LOCAL PAYMENT FOR ECOSYSTEM SERVICE MODEL FOR WORKING LANDS STEWARDSHIP

Spring 2024

Alaina Geibig (MEM '25)

Dimitria Spathakis (MEM/MBA '25)

TABLE OF CONTENTS

INTRODUCTION

PROBLEM STATEMENT

Wet meadow ecosystems play a disproportionate role in maintaining ecological health in dry landscapes. Intact wet meadows support diverse forage, increase carbon sequestration, enhance water infiltration, among other benefits. Ranchers have long recognized the benefits of wet meadows; since the homesteading era, much of this habitat has been incorporated into private land ownership. As such, private landowners are critical stewards of these resources. At present, wet meadow restoration on private land relies on voluntary efforts and receives little financial incentive. Colorado Cattlemen's Agricultural Land Trust (CCALT) believes there are creative solutions to support ranchers doing restoration through an incentivized, compensated model. In this report, CCALT investigates the potential of implementing a payment for ecosystem services (PES) market to support restoration. CCALT's market model values (a) low-cost, high-conservation value projects, (b) capturing the radiating and essential benefits of small-scale restoration projects, (c) local dollars funding local, homegrown projects. The primary questions this report seeks to address are:

1. What are the ecological and economic costs and benefits of wet meadow restoration projects in Colorado?
2. How do we incentivize additive conservation that promotes stewardship of wet meadows?
3. What are the factors to consider in building a local, voluntary PES market?

WHY WET MEADOW RESTORATION IN THE YAMPA RIVER BASIN?

Since 1995, CCALT has collaborated with working landowners to conserve over 780,000 acres of land throughout Colorado using conservation easements. These voluntary agreements ensure the perpetual protection of land by limiting development and fragmentation. In Routt County, the headwaters of the Yampa River, CCALT holds conservation easement on 71,729 acres. With this presence, CCALT has the opportunity to work with landowners interested in voluntary restoration and stewardship efforts on a landscape scale that holds abundant agricultural and ecological values. In the area around Steamboat Springs, there is also a robust network of conservation and restoration organizations that support a land ethic focused on the multiple benefits of agricultural open space and ecological outcomes. As one of the economic hubs of northwest Colorado, the Steamboat Springs area also hosts many private businesses and public corporations that are keen on being positive stewards of the landscape that attracts residents and tourists alike. The combination of these factors makes the upper Yampa watershed an ideal location for innovative land restoration and stewardship incentives on a landscape with enormous conservation significance.

Private working lands in the area encompass lands and waters that possess an outsized ecosystem service value for the region. One such example is the presence of wetland and riparian systems in lower elevation properties, which are predominately owned by private landowners and are often incorporated into agricultural operations. Wet meadows and their stewardship present a myriad of benefits to agricultural operations and the public. When managed correctly, these areas provide abundant and diverse forage for livestock and protect water resources on the property. As this report will make clear, these wet meadows also offer a suite of ecosystem services which yield benefits far beyond the boundaries of these private lands and can act as nature-based solutions for a suite of environmental challenges. Specifically, the wet meadows of the upper Yampa watershed provide habitat to imperiled species, the most iconic of which is the Greater Sage Grouse. A species of national significance, there are enormous efforts across the American West to protect its habitat and ensure the population's long-term viability. As the last major free-flowing river in the Colorado River Basin, watershed health in the headwaters of the Yampa River is felt, positively or negatively, all the way to its confluence with the Green River. As climate changes, and a hotter and dryer reality impact the agricultural and ecological systems of the Mountain West, there is an imperative to find nature-based solutions that address a variety of challenges. Wet meadow restoration is one of those solutions. Through the proper incentives and an alignment with the public and private sectors, wet meadows restoration on working lands can offer both ecological benefits and an additional source of income for land stewards.

Part I: Wet Meadow Restoration: Benefits, Monitoring, Costs, and Implementation

Defining Additive Conservation

Additive conservation projects aim to benefit both agricultural and ecological systems. When paired with the perpetual protection of conservation easements, these projects generate important benefits to rural communities and enhance working lands as nature-based solutions. Examples of additive conservation include wildfire mitigation, river restoration, habitat enhancement, grassland improvement, and water infrastructure upgrades. Implementation of these projects can have direct operational benefits. Projects like these build climate resilience into agricultural operations, which is becoming more important as drylands regions of Colorado are projected to have increased temperatures and varied intensities and frequencies of precipitation events in the future. These changes in temperature and precipitation regimes particularly affect sagebrush and grassland plant communities (Remington et al., 2021).

Wet Meadow Restoration

Wet meadow restoration is an example of additive conservation that focuses on improving water resources in degraded, yet critical areas of the landscape. While wet habitats only account for a small percent of drylands area, water sources provide disproportionally high benefits to wildlife, vegetation, and livestock. Despite their importance, wet habitats often suffer from degradation. Visual indicators of degradation are head cutting, gully erosion, channel incision, and vegetation loss. Given their high ecosystem benefits and susceptibility to degradation, wet meadows are crucial ecological systems to prioritize for restoration.

Wet meadow restoration addresses erosion challenges using low-tech and low-cost processes. The primary objective of wet meadow projects is to “slow the flow” of water. When unaddressed, erosion can create a positive feedback loop, which is a process that once started, increases the rate of sediment loss, incision, and steepness of slope. As part of these restoration projects, rock and log structures act as physical barriers that slow down water allowing for soil water infiltration, instead of erosion. Reducing erosion and increasing soil water allows for the re-establishment of plants which further stabilizes the soil. This is called *process-based restoration*: restoration interventions, in this case rock/log structures, facilitate natural processes including revegetation and soil stabilization that enhance the effectiveness of the introduced intervention. As a result, maintenance costs are low as the structure becomes adopted into the natural ecosystem.

Wet Meadow Benefits

System Impacts from Processed-based Restoration

Wet meadow restoration does not target a single benefit; instead, it simultaneously supports interrelated habitat characteristics. Much like the erosion feedback system, restoration interventions aim to implement positive feedback cycles. For example, installing structures that slow water flow leads to increased water infiltration which stabilizes sediment and supports vegetation. The following report sections aim to delineate the benefits of hydrologic function, vegetation and biodiversity, soil quality, and erosion control. However, it's important to emphasize that the value of wet meadow restoration lies in strengthening the relationships between these habitat characteristics rather than focusing solely on discrete benefits.

Scope of Benefits

Wet meadow restoration projects offer ecological benefits above, below, and at the site of the restoration intervention. The potential benefits of wet meadows restoration projects should be considered on spatial and temporal criteria. At the site, rock structures increase soil water infiltration and promote revegetation. Below and above the site, the structure mitigates potential or worsening erosion by slowing the flow of water. Therefore, the restoration area captures both the existing incised area as well as those that were vulnerable to potential erosion. A study evaluating the scale of impacts in arid landscapes found that restoration rock structures affect areas up to 5 km downstream and 1 km upstream of the project site (Wilson & Norman, 2018). Scale of restoration benefits are variable based on the number of introduced rock structures, landscape characteristics, and degree of degradation. Further, in a temporal study that evaluated the timeline of restoration benefits, Norman et al. found that rock structures had positive hydrologic impacts up to 30 years after introduction (2015).

Additionally, upslope and downslope channel stabilization increase wet meadow resilience, particularly during high sediment loading periods that follow large precipitation or wildfire events (Norman et al., 2015). In comparing two watersheds that experienced wildfires, Long & Davis (2016) found that sites with restoration rock structures had faster vegetation and sediment stability recovery as compared to untreated sites. Although these findings may seem intuitive, it's crucial to consider how these structures can proactively support wildfire recovery rather than merely reacting to it (Jones et al., 2017). As such, these structures have a high potential to offer benefits as the landscape changes in the future. The following sections consider the benefits of wet meadow restoration in conjunction with challenges of monitoring and capturing the value of such benefits. Importantly, this is not an exhaustive list of benefits, rather prioritizes benefits based on in-the-field capacities.

Types of Benefits

Hydrologic function:

A primary benefit of wet meadow restoration is improving the hydrologic function of drylands landscapes. This is especially important in wet-meadow, sagebrush ecosystems because water availability strongly influences vegetation type and soil quality. In “slowing the flow”, rock structures allow for increased soil water infiltration and base flows. While these benefits may not be readily apparent, such hydrologic changes can enhance the resilience of local water cycles.

In a study evaluating the effects of restoration rock structures in arid landscapes, findings show that during drought years, rock structures support percolation of precipitation into groundwater. Sites without rock structures showed no significant effects on groundwater storage; instead, precipitation was likely prone to evaporation (Uhlman et al., 2021). Additionally, research supports that restoration rock structures reduce the flashiness of high runoff events. Flashiness of a stream is determined by how quickly and frequently instream flow responds to precipitation events. A less flashy response indicates increased infiltration of water, which is influenced by surface roughness (vegetation and soil types), slope gradient, and distribution of rainfall events. When compared to untreated drainages, those with rock structures generally had higher overall base flows. However, during large precipitation events, the peak flows were lower (Norman et al., 2015; Gooden & Prizladd, 2021).

While hydrologic changes can have radiating ecosystem impacts, they are notoriously challenging to measure. In part, this is because groundwater and soil water are not directly observable. While vegetation and soil quality measures may serve as proxies for hydrologic function, it is challenging to directly measure the movement of water underground. Soil moisture sensors are a tool that may be used to capture this information. There are a variety of measurement tools, including capacitance sensors and gypsum block sensors. These sensors are buried at different depths in the soil and measure the volumetric water content based on changes in electrical conductivity or capacitance. These tools vary widely in cost, with market-estimates of $20 to $500 per sensor. These tools have limitations as they are sensitive to environmental conditions (i.e., humidity and temperature). Additionally, the usability of these tools poses further challenges to implementation and accurate data collection. In a conversation with Yale Professor in freshwater management, Shimon Anisfeld, he emphasized the challenges of collecting accurate soil/groundwater measures even with the best available technology. In discussion about the practicality of introducing such monitoring methods into small-scale projects, he expected the costs of monitoring to far exceed the low-cost benefits of the restoration structures. For these reasons, there may be more practical, user-friendly, and cost-effective methods of documenting hydrologic changes in wet meadow landscapes through vegetation monitoring and soil samples.

VEGETATION AND BIODIVERSITY:

Greater available soil moisture and increased base flows support vegetation growth within the restoration area. Mesic habitat is defined by the presence of seasonal water that supports specific grass species (e.g., big bluestem, Indian grass, cordgrass, and bluejoint grass), sedges, and a diversity of forbs. This native vegetation reduces bare ground cover, increases forage, and reduces invasive species dominance (Rondeau et al., 2023). In arid regions, mesic habitat is critical for 80% of animal species and 50% of breeding birds (Krueper 1995; Fischer & Reese, 1996). Notably, mesic habitat is especially important for the Greater sage-grouse because the mother hens and their broods favor wet meadows because the mesic vegetation supports insects that account for nearly 80% of chicks' diets (Peterson 1970). Degradation of sagebrush and grassland ecosystems continues to place pressure on fragile populations. Despite the importance of vegetation, monitoring vegetation changes through plant surveying is time, resource, and knowledge intensive. Therefore, these methods may not be practical for working lands practitioners. Instead, this report considers remote sensing and photo points as potential monitoring techniques that are more accessible while still capturing vegetative changes.

Using open access, remote sensing data from the Landsat surface reflectance archive, researchers found that vegetation productivity increased by 24% at rock structure restoration sites in the Gunnison Valley in Colorado. This study also found that vegetation productivity extended longer into the growing season at rock-structure sites as compared with control sites (Silverman et al., 2018). These findings support the idea that restoration rock structures build ecosystem resilience by increasing the amount of site vegetation and extending the growing season making vegetation (forage and habitat) more available for wildlife. Further, Wilson and Norman (2018) considered vegetative greenness (NDVI) and water content as measures of vegetation productivity from the Landsat data set. Their results support that rock restoration structures result in higher greenness and greater water content through time. Through using open access data, these methods attempt to address the economic barriers of site monitoring—a critical component to the quantification of ecosystem services. However, the tradeoff of this design is that data collection is coarse, making it challenging to capture fine grain, small site benefits. There are further limitations to the usability and subsequent analysis of Landsat data.

The NRCS Mesic Habitat Conservation Planning Guide (2017) suggests using photo points to provide a visual record of vegetation and ecosystem changes. This method relies on qualitative judgements about habitat changes and lacks quantitative values. However, it is an accessible monitoring method that can tell a powerful visual story to generate support for these types of projects. For example, in some time-lapse photo points, cameras capture wildlife and cattle gathering around the vegetation of the project site, suggesting direct habitat benefits. Further, through photo points or coarse surveying, landowners can record changes in relative abundance of mesic plant species. The Common Native Forbs of the Northern Great Basin Important for Greater Sage-Grouse is a field vegetation guide to identifying essential mesic vegetation (Luna et al., 2018).

EROSION CONTROL:

There are clear inter-related benefits to soil, vegetation, and hydrology that result from restoration rock structure projects. However, many of these benefits are secondary to the immediate intervention to the erosion feedback cycle. Restoration rock structures aim to stabilize incised drainages. Initially, these structures do so from the placement of rocks that anchor and support the channel. This captures sediment which then supports vegetation growth. From a practitioner lens, these effects are visually obvious because the incision is no longer deepening and/or widening. However, it can be hard to comprehend how much sediment is captured by these structures. Through modeling, data estimated that 2000 check dams along an ephemeral water drainage captured approximately 630 tons of sediment over a three-year simulation. A study that sought to understand the effects of rock structures, specifically gabions (wire caged rock structure), found that the structures slowed the velocity and reduced sediment loading (Norman et al., 2017). Through further modeling, research supports that rock structures stabilize sediment in-channel and the areas flanking the channel called hillslope areas (Cucchiaro et al., 2019). Much of this research utilized complex modeling of sediment movement. However, in our conversation with Anisfeld, he suggested there is likely a straightforward back-of-envelope process to estimate previous and potential sediment loss through measuring site characteristics and incision size. This would require comparing the estimated sediment loss before and after the implementation of the structure. While there remains further need to develop these estimate equations, there is potential for in-the-field calculations.

SOIL QUALITY AND CARBON STORAGE:

Changes in vegetation and sediment loading would likely be reflected in the soil through increased soil water content, soil organic matter, and microbial abundance. In a study evaluating the effects of restoration rock structures, findings suggest that just one year after the introduction of the structures, sites had increased soil moisture, litter, fungal richness, and spring seedling germination (Martyn et al., 2022). These findings directly and indirectly suggest that there are immediate soil quality improvements as a result of these restoration efforts. Soil sampling has the potential to be particularly impactful for monitoring these types of projects because samples are easy to conduct, affordable, can happen on an annual to quarterly frequency, and data are easy to interpret. Additionally, many agricultural producers already have experience with soil sampling through statewide programs offered by Colorado State University (CSU) to provide technical assistance and run lab samples. They offer a variety of tests including feed and forage analysis, plant analysis, and soil analysis. Sample prices range from $20 to $80 and can be selected based on desired soil qualities. Analysis would likely capture the effects of restoration structures.

(a) Gravimetric Soil Moisture Analysis involves collecting soil samples from the field, weighing them, drying them in an oven to remove all moisture, and then re-weighing them. The difference in weight between before and after drying gives the gravimetric water content of the soil. This soil test can provide additional information about hydrological function without having to conduct soil moisture monitoring.

(b) Soil organic matter is a key indicator of soil quality, as it influences soil structure, nutrient availability, water retention, and microbial activity. Increased organic matter content is generally associated with improved soil quality.

(c) Soil microbial communities play crucial roles in nutrient cycling, organic matter decomposition, and soil health (Belnap et al., 2005). Tests such as microbial biomass carbon (MBC) analysis, microbial respiration assays, or enzyme activity assays can be used to quantify microbial abundance and activity in soil samples.

(d) Soil nutrient testing assesses the availability of essential nutrients for plant growth, such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and micronutrients. Balanced nutrient levels are essential for supporting healthy plant growth and ecosystem functions. While proportions of these nutrients vary based on soil and vegetation type, it could be interesting to evaluate relative proportional changes over time after the introduction of a rock structure.

(e) Soil aggregate stability refers to the ability of soil particles to resist disaggregation and maintain structural integrity. Improvements in soil aggregate stability are associated with enhanced soil structure, water infiltration, and resistance to erosion. Tests such as the wet sieving method or the slake test, can be used to assess soil aggregate stability in soil samples.

With rising carbon markets, an expanding body of research is working to calculate the carbon storage potential of dryland ecosystems. Carbon sequestration in carbon markets is typically measured in terms of the amount of carbon dioxide (CO_2) removed from the atmosphere and stored in long-term carbon sinks, such as forests, soil, or geological formations. Carbon markets typically express measurements in metric tons of CO_2. Carbon sequestration projects often focus on large scale forestry areas. There has been a limited focus on grasslands or sagebrush systems. However, research using remote sensing, CO_2 flux measurements, and meteorological data supports that sagebrush environments provide a net carbon sink and northern mixed-grasslands are carbon neutral (Hunt et al., 2004). Further, findings suggest that up to 136 metric tons of carbon per year are sequestered in large areas (485-623 km^2) of sagebrush dominated basins (Provencher et al., 2023). Despite these positive findings, there are limitations in applying them to small-scale restoration projects. In terms of carbon markets, the small-scale projects are not likely to yield economically meaningful quantities of carbon. That doesn't mean that the carbon sequestration in these systems is insignificant, rather it is more reflective of the capacity of nascent carbon markets. Likely, carbon markets will develop to better capture carbon benefits of grassland and sagebrush systems. Research is providing evidence for that change, recognizing grasslands as more reliable carbon sinks than forests because of below ground storage in the face of wildfires threatening above ground storage (Dass et al., 2018). In considering carbon impacts, it is critical to think of these restoration structures as both reactionary and preventative; they support site revegetation and minimize the potential large-scale effects of further erosion/degradation. Therefore, we expect that restoration rock structures (a) directly capture carbon through increased vegetation and (b) support existing carbon by limiting degradation and loss of biomass. Importantly, we would expect the new carbon capture capacity of these structures would be marginal compared to protecting and maintaining the carbon that is already captured in grasslands ecosystems.

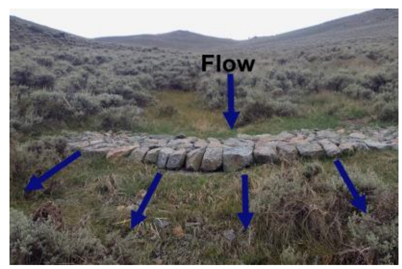
Land Use Considerations

There have been long standing research tensions around the ecological benefits and detriments of grazing. Specifically, certain approaches to grazing have been found to have negative impacts on water quality, seasonal quantity, stream channel morphology, hydrology, riparian zone soils, vegetation, and wildlife in riparian ecosystems (Belsky, 1991). However, in this literature review, researchers noted that drawing these direct causal relationships is very challenging. More so, this research illuminates the importance and fragility of wet meadow systems and affirms the effort to increase ecosystem resilience through restoration projects. However, there remains an important question: if restoration rock structures increase forage diversity, quality, and abundance, how do you ensure that those benefits are captured by the ecosystem, not just the rancher's cattle? This question is not directly addressed in the literature. However, local restoration experts, Tim Sullivan and Ryan Messinger from the Yampa Valley Sustainability Council, discussed that through their observation cattle do not overgraze restoration areas. It may be beneficial to minimize disruption while vegetation gets established, however there is limited evidence to suggest that in the long term, cattle impact restoration potential. These concerns can further be addressed through monitoring and reporting.

Wet Meadow Restoration Implementation

The first step to implementing wet meadow restoration projects is site selection. As previously mentioned, eroded drainages are typically found in low-lying areas of a meadow. The evidence of erosion and incising can vary greatly in depth and width. Although addressing the largest areas of degradation may seem intuitive, strategic restoration can prioritize smaller and early incision sites. This is because it is easier and more cost effective to address a problem before the positive erosion loop begins.

This report considers rock and log structures as wet meadow restoration tools. This resource focuses on ephemeral drainages, which may have flowing water intermittently throughout the year but remain dry most of the time, because these are common in drylands due to variable precipitation in conjunction with high rates of evaporation. However, similar restoration approaches exist for perennial water sources, those that run year-round, and are briefly addressed below in the subsection Log Structures: Beaver Dam Analogs (BDAs).

Structure Name	Description	Image
One Rock Dam	One rock dams fill a shallow drainages with a single layer of rocks placed perpendicular to the direction of flow. Larger rocks are situated up-slope to slow the flow of water and create a shelf. Smaller rocks, called an apron, are positioned below the shelf to reduce erosion from spillover. This image shows vegetation starting to grow between the rocks.	
Zuni Bowl	Zuni Bowls fill an in-channel head cut by lining the sides with rocks. It consists of an upper pour-over rock dam that flows into the armored plunge pool to capture and slow water. A second, lower pour-over consists of rocks to allow plunge pool spillover onto a splash apron similar to the one rock dams.	
Media Luna	Media Luna is a single layer of rocks laid tightly together perpendicular to flow direction. The image shows a sheet flow spreader, spreading the incoming flow below the structure. A sheet flow collector would have multiple flow arrows above the structure collected into a single flow arrow below.	
Log and Fabric Step Falls	Fabric Log Step structures use logs varied in length to create a tiered structure for flow. The logs are embedded into the sides of the channel and secured by the geotextile fabric and wire.	
Beaver Dam Analogs	BDAs are fence posts driven into the channel in a line spaced 1-2.5 feet apart perpendicular to the flow. Willow and other smaller material are interwoven to support the collection of cobble, gravel and sand to form a semi permeable dam, similar to those constructed by beavers.	

(Photos sources from NRCS Zeedyk Structures for Riparian Areas and Wet Meadows Document and the National Wildlife Foundation)

Rock Structures

Types:

1. One Rock Dams

   These projects are effective for low-grade sites. One rock dams slow the flow, increase vegetation and surface roughness. As a result, over time this captures sediment allowing gradual raising of the bed level.

2. Zuni Bowl

   Zuni Bowls control head cutting and incision by reinforcing channel sides. Zuni Bowls use similar mechanisms of the one rock dams because these structures also disseminate the force of flowing water through slowing flow and dispersing water.

3. Media Luna

   These structures are used to address sheet flow, dispersed and shallow drainage across a broad area. Media Lunas can be used to consolidate sheet flow into a single channel (sheet flow collector) or disperse flow from a narrow channel into a broader flow (sheet flow spreader). These can limit upslope eroding and minimize channel incision.

Materials:

❖ The primary material for these projects are rocks, which often can be sourced from the project site. The structures should be constructed with angular granite rocks between 6 and 18 inches:

  ➢ 70-80% between 6 and 12 inches

  ➢ 10% between 12 and 18 inches

  ➢ 5-10% gravel and rock fragments

  ** If unable to source from the project site, quarries can screen smaller material out to minimize gravel and dirt content.

  Note: these are primarily hand-built structures, so it is important to consider the movability of rocks when sourcing materials

Log Structures

1. Log and fabric step falls

   These projects address deep head cutting by filling the incised area with timber to slow erosion and allow for revegetation. These projects are effective but more complicated, cost/labor intensive than rock structures, and use non-biodegradable material (geotextile fabric).

   Materials: The primary material for these projects is raw timber, which can often be sourced from the project site. Best practice is to remove the bark to minimize rotting.

- Geotextile fabric
- Logs 6 to 10 inches in diameter, varying in 4 to 8 feet in length
- One role of smooth wire, one roll of barbed wire
- Fencing staples

2. Beaver Dam Analogs (BDA)

BDAs address incised channels of perennial streams through mimicking the form and function of natural beaver dams in wet meadows. The objective of the projects is to restore wetlands in meadows to support revegetation, soil water availability, and flood control.

Materials:

The primary materials for these structures are logs and woody materials.

- Fence posts/ 8-10 inch in diameter logs
- Willow or other limber branches for weaving
- Earth (soil and sod clumps)
- Saws/clippers/log carriers
- Shovels

**BDAs are introduced here because these structures can be captured within additive restoration projects. This report is more focused on ephemeral streams, however, there is opportunity to extend the conceptual understanding of ecosystem benefits to BDA projects. We assume there is overlap in types of projects, however BDAs may require additional considerations for costs, benefits, and monitoring.

Cost of Implementation

Cost of project implementation will vary by site and depend on material available, project size, and technical assistance needed. In the appendix, Figure 2 offers rough pricing for project materials, monitoring, and tool and equipment. These estimates are intended to assist with project design and should be used as rough guidelines. Literature suggests that, based on an established rate of ~6.4 check dams/acre restoration, rock projects cost roughly $2,210 (Norman, 2022). This estimate includes raw materials, labor costs based on 2022 wages, and planning expenses. They estimated 16 hours of labor per structure. As more projects are implemented in the Yampa River Valley, there will be a clearer understanding of the cost of these projects. As such, recording and reporting costs will be crucial for refining estimates in the future.

Table 1. provides a cost analysis for raw materials, tools and equipment, labor, maintenance and monitoring.

Part II: How to incentivize additive conservation? Building a Market for the Stewardship of Wet Meadows

Overview

Recently, there have been significant flows of public funding for wetland restoration to public lands in Colorado and the Yampa Valley. As discussed in the first section of this report, wet meadows are disproportionally located on private lands. How can landowners of private lands under conservation easement be incentivized to provide stewardship of wet meadows? Outside of conservation easement restrictions preventing development, what additive conservation measures and restoration practices can be sustainably financed? This section of the report will provide a brief overview of market-based models for conservation, highlighting relevant case studies and discuss applicability to additive restoration measures for Yampa Valley wet meadows.

Payment for Ecosystem Services

Beginning in the 1990s, Payment for Ecosystem Services (PES) emerged as a financial tool to promote conservation practices. Environmental credit trading involves market-like transactions where an amount of an environmental benefit being created is defined as a credit and its value is monetized and traded. PES markets address externalities not captured within our current economic system, internalizing the positive externalities generated by natural systems. Ecosystem services are the direct and indirect benefits that ecosystems provide humans. The Millennium Ecosystem Assessment identified four major categories of ecosystem services: provisioning (food), regulating (water purification, erosion/flood control, carbon storage), cultural (recreation) and supporting services (wildlife habitat, nutrient cycling) (M.E.A. 2005). PES markets have been implemented to incentivize a variety of ecosystem services within the different categories listed above. As ecological crises mount globally, PES markets are growing (Salzman et al. 2018).

Current Finance Flows to Nature

While compliance-led biodiversity offsets are a large source of private finance ($12B in 2022) for nature-based solutions (NbS), the market for biodiversity credits is currently small ($2–8M). However, a shift in regulatory requirements is expected to stimulate rapid, compliance-led growth of biodiversity credit markets (UNEP 2023). Private finance for NbS currently comprises just 18% of total NbS finance flows; the majority of funding comes from the public sector. Within private finance, over half of the funding is channeled through biodiversity offsets and sustainable supply chains (UNEP 2023). Restoration NbS is projected to require the highest levels of investment by 2030, reaching $177B annually. Additionally, annual NbS investment opportunities in sustainable land management (SLM) will likely increase, projected to go from $63B in 2025 to $241 billion by 2050 (UNEP 2023). SLM and restoration provide an important opportunity for private investment and is critical to scale NbS finance.

Financing Ecosystem Restoration

Ecosystem restoration is not currently a distinct category within many sustainable finance taxonomies and reporting frameworks (World Bank 2022). Restoration encompasses a wide range of activities, including agroforestry, silvopasture, reforestation, mixed species plantations, riverbank restoration, natural regeneration, assisted natural regeneration, and farmer-managed natural regeneration. The World Bank's

Scaling Up Ecosystem Restoration Finance report argues "there is a need for financing approaches, standards, and best practices to be developed for each category of restoration activities. Projects and businesses operating in each category can then be aggregated together within a given geography to increase the size of investment, diversify risk, and reduce the cost of capital" (World Bank 2022). This report seeks to explore one method of aggregating resources and capital to catalyze wet meadow restoration in the Yampa Valley.

Types of PES Markets

Regulated & Voluntary

PES markets can be broadly categorized in two key buckets: 1) regulated markets and 2) voluntary markets. To date, the largest PES markets are based on transactions mandated by government regulations or government-financed subsidies. Regulation allows governments to create demand and organize buyers on ecosystems that are public goods. Voluntary PES markets exist outside of government regulation where buyers willingly purchase offsets. Key motivations for voluntary buyers are corporate social responsibility (CSR) or risk management (Salzman et al. 2018). Many voluntary offsets have been undertaken in anticipation of future environmental regulation or to demonstrate sufficient conservation to prevent regulation. Demand for voluntary offsets has historically come from the energy and mining/minerals sectors (Salzman et al. 2018).

Transactions for PES markets can occur through bilateral negotiation between the buyer and seller or through an auction mechanism in an open market.

Measurement

For measurement of PES credits there are two categories: outcomes-focused and process-focused/ "pay for practice." Outcomes-focused denotes a certain amount (i.e., percentage increase) of quantified biodiversity gain. Whereas process-focused quantify the stewardship efforts to conserve or restore and then package the relevant amount of such efforts into one unit of biodiversity credit (i.e., acres of land).

Case Studies

Voluntary Carbon Market

Carbon offsets are traded on both the compliance (i.e., California) and voluntary carbon markets. To certify a project within the voluntary market, a carbon standard must be chosen; the standards specify technical methodologies with which accredited projects align. Small-scale, nature-based solutions credits tend to fall within the voluntary carbon market, these projects related to forestry and land-use and agriculture are growing and comprise almost half of the voluntary market share (State of Voluntary Carbon Market 2023). Buyers tend be motivated by net-zero commitments, however currently, supply exceeds demand for voluntary carbon credit. Credits with additional environmental and social co-benefits "beyond carbon" had a significant price premium (State of Voluntary Carbon Market 2023). Vera, a major offset registry, created the Climate, Community and Biodiversity Standards to earmark projects with these co-benefits (BloombergNEF 2023).

Habitat Exchange

Habitat exchange programs are a form of biodiversity markets which often involve offsetting, compensate for negative impacts in one area by habitat conservation in another. There are approximately 10 habitat exchanges in the United States. Three common characteristics have emerged in these markets: (1) credits can be temporary ranging from 5 to 30 years (versus only permanent), (2) exchanges are overseen by nonregulatory, independent administrators; and (3) exchanges exist in the absence of mandatory mitigation policy. These features provide greater flexibility and practicality in areas where environmental regulation is unpalatable politically (Davis et al. 2022).

Rather than use a blunt measurement of habitat acreage, standardized protocols known as habitat quantification tools, specific to the focal ecological system have been developed by nonregulatory entities to determine credits for projects (Environmental Defense Fund 2019). One example of a habitat exchange is Nevada's exchange for sage-grouse habitat restoration. The Nevada Conservation Credit System habitat quantification tool integrates more than 15 metrics of vegetation and other habitat components across four spatial extents and three life stages of Greater Sage-Grouse to estimate the functional area of habitat. Functional area accounts for both habitat size and habitat quality, quantifying ecological equivalency for like-for-like trades of debits and credits (Davis et al. 2022). In the Yampa Valley, many wet meadows under agricultural conservation easements within the Yampa Valley include sage-grouse habitat.

Bundling of Ecosystem Services

Bundling ecosystem services is an emerging model argued to be more cost-effective, result in increased payments for conservation practitioners. One example of bundling ecosystem services is the Soil and Water Outcomes Fund, which pays participating farmers per-acre payments for implementation of conservation practices that generate positive environmental outcomes such as water quality improvement and carbon sequestration. Often the payments farmers receive are greater than existing state, federal or private conservation programs. "The stacking of multiple environmental outcomes together within a single transaction allows each beneficiary to pay only for the outcomes they desire rather than the full cost of program implementation" (Quantified Ventures 2023). The fund therefore uses a multi-payor financing vehicle where investors can purchase various environmental outcomes: water quality improvement, soil carbon sequestration, biodiversity and habitat protection, and flood mitigation. For example, a public corporation could pay for the carbon sequestration outcomes while a municipal wastewater utility pays for the water quality improvement outcome.

Outcomes-focused & Process-focused

Many current PES markets operate as a "pay for practice" model, for example, paying farmers to plant cover crops to improve carbon sequestration. The Soil and Water Outcomes Fund uses a hybrid model, incorporating both "payment for practice" and an outcomes-focused approach. Farmers enrolled in the annual program receive 50% of the per-acre payment for participation and then receive the remaining 50% payment after the farm's environmental outcomes are measured and verified (Soil and Water Outcomes Fund 2024).

Building a PES Market

Value for Ecosystem Services & Pricing Credits

For a PES market to ensure an ecosystem service provision, landowners need to be paid at a price sufficient to provide the desired sustainable land management practice. The payment to landowners must be competitive with the opportunity costs. For example, in a preservation case, PES needs to make trees worth more standing than cut down, priced higher than the extractive values of timber (Salzman et al. 2018). However, in the case of additive conservation incentives, the PES revenue is an additional revenue stream rather than the primary revenue stream for the landowner.

There are some bounds on what the credit price may be. For a credit price upper bound, it is the value to the buyer of the ecosystem service being provided. This is challenging in voluntary PES markets when the ecosystem benefit is also a public good and may be hard to quantify in terms of value within the current economic system. In regulated PES markets such as the United States wetlands development market, the upper bound for mitigation credits for an energy company may be the costs associated with postponing/cancelling the drilling due to lack of approved permit (Salzman et al. 2018). Within a voluntary market, the credit price upper bound may be the relative cost of alternatives, for example, the cost of building a water treatment plant versus investing in natural ecosystem service-based filtration. A lower bound on the credit price is the cost to the landowner of implementing the conservation practices necessary to achieve the ecosystem service in addition to the market transaction costs (Forest Trends et al. 2008). Therefore, in the case of low-technology restoration practices, the lower bound credit price would be the cost of labor and raw materials to construct the structures as well as any required ecosystem service monitoring costs. Additionally, in a market, credit prices are subject to supply and demand forces, especially in the case of a voluntary market, absence of regulation. If there is low demand for credits, prices will be low and vice versa.

Metrics and Transaction Costs

PES markets are only feasible where metrics are easily assessed, and services are fungible (Salzman et al. 2018). This presents an inherent challenge as metrics for ecosystem services tend to be challenging to measure, even carbon storage. Nature based systems often require measurement proxies. In terms of comparability, habitat and biodiversity's heterogeneous nature creates measurement challenges, as levels vary throughout different ecosystems. In defining the goal of no "net loss" driving biodiversity offset market demand, determining a level of biodiversity to be considered the baseline requires subjectivity (Bennett et al. 2017). Metrics used often vary depending on the developers creating the credits and the methodology they use.

Fungibility is the ability of a good or asset to be readily interchanged for another of like kind. Fungibility is most easily achieved in carbon markets where credits trade for the equivalent of one ton of CO2-equivalent emissions. Again, biodiversity and habitat credits present further challenges due to ecosystem variability. However, counter arguments to the importance of fungibility advocate that there can be different quality PES markets. For example, Mirova, an asset management company, used a wine market analogy to argue that biodiversity credit prices can differ too based on quality; sub-markets can exist within a global market (Cox 2024).

In the United States, wetland and stream mitigation programs provide low-cost metrics, defining credits in terms of area of wetland and linear stream habitat lost/restored (Salzman et al. 2018). In this model, proxies are used in attempts to capture provision of ecosystem services. The choice of metrics presents a tension: easily assessed metrics reduce transaction costs but they risk accuracy and alignment with conservation goals. More rigorous metrics may more accurately capture service values, but transaction costs could be prohibitive to market function (Salzman et al. 2018).

Permanence & Additionality

How long should a purchased credit last for? In carbon markets, a credit may last for 100 years. This timescale would need to be shorter length for a restoration credit. Additionally, there is inherent uncertainty in dealing with natural systems. For example, how would the value of a wet meadow restoration credit be affected by a flooding event that instead increased erosion to the landscape post restoration credit sale? As monitoring techniques evolve and scientific studies provide additional layers of ecosystem knowledge and uncertainty, it can be challenging to determine the permanence and additionally of an ecosystem credit.

PES Credit Buyers

Many businesses, like developers, are unlikely to buy credits without a regulatory driver. What kinds of businesses may be interested in a voluntary, local PES market? Does a local PES market have an advantage in appealing to local, regional businesses?

Attitudes towards PES market – Benefit expectation

A qualitative study investigating factors influencing the willingness of German companies to engage in a voluntary online PES market for nature conservation identified enhancing business reputation and creating positive external communication, through their corporate sustainability strategy as top benefit expectation (Krause & Matzdorf, 2019). Some companies believed that nature conservation activities could help to differentiate themselves from competitors for customers as well as be more attractive to potential employees. Few businesses viewed nature conservation as a risk management strategy, for example, businesses within the food sector described the protection of natural resources as method of risk reduction within their value chains. However, most businesses did not see many ways in which voluntary nature conservation engagement would contribute to direct financial success (i.e., increased revenue, reduction in costs). Additionally, companies within strongly regulated sectors (e.g., mining, chemicals) highlighted anticipated regulation as a key motivation, using voluntary nature conservation activities to manage stakeholder relationships, especially with local communities and NGOs.

Another study found that the strongest predictor for participation in a voluntary nature conservation engagement was company leadership recognizing a link between nature and their business. Potential links include: when a business depends on natural resource inputs within their supply chain, when it has environmental goals and strategies, when it targets environmentally conscious customer markets, and/or when it has company locations in or nearby protected areas (Krause et al. 2021).

One feature of the PES market that appeared attractive was the spatial definition of certain kinds of credits, allowing businesses to compensate for a specific area, for example, buying PES credits with same area surface as the office or a parking lot (Krause & Matzdorf, 2019).

Perceived ability to act for nature conservation

Does an online market facilitate easier engagement for businesses to promote nature conservation by reducing current barriers? For example, investment in time, resources and internal capacity to find suitable conservation projects for donations, organize and monitor own projects, or coordinate external NGO partnerships. Some businesses perceived an online marketplace as facilitating easier engagement for nature conservation, for example, revealing regional engagement opportunities to the businesses (Krause & Matzdorf 2019).

Business sector appeal

In the German study highlighted above, companies with higher environmental risk associated with their business operations (i.e., mining, energy, agriculture) had partnerships with environmental organizations or worked on environmental initiatives related to their value chain (Krause & Matzdorf 2019). Therefore, high risk sector companies may have less need for PES credits since they are already engaged in environmental initiatives to offset or improve current environmental impacts.

Attitudes towards PES market -- Risk expectations

Most companies highlighted potential greenwashing accusations from either company stakeholders or the public as a risk in engagement with voluntary nature conservation markets. Some businesses perceived nature conservation as a controversial topic having the potential to bring forward opponents (Krause & Matzdorf, 2019). Other businesses were wary of the administration costs associated with a credit, decreasing direct funding to project causes. However, research by Torelli et al. (2019) found that stakeholders had higher perceptions of corporate greenwashing if the companies belonged to environmentally sensitive/high-risk industries (i.e., mining, energy or chemical).

Governance

PES markets require a 3rd-party body to establish credit-trading rules as well as transparent administration. In the case of US regulated markets, state and federal agency guidelines govern how mitigation PES markets are established and subsequently governed (Bennett et al. 2017).

As with the carbon market where there are standards specifying technical methodologies with which accredited projects align. In the case of wet meadow restoration, a technical methodology relating to the implementation of erosion control structures would need to be agreed upon by the governing body so projects could follow market guidelines ensuring quality control and a method for accreditation.

Mitigation Banks

Mitigation banks, while more complex, have been shown to streamline the offsetting process in compliance markets. By managing several projects simultaneously, banks can achieve economies of scale in design, implementation, and monitoring, reducing overall costs of mitigation and improving ecological outcomes. Mitigation banks take on from developers the risks and complexity of undertaking an offset (Salzman et al. 2018). In the United States, banking has been demonstrated to reduce regulatory permitting times compared to financial compensation or permittee-responsible offsetting (Bennett et al. 2017). While this report explores a voluntary, local PES market structure rather than a regulated offset market, the goal would be to harness the efficiency benefits observed regulated mitigation banks to the Yampa Valley market context, pooling multiple types of wet meadow restoration credits.

What type of organization is best suited to facilitate the sale of credits in a wet meadow restoration marketplace? For example, would a county government have this capacity or a third-party nonprofit organization, unaffiliated with the land trusts/farmers selling the credits?

Wet Meadow PES Market Discussion

Definition and Quantification of Credit

For the case of the wet meadows, it makes sense to pursue a process-focused PES credit, exchanging value for land management practices intended to provide ecosystem services on a market since measurement of the ecosystem services in quite challenging and our goal is to incentivize land management practices. While the restoration methods' ecosystem service benefits are still in the process of being quantified, the overall positive benefits of the technology in terms of erosion, groundwater, vegetation improvements have been documented (Gooden & Prizladd, 2021; Norman et al., 2015; Silverman et al., 2018). Of ecosystem service benefits, these are some of the most challenging to measure. Additionally, the ecosystem benefits resulting from these restoration techniques may vary across sites. Recent projects have occurred in Arizona and Gunnison, Colorado. With little monitoring to-date of Yampa Valley wet meadow restoration projects it is challenging to project accurate ecosystem service benefits.

Fungibility

One of the cruxes to market creation is credit fungibility, necessary for a Yampa Valley wet meadow market to function as an open, larger marketplace trading credits from other wet meadow restoration projects. How do the restoration structures equate to a quantity of wet meadow restored to then be packaged into a credit? For example, is there a number of acres of wet meadow restored that can be related to the size/quantity of restoration structure? With these structures, larger structures tend to be utilized for more degraded systems whereas smaller structures are best used to prevent wet meadow degradation.

Measurement and Credit Verification

One of the critical constraints of a local, smaller-scale market is the capacity of ecosystem benefit verification and general administration. Credit verification for a "Yampa valley wet meadow" credit would likely need to be qualitative in nature, either "yes/no or a Likert scale based on photo evidence at approximately one-year post project completion. Various monitoring techniques listed in Section 1 of this report.

Advantages

Risk transfer

A market-based approach reduces additive conservation barriers, CCALT is able to transfer risk from the rancher and corporate buyers to itself and a regulating agency like Routt County or another NGO. This can catalyze further wet meadow restoration projects, reducing the barriers of local, NbS projects typically face.

Scaling finance for sustainable land management

A market-based approach provides efficiency benefits for sustainable land management with greater access to capital for private landowners to pursue ecosystem restoration. This would increase speed and scale of restoration in comparison to the current practice of applying for grant funding and following associated program timelines or lack of incentives for private landowners to engage in restoration activities.

NEXT STEPS

To move forward in the creation for a PES market for wet meadow restoration in the Yampa Valley there are few key areas of further research to assess market viability:

DEFINING AND QUANTIFYING RESTORATION SERVICES

Questions about the linkages between practices undertaken and resulting provision of ecosystem service must be answered before a PES market can be implemented. It will be helpful to monitor current projects on public lands in the Yampa River Valley to better understand ecosystem services benefit, specifically the correlation between type/quantity/size of structure and wet meadow acreage positively impacted. This data will help determine and appropriate wet meadow restoration technical methodology to accredit projects.

DEMAND ASSESSMENT

1. What businesses benefit either directly or indirectly from the ecosystem services in the Yampa Valley wet meadows?

    a. For example, would a local brewery be motivated to buy local watershed credits, recognizing the link between local water quality/quantity and water as an ingredient for its beer? Or would businesses involved in outdoor recreation equipment or services company be motivated to enable improvement of "sage-grouse habitat" to promote quality wildlife habitat that is also crucial for thriving big game—elk, deer, and pronghorn—that are vital to the outdoor recreation?

2. Do their business models involve medium to low environmental risk outside of environmental regulations?

    a. In this proposed voluntary PES market, "wet meadow stewardship" credits would not help a business offset their carbon emissions or provide assistance in attaining new development permits. Therefore, motivation from business would most likely involve positive communications to customers and employees to increase brand image.

3. Do these businesses have the capacity to self-organize their own conservation efforts or identify relevant conservation opportunities?

    a. What small and medium size businesses exist within Routt County, Colorado? A smaller business may not employ a social impact or sustainability team with the capacity to organize CSR projects and therefore would have a higher interest in buying credits.

ANALYSIS OF CREDIT LANDSCAPE

A key advantage of a market-based approach utilizing a restoration bank is to achieve economies of scale in design, implementation, and monitoring related to sustainable land management practices and credit transactions. Outside of CCALT's proposed wet meadow restoration projects, are there additional county/regional projects on private lands that could help a sage-grouse habitat and wet meadow restoration?

BLENDED FINANCE APPROACH

Within a voluntary market, buyers will likely be more impact driven rather than returns driven. Additionally, it is unlikely that a new small-scale PES market could be created without some public finance or philanthropic support to overcome initial funding barriers. Is there interest from other non-profits in the Yampa River valley or public funding from Routt Country to help catalyze a wet meadow PES market?

CONCLUSION

PES markets are young and early lessons can be learned and applied from the voluntary carbon market and regulated wetlands development market to ecosystem restoration markets. Current regulated markets for carbon and biodiversity involve offsets, however the market model discussed in this report would likely not involve development offsets, but credits purchased for internal business CSR/Environmental Social Governance initiatives, environmental brand image, local connection to community, direct/indirect environmental benefits associated with risk management. In the future, regulation could provide additional incentives through state or county laws mandating PES market participation for businesses.

While there are many next steps to building a market-based model for wet meadow restoration, the call to action is clear: there is a substantial funding gap in private finance for nature. PES markets would provide additional revenue streams to land stewards, increasing the resilience of local communities their working lands.

REFERENCES

Biodiversity Credit Alliance (2023). Communities and Nature Markets: Building Just Partnerships in Biodiversity Credits. Discussion paper. New York: Biodiversity Credit Alliance.

Belnap, J., Welter, J. R., Grimm, N. B., Barger, N., & Ludwig, J. A. (2005). Linkages between Microbial and Hydrologic Processes in Arid and Semiarid Watersheds. Ecology, 86(2), 298–307. http://www.jstor.org/stable/3450948

Bennett, G., Gallant, M., Katherine Birnie, Stephen Edwards, Ben Guillon, Christopher Hartley, Travis Hemmen, George Kelly, Conrad Savy, Yves de Soye, Wayne White, Eszter Bodnar, & Clarise Frechette Design, LLC. (2017). State of Biodiversity Mitigation 2017. In Ecosystem Marketplace & Forest Trends, State of Biodiversity Mitigation 2017. https://www.forest-trends.org/wp-content/uploads/2018/01/doc_5707.pdf

Cucchiaro, S., Cazorzi, F., Marchi, L., Crema, S., Beinat, A., & Cavalli, M. (2019). Multi-temporal analysis of the role of check dams in a debris-flow channel: Linking structural and functional connectivity. Geomorphology, 345, 106844.

Cuming, V., Bromley, H., & BloombergNEF. (2023). Biodiversity Finance Factbook: 1H 2023. https://assets.bbhub.io/professional/sites/24/REPORT_Biodiversity_Finance_Factbook_master_230321.pdf

Cox, T. (2024) Full tradability not crucial for functioning environmental markets, Mirova says. Carbon Pulse. https://carbon-pulse.com/274038/

Dass, P., Houlton, B. Z., Wang, Y., & Warlind, D. (2018). Grasslands may be more reliable carbon sinks than forests in California. Environmental Research Letters, 13(7), 074027.

Davis, K. P., Heinrichs, J., Fleishman, E., Iranah, P., Bennett, D. E., Berger, J., & Pejchar, L. (2022). Strengths and shortcomings of habitat exchange programs for species conservation. Conservation Letters, 15(2), e12846.

Donofrio, S., Procton, A., Ecosystem Marketplace, Calderon, C., & Weatherer, L. (2023). State of the Voluntary Carbon Markets 2023. In G. Bennett & C. Coxon (Eds.), Ecosystem Marketplace Insights Report. Ecosystem Marketplace. https://3298623.fs1.hubspotusercontent-na1.net/hubfs/3298623/SOVCM%202023/2023-EcoMarketplace_SOVCM-Nov28_FINALrev-Mar2024.pdf

Farmer Resources — Soil and Water Outcomes Fund. (2024, May 30). Soil and Water Outcomes Fund. https://theoutcomesfund.com/farmer-resources

Fischer, Richard A., Reese, Kerry P., Connelly, John W., Influence of Vegetal Moisture Content and Nest Fate on Timing of Female Sage Grouse Migration, The Condor, Volume 98, Issue 4, 1 November 1996, Pages 868–872, https://doi.org/10.2307/1369875

Forest Trends, The Katoomba Group, & UNEP. (2008). Payments for ecosystem Services: Getting started: A primer [Book]. Forest Trends and The Katoomba Group. https://issuelab.org/resources/17784/17784.pdf

Gooden, J., & Pritzlaff, R. (2021). Dryland watershed restoration with rock detention structures: A nature-based solution to mitigate drought, erosion, flooding, and atmospheric carbon. Frontiers in Environmental Science, 9, 679189.

Habitat Quantification Tool. (2019). Environmental Defense Fund. https://www.edf.org/ecosystems/habitat-quantification-tool

Hayes, T., Grillos, T., Bremer, L. L., Murtinho, F., & Shapiro, E. (2019). Collective PES: More than the sum of individual incentives. Environmental Science & Policy, 102, 1-8.

Hunt, E. R., Kelly, R. D., Smith, W. K., Fahnestock, J. T., Welker, J. M., & Reiners, W. A. (2004). Estimation of carbon sequestration by combining remote sensing and net ecosystem exchange data for northern mixed-grass prairie and sagebrush–steppe ecosystems. Environmental Management, 33, S432-S441.

Jones, K. W., Cannon, J. B., Saavedra, F. A., Kampf, S. K., Addington, R. N., Cheng, A. S., ... & Wolk, B. (2017). Return on investment from fuel treatments to reduce severe wildfire and erosion in a watershed investment program in Colorado. Journal of Environmental Management, 198, 66-77.

Krause, M. S., & Matzdorf, B. (2019). The intention of companies to invest in biodiversity and ecosystem services credits through an online-marketplace. Ecosystem services, 40, 101026.

Krause, M. S., Droste, N., & Matzdorf, B. (2021). What makes businesses commit to nature conservation?. Business Strategy and the Environment, 30(2), 741-755.

Krueper, David J. Conservation priorities in naturally fragmented and human-altered riparian habitats of the arid west. US Bureau of Land Management, 1995.

Luna, Tara, et al. Common Native Forbs of the Northern Great Basin Important for Greater Sage Grouse. United States Department of Agriculture, 2018.

Martyn, T. E., Barberán, A., Blankinship, J. C., Miller, M., Yang, B., Kline, A., & Gornish, E. S. (2022). Rock structures improve seedling establishment, litter catchment, fungal richness, and soil moisture in the first year after installation. Environmental Management, 70(1), 134-145.

M.E.A. (2005) A Report of the Millennium Ecosystem Assessment. Ecosystems and Human Well-Being. Island Press, Washington DC.

National Resource Conservation Service (2017) Mesic Habitat Conservation Planning Guide, https://www.wlfw.org/wp-content/uploads/2017/04/Mesic_Habitat_Conservation_Planning_Guide1.pdf

Norman, L. M. (2022). Commentary: Dryland watershed restoration with rock detention structures: A nature-based solution to mitigate drought, erosion, flooding, and atmospheric carbon. Frontiers in Environmental Science, 10, 853684.

Norman, L.M., 2020. Ecosystem Services of Riparian Restoration: a review of rock detention structures in the madrean archipelago ecoregion. Air Soil Water Res.h 13. https://doi. org/10.1177/1178622120946337 117862212094633.

Norman, L. M., Brinkerhoff, F., Gwilliam, E., Guertin, D. P., Callegary, J., Goodrich, D. C., Nagler, P. L., and Gray, F. (2015) Hydrologic Response of Streams Restored with Check Dams in the Chiricahua Mountains, Arizona. River Res. Applic., 32: 519–527. doi: 10.1002/rra.2895.

Norman, L. M., & Niraula, R. (2016). Model analysis of check dam impacts on long-term sediment and water budgets in Southeast Arizona, USA. Ecohydrology & Hydrobiology, 16(3), 125-137.

Norman, L. M., Sankey, J. B., Dean, D., Caster, J., DeLong, S., DeLong, W., & Pelletier, J. D. (2017). Quantifying geomorphic change at ephemeral stream restoration sites using a coupled-model approach. Geomorphology, 283, 1-16.

Peterson, J. G. (1970). The Food Habits and Summer Distribution of Juvenile Sage Grouse in Central Montana. The Journal of Wildlife Management, 34(1), 147–155. https://doi.org/10.2307/3799502

Provencher, L., Byer, S., Frid, L., Senthivasan, S., Badik, K. J., & Szabo, K. (2023). Carbon Sequestration in Degraded Intermountain West Rangelands, United States. Rangeland Ecology & Management, 90, 22-34.

Remington, T.E., Deibert, P.A., Hanser, S.E., Davis, D.M., Robb, L.A., and Welty, J.L., 2021, Sagebrush conservation strategy—Challenges to sagebrush conservation: U.S. Geological Survey Open-File Report 2020–1125, 327 p., https://doi.org/10.3133/ofr20201125.

Rondeau, R.J., Austin, G., Miller, R.S., Parker, S., Breibart, A., Conner, S., Neely, E., Seward, N.W., Vasquez, M.G. and Zeedyk, W.D. (2024), Restoration of wet meadows to enhance Gunnison sage-grouse habitat and drought resilience in arid rangelands. Restor Ecol, 32: e14039. https://doi.org/10.1111/rec.14039

Salzman, J., Bennett, G., Carroll, N., Goldstein, A., & Jenkins, M. (2018). The global status and trends of Payments for Ecosystem Services. Nature Sustainability, 1(3), 136-144.

Shilland, R., Grimsditch, G., Ahmed, M., Bandeira, S., Kennedy, H., Potouroglou, M., & Huxham, M. (2021). A question of standards: Adapting carbon and other PES markets to work for community seagrass conservation. Marine Policy, 129, 104574.

Silverman, N.L., Allred, B.W., Donnelly, J.P., Chapman, T.B., Maestas, J.D., Wheaton, J.M., White, J. and Naugle, D.E. (2019), Low-tech riparian and wet meadow restoration increases vegetation productivity and resilience across semiarid rangelands. Restor Ecol, 27: 269-278. https://doi-org.yale.idm.oclc.org/10.1111/rec.12869

Soil and Water Outcomes Fund | Quantified Ventures. (2023, November 1). Quantified Ventures. https://www.quantifiedventures.com/soil-and-water-outcomes-fund

Uhlman, K., Eastoe, C., Guido, Z., Crimmins, M.A., Purkey-Deller, A. and Eden, S. (2020), Assessing the Vulnerability of an Aquifer to Climate Variability through Community Participation in Arivaca, Arizona. Journal of Contemporary Water Research & Education, 170: 2-18. https://doi-org.yale.idm.oclc.org/10.1111/j.1936-704X.2020.03337.x

UNEP (2023). State of Finance for Nature: The Big Nature Turnaround – Repurposing $7 trillion to combat nature loss.

Wilson, Natalie R. & Norman, Laura M. (2018) Analysis of vegetation recovery surrounding a restored wetland using the normalized difference infrared index (NDII) and normalized difference vegetation index (NDVI), International Journal of Remote Sensing, 39:10, 3243-3274, DOI: 10.1080/01431161.2018.1437297

World Bank. 2022. Scaling Up Ecosystem Restoration Finance : A Stocktake Report (English). Washington, D.C. : World Bank Group.

World Bank. 2024. Blueprints for Private Investment in Ecosystem Restoration: Lessons from Case Studies. Washington, DC: World Bank.

APPENDIX

Figure 1: Slow the Flow Diagram

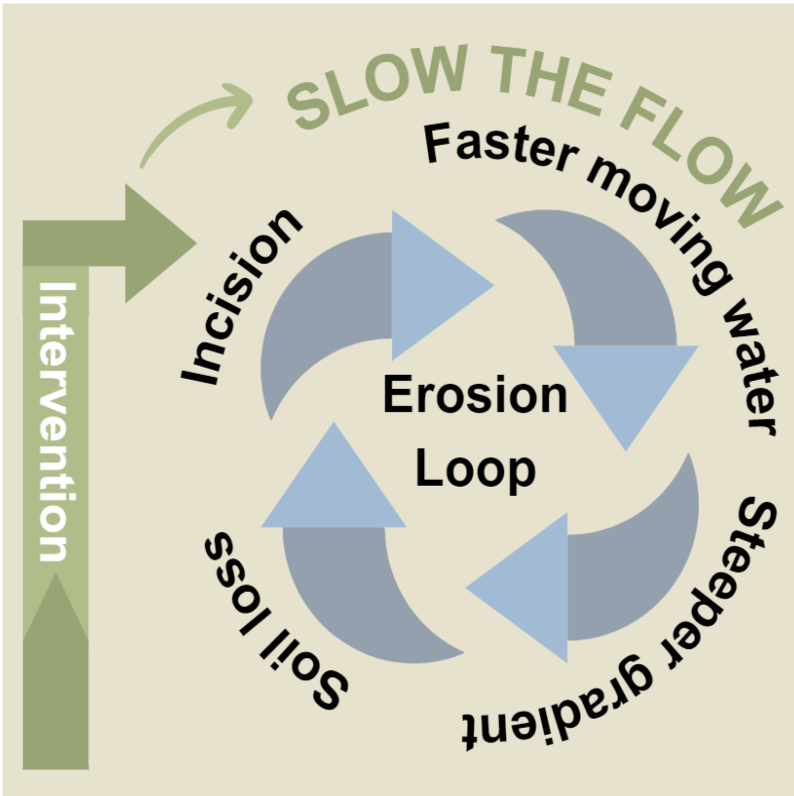


Figure 2: Wet Meadow Restoration Structure in Yampa Valley

(Photo Source: CCALT)

Figure 3: Wet Meadow Restoration Structure Construction Process

(Photo Source: CCALT)

Figure 4: Wet Meadow Restoration Structure on Working Lands

(Photo Source: CCALT)

Table 1: Wet Meadow Restoration Cost

Project Type	Purpose	Item	Estimated Cost	Notes
Rock Structures	Raw materials	Granite rip rap rock	$20-$60/ ton	The prices provided may be used to plan, fund, or implement a restoration project. It is likely that raw materials may be harvested from the project site. Similarly, many of the tools and equipment are frequently tools and likely already owned or easily borrowed.
	Tools and equipment	Shovel	$40-$60/each	
		Wheelbarrow	$70-$150/each	
		Backhoe	$30-$100/hour	
		Webbing rock sling	$25/each	
Log Fabric Step Falls	Raw materials	Logs	$12-$25/ log	
		Geotextile fabric	$1.50 to $5.40/square meter	
		Smooth wire	$135/spool	
		Barbed wire	$135/spool	
		Fencing staples	$30/ pack	
	Tool and equipment	Shovel	$40-$60/each	
		Pick	$25-$50/each	
		Crowbar	$25/each	
		Wheelbarrow	$70-$150/each	
		Fencing pliers	$30/each	
		Utility knife	$10/each	
		Log carrier	$150/each	

Labor	--	--	Variable	See *Costs of Implementation* section for back-of envelope estimates of labor costs. Maintenance may include invasive species removal and/or structure adjustments. Maintenance costs vary but are generally limited. Typical maintenance captures labor and materials for structures.
Maintenance	--	--	Variable	Maintenance may include invasive species removal and/or structure adjustments. Maintenance costs vary but are generally limited. Typical maintenance captures labor and materials for structures.
Monitoring	Hydrologic Function	soil moisture meters	$20-$500 per sensor + variable technical assistance	
	Vegetation Monitoring	Aerial imaging	open access ($0) + variable technical expertise	Costs vary by monitoring method. Not all monitoring methods may be appropriate or accurate for each site.
		Photo points	$50- $500	
		Plant surveying	free online resources	
	Erosion control	Sediment estimates	variable technical expertise	
	Soil quality	Soil tests	$10-$200 a sample depending on measurements	

**All price estimates are from Feb 2024. Materials and equipment are subject to change over time*