2. Stewardship for Climate Change Adaptation and Mitigation

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“What are we learning about the science of stewarding conserved land to maximize climate benefits, including both adaptation and mitigation?”

“I have read many definitions of what is a conservationist and written not a few myself, but I suspect that the best one is written not with a pen, but with an axe… A conservationist is one who is humbly aware that with each stroke he is writing his signature on the face of the land”

—Aldo Leopold

What are we learning about stewarding conservation land to maximize climate benefits, such as greenhouse gas reduction and resilience in the face of changing weather patterns? This question is particularly relevant as land trusts transition from primarily focusing on acquiring properties for their conservation values to stewarding those same values in perpetuity. Looking ahead, it seems likely that the relevance of land conservation as a field will be increasingly viewed in terms of the benefits that land trusts bring to the environment and society through their management of the lands they are entrusted with. In this light, climate change presents an opportunity for increasingly stewardship-focused land trusts to address two major problems at once.

By positioning themselves as forward-looking stewards of conservation land with an eye towards securing climate benefits for the communities they serve from the properties they protect, land trusts can elegantly transition away from an acquisition model as the demand for this work declines. At the same time, by helping communities respond to climate change, land trusts will be making key contributions to the most pressing environmental challenge of the 21st century. In this chapter, we address these opportunities in two sections, dealing respectively with management strategies geared towards climate change adaptation and mitigation.
The initial section of this chapter addresses climate change adaptation — the work of bolstering social and ecological systems against anticipated climate change conditions — through a discussion of the science of climate change as it pertains to human concerns such as health and economics. This treatment expands on the habitat management strategies introduced in the preceding chapter by taking a forward-looking approach to questions of stewardship and focusing on opportunities to maximize the social benefit of conservation land in an uncertain future.

The second section addresses climate change mitigation as a stewardship opportunity. Mitigation — the work of minimizing climate change impacts through reduction of atmospheric greenhouse gas concentrations — is most often discussed in terms of market regulations and changes in consumption and lifestyle. However, land use change and management practices contribute to the U.S. carbon budget as well, and the land conservation community is well positioned to help reduce land-related emissions through innovative stewardship techniques.

Taken together, these topics aim to advance the conversation surrounding the role of land trusts in a changing world with an emphasis on strategy and stewardship. In the sections below, we will (A) introduce the science behind climate change processes relevant to conservation land; (B) discuss key stewardship implications stemming from current research; (C) examine case studies of conservation organizations leading the way in adaptation and mitigation stewardship; and (D) consider the implications of these topics for land stewardship and the conservation community going forward.

2.1 Adaptation

When the land conservation community considers climate change adaptation, much of its attention has historically focused on the anticipated impacts of climate change on natural systems as distinct from human ones, as discussed in the preceding chapter. There, we considered a range of potential management strategies for helping wild places and wildlife adapt to the warmer temperatures, shifting water regimes, and evolving landscapes.

However, a broader conversation about adaptation is taking place in the scientific community, one that addresses the impacts of climate change on humans through our participation in linked social-ecological systems. In this section, we consider the ways that the land conservation community can advance human adaptation to a warmer world faced with new extremes of both precipitation and drought, through proactive land management.

2.1.1 Temperature

We know that the planet is warming, but by how much, and with what consequences? The Intergovernmental Panel on Climate Change’s 5th assessment (IPCC 2014) suggests a range of temperatures dependent on emissions scenario. With aggressive emission controls, the planet might warm between 0.3 and 1.7º C by the end of the century. However, under a high emission scenario, warming between 2.6 and 4.8º C is expected. And, in all emissions scenarios, more extreme high temperatures and less frigid lows are virtually certain (IPCC 2014).
Looking at global average temperatures can be problematic for getting a sense of what life—and land management—in a particular region will be like in a changing climate. In a well-publicized article in Nature, researchers interpreted global warming using the concept of climate departure. Climate departure refers to the point at which the average annual temperature for a given region will exceed the highest recorded averages for that same place from the beginning of record keeping until 2005. Mora et al. (2013) found that for mid-latitude cities like New York City and San Francisco, climate departure is expected to occur by the mid-21st century.

Research suggests that wildlife with strict thermal habitat requirements will either migrate to cooler regions as their native ranges warm, or perish (Malcolm et al. 2002), but what about humans? Unlike a population of migratory birds, major human settlements will not easily relocate as the planet warms. And, the impacts of a warming planet are expected to be particularly severe in urban areas. Pavement and concrete have a lower albedo—the capacity to reflect solar radiation—than the dense vegetation of a rural or forested landscape, translating into more solar heat stored by the land. These impervious surfaces also prevent the infiltration of water into the landscape, which helps greener landscapes mediate temperature (Kenward et al. 2014). As a result, urban areas are often considerably warmer than their rural surroundings (figure 1).

![Figure 1: Urban Heat Island Temperature Distribution](http://www.cleanairpartnership.org/files/urbanheatisland.jpg)

This effect—the urban “heat island”—averages roughly 1.3̊C in the 60 warmest cities in the US during the day, with an even more pronounced nighttime effect (Kenward et al. 2014). In the most extreme cases, the urban heat islands can average as much as 4̊C warmer than their rural surroundings. Because of these effects, urban areas see about one additional week per year of days over 90̊F, and a slew of associated health impacts including heat stress and
degraded air quality (Kenward et al. 2014).

2.1.1.1 Stewardship on a Warmer Planet

Against the backdrop of climate change, the urban heat island effect is a serious health risk. In cities, heightened global warming threatens respiratory health through increased exposure to ground level ozone and higher risk of heat stroke (Kenward et al. 2014). As in wild systems, land managers in urban areas have an opportunity to help respond to these changes through adaptive land management.

Urban land trusts often work in considerable areas of green space within the cities they operate in, placing them in a unique position to manage the land to help reduce the heat island effect. Because urban heat islands are largely driven by reduced albedo and decreased retention of soil water, management strategies that increase albedo and water retention can help to locally counter the heat island effect (Mackey et al. 2012). Two management strategies for this purpose have received considerable attention: the use of green infrastructure, such as shade trees and urban green spaces, and the installation of reflective roofs and pavement.

Street Trees, Ground Level Ozone, and Other Air Quality Concerns

Street trees can do more than simply keep the air cool; they can also help keep it clean. Ozone, formed when O2 molecules are split in high-energy environments and re-assemble as O3, is a double-edged sword. Atmospheric ozone helps shield the planet from incoming radiation, but at the ground level this same molecule can become concentrated and contribute to a wide range of respiratory health risks (EPA).

As city planners and conservationists prepare for a warmer future where urban conditions are increasingly conducive to the formation and accumulation of ground level ozone (Akimoto 2003), street trees may play a front-and-center role (Kroeger et al. 2014). In addition to providing shade that both blocks incoming radiation and decreases temperatures, street trees can absorb ozone — and other air pollutants linked to climate change, like particulate matter and sulfur dioxide — directly. Modeling studies suggest that during peak ozone-producing conditions, citywide street tree plantings could help reduce ozone by 16% during concentrated time intervals (Nowak et al. 2010).
However, planners considering street trees to combat air pollutants should be careful not to create new health concerns. For example, under warming conditions, research suggests increased intensity and duration of pollen production from a wide range of plants, including the notorious ragweed and many urban street tree species (FAO). Although the linkage between climate change, increased pollen production, and urban street trees requires further research, recent reviews of the primary literature suggests that climate change-heightened pollen production should not be discounted as a public health concern (Roy et al. 2011).

Fighting for the benefits of urban green space is familiar ground for the land trust community, which has taken on a new significance in the context of global warming. At the scale of a single building, shade trees can offset direct insolation and reduce the need for air conditioning by 35% (Rosenfeld et al. 1995). At a larger scale, modeling studies suggest that citywide shade tree plantings can reduce average temperatures by between 0.3 and 1º C during midday (Akbari et al. 2001). Urban shade trees cool their surrounding environments through two mechanisms:

- Shading: shading reduces the amount of solar energy which makes direct contact with thermal reservoir surfaces like building walls and street pavement. Shade trees absorb or reflect between 70% and 90% of sunlight in their immediate footprint, which translates to surface temperature reductions of 20-45 ºF for walls and pavement immediately beneath them (EPAb).

- Evapotranspiration: evapotranspiration is the process by which trees absorb water from the soil, process it, and release it as water vapor through their leaves (EPAb). The phase change that occurs during this process draws heat from the surrounding environment, cooling the air around the trunk and leaves (Bowler et al. 2010). This “oasis effect” can range from 3.6-14.4 ºF for urban street trees (Taha 1997).

Urban vegetation, including both street trees and green space like parks and green roofs, can also reduce urban heat island effects by increasing the amount of solar energy reflected back into space. Very simply, highly light-absorbent surfaces like dark pavement capture more solar energy as heat than do reflective surfaces. Researchers have found that green space can have roughly four times the albedo of dark surfaces like pavement (Susca et al. 2011).

Combining the mechanisms of shading, evapotranspiration, and increasing albedo, replacing pavement with vegetation at a parcel scale—a building parking lot, for example—has a pronounced cooling effect, which can be heightened as plant life grows denser and more diverse (Mackey et al. 2012). While cities may be loath bear the costs of managing heavily vegetated green spaces year after year, land trusts are well positioned to advocate for and maintain such areas, which offer habitat and water control benefits in addition to providing some relief for intense heat islands.
Green Space & Baltimore

Owning and managing green space in an urban environment is a challenge for public and private landowners alike. The pressure to cash out and develop is considerable, and the effort involved in maintaining wild spaces in a jungle of concrete is significant.

Land trusts like Baltimore Greenspace are perfectly suited to helping cities and communities retain beneficial urban green space, by taking on the mission of owning and stewarding forest patches, community gardens, and small parks. Baltimore Greenspace is a small land trust that currently stewards a handful of parks and community gardens in Baltimore, Maryland, and has reached an agreement with the city for the purchase of municipally-owned lots with green-space value. Moreover, the organization recognizes that the habitat, health, and climate adaptation benefits of urban forest protection offer an avenue for expansion. By highlighting the benefits of urban forests and partnering with state and community groups interested in forest stewardship, Baltimore Greenspace is helping to raise awareness of the importance of green infrastructure and raise its profile.

For more information, visit:

http://baltimoregreenspace.org/forest-patches/how-we-help-2

While green space has many benefits, in terms of maximizing albedo for heat reduction the most effective management strategies are not strictly green. Reflective roofing and white pavement have been shown to significantly increase albedo in areas where they are implemented (Lei et al. 2014). Similarly sized areas of reflective roofing out-perform even the densest vegetation in terms of their ability to reflect solar radiation (Mackey et al. 2012), with albedos roughly 16 times as great as dark pavement, and eight times as great as green space (Susca et al. 2011). White roofing can also be installed in areas not suited for green space or urban tree planting, a useful feature given that roof space alone accounts for 20-25% of the urban surface (Susca et al. 2011). Models suggest that if implemented aggressively and globally, reflective pavement and roofs have tremendous cooling potential, roughly equivalent to the capture of 44 gigatons of CO2, an offset worth around $1,100 billion at a value of $25/ton of carbon (Akbari et al. 2009).
Green Infrastructure Synergies

Although rarely discussed in the primary literature, the potential for synergy between green infrastructure like street trees, bioswales, and reflective pavement and roofing is considerable. To date, the best applications of both strategies can be seen in green alley projects which incorporate reflective pavement made of permeable substrates, in tandem with green infrastructure, to reduce stormwater management problems while also minimizing heat island effects. Section 2.1.2.1 details the mechanisms behind bioswale and green alley technology more thoroughly, and cites high-profile cases of their successful application.

2.1.2 Changing Weather: Wetter, Drier, and Higher

Water resources will pose a major challenge for managers across the U.S. as climate change intensifies. As temperature warms and weather patterns shift, regions like the American west and southwest are expected to face increasingly severe and frequent droughts and fires, while northern states and the Pacific Northwest will likely become wetter even as seasonal extremes in wet and dry spells intensify (Union of Concerned Scientists). With regards to fresh water availability, wet areas will get wetter, dry areas will get drier, and management challenges in both will be exacerbated (Figure 2; NCAS). At the same time, sea level rise will present its own suit of challenges in coastal communities (IPCC 2013).

In areas expected to see increased precipitation, primary management concerns center around adapting to the impacts of flooding, erosion and runoff management (Purdue Extension). Rainstorms historically categorized as 1 in 20 year events are expected to become more common, occurring roughly 4 in every 15 years. The intensity of rainfall during harsh storms is expected to increase as well, by between 10% and 25% over the course of the 21st century (Union of Concerned Scientists). The impacts of intense precipitation to riverbanks, agricultural lands, and municipalities will require innovative management responses.

In addition to storm water management, climate change will require coastal communities and land trusts to confront yet another water management challenge: sea level rise. Although the exact degree of sea level rise is expected to vary regionally, the IPCC’s 5th assessment broadly suggests that average global sea level rise should be between 0.26 and 0.97 meters by the end of the century, depending on emissions scenario (IPCC 2013). In some areas, these numbers translate into much higher figures. Areas along the Hudson River valley and New York coastline are bracing for a figure closer to two meters (Scenic Hudson).

In contrast to the challenges of rising seas and intensifying precipitation, some land trusts will be faced with the work of managing for increasingly dry conditions. The western United States have experienced a period of sustained drought which, though not yet comparable to historic ‘megadroughts’ of the past millennia, are thought to be a harbinger of things to come under an increasingly warm and arid climate (Cooke et al. 2004). Warming temperatures and correspondingly earlier snowmelt also correlate with increased risk of and intensity of
wildfire (Westerling et al. 2006). Accordingly, land managers in the western U.S. will need to consider management that minimizes fire risk and maximizes water availability, quality, and retention in a more arid, fire-prone environment.

2.1.2.1 Stewardship Under Changing Weather Regimes

Land management that accounts for changing precipitation and water availability is a rapidly growing discipline. In the northern U.S., both urban and rural land trusts are bracing for
more intense and more frequent storm events with novel management strategies.

In the rural landscape of the northeast, natural systems offer promising opportunities for managing increased storm water. Research suggests that land management geared towards reconnecting rivers with their native floodplains can have marked flood control benefits, in addition to improving habitat for aquatic species (Sommer et al. 2011). Likewise, riparian forests along naturally meandering stream channels—especially those in system headwaters—provide both water quality and flood and erosion control services (Kozlowski 2002). The mechanisms by which both processes benefit watershed health and downstream water quality are similar to those described later in this section for bioswales and other green infrastructure, but at a grand scale. In situations of intensified precipitation, riparian forests slow the flow of surface and groundwater entering river systems (Chesapeake Bay Program). This mediation can help keep peak flow from reaching damaging intensity, and can also help stabilize flows over time. Both erosion risk and fluctuation in flow are anticipated climate change impacts for many rivers (Palmer et al. 2009), and both have consequences for stream ecology and for down-stream users, such as farmers or city water districts. As such, municipalities like New York City are investing in conservation and forest management in their up-stream watersheds to ensure reliable, clean drinking water as climate change intensifies.

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**Water Quality as a Land Conservation Benefit**

Rural land conservation to benefit regional water quality has a long history. New York’s Catskill Mountains are perhaps the most iconic example of this tradition, which has now entered a new stage thanks to a partnership between New York City and the Catskill Center, a local land trust. With funding from the city, the Catskill Center is protecting riparian forestland essential not only to ensuring the city’s supply of quality water, but also to maintaining the health of local watersheds in the face of climate change. The partnership takes advantage of the Catskill Center’s local reputation and investment in a healthy landscape and the City’s interest in regional water quality, to benefit both rural and urban communities.

For more information, visit:

http://catskillcenter.org/streamside/

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Urban areas in the northern U.S. will also have to contend with increased storm water issues, but unlike rural regions, urban areas largely rely on engineered systems for storm water management. As in the previous section, the land conservation community is helping to meet this challenge of climate change with green infrastructure solutions. A prime example of this effort is the installation of bioswales, engineered depressions in the urban landscape filled with highly permeable soil and flood resistant plants, to help capture and control runoff from impervious paved areas (Soil Science Society of America).
Bioswales perform a range of water management functions, which include collecting and moving stormwater, improving water quality through filtration, and improving water infiltration into (and retention in) the underlying soil. These benefits are all achieved using the same basic mechanisms, described in detail on the SUNY ESF web page and summarized below:

- Bioswales collect stormwater through strategic placement at low points on the landscape, often replacing traditional gutters or storm drains. This provides a useful means of reducing sewer loading or surface water accumulation over impermeable pavements.

- Once trapped, stormwater velocity is significantly reduced by the bioswale's plant community and depth, allowing for long term storage or conveyance with minimal risks of erosion.

- Trapped or conveyed water is filtered and suspended sediments are removed as it flows through the bioswale's plant community and porous soils.

- Porous soils enable trapped stormwater to infiltrate back into the groundwater, rather than being conveyed out of the city's catchment by a more traditional grey infrastructure system.

Bioswales are not the only form of green infrastructure. Street trees, in addition to their thermal and air quality benefits, can also help reduce the impacts of runoff from intense rain
by intercepting and slowing the accumulation of surface water (American Forests). And, “green alleys” outfitted with permeable soil and a wide range of vegetation can help slow and store runoff at a large scale, while also mediating heat island effects (Newell et al. 2013). Conversely, green alleys can also help with water retention in arid regions, as described in the box below. Additionally, green infrastructure techniques can be applied outside of the urban landscape to benefit population centers. The Connecticut Institute for Resilience and Climate Adaptation (CIRCA) notes that engineered wetlands along the Connecticut coast could reduce the impacts of storms and floods within urban areas (CIRCA).

Los Angeles’ Green Alleys

The city of Los Angeles is teaming up with the Trust for Public Land to address its paucity of parks, help manage a strong urban heat island effect, and improve its storm water treatment and storage infrastructure all in one fell swoop. Green alleys, with light-colored, permeable pavement, extensive plantings, and improved public access make the project a compelling and versatile solution to a suite of problems. Los Angeles’ program is part of a larger movement to address urban green space, water management, and heat island effects with green alleys that also includes cities like Chicago and Montreal.

For more information, visit:
https://www.tpl.org/media-room/green-right-our-alley

To address the risks of rising sea levels, a medley of management and planning strategies are relevant to coastal land trusts. In the short term, managing for healthy wetlands to defend against the effects of higher-than-average storm surge applies strategies similar to floodplain conservation and management along inland river systems (Coastal Resilience). However the long-term implications of sea level rise mean that land trusts must also contend with the reality of permanent inundation of some parcels, and the inward migration of the tidal zone and marshlands (Feagin et al. 2010). Both rural and urban land trusts are responding to this science with marsh restoration and land acquisition projects designed to provide resilient coastal zones now and in the future. Support for such projects is increasingly coming from cities concerned with stormwater management and coastal encroachment, a pathway described in detail in the subsequent chapter on urban resilience below.

The benefits of green infrastructure solutions to stormwater management, rising sea levels, and rising temperatures (as described in section 2.1.1.1) can extend beyond the strictly environmental. Relative to traditional grey infrastructure solutions, green infrastructure can be cost-effective. Financing green infrastructure projects is further discussed in Chapter 4 on financing urban resilience.
Managing for a Rising Tide

The Hawaiian Islands Land Trust faces a remarkable predicament as it plans for the management of its Waihe'e Refuge. The property, which is home to endangered species and historic sites, could see inundation of considerable swaths of its 227 acres as sea level rises. To manage for this possibility, the land trust is applying restoration ecology to return the refuge to the most resilient state possible. It is hoped that intact sand dunes and diverse communities of native vegetation will facilitate a smooth adaptation to changing conditions.

For more information, visit:
http://climatechange.lta.org/case-study/hilt_waihee_restoration/

Both urban and rural landscapes in the American west are preparing for a different suit of climate change challenges: wildfires and drought. Wildfires are a natural element of forest processes in much of the west and southwest, where low-intensity, relatively frequent fires historically helped mediate forest dynamics (Stephens 2005). However, fire intensity and frequency is expected to increase with climate change. Beginning in the early 20th century, federal fire suppression policies began to lay the foundations for more intense fires made possible by more densely stocked forests with greater buildup of understory vegetation and downed woody debris (Stephens 2005). Today, these conditions interact with increasingly warm, dry climate to heighten the risk of intense, large scale fires even further (Brown et al. 2004). Such fires impact a wide range of conservation values including:

• Habitat: intense forest fires can level large forested areas in a way not common under natural fire regimes, and recovery from such fires can take decades. This is especially concerning in the boreal forests, where warming temperatures may make it impossible for traditional cold-tolerant tree species and communities to re-establish after intense fires (Kelly et al. 2013).

• Forest carbon storage: fires release above ground forest carbon both during the immediate combustion of biomass, and through the subsequent decay of dead biomass. Additionally, burnt-over landscapes take time to regain primary producer communities to begin storing carbon again through photosynthesis, and even longer to re-establish as forests with long-term above ground carbon storage potential (Buckley et al. 2014).

• Water quality: wildfires compromise water quality by destroying the plant communities which stabilize soil across watersheds, increasing the vulnerability of downstream rivers and reservoirs to high concentrations of sediment-rich runoff, and in some cases producing ash that can contaminate water bodies directly (Buckley et al. 2014).
Managing conservation land for increased fire frequency and intensity centers around forestry practices which reduce fuel-loads and alter forest structure to minimize vulnerability to intense fires. Fuel-treatment—the reduction of woody debris, dense understory vegetation, and heavily stocked forest stands—mimics the impacts of frequent, low intensity fires. With reduced fuel availability, modeling studies show that the footprint of wildfires can be reduced by 30-76%, and the acreage of high-intensity burning that is most damaging to forests and watersheds can be decreased by 75%. Additionally, by reducing available fuel through both mechanical thinning and removal, as well as controlled burns, managers can improve forest health and generate biomass and other timber products (American Forest Foundation).

The Finance of Fire Management

Forestry designed to increase the resilience of watershed lands to wildfires is rapidly gaining the interest not only of conservation organizations, but of municipalities and private sector funders. Through the fuel-treatment management techniques described above, modeling studies suggest that investors can make tremendous savings in avoided costs that would be incurred in a high intensity wildfire, such as property damage and watershed restoration (Buckley 2014). Two very different organizations—Morgan Stanley and the City of Santa Fe, NM—showcase the wide appeal of this sort of proactive management to a range of investors. UC Berkley business students won Morgan Stanley’s 2015 Sustainable Investing Challenge with an innovative proposal to monetize the benefits of watershed timber management among stakeholders including water districts, energy utilities, and municipalities in order to finance proactive fire control (Morgan Stanley). The City of Santa Fe is working along similar lines, implementing a payment for ecosystem services program to expand funding available for the management of its watershed lands beyond the limited federal dollars it has previously relied on (City of Santa Fe 2013). Funding mechanisms for fire adaptation management are discussed in greater detail in the chapter on rural conservation finance below.

Land managers in the west are also looking to strategies for increasing the availability and conservation of water in an arid landscape. The Clark Fork Coalition, a watershed advocacy group, in partnership with the Bitterroot Land Trust, applies habitat restoration work to maximize water available for irrigation and stream-flow in the headwaters of the Bitterroot watershed (LTA). Strategies such as improved irrigation techniques and dam removal have benefitted both organizations by improving stream health and meeting the agricultural needs of the local irrigation district (Clark Fork Coalition). Strategies for water conservation are available to rangeland managers as well. Research and anecdote suggest that rotational grazing and careful livestock management—such as the holistic management approaches pioneered by the Savory Institute—can help recover rangeland plant communities, which benefit water retention and quality on rangeland systems (Sherren et al. 2012).
2.1.3 Implications

The adaptation strategies discussed in the sections above should not be viewed as single-problem fixes. Rather, many of these techniques have the potential to address multiple challenges, and should be engaged with an eye towards capturing these co-benefits.

As cities plan not only for warming temperatures, but also increasing storm water management challenges, the ability of green spaces to address these concerns in addition to their albedo benefits are compelling. And, partnerships like the Trust for Public Land and the City of Los Angeles, recognizing that these strategies should not be mutually exclusive, are finding ways to integrate reflective pavement and green infrastructure into innovative green alley landscapes that function optimally to reduce heat islands and manage storm water.

In rural landscapes, protecting watersheds from the effects of increased runoff goes hand in hand with wildlife habitat conservation. From the headwaters of the Catskills to coastal deltas in the west, connecting streams with their floodplains and protecting riparian forest offers benefits ranging from erosion control to shade for coldwater fisheries to expanded habitat for a range of wildlife. Likewise, sound watershed management in the American west also buffers the landscape again the risk of wildfire, in both cases relying on proactive silviculture.

As the land conservation community addresses climate change adaptation with human systems in mind, a clear theme with regards to best management practices is beginning to emerge. The most economic, innovative, and effective strategies for adaptation—whether in response to warming temperatures or increasing precipitation impacts on rural landscapes—are those that work in natural systems to marry many interests and provide a multitude of services.

2.2 Mitigation

Adaptation strategies offer land trusts a wide range of options for dealing with a warmer world subject to more extreme weather, but do not address the pressing question of whether the land trust community can help reduce the threat of climate change proactively. In this section, we examine the science behind climate change mitigation through the reduction of greenhouse gas emissions and concentrations, and consider stewardship options for land trusts interested in taking part in the global movement to minimize the intensity of climate change, rather than just simply bracing for its impacts.

The terrestrial carbon stock, including carbon trapped in organic and mineral soils, shrubs and herbaceous plants, and trees, accounts for a tremendous amount of the earth's carbon budget. Soil carbon in particular is a crucial store, almost triple the size of the atmospheric carbon stock (Ontl & Schulte 2012). Recognizing the importance of terrestrial carbon as an opportunity to combat climate change, government agencies and NGOs in the U.S. and abroad are taking steps to study and encourage carbon management in terrestrial systems (McGlynn et al. 2016). With its stewardship interest in much of the privately protected land in the U.S., the land conservation community is well positioned to lead the charge in the realm of land management for carbon sequestration as a means of climate change mitigation.
However, a wide range of obstacles running the gamut from technical, to legal, to political and ecological stand in the way of the conservation community’s full engagement with mitigation stewardship. While the carbon cycle dynamics of forest and grassland communities—both working and wild—have received considerable scholarly attention, uncertainty remains with regards to best management practices for carbon sequestration in many cases (Ballessan & Luyssaert 2014; DeLonge et al. 2012). In cases where best practices have been identified with confidence, encouraging adoption of what may be perceived as restrictive measures by private landowners and other stakeholders can be difficult. Additionally, the continuously evolving nature of climate change raises questions about the long-term relevance of mitigation techniques that make sense today.

In response to these challenges, leaders in the land conservation community have applied a wide range of strategies to gain a beachhead in the arena of mitigation stewardship. Forest managers are increasing their emphasis on curbing the rate of deforestation and managing for forest diversity to pave the way for adoption of more novel approaches to carbon sequestration silviculture as scientific consensus and political climate allow (USDA). Agricultural land trusts and think-tanks are building on the linkages between carbon sequestration techniques and improved range condition to engage their ranching constituents (Savory Institute 2013). Taken together, these cases suggest that mitigation stewardship has the potential to be an important area for stakeholder engagement and innovation in land conservation, and a crucial piece in the fight against climate change.

### 2.2.1 Carbon Cycling & Sequestration

Climate change mitigation encompasses the full range of strategies for limiting the accumulation of atmospheric CO2 and other greenhouse gases, whether by decreasing emissions or recapturing greenhouse gases already in the atmosphere. In both forest and grassland systems, a range of stewardship techniques can be applied to prevent the loss of presently sequestered carbon, and to recapture and sequester atmospheric greenhouse gases. In order to grasp these opportunities, a basic understanding of the carbon cycle is useful.

In both forest and grassland systems, photosynthesis drives the carbon cycle. Plants capture atmospheric carbon and convert it into carbohydrates which are stored in biomass—the leaves, stems, and roots of plants. In a simplified system, aboveground (plant-based) carbon is eventually converted to below-ground (soil) carbon as plants die and are incorporated into the soil as soil organic carbon. Ultimately, soil organic carbon can be slowly transformed into inorganic forms in the mineral soil (USDA). Systems continue to acquire carbon through these mechanisms until the rate of accumulation slows to match the rate of carbon loss through leaching and decomposition, at which point the soil carbon pool is said to have reached equilibrium (Jandl et al. 2007).

Although the basic mechanisms of carbon capture and storage in forest and grassland systems are similar, some key differences between them exist. Due to the short lifespans of grassland plans, the vast majority of grassland carbon is stored in the soil (Diaz et al. 2009). While forests store considerable amounts of carbon in the soil as well, they can also sequester significant carbon in their comparatively long-lived dominant plant species.
Most scientists believe that because of this two-fold sequestration potential, forest systems have greater total carbon storage capability than grasslands (Science Daily), although some disagreement on this point exists (Wei et al. 2012). Additionally, because forests have both above and below-ground carbon sequestration potential, and because it is relatively easy to measure forest above-ground carbon storage, much more is known about forest carbon sequestration than grassland carbon sequestration (Diaz et al. 2009).

Carbon that is generally stored in above ground plant structures or in organic soils does not always remain sequestered. In forests and grasslands, a range of pathways allow stored carbon to escape and return to the atmosphere as a greenhouse gas.

2.2.1.1 Forest Carbon

Even without human influence, carbon trapped in plants and soils in forests can return to the atmosphere. Decomposition naturally accounts for the release of carbon from dead organic matter, and processes like wildfires can release vast amounts of carbon stored in both live trees and organic (and in some cases mineral) soils through combustion (USDA). Adding human activities to the equation, forest carbon is lost in tremendous quantities through deforestation, as timber harvested for fuel is burnt, wood products decomposes, and erosion and disturbance to the soil releases soil carbon (figure 3).
2.2.1.2 Grassland Carbon

In grassland systems, decomposition and fires also release sequestered carbon naturally. However, a range of other processes—both human and natural—can also account for greenhouse gas emission. In fertilized systems, addition of synthetic nitrogen supplements can increase plant production of N2O, soil compaction by livestock and agricultural machinery can lead to erosion which can physically remove soil carbon from the system and disturb microbial and fungal processes associated with soil carbon storage, and respiration by livestock can indirectly convert sequestered carbon into emissions (DeLonge et al. 2014).

2.2.2 Mitigation Stewardship

Best practices for mitigation in forest and grassland systems have been the subject of considerable research, and continue to receive much attention. Although certain practices specific to each system bear key similarities, this section divides its review by system type for clarity.

2.2.2.1 Forest Management For Mitigation

Three broad strategies exist for managing forestland with climate change mitigation in mind:

Avoided Conversion: The central tenet of mitigation management in forest systems has been a rallying cry for the conservation movement for decades: keep forest as forests. When forests are leveled, much of the carbon stored in above ground biomass like the leaves and stems of plants is released into the atmosphere, while a relatively small amount is slowly transferred to the soil (Houghton et al. 1983). Depending on the fate of the wood products from a given act of deforestation, the speed of carbon release from above-ground biomass can vary; wood incorporated into long-lasting structures contributes carbon to the atmosphere slowly, while wood burned to make way for agriculture or other non-forest uses transmits huge amounts of carbon to the atmosphere quickly (Moutinho & Schwartzman 2005). Above-ground biomass accounts for about one third of the planet's forest carbon stock (Dixon et al. 1994). Below-ground carbon, equal to roughly two thirds of the planet's forest carbon stock, can also be influenced by deforestation. Deforestation increases the rate of organic matter decomposition in surface soils (IPCC 2000), and burning can also impact organic soil carbon—and in some cases even carbon stored in the mineral soil (USDA). Thus, preventing deforestation outright is one of the most effective forest management strategies for limiting carbon emissions.

• Afforestation & Reforestation: Afforestation is the practice of establishing tree cover on a site which has been bereft of it for a significant period of time, while reforestation is returning a recently deforested site to a forested state. Both practices have similar mitigation benefits in the eyes of the IPCC (2014). Afforestation and reforestation advance mitigation goals by increasing the ability of the landscape to capture atmospheric carbon through photosynthesis. This increases a landscape's aboveground carbon store in the form of new tree biomass, and also replenishes its below ground soil organic carbon. The effects of afforestation are most pronounced when fast-growing species are introduced to landscapes that have been free of forest cover for some time (Jandl et al. 2008).
• **Improved Forest Management**: A range of management practices designed to enhance the capture of atmospheric carbon are available to land managers once forestland is protected from conversion or reestablished through afforestation or reforestation. Because photosynthesis drives the capture and sequestration of atmospheric carbon, and because plants both store carbon in their living tissue and facilitate its transfer to the soil, forest managers can tailor practices to maximize these pathways for sequestering atmospheric carbon. Depending on location, tree community and structure, and landowner goals, such strategies may include:

  • Extending rotation between cuttings, to increase the length of time that carbon stored in living trees is allowed to stand on the landscape (Perschel et al. 2007).
  
  • Increasing stocking and productivity through timber improvement cutting that favors highly productive individuals and species (Perschel et al. 2007).
  
  • Minimizing erosion and damage to non-harvest trees and other primary producers during silvicultural activities (USDA).
2. Stewardship for Climate Change Adaptation and Mitigation

The Downeast Lakes Land Trust in Grand Lake Stream, Maine, presently holds 19,000 acres in the California Air Resource Board’s greenhouse gas cap and trade program. Enrolled in the program to generate income for the protection of additional land and to produce management income, the Downeast Lakes Land Trust woods were an excellent fit for mitigation management. Much of the forestland in northern Maine’s Washington County has been heavily and repeatedly harvested, resulting in dense, young stands. Such woodlots are prime candidates for management that maximizes stocking and productivity, which in the case of the Downeast Lakes Land Trust property results in a fairly hands-off approach at this stage in the forest’s life with high potential for capture and sequestration of above-ground carbon.

While laissez-faire mitigation stewardship was a natural fit for the young, rapidly growing woods managed by Downeast Lakes Land Trust, its managers acknowledge the possibility of challenges down the road. Downeast Lakes Land Trust is deeply embedded in the community of Grand Lakes Stream, a politically diverse town where forest management for extra revenue and in support of further traditional conservation goals is well received…but where the idea of stewardship for climate change mitigation might be less readily accepted. Enrolling additional acreage in cap-and-trade programs is a compelling opportunity for the land trust, but one that will require careful community relations. Additionally, the minimal harvesting conducive to carbon sequestration in today’s young forests could come into conflict with incentives to cut for market as the woods mature, or with funding for wildlife management that requires habitat conditions not easily reconciled with mitigation stewardship. Such concerns must be carefully weighed before enrolling additional acres in cap-and-trade.

For more information, visit:
- https://www.downeastlakes.org/

2.2.2.2 Grassland Management For Mitigation

In grassland systems, carbon sequestration in biomass is a relatively brief process due to the short-lived nature of the dominant plant species. Much more significant is the incorporation of carbon into the soil organic matter. As such, management strategies designed to maximize grassland carbon sequestration focus on improving the carbon storage potential of grassland soils. Because these strategies are often relevant in both ‘true’ grassland settings, such as the California range, and in a wide range of other agricultural systems, this section discusses both grassland management and agricultural practices suited to improving carbon sequestration.

In the U.S., the land conservation community’s stake in the management of true grassland systems may be best embodied in pastures and rangelands. In these settings, carbon cycling
and sequestration is significantly impacted by both plant community processes and by the activities of domesticated ruminants such as cattle. In such settings, the following strategies are valuable to mitigation efforts:

- Rotational grazing and other holistic management practices to limit and direct the impact of ruminants on pasture land to minimize erosion and compaction and maximize soil fertilization (Savory 2013).
- Seeding with native plant mixes to maximize photosynthesis for a given habitat type and region (DeLonge et al. 2014).
- Soil amendment with organic fertilizers—rather than synthetic nitrogen or phosphorus rich substances—to increase plant uptake of carbon and microbial activity (DeLonge et al. 2014).

In non-range agricultural systems, several additional techniques are also useful:

- Use of cover crops during the off-season to maximize photosynthetic carbon capture on the land (USDA).
- Reduced tillage/no-till practices to minimize disruption of soil and microbial communities associated with soil organic carbon storage (NOFA 2015).
- Soil supplementation with biochar—a technique similar to organic fertilizer amendment—that has not yet been tested in rangeland systems, but is practiced in some agricultural settings (Lehmen et al. 2006).
Marin Agricultural Trust and Grassland Carbon Sequestration

The Marin Agricultural Land Trust (MALT) serves farmers and ranchers in Marin County, across the bay from San Francisco. Aware of the carbon emissions associated with traditional farm and rangeland management practices, MALT has developed a management guidance process that incorporates elements of NRCS conservation planning to evaluate carbon sequestration potential on protected rangeland and provide prescriptions for its improvement.

To date, these Carbon Farm Plans have been implemented on three pilot ranches. In addition to holistic management prescriptions for the full range of systems on the ranch designed to enhance water and soil quality and habitat, specific carbon sequestration goals for rangeland have been identified. As an initial step, these pilot ranches have applied organic compost to amend their rangeland soils for improved soil carbon sequestration. With baseline data in place, these pilot projects will be monitored post-amendment, and additional practices for improvement of carbon sequestration after will be identified and applied based on emerging data.

While these pilot efforts are promising, MALT and other land trusts interested in grassland carbon sequestration do, like Downeast Lakes Land Trust, anticipate obstacles to wider application of their efforts. Although grassland carbon management is gaining credibility in the climate mitigation dialogue (USDA), government and private funding for application of grassland mitigation stewardship techniques lags behind similar support for forest mitigation stewardship (McGlynn et al. 2016). And, changing future conditions may complicate efforts that make good sense in the present. While rangeland soil amendment with organic fertilizer is a practical measure for improving carbon sequestration in pastures, some conservationist question whether rangeland carbon will stay in the ground if climate change forces major changes in the land use of the present-day range (Kelly, personal communication, 2016). Finally, as in Grand Lake Stream, Maine, the social nuances of introducing climate mitigation-driven management to a politically diverse demographic like ranchers can be challenging. Gaining widespread support for mitigation stewardship in the larger context of the American range remains a challenge for the future.

For more information, visit:

http://www.malt.org/
2.2.3 Implications

Like any form of stewardship, management for climate change mitigation is sensitive to ecological context, and as such will be variously applicable in different settings. However, a wide range of best practices for both forest and grassland systems are already available and new research is continuously delving further into the possibilities of management for climate change mitigation. Thus, the greater obstacles to the land conservation community in engaging with climate mitigation are not ecological, but economic and political.

The potential conflicts of interest between management for wildlife goals, future timber harvests, and forest carbon sequestration discussed in the Downeast Lakes Land Trust case, and the implications of social context for rangeland carbon sequestration in Marin County, highlight the reality that climate change mitigation remains one of many management priorities even in best case scenarios. Whether it is the place of the conservation community to prioritize climate mitigation, habitat, and economic goals broadly, the potential for conflict between them emphasizes that more thought needs to be given to establishing mitigation as a stand-alone conservation interest on par with traditional values.

A Role for Community Conservation?

The Mendocino Land Trust is finding opportunities to support its traditional land conservation and recreation mission while also making the case for mitigation behaviors that go beyond land management. MLT received a nearly $500,000 grant to partner with state agencies and other NGOs to install electric car charging stations at remote hiking trailheads along the northern California Coast. The initiative sends a strong signal that MLT supports emission reduction through personal choices—like driving fuel efficient vehicles—in addition to the more traditional management strategies that fall in the land conservation wheelhouse.

Projects like this, which straddle the divide between mitigation management and outright political advocacy, may be a powerful way for land trusts—and other conservation organizations—to become more active in shaping a community-wide response to climate change. For example, the Shannondale, MO, branch of the United Church of Christ was able to save its historic outdoor church and tree farm by enrolling in the California Carbon Air Resource Board’s cap-and-trade-program (Finite Carbon 2013).

Judy Anderson, principle at Community Consultants, sees this alignment of interests as crucial. “My observation is that community relevance, equity, and transitioning to a ‘service leadership’ model is increasingly seen as the core to the long term viability of conservation”, she writes. “That’s true for climate action, too”.

For more information, visit:

http://www.mendocinolandtrust.org/?What_We_Do:Current_Projects%26nbsp%3B:EV_Charging_Stations
2.3 Conclusions

Establishing new priorities in a field as venerable as land conservation takes time. As evidenced throughout this section, planning tools that suggest novel strategies for land management in the face of climate change are abundant, but the barriers to their implementation are high (Stein et al. 2013). While it is natural for conservationists—whose decisions will impact landscapes and both natural and human communities for generations—to be conservative in acting on cutting edge science when much about climate change remains uncertain, there are great costs associated with inaction. Chronesky et al. 2015 illustrate this point best in their observation that present day management choices have the potential to either limit or expand the range of future management options for a given natural system, but that inaction almost always results in limited options down the road. A crucial first step in incorporating climate change adaptation and mitigation into the conservation community’s core priorities may thus be overcoming our collective fear of managing under uncertain conditions, and learning to embrace adaptive management practices that will preserve a wide range of options for both mitigation and adaptation in the future. Recognizing the importance of this paradigm shift, the National Wildlife Federation outlines a nine-stage process for “climate smart conservation”, which centers on practical measures for making management decisions today that keep as many doors open for the ecosystems of tomorrow as possible (Stein et al. 2014).

Possible Questions for Discussion

- Adaptation and mitigation stewardship should be seen as complementary, but in cases when land trusts have limited resources to apply to addressing climate change, how should they allocate them? Does practicality justify a focus on adaptation? Does the commitment to perpetuity demand a focus on mitigation?

- Does the land conservation community have a role to play in advocating for emissions reduction behavior that goes beyond stewardship? Should land trusts allocate resources to promoting renewable energy, energy efficient technologies, and personal commitments to emission reduction such as plant-based diets?

- How can the urban land trust community expand its influence/mission to include the most effective adaptation strategies, like implementation of reflective roofing and pavement, when these approaches are not strictly ‘green’?

- Can we find funding opportunities for urban heat island reduction, which presently seems to receive less attention than urban water management and sea-level buffering as an adaptation and resilience topic?

- Mitigation science, especially for forestland, often assumes that forest productivity will continue under climate change scenarios basically un-changed. But, we know trees will become more stressed as the climate changes. Will the forests of tomorrow be as effective carbon sequestration vehicles as contemporary forests? How should managers plan for changing forest health in relation to forest carbon?
Some of the Organizations Doing Interesting Work on this Topic

- American Forests — a forestry think-tank with a wide range of information on traditional and urban forestry approaches for carbon sequestration, as well as more general forestry topics.
  https://www.americanforests.org/who-we-are-about-us/

- City of Chicago Green Alley Program — a useful resource on integrating green infrastructure, particularly green alleys, into an urban landscape. An excellent case book in PDF form, detailing program goals and a range of pilot projects, is available via link from the program's home page.

- Clark Fork Coalition — a watershed advocacy organization working in several Montana watersheds to manage for ecological and economic vitality. Their projects offer useful examples of the kinds of management activities that can be undertaken to improve stream health in a mixed-use landscape.
  http://clarkfork.org/

- Coastal Resilience (The Nature Conservancy) — an information hub organized by The Nature Conservancy to aggregate science and other resources for adaptation to sea level rise, and to support and promote proof-of-concept projects in a wide range of coastal systems.
  http://coastalresilience.org/

- EcoAdapt — an information hub which helps governments, NGOs, and other groups look at their policies and practices with an eye towards climate adaptation. Website includes links to consultant web pages, knowledge exchange programs, and resources for adaptive behaviors and management.
  http://ecoadapt.org/about

- Marin Carbon Project — a collaboration of researchers and practitioners in Marin County, CA, working to better understand and promote rangeland carbon sequestration through carbon farming techniques. Loosely affiliated with the Marin Agricultural Land Trust.
  http://www.marincarbonproject.org/

- Northeast Organic Farmers Association (Massachusetts) — the Massachusetts branch of a regional consortium of organic farmers, with a wide range of information on best practices and resources within the trade. NOFA provides useful recommendations for vegetable growers and non-rangeland farmers interested in managing for carbon sequestration.
  http://www.nofamass.org/
• Savory Institute — a global think tank that researches and promotes holistic grazing and land management techniques with the primary goal of improving the quality of rangeland systems, especially in the face of drought and desertification.

http://savory.global/institute

Useful Readings/Works Cited


