intensive pedestrian survey of the ranch and found a series of 13 check dams built within a wide wash to facilitate farming by the Mimbres Indians who occupied dozens of sites along the Burro Ciénaga between 750 CE and 1300 CE. These structures appear similar to the 500 one-rock dams we have installed in the 33 side channels that drain into the reach of the Burro Ciénaga on the Pitchfork.

This survey of restoration and sequestration practitioners — ranging from an individual renting a city lot to county and federal government organizations, not to mention prehistoric Indians — demonstrates a variety of techniques to capture water and replenish the aquifer, to restore land and sequester carbon, to harvest city water runoff with curb cuts, to restore ciénagas with grade-control structures and to restore rivers with similar, larger-scale structures. There are four aspects to the habitat repair in these six size-described illustrations: *impact,* by encouraging others to follow suit; *restoration,* by reversing erosion of the land itself; *adaptation* to the repercussions of climate change; and *sequestration* of the legacy load of atmospheric carbon. There is not one healthy person on the planet who can't take part in these efforts.