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Markets for Ecosystem Services on Public Grazing Lands: Assessment of Potential Services and Considerations for a Successful Program

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Executive Summary

Land and grazing management practices adopted by livestock producers on western rangelands have the potential to contribute to enhanced ecosystem service production at local and global scales. Ecosystem services are the functions performed by natural systems that produce benefits for humans, such as carbon storage and water purification. Markets for ecosystem services are payment schemes that compensate private actors for enhancing the production of ecosystem services that benefit the public. If designed carefully and inclusively, ecosystem service markets can be created to incentivize adoption of livestock and land management practices that enhance carbon storage and hydrological ecosystem services. This white paper summarizes the insights and recommendations for designing markets for ecosystem services specifically geared toward livestock producers who utilize both private and public lands for grazing. Our assessment stems from existing information and knowledge gaps about ecosystem services produced by rangelands and characteristics of existing payments for ecosystem service programs that work and do not work.

Introduction

There is growing evidence that the natural environment performs services that create a diverse range of benefits, referred to as ecosystem services, to humans. Lands classified as rangelands in the western United States (both publicly and privately owned) aid in producing services that benefit humans, such as food and energy, regulating atmospheric carbon and hydrological cycles, and providing recreational opportunities and cultural sense of place. The magnitude of production of these benefits depends on the health and management of the rangeland systems themselves. On western rangelands, land managers, including livestock producers, hold the potential for protecting and enhancing production of ecosystem services through chosen management practices.

The production of ecosystem services is influenced by actions of individual decision makers, but the benefits of these services accrue to the public. Some of these services (food and energy) are exchanged in well-established markets and there, prices signal how producers should optimally allocate resources. Other ecosystem services, including carbon storage and hydrological cycles, do not have established markets, no price or monetary value, and accrue to the public, not just the land manager. Often these ecosystem service values do not appropriately weigh costs and benefits of individual production decisions; incentives to enhance ecosystem services that accrue to the public are misaligned and are therefore often undervalued and underprovided from the public's perspective.

Americans increasingly recognize the existence and significance of ecosystem services that do not have well-defined market values. The concept of creating markets for ecosystem services, where those that invest in the enhancement of ecosystem service production are compensated for their efforts, has emerged as a possible solution to this challenge of misaligned public/private incentives. Payments that incentivize the conservation of natural ecosystems and the services they provide may produce the desired public benefits, such as carbon sequestration and water storage, at considerably less cost than using built capital to produce the same outcome (e.g., *Kroeger and Casey, 2007*). Typically, markets for ecosystem services are programs in which beneficiaries of ecosystem service production compensate other parties for providing enhancements (additional production over some baseline) to particular ecosystem services, however in some cases (e.g., foregone deforestation) prevention of potential degradation (maintenance of existing ecosystem service production) is rewarded. In the case of western rangelands (both public and private), land managers and livestock producers can be encouraged to increase ecosystem service provisioning in the form of payments to increase the "supply" of a certain level of ecosystem services.

In this paper, the authors focus on three ecosystem services provided by western public rangelands where there are opportunities for market creation – air quality and greenhouse gas control/carbon storage water quantity, and water quality. This paper briefly discusses how these services can be influenced by livestock producer decisions and then identifies opportunities and challenges for creating markets that can incentivize private decision makers to change practices that enhance or create additional ecosystem services.

Potential for Ecosystem Service Markets on Public Rangelands

Livestock producers that utilize public rangelands as grazing lands produce commodities for consumers (food and fiber). The price of these commodities informs how valuable the products are to consumers, and these values in turn inform production decisions of these commodities. Land and cattle management practices on both private and public rangelands impact production of other ecosystem services that are also valued by consumers such as carbon sequestration and hydrological cycles. These ecosystem services are not readily exchanged in markets and do not have well-defined prices. Yet, many of these ecosystem services provide benefits to the public, meaning that in the absence of markets, the price received by individuals for supplying ecosystem services is zero. In the absence of markets for these ecosystem services, producers choose the level of ecosystem service provision based on their own personal preferences as they have no market signal from consumers for whether more or less of the service should be "produced". Since there is no financial incentive to supply ecosystem services, they are often underprovided from a public perspective.

The relationship of ecosystem services demand and supply can be conceptualized over time (*Figure 1*). Considering the period before European settlement of the Americas, many of the ecosystems of the Americas were much closer to the climax community mixes of plant species. Since then, landscapes have become more homogeneous as more of the terrestrial land surface has been converted for human uses (*Carpenter et al., 2009*). During the pre-European period, supply of ecosystem services is hypothesized to have exceeded the demand for those services (*Carpenter et al., 2009*). Along with the conversion of land to more intensive use (e.g., farming, and development), European settlement of the Americas also brought invasive plant species from Afro-Eurasia, along with intensive grazing of domesticated species (*Masters and Sheley, 2001*) – although the impacts of intensive grazing by domesticated is species is likely partially off-set by the decline in large native herbivores over that time.

Presently, the demand for ecosystem services is not fully satisfied by the supply. This is largely because there are currently no price signals that cue rangeland managers to change practices in order to enhance ecosystem service production. Further, thin profit margins and large up-front investment costs and uncertain outcomes limit willingness to change management practices (*Goldstein et al., 2011*). Sala et al., (*2017*) speculate that demand for ecosystem services will continue to exceed the supply in the future, and this point is echoed within the literature (e.g., *Goldstein et al., 2011, Scheiter et al., 2019*). Further exacerbating this issue are the social processes that alter the state of rangelands, and the ecological processes that drive ecosystem change and shape human benefits which occur at multiple scales and often with uncertainties.

A well-designed payment for ecosystem services (PES) regime could push against the tide of a failure of rangelands to provide sufficient ecosystem services to meet demands and could alter the trajectory of land development – of which 3 million acres (1.2 million hectares) are developed and urbanized per year in the United States (*Macie and Hermansen, 2003*). To improve natural resource use on rangelands, managers need a clear understanding of where, when, and what management practices lead to greater production of ecosystem services, as well as which ecosystem services to

prioritize. While there are many ecosystem services that are produced by rangelands, this paper focuses on three major services: air quality and greenhouse gas control/carbon storage, water quantity, and water quality. In part, this is because these are the best studied ecosystem services, but also there is evidence that specific rangeland and livestock management practices can enhance the production of these services.

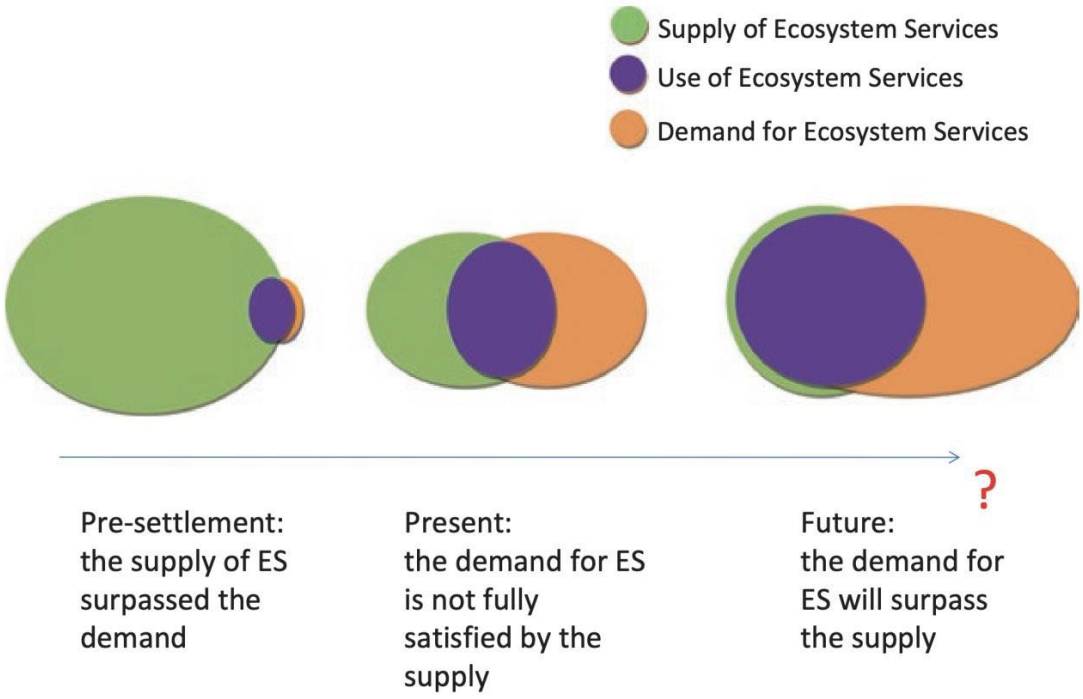

Figure 1 - Demand and Supply of Ecosystem Services Following European Settlement of the Americas (Sala, et al., 2017)

Air Quality and Greenhouse Gas Control

Many facets of the economy are vulnerable to global climate change. Stabilizing atmospheric CO_2 concentrations is the primary objective in mitigating global temperature rise and the impacts of climate change. Natural systems, including rangelands, have the ability to act as a sink for carbon dioxide. Grazing lands represent 15% of the potential for US soils to sequester carbon (*Lal et al., 2003*). The capacity for rangelands to sequester carbon is dependent on climate trends and variability, vegetation, and land management practices. In contrast to forests, in rangelands, most of the sequestered carbon is stored below-ground – in biomass (roots) and decomposed vegetation.

There is little literature on management practices that can enhance carbon sequestration on rangelands. Interseeding alfalfa, planned burns, and grazing lands restoration all have been shown to increase carbon storage (*Derner and Schuman, 2007; Mortenson et al., 2004; Schuman et al., 2002*). In Wyoming, researchers found that carbon sequestration can be impacted by range utilization through placement of water and mineral supplements (*Campbell et al., 2004*). In addition, destocking during drought on vulnerable lands can mitigate release of stored carbon.

The capacity of rangelands to sequester carbon is important, because of the area that rangelands occupy around the world. While rangelands store less carbon per unit area than other ecosystems,

such as forests and wetlands (*Reynolds et al., 2007*), the surface area that rangelands cover constitutes a major fraction of the global carbon cycle. Rangelands also account for a significant fraction of the interannual variability in the global carbon sink (*Ahlström et al., 2015*).

Water Quantity

The availability of fresh water is critical for all life and is fundamental in the ecosystem functions. In the American West, most water supply is derived from precipitation and snowpack, which is transported across landscapes by rivers, and then built infrastructure delivers it to users. Because much of the west's water supply falls in the winter and the greatest demand occurs in the summer, ecosystem services that facilitate the storage and release of water are critical to life and livelihood. While water storage can be manmade (dams and reservoirs), functioning watersheds and sustainably used aquifers can also contribute to water storage, treatment, and flood control.

Increased water-yield benefits may be a result of native species restoration; proponents of this hypothesis posit stream and aquifer recharge benefits following brush eradication. This hypothesis is formed around the argument that reducing evapotranspiration loss by managing rangelands for a greater grass component and a lesser tree and shrub component will provide more water availability for runoff and deep percolation. While that argument has been shown to be true in a variety of humid, montane, and Mediterranean climates, where studies have tied increases in water yields to removal of trees and shrubs (*Wilcox and Thurow, 2006*), the research is more pessimistic for arid and semiarid rangelands, as water-yield benefits have not been demonstrated on scales that would greatly alter regional water supplies. Lack of total water availability in upland sites leaves little available water for increased streamflow or deep percolation to aquifers (*Hibbert, 1983*). However, the Bureau of Land Management notes that once target brush species are removed, water availability increases for use by desirable grass, shrub, and tree species, which further improves conditions that allow for the return of native vegetation (*Lister et al., 2012*). The research shows that with more native plants, there is more water retention in the soil and less runoff and erosion (e.g., *Hibbert, 1983; Kuhn et al., 2007; Sturges, 1983*).

Water Quality

Because water in the western United States is primarily derived from surface water, land use practices that influence water quality can potentially have large impacts on human and ecosystem wellbeing. For example, water quality is considered an input in the various production processes on the range (*Freeman III, 2010*) and translates directly to habitat for aquatic species. Water quality also directly impacts the costs to treat human drinking water. Cattle grazing in riparian zones and mesic areas can impact nutrients, sediments, streambanks, microorganisms, and vegetation, and altering grazing management practices, including the timing and intensity of cattle use of riparian areas, can affect these impacts. Also, research indicates that vegetation treatments that target the return of native species can potentially reduce polluted runoff and deposition of natural and human-made pollutants into lakes, rivers, wetlands, and ground waters (*Lister et al., 2012*). Enhancing water quality would benefit both rural and urban areas downstream.

Considerations in Designing Markets for Ecosystem Services

Some ecosystem services can be provided through government regulation or conservation programs, but creating markets is often considered a more desirable way of achieving these goals. If they can be successfully created, markets tend to be more efficient than regulations, since they can be created such that those that derive value from ecosystem services pay for the provision of them.

Demand for Rangeland Ecosystem Services: Scale of Benefits

While some ecosystem services are generated and consumed locally, many accrue to parties that are considerable distances from the point of origin. On a spatial level, the benefits from ecosystem services produced on western rangelands can accrue at the local, regional, and global level. For example, consider greenhouse gases that are sequestered by rangelands; every unit of sequestered greenhouse gas reduces the environmental and economic damage that would have occurred otherwise. Management practices that sequester greenhouse gases provide a global benefit regardless of where the sequestration took place, because greenhouse gases mix thoroughly in the global atmosphere. However, management that alters water quantity or quality may provide benefits at smaller scales (local or regional). In principle, as the benefits of ecosystem services accrue at a larger scale, the costs of developing a PES program increase.

Interestingly, all spatial scales have both public and private benefactors of the ecosystem service produced and should be considered when determining fair payments.

Local Services

Local public goods associated with rangeland management practices include hydrological services, such as water quality and quantity. These services may be of particular interest to cities concerned with water supply. In these cases, there may be private buyers for ecosystem services. For example, if a municipality is interested in improved drinking water quality from surface water sources, a PES program could be developed, which creates a method whereby rangeland managers can be directly paid by the municipality for producing specific water quality improvements.

Regional or National Services

Regional agreements are usually driven at the state or national level because of the large number of parties involved. Examples of these types of services include changes to water quantity that impact entire hydrological basins.

Global Services

Carbon sequestration, provision of biodiversity and potentially water quantity/quality (e.g., Colorado River) are examples of ecosystem services that transcend national boundaries, and both public and private parties need to be active in these types of markets.

Supply of Rangeland Ecosystem Services

In contrast to demand for ecosystem services, which can accrue across various spatial scales, the suppliers who participate in PES programs are mostly individuals or small groups. Livestock managers, who have the power to alter location, timing, and intensity of cattle grazing, as well as rangeland restoration projects should be the focus. One important factor is the ability to target and calibrate payments so that producers who are capable of producing the desired services choose to enroll.

Compensation for Actions Versus Outcomes, and Who Takes on Risk?

One important consideration in PES design is whether individuals will be compensated for adopting recommended practices, or the changes in ecosystem service production resulting from adopting practices. There are many reasons to reward outcomes rather than practices, even as the latter option has been commonly used in many PES programs in the past. While payment for practices is often easier to implement, there is often a disconnect between recommended practices and observed outcomes for a variety of reasons (e.g., lack of site-specific understanding of linkages between practices and outcomes, climatic/weather outcomes, wildfire, etc.). Further, verifying practice implementation requires intensive monitoring to ensure practices (whether structural or non-structural) occur when and where they were proposed.

Outcomes-based payments allow for producers to use their existing knowledge of the land they manage to implement the practices that they think will be most beneficial for a specific outcome, which can be a far more efficient use of resources than simply paying for practices (*Reed et al., 2014*). The understanding that land managers are often better positioned to manage for outcomes has recently been adopted by the US Government, and Outcomes-Based Grazing Authorizations are being tested as a way to allow for more flexible management by permittees on public lands (*Bureau of Land Management, n.d.*).

Uncertainty in Producing Desired Ecosystem Service Outcomes

Reed et al. (*2014*) points out that payment for outcomes is inherently riskier for producers as outcomes are dependent on a large number of factors, many of which are not under direct control of the producer. For example, in range/livestock systems in the Western U.S., ecosystem services provision is highly dependent on climate and annual environmental factors. Further, managing for enhanced ecosystem services beyond food and fiber production in western rangelands tends to result in lower returns to the livestock producer (greater input costs, smaller herd size), and therefore these services should not be expected to be provided for free (*Ritten et al., 2018; Tanaka et al., 2014*). Further, livestock management must adapt to dry years, and the negative impacts of common strategies (e.g., destocking) will be felt for many years after the drought has abated (*Hamilton et al., 2016; Torell et al., 2010*). For many operations, the ability to take advantage of wet years is the only option to remain in business as dry years result in financial losses. If management actions are further impacted by drought cycles to ensure the continued provision of ecosystem services, there must be sufficient incentives for producers to adopt (or continue) these practices, especially if these events are expected to increase in frequency and/or severity under future climate projections. Also, Dyer (*2017*) shows that the timing of implementation costs and benefits accrued due to restoration practices can have a large impact on the net present value of a project. Even if the

total benefits outweigh the costs, if the majority of costs occur at implementation and benefits accrue over time, producers may not have sufficient private incentives to participate in a project, and this will be exaggerated if there are risks of not accruing benefits due to outcome uncertainty through external factors such as weather and fire.

Maintenance Versus Additionality and Stackability of Credits

Goldstein et al., (*2011*), referencing the Millennium Ecosystem Assessment (*2005*), report that around 63% of rangeland ecosystem services have been degraded or are being used unsustainably. Therefore, they state, it is important to focus on maintaining the ecosystem services currently provided by the existing working landscapes as well as working to restore degraded lands. While 'additionality' in ecosystem service production, or enhancing ecosystem service production on landscapes, is often emphasized in PES programs, maintaining the existing suite of ecosystem services on western landscapes can be just as important as increasing production of these services. This decision should be evaluated after collecting some baseline information on the starting condition of a specific allotment. Huntsinger and Oviedo (*2014*) further this point by stating that the typical definition of ecosystem services as "benefits people receive from ecosystems" obscures the reality of how these services are produced. They argue that existing ecosystems (Californian Mediterranean Rangelands in their case) often exist either due to modification, or even creation, by humans, and human activity is not always harmful to an ecosystem, at least not when related to ecosystem service provision. Further, the way these landscapes have been shaped by past human activity is often overlooked, and human impacts on the structure and function of existing ecosystems cannot be ignored. It is the management of these landscapes that currently provides these specific values to society, and the public value created is due (at least in part) to the people who manage these lands. Ecosystem service provision therefore is reliant on both the land and the management of that land.

Payments to ensure a maintained supply of ecosystem services are no different than conservation easements which are an already accepted method to preserve the services provided by working landscapes. Any market for ecosystem service production needs to be structured so that payments can be determined for all possible lands – not just those which were historically degraded, but also those that have the potential to provide additional ecosystem services.

Removing the need for 'additionality' and rewarding producers for continued supply of outcomes will reward both the early adopters of practices as well as the historically good land stewards. Through incentives to continue providing ecosystem services, managers that are producing public goods will be more likely to be financially able to operate, and therefore less likely to sell their land/lease to other managers that may not provide the same level of outcomes, or even subdivide the land resulting a permanent loss of ecosystem service provision from the landscape. Paying producers to maintain specific ecosystem services also alleviates the concerns of the potential for perverse incentives that may be created by a PES program. For example, if payments are sufficiently high for land restoration, it may be profitable to temporarily degrade land before enrolling in such a program. It is also important to note that not all potential services can be provided at their highest level at all times on a landscape, and land managers must decide which services to provide (*Ritten et al., 2018*). Ecosystem services are often not created in a bundle, and therefore land managers should

be rewarded for each ecosystem service that is provided under their management, as each will require specific attention and management to produce. “To effectively link ecosystem service provision with payments, it is necessary to identify and put a price on each service, either directly by offering contracts for a set of outcomes, or indirectly by offering contracts for a set of actions (*Reed et al., 2014*).”

Credit Generation and Ownership of Ecosystem Services on Public Lands

If private producers hold a grazing lease on public lands, their management actions have the potential to contribute to the provision of ecosystem services on those lands. There is a mismatch between private investments in environmental benefits for public benefit which result in less-than-optimal investments in ecosystem service production. To incentivize individuals to invest in management actions that preserve or enhance ecosystem services that benefit the public, a transfer of benefits needs to occur from the public to the individual. Markets can facilitate this transfer of value from the public to individuals.

Programs are already in existence that allow producers to earn credits from ecosystem service generation on private lands, even if the projects that generated those credits are in part federally funded. Livestock producers benefit from selling livestock that were, in part, raised on public lands, and the same should hold to other ecosystem services. Further, while the grazing fee associated with public lands is lower than on private lands, the total cost of these lands (including the non-fee costs such as moving livestock, monitoring/herding, infrastructure maintenance, etc.) is often as high or higher than the cost of using private lands. As stated by Van Tassell et al., (*1997*), “(t)he common belief that public land ranchers pay less on average than those leasing private lands is not true.” Since producers are paying to use (and manage) these lands, the value of the service should be credited to their management. Without proper incentives, these lands will not provide the current level of, and certainty not an increase in, ecosystem services the public desires.

Existing Policies to Facilitate Private Markets for Ecosystem Service Production on Public Lands

Ecosystem services and PES programs have a very short history in US environmental law. The concept of ecosystem services was first introduced to law in 2008, initially by the US Army Corps of Engineers and the Environmental Protection Agency (EPA), under section 404 of the Clean Water Act. That same year, Congress added ecosystem service markets provisions to the 2008 Farm Bill. Section 2709 of the Food, Conservation, and Energy Act of 2008 required the United States Department of Agriculture (USDA) to “establish technical guidelines that outline science-based methods to measure the environmental services benefits from conservation and land management activities in order to facilitate the participation of farmers, ranchers, and forest landowners in emerging environmental service markets”. Section 2707 also established the Office of Environmental Markets (OEM) (https://www.oem.usda.gov) as a resource for exploring the potential for market creation. While the OEM is a source for various government reports and guidelines on creating markets, evaluating and valuing ecosystem service production, and current programs and partnerships, the content considers credit generation on private lands. There is currently no content available for market creation specifically on public lands.

To date, there are no government programs that provide payments to landowners for carbon sequestration on private property, nor similar actions on public lands. Currently, any payments within a PES on public lands in the US would be paid to the US Treasury, rather than the producer whose management contributed to the specific ecosystem service, or even the agency that manages the lands (*J. Brown, USDA NRCS, personal communication, January 27, 2021*). Under the current law, the landowner (on federal public lands – the federal government) would own the rights to any credits generated on that land. While the public lands grazing permit holder purchases the right to the forage produced on public lands, their grazing fee does not entitle them to any other property rights attributed to the land. With the lack of full property ownership by the producer, it is likely that further legislative changes would be necessary before a PES program could be implemented on public lands. It is therefore expected that lease holders will manage in a way that provides lower quantities of ecosystem services than desired by the public as it is economically rational that producers that pay just for forage will optimize livestock performance at the expense of other ecosystem services. If public land managers require that management provide enhanced ecosystem service provision on public lands as part of a lease, potential lessees will be expected to lower their bids, as the costs of utilizing the forage will increase, and therefore be less desirable as a potential forage source.

Voluntary ecolabeling or eco-certification are alternative policies that have seen various degrees of success across other industries as a way to create price premiums for producers that adopt improved environmental management and production practices. Products sold under some established ecolabels must meet standards set by the federal government or agencies, such as the USDA or EPA. While ecolabels have seen mixed success across the food industry, in the absence of the legislative framework to facilitate PES markets on public lands, labels and/or certification could incentivize ecosystem provision on public lands.

Challenges in Designing Markets for Ecosystem Services

Establishing Ecosystem Service Production Baselines

Before development of a market, the baseline production of ecosystem services must be determined for individual allotments. This includes standardizing measurements and data collection and clear descriptions about how changes in the services will be tracked over time. The authors recommend that information should be collected using publicly available datasets maintained for public and private lands and made readily available. Often, the costs of quantifying ecosystem service provision can be prohibitive. Using publicly available data to estimate the change in ecosystem services resulting from management changes is critical to eliminate the high costs of 'boots on the ground' verification.

Establishing how ecosystem service production will be measured requires agreement from market participants on what data will be used, and how provision of ecosystem services will be estimated (and rewarded) using this data. For example, if markets evolve beyond carbon sequestration and water quantity and quality provision, it should be explicit that a specific service will be rewarded (e.g., creating suitable habitat for a specific migratory bird at a specific time of year) as opposed to an ecosystem good (number of birds at a given location) as often population dynamics can be impacted by global events. Credits should be awarded based on multi-year outcomes, as annual unforeseen events could affect ecosystem service production that are out of the managers' control. Further, there needs to be transparency as to how the 'baseline' will be calculated across various landscapes. This baseline should be set at an agreed upon counterfactual scenario that estimates the expected provision of ecosystem services in the absence of domestic grazing animals and human management of the system. Finally, to assist producers determine whether they are willing to participate in the market, the current state of ecosystem service production on rangelands science needs to be publicly available through any payment clearinghouse. This information source must include the current state of knowledge on how grazing and land management practices influence short and long-term changes in ecological conditions.

Determining Monetary Exchanges for Ecosystem Service Provision

Developing markets for ecosystem services requires evaluating the monetary value that the service provides to society, so that participants can be compensated for enhancing the valuable services they provide. For benefits that are not readily bought and sold in markets, such as clean water, identifying this value can be a challenge.

There are a number of possibilities on determining specific payment values transferred to producers for conservation actions. A starting point for determining whether the costs of enhancing ecosystem services is aligned with society's willingness to pay could be modeling a market after the United States' Conservation Reserve Program (CRP). CRP is a voluntary land conservation program, funded by the federal government, in which landowners commit to retire ecologically sensitive croplands, pasture, and grassland from production for a minimum of 10 years. The goal of the program is to enhance ecosystem services such as wildlife habitat, water quality, and soil retention. CRP participants receive annual rental payments as well as cost-share assistance for implementing

conservation practices. Landowners must submit bids to participate in the program. Applications are evaluated based on an index of potential environmental benefits from proposed conservation practices. The payments that landowners receive for enrolled land are determined using a combination of dryland cash rental rates determined by the National Agricultural Statistics Service and the costs of conservation practices.

While a market for ecosystem services for working rangelands would not include land retirement, the payments could be initially based on land manager estimates of conservation practice implementation costs. Then, over time, this could be adjusted with the input of suppliers (producers) and demanders (society) of ecosystem services, as well as continued research on how land use practices influence ecosystem services. Producers could submit bids to a clearinghouse, proposing conservation actions to take place on public grazing allotments and estimate the costs and duration of activities. This clearinghouse would estimate the amount of ecosystem service(s) provided given the unique characteristics of the land/climate (which would inform the baseline condition) and proposed (and potentially historical) management. The clearinghouse could match this suite of ecosystem services to buyers of these specific services. One concern that producers may have with program participation is the risk of unforeseen circumstances (fire, prolonged drought) occurring, thwarting their efforts to provide specific amounts of ecosystem services. It is possible that a producer will invest in enhancing ecosystem services and yet not achieve their objectives due to factors outside of their control. In this case, a risk premium would also likely be a component of their bid. Parties willing to pay for the ecosystem services can evaluate bids and determine which producers to fund. Cost sharing of any up-front actions may alleviate some concern over the risk of failure to enhance services. On semi-arid rangelands, measured changes in ecosystem services may take place over a long time. Below are necessary considerations in determining compensation for ecosystem service production in the long-term.

Quantifying, Monitoring, Verification, and Permanence of Ecosystem Service Production

Given the argument by Huntsinger and Oviedo (*2014*) that ecosystem services accrue to the land in combination with historic and current human interaction with that land, credits should be earned above a 'baseline' that would exist in the absence of human management and/or grazing animals. Any PES model will need to quantify the difference in ecosystem services provided under existing management compared to the baseline. Both the current levels of ecosystem service provision and the baseline levels will need scientific verification. Under this model, some producers will likely qualify for credits given their existing management practices. The model must reward early-adopters to prevent any perverse incentives such as land degradation before program participation.

Credits for payment should accrue to outcomes rather than practices, which is in alignment with demand for the provision of ecosystem services and begins to address the issue of monitoring and verification. While monitoring and verification of infrastructure projects (one type of 'practice' that is often recommended) is relatively straightforward, monitoring and verification of other practices such as rotational grazing can be difficult and costly due to the requirement for timely tracking and documentation of animal movement across a landscape. However, payments for outcomes rather than practices also places non-attainment risk on producers, which is why the services provision

price will need to be at a minimum based on the risk premium. If credits accrue to outcomes, rather than practices, and as compared to a counterfactual baseline (not actual existing conditions), verification can be far easier with the help of agreed-upon technology.

The market must agree to a set of desired outcomes, and measurements of these outcome based on scientific literature to determine if (or how many) credits producers earn in a defined timeframe. Using publicly available data to feed these sorts of decisions (e.g., satellite data) alleviates many costs associated with monitoring and verification on specific allotments, which has made markets for ecosystem services costly to create historically.

Finally, livestock producers should be rewarded for providing specific ecosystem serves for a set period. While 'permanence' has often been a desire of PES programs, this requirement will likely limit participation in these markets. Further, the permanence requirement could limit alternative land management activities that may result in decreasing a specific service in the short-term even if that management change will result in higher levels of ecosystem service provision overall. The authors expect that land management recommendations will change over time either as scientific understanding of the linkages between management and outcomes become clearer, or the public shifts focus to other ecosystem services of concern. This approach also has the benefit of not penalizing producers that fail to meet the expectations of a practice in a given year, especially if this non-attainment is due to events outside of their control (e.g., extreme drought or wildfire) – they simply would not receive any credits during that time which would alleviate at least some of the non-attainment risk. However, initial agreement must be determined on the length of time that is required for a specific ecosystem service (e.g., annual, decadal, longer) as well as how and when payments will occur.

For any contract longer than one year, there needs to be agreement on how total credits will be calculated (e.g., average production over the length of the contract, or simply the sum of annual outcomes) which will likely impact how/when payments will be made. For example, if payments are based simply on the sum of annual outcomes, payments can occur annually with little risk to the purchaser, and these annual payments will likely be attractive to those considering enrolling their land. However, if payments are based on the average outcome across the contract period, there is a risk that if purchasers make any payments prior to the end of the contract, they could pay for services that ultimately were not generated. However, waiting until the end of a contract that is greater than a year in length for payment will likely deter many land managers from participating in markets. Therefore, the authors recommend using the shortest contract the market will bear, and possibly providing bonus payments if lands are enrolled for certain lengths of time (e.g., 5- or 20-year enrollment bonuses). This also removes some of the market risk to both buyers and sellers of credits and allows the market to adapt to changing public preferences.

Timing of Conservation Costs and Realization of Environmental Benefits, Specifically on Public Lands

As noted above, many management practices aimed at increasing the provision of ecosystem services over time require initial costs that will be borne by producers. Under a PES program that pays for outcomes rather than practices, there may be a lag between investing in a management

practice and realizing enhanced ecosystem services and benefits. There will likely need to be a policy mechanism to offset these up-front costs and incentivize adoption of management practices that encourage an increase in ecosystem service provision. On private land, cost-sharing or lower lending rates for costs associated with ecosystem service provision can incentivize management changes. Public lands present additional challenges for long-term investments, as grazing permit holders lack full property rights and land ownership. In the long term, grazing permit agreements may change, along with which producer holds the right to graze on the allotment. Public policy should consider how enhanced ecosystem service production on allotments may change their desirability of the allotment for grazing, perhaps increasing the number of bids for that lease in the future. More and higher bids could put the producer's continued access to that land at risk. To make a producers' property rights to the land more certain, the federal management agency could guarantee extension of the producers' grazing permit.

Conclusion

Rangelands may present a unique opportunity for establishing markets which compensate livestock producers with the rights to public lands grazing an opportunity to enhance the ecosystem services that accrue to the public. The authors propose prioritizing market creation for three services, namely, 1) air quality and greenhouse gas/carbon storage, 2) water supply, and 3) water quality. These are all ecosystem services that have proven to be impacted (positively or negatively) by livestock management practices. The authors then discuss further requirements to create a successful market for these ecosystem services, including information sharing, measurement, payments for outcomes versus practices, and the importance of uncertainty and timing. If designed carefully, the program can aid in improving carbon sequestration and hydrological ecosystem services, and simultaneously contribute to economic stability of ranching communities.

One of the critical components of the creation of a PES program is that the program model anticipates and prevents the creation of incentives that undermine the fundamental goals of the program.

While setting the conditions for payment to be outcome-based rather than practice-based can address many perverse incentives, the program must also carefully consider how time and pre-existing range conditions factor into the payment structure. Further, the program must be able to compensate producers sufficiently to incentivize the production of ecosystem services in dry years, to keep producers from abandoning conservation practice changes.

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