



Rangeland Ecosystem Service Markets: Panacea or Wicked Problem?

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Rangelands support nearly one-third of Earth's population and provide a multitude of ecosystem services. Land managers and society face increasing pressures to sustainably intensify rangeland food systems; therefore, the time is ripe for thoughtful approaches to simultaneously produce more food, provide economic opportunities for livestock-dependent communities, and enhance environmental benefits from rangeland ecosystems. Payments for ecosystem services (PES) programs have been put forth as potential mechanisms to maintain the quality and quantity of ecosystem services while enhancing economic viability of livestock operations. Free markets have long been proposed as solutions for mitigating trade-offs from ecosystem services that are not co-produced with livestock production; such markets have failed to emerge at the scale required to address global threats to sustainability. We highlight fundamental obstacles on demand and supply sides that challenge the concept of a market as a panacea; we do so through an interdisciplinary lens of fundamental economic underpinnings overlaid with a social survey of cattle producers' perspectives. Relevant to the demand side, we discuss the most significant impediments to development and function of non-bundled ecosystem service markets; on the supply side, we provide unique perspectives, using novel interview data from California rangeland cattle producers. Producer interviews highlighted substantial financial challenges threatening the economic sustainability of their operations. Among interviewed producers, 85% identified government regulations as the central threat to their livelihoods. Producers identified opportunities for enhancing enterprise sustainability via improved value and marketing of livestock goods co-produced with ecosystem services, participation in conservation easements, and improved connections with society. Only 11% of producers identified PES programs as future opportunities. When asked about willingness to participate in PES markets, 13% of interviewees indicated they would not, 45% were neutral, and 42% indicated they would consider participating. Interviewees stated trust in the market broker is key and they would be less willing to participate if there was government involvement. Ecosystem service markets—whether voluntary or

non-voluntary—are likely not sustainable solutions to the complex social-economic-ecological dilemma ranchers and society face. Sustainability on working rangelands will require partnerships to co-develop strategies to build more equitable food systems and sustain these ecosystems.

Keywords: conservation, ecological tradeoffs, environmental markets, grazing, payments for ecosystem services, producer survey, sustainable livestock production

INTRODUCTION

Rangeland ecosystems such as grasslands and savannas cover ≈50% of the Earth's land surface (Lund, 2007). These diverse landscapes support nearly one-third of the world's population, and provide society with a multitude of material and non-material benefits, or ecosystem services, including food, fiber, water, and biodiversity (Havstad et al., 2007; Sayre et al., 2013). Global food demand is estimated to increase 70–110% from 2005 to 2050 (Tilman et al., 2011; Alexandratos and Bruinsma, 2012; Ray et al., 2013), and demand for animal-based protein is anticipated to increase substantially with income in developing countries (Tilman and Clark, 2014; Saitone and Sexton, 2017). Pressures to sustainably intensify rangeland food production systems will only escalate and, thus, the time is ripe for thoughtful approaches to simultaneously produce more food, provide economic opportunities for livestock-dependent communities, and enhance environmental benefits generated from rangeland systems (e.g., Capone et al., 2013).

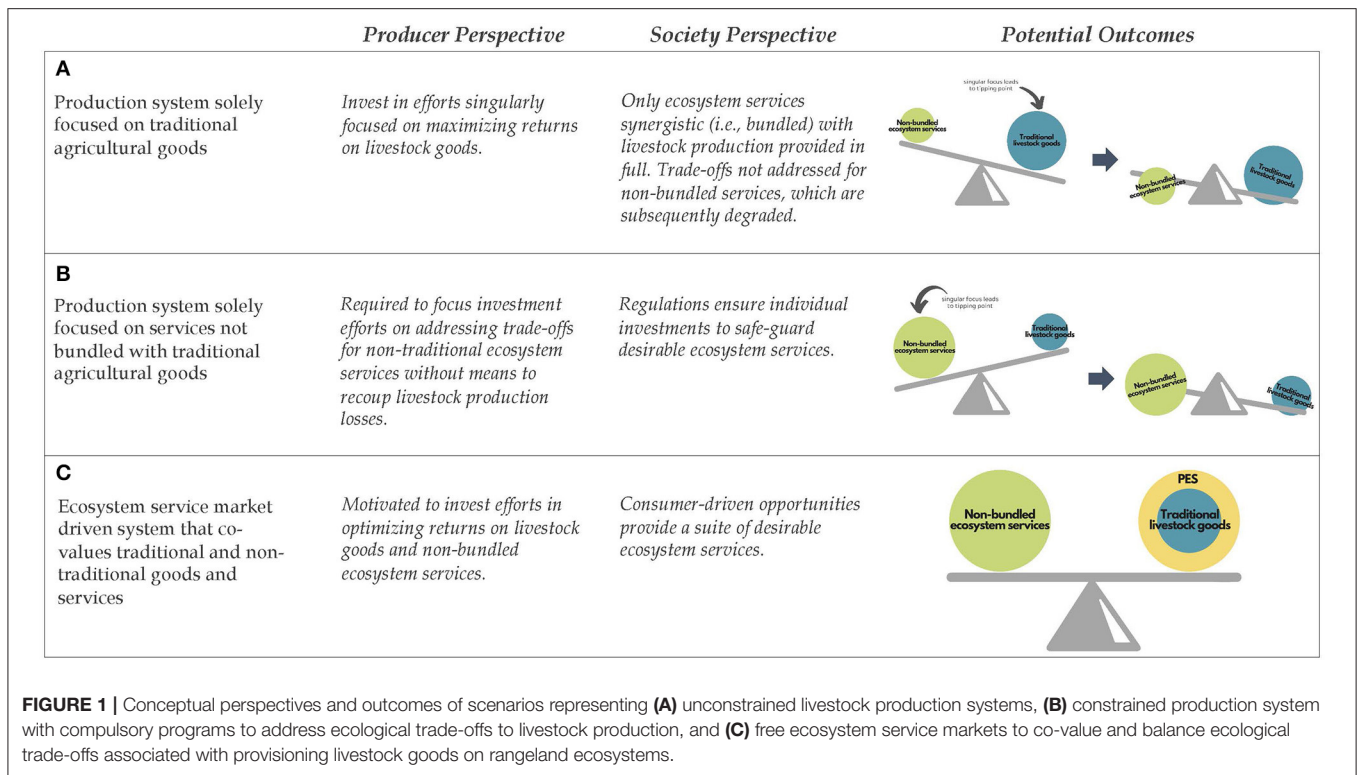
Some posit that the up-cycling of rangeland vegetation to animal-based protein remains the only economically and ecologically sustainable food production system for vast rangeland landscapes (e.g., Alexandratos and Bruinsma, 2012), while others conclude that livestock grazing on rangelands leads to dangerous ecological trade-offs and declines (e.g., Eldridge et al., 2016) that make livestock production unsustainable in these ecosystems (e.g., Beschta et al., 2013). In fact, rangelands are complex systems in which agricultural and conservation synergies (e.g., Marty, 2005; Roche et al., 2012; Huntsinger and Oviedo, 2014) and trade-offs (e.g., Fleischer, 1994; Belsky et al., 1999; Thorburn et al., 2013) regularly occur; the challenge is overcoming *trade-offs* in a manner that is economically, socially, and ecologically sustainable. A suite of tested grazing best management practices (BMPs) exist to remedy many of the trade-offs associated with livestock grazing (e.g., Collins et al., 2007; George et al., 2011). However, implementing these BMPs can come at substantial added cost to livestock producers—the individuals best positioned to improve on-the-ground environmental outcomes.

Addressing these financial investments for individuals to enhance ecological conditions is an essential aspect of achieving sustainability on these working landscapes. In **Figure 1**, we illustrate three scenarios reflecting potential outcomes for traditional livestock market goods and other ecosystem services from the individual producer and societal perspectives. **Figure 1A** depicts a scenario with an unconstrained rangeland-based livestock production system where the singular focus of

the producer is on maximizing profits from livestock goods (i.e., provisioning ecosystem services). In this scenario, producers' returns determine the effort (i.e., management practices) they invest. While this scenario is likely economically sustainable from the producers' perspective, trade-offs associated with the provision of other ecosystem services may occur. This is primarily a concern with ecosystem services that are not bundled (Raudsepp-Hearne et al., 2010; Spake et al., 2017) such that they are not co-produced with livestock production in space or over time. This singular focus causes the scale of net benefits derived from ecosystem services (**Figure 1A**) to tip toward traditional livestock goods at the expense of non-bundled ecosystem services. Depending on the severity and duration of the imbalance, this could lead to long-term ecological degradation that compromises environmental and economic sustainability such that the whole system collapses.

Regulations and policies are one approach to address trade-offs associated with agricultural production by requiring producers to implement BMPs. Scenario B (**Figure 1B**) illustrates the dilemma that may occur if producers are required to implement BMPs that address trade-offs for non-bundled ecosystem services (e.g., limit grazing in critical habitats) at the cost of the production of livestock goods. In this scenario, producers incur additional costs via labor (e.g., monitoring and management of livestock access to critical habitats), capital investments (e.g., fencing to exclude livestock from critical habitats), reduced livestock goods (e.g., fewer livestock due to loss of access to forage in critical habitats), and regulatory compliance (e.g., fees, monitoring, reporting, litigation). Ultimately, producers forgo some portion of their income from livestock goods and are unable to replace the loss with income from the enhanced, non-bundled, ecosystem services (e.g., clean water, carbon sequestration) that the regulatory interventions generate. While some in society might view this scenario as sustainable, producers are eventually crushed under the burden of additional costs, without commensurate financial return. The result (**Figure 1B**) tips the net benefits scale and eventually leads to collapse of the system (e.g., conversion of rangelands to alternative, more profitable uses) (Cameron et al., 2014). Regulatory programs are also vulnerable to shifting political agendas (e.g., repeal of laws and policies). While regulations certainly have a role to play in moving toward sustainability, we suggest that the current level of dependence is not sustainable over the long-term for society, livestock-dependent communities, or individual producers.

Increasingly, payments for ecosystem services (PES) programs have been put forth as potential mechanisms to match private



and public interests; some claiming them to be a solution where it is possible to maintain the quality and quantity of ecosystem services supplied while enhancing the economic viability of rangeland-dependent livestock operations. Payments for ecosystem services programs may manifest in a multitude of ways and forms including voluntary or regulatory, government-mediated or private, and incentive-based or market-based. However, in practice “...very few PES can be considered as pure markets” (Muradian et al., 2013). Rather, long-standing examples of PES are publicly funded cost-share programs (e.g., US Environmental Quality Incentive Program; AU National Landcare Program), which financially incentivize and offset costs (i.e., trade-offs) producers incur in implementing practices prescribed to enhance ecosystem services that are not bundled (Raudsepp-Hearne et al., 2010; Spake et al., 2017), or co-produced, with livestock production. These programs are substantial public investments (e.g., US Environmental Quality Incentive Program funding totaled USD \$1.7 billion in 2017) that are dependent on factors such as national economic conditions and recession-driven budget cuts, efficiency in achieving actual additional conservation efforts (Claassen et al., 2013; Howard, 2020), and producer willingness to participate in voluntary subsidy programs (Lubell et al., 2013; Rolfe and Gregg, 2015).

Ecosystem service *markets* (one type of PES) have been proposed as a solution, perhaps a panacea, to fund the costs of mitigating trade-offs in a manner that is economically, socially, and ecologically sustainable for individual livestock producers, livestock-dependent communities, and society (e.g., Goldstein et al., 2011; Sayre et al., 2012; Yahdjian et al., 2015; Gordon et al.,

2019). In this conceptual rangeland *ecosystem services production system* (Figure 1C), livestock goods, and other non-bundled ecosystem services are both able to generate value and society (i.e., consumers) can reward producers of ecosystem services (e.g., meat, fiber, clean water, habitat, carbon sequestration) in a market-based setting. Thus, investments in BMPs made by livestock producers, to address trade-offs and deliver non-bundled ecosystem services, can be profitable and consumers can influence the quantity and quality of ecosystem services generated by producers. In this scenario, payments derived from markets for non-bundled ecosystem services can increase net benefits derived by producers such that society’s net benefits from non-traditional ecosystem services is balanced (Figure 1C) with the sum of producer net benefits from traditional livestock goods and the sale of ecosystem services from the rangeland-based operation. Eliminating the singular focus on any ecosystem service (e.g., maximizing livestock goods for traditional markets, regulation-dictated single species conservation) would allow for co-valuation and market-driven outcomes to sustainably balance producers’ individual self-interests with society’s demand for other, non-bundled services.

Some have credited the ecosystem service markets concept with bridging a gap between ecology and economics such that the full “worth” of ecosystems can be communicated to stakeholders (e.g., Chan et al., 2012). Since the time that ecosystem functions were defined, work has been ongoing to commoditize, value, and monetize ecosystem services (Silvertown, 2015). Certainly, there are some niche-type market transactions that have the potential to improve the sustainability of livestock producers and generate

premiums for ecosystem services that are co-produced with livestock goods (i.e., provisioning services), albeit on a limited scale. The market for organic products is often considered the quintessential niche market in the US. However, a mere 0.14% of beef cow inventory in the US are certified organic. Clearly this and other niche opportunities are not at a sufficient scale to support livestock producers who are dependent upon hundreds of millions of acres of rangelands in the US alone.

Why then, have markets of sufficient scale for rangeland ecosystem services failed to develop as a stable, widespread solution (panacea) to the socio-economic-ecological crisis livestock producers and society face in conservation of non-bundled ecosystem services globally? In this paper, we highlight fundamental obstacles on both demand and supply sides, which make the creation of such a market a “wicked problem.” Wicked problems typically involve multiple stakeholders with different perspectives, include complex interconnections, and have no single solution or one “right” answer; consequently, this wickedness defies normal problem-solving processes and attempts at resolution can reveal or even generate additional problems (Rittel and Webber, 1973; Balint et al., 2011).

To untangle the wickedness of this particular socio-economic problem, we address demand- and supply-side considerations for rangeland ecosystem service markets through an interdisciplinary lens of fundamental economic underpinnings overlaid with a social survey of livestock producers’ perspectives. Relevant to the potential demand-side of the market, we discuss the most critical, and often overlooked, impediments to development and function of free ecosystem service markets for non-bundled ecosystem services; responding to recent reviews of a large literature that points to gaps in knowledge and understanding associated with this portion of the ecosystem service market interaction (e.g., Yahdjian et al., 2015; Sala et al., 2017). On the supply side of the market, we provide unique perspectives, using novel interview data, from a sample of 100 rangeland livestock producers across California, USA. This ultimately culminates in what we consider to be a long-overdue qualitative and quantitative analysis of the possibility of ecosystem service markets to contribute to the economic viability and ecological sustainability of rangeland-dependent communities at a large scale.

FREE MARKETS FOR RANGELAND ECOSYSTEM SERVICES—PANACEA OR WICKED PROBLEM?

What Is Required for a Market to Function Efficiently?

The supply of traditional livestock goods has historically been recognized as the primary value derived from rangelands (Havstad et al., 2007). These traditional ecosystem services (e.g., beef) are private goods (e.g., branded livestock), easily identifiable as units for sale and purchase (e.g., 1 pound of ground chuck), and are fungible (i.e., substitutable or interchangeable) such that supply and demand are represented concisely through market-based prices. Free markets are built

upon a number of characteristics including freedom of choice, self-interest, competition, efficiency, private ownership, and limited government involvement. When one or more of these characteristics are not met, a market failure is said to occur; this is a situation where a market is not able to efficiently allocate goods or services. It is when we begin to consider non-bundled ecosystem services that complications arise with the development of a free market-based system for exchange. While challenges abound and many have been widely discussed (e.g., Kroegeer and Casey, 2007; Redford and Adams, 2009; Goldstein et al., 2011), we focus on the most fundamental impediments: (i) many non-bundled ecosystem services are public goods and produce positive externalities, (ii) society lacks any incentive to pay for ecosystem services they receive for free—limiting demand for these services; and (iii) market intermediaries (e.g., brokers, certifiers, government) are necessary to verify the quality of the services being exchanged and mitigate transaction costs.

Is There Demand for Non-bundled Ecosystem Services?

In the context of economics and a market-based system, *demand* is defined as consumers’ willingness and ability to pay for a good or service at all possible prices. Herein, lies the fundamental wicked problem—non-bundled ecosystem services (e.g., carbon sequestration, clean water, provision of wildlife habitat) are not private goods that the landowner or manager can sell. Rather, these are public goods and, as such, generate positive externalities (a type of market failure) that eliminates the need or incentive for consumers to purchase (i.e., demand) them in a market setting. Responses to this type of market failure are typically taxation and/or regulation (e.g., cap and trade). As such, an additional impediment to the creation of ecosystem service markets is the lack of existing regulatory infrastructure to generate demand and establish a price that reflects the true value of the service.

Public goods are defined as those that are non-excludable and non-rivalrous; goods or services where it is not possible to exclude individuals from consuming or benefiting from them and the consumption of the good or service does not take away from others consuming it as well. When public goods generate positive externalities, those who enjoy the service do so without compensating those individuals or entities that produce it. In fact, it can be argued that consumers take these non-bundled services for granted and only begin to care about their provision after they are perceived to be “degraded” (Goldstein et al., 2011). Society (consumers) *expects* these ecosystem services, but are unwilling to purchase them (i.e., create market demand) when they are able to consume them for free. The market failure (i.e., producers not receiving compensation for the services they supply) results in an under-provision of those services (**Figure 1A**). Simultaneously, existing public institutions and interventions fail to make up the growing gap between what society needs (or expects) and what is being provided (Lant et al., 2008).

This does not mean there are no consumers willing and able to compensate producers for practicing sustainable rangeland livestock production practices via the purchase of traditional livestock goods in niche markets or through direct to consumer

sales channels; however, these exchanges are often focused on bundled services, and are woefully insufficient to create market demand of the scale required to address global threats to sustainability on rangeland ecosystems. Further, such niche markets often increase prices for traditional livestock goods thereby limiting food access for lower income population while increasing food insecurity (Gundersen and Ziliak, 2018).

What Is the Role of Market Intermediaries?

In order for exchange to occur between buyers and sellers, there must be a common understanding of the product or “unit” that is being exchanged such that its value can be established via negotiation. Yet, for many non-traditional ecosystem services it is extremely challenging to define the quantity and quality of a specific ecosystem service, both of which will affect market valuation. For this reason, many have asserted there will be large transaction costs (e.g., contract design, certification, monitoring) associated with the exchange of ecosystem services (e.g., Jacka et al., 2008; Gosnell et al., 2011). In the context of rangeland-based ecosystem services, transaction costs are likely to be relatively high given that the resource is maintained and controlled by a large number of diverse suppliers. For these and other reasons, intermediaries or brokers may be necessary to create market opportunities and facilitate information transfer among market participants (Davis et al., 2015). Brokers of services or market intermediaries could reduce transaction costs by acting as “aggregators;” purchasing and aggregating blocks or groups of services or service providers and selling them to buyers (Ribaudo et al., 2010). Market intermediaries may also be able to play a role in reducing the inherent informational asymmetries that exist between buyers and sellers (e.g., provide quality assurance services, verify that practices are in place on the ground, offering compliance certification; Ribaudo et al., 2010; Davis et al., 2015). Verification by a third party provides consumers with assurance that they are purchasing goods or services with the documented benefits they seek to purchase. In contemporary settings, where markets have yet to be created, government entities, and regulatory agencies are often considered logical intermediaries as they are often necessary for the market creation. This poses a challenge given that trust in the broker is critical in determining livestock producers’ willingness to participate as suppliers in such markets (e.g., Davis et al., 2015).

LIVESTOCK PRODUCER PERSPECTIVES ON THE POTENTIAL OF ECOSYSTEM SERVICE MARKETS

We examine livestock producer responses to interview questions designed to gain insight into potential challenges and opportunities to the development and function of non-bundled, rangeland ecosystem service markets. First, we examine ranch structure given that operation characteristics fundamentally shape management decision-making and operators’ capacity to consider and adopt new strategies (Prokopy et al., 2008; Lubell et al., 2013). We then explore producer-identified threats and

opportunities to California’s ranches and rangelands and the sustainability of their livelihoods. Finally, we specifically examine key questions about producer interests in ecosystem service markets, including whether or not there is evidence they would participate in such markets and under what conditions.

Interview Structure

As a case study, we present information we collected via semi-structured, in-person interviews of 100 experienced cattle producers from across California’s 17M hectares of grazed rangelands. Interviews were designed to gain insight into key questions regarding the potential for livestock producers to supply a multitude of rangeland ecosystem services to a market and their views on sustainability threats and opportunities. Using network-sampling techniques, interviewees were selected based on their rangeland management and ranching experiences and interests (Noy, 2008). Participants were identified through the University of California Cooperative Extension network. Interviews were led by the first author and were semi-structured using an interview guide containing questions about ranch operation structure, potential threats and opportunities for ranching and rangelands, and perspectives on ecosystem service markets. Interviews were audio recorded and transcribed. Interview text was analyzed using an iterative process of summarizing and organizing text passages into major themes using *a priori* and emergent codes (Knapp and Fernandez-Gimenez, 2009; Wilmer et al., 2018). The first and second authors conducted a peer-review process to cross-check interpretations and ensure validity of coding. These interviews are not a random sample and, therefore, are not intended to draw broad inferences; rather, this type of approach is useful for more in-depth explorations of experiences and perspectives. Participants were interviewed until no new information emerged from continued data collection (Gentles, 2015).

Ranch Structure

All interviewed livestock producers reported managing family-owned and operated rangeland-based cattle enterprises. Seventy-one percent were third or more generation owners and managers—suggesting a history of successful generational transfer and sustained production of livelihoods and livestock goods (Marshall and Stokes, 2014; Roche, 2016). Fourteen percent of interviewees identified as first generation owners and managers of ranching enterprises. This new segment of the livestock community is essential to recruit, but faces substantial obstacles to successfully entering ranching (Ahearn, 2011; Munden-Dixon et al., 2019).

Table 1 summarizes the operational characteristics of the interviewees. The vast majority (99%) of rangeland cattle producers interviewed are engaged in a cow-calf operation where they maintain a permanent herd of brood cows that annually yield a crop of calves, which they either market upon weaning (71%) or retain ownership to market later (28%). One (1%) producer reported they only owned and managed yearling cattle they purchased from cow-calf operators. Rangeland-based cow-calf operations are the foundation of the beef industry in countries around the globe; for example, these

TABLE 1 | Operational characteristics.

Size of cow herd	Cow-calf operations (n = 71)	Combined operations (n = 28)	Size of stocker herd	Combined operations (n = 28)
	Percentage of respondents (%)	Percentage of respondents (%)		Percentage of respondents (%)
1–65 Head	8	0	1–40 Head	11
66–150 Head	23	11	41–150 Head	11
151–300 Head	27	25	151–500 Head	25
>300 Head	42	57	>500 Head	39

Percentages for combined operations do not sum to 100 because three combined operations failed to report cow numbers. The one operation that solely owned and managed yearling cattle is not included in the table.

operations comprise $\approx 90\%$ of cattle enterprises in Australia. Among interviewed producers, $\approx 58\%$ of cow-calf herds were reported to be 300 cows or less, and 47% of yearling herds were reported to be 500 head or less. This sample of rangeland cattle producers is reflective of the diversity of operational scales in the state. According to the U. S. Department of Agriculture's most recent Census of Agriculture (U. S. Department of Agriculture, 2017), 24% of beef cattle operations in California managed <100 cows, 34% of operations had 100–499 head, and the remaining 42% had operations with 500 head or more. Rangeland cattle producers in California manage extensive grazed systems with an average stocking rate of one cow (head) to 37 acres (Roche et al., 2015a). Common grazing strategies include year-long continuous, growing season-long continuous, and simple rotational grazing strategies (Roche et al., 2015a). There is limited, if any, use of fertilizers, irrigation, or imported feedstuffs to support livestock herds on these rangelands.

The share of household income derived from on-ranch activities varied substantially across participants. While 34% of interviewees reported they derived the majority (76–100%) of their household income from the ranch, it was far more common for interviewees to have alternative, off-ranch, sources supplementing their household income; 19 and 12% responded they earned 25–50% and 51–75% of their household income from ranch operation activities, respectively. The remaining 35% of producers interviewed indicated they received <24% of their household income from their ranching operations. This is broadly consistent with statistics for the United States; 87% of beef cattle operations made <50% of their income from the enterprise (U. S. Department of Agriculture, 2017). Producers were also asked if they were dependent on the ranch as a source of income and 24% disagreed, 5% were neutral, and 71% agreed.

For 75% of interviewees, alternative sources of revenue were critical to keeping the ranch financially stable. This is consistent with previous research findings that producers often value the “ranching lifestyle” over economic return and profit motives (Gentner and Tanaka, 2002; Roche et al., 2015b). The most cited diversification strategies included converting some rangeland

acreage to specialty crops cultivation (e.g., avocados, almonds, walnuts, vegetables, grapes), farming hay, harvesting timber, and facilitating game hunting (i.e., developing hunting clubs or offering guided hunt services).

Threats to Ranches and Rangelands

Among a growing diversity of groups, including livestock producers, environmental organizations, scientists, and public agencies, there is increasing recognition of social, ecological, and economic benefits from the conservation of ranching as a land use. For producers, who typically hold strong and multigenerational connections to the land (Roche et al., 2015b), maintaining and stewarding ranchlands can bring a strong sense of responsibility, as one-fifth generation producer related,

“It’s a good life. Years ago my daughter said, ‘I don’t want to be the one that fails at ranching, it’s six generations.’ That’s something there that nobody ever talks about and nobody really wants to think about.” (Interviewee 1)

“I’ve heard a couple of them [his children] say, we don’t want to be the one to lose the ranch. We don’t want to be the generation that loses the ranch. They [his children] have a strong sense of obligation.” (1)

To better understand current and future challenges faced by producers, we asked, “What do you view as major threats to California’s cattle ranches and rangelands?” Transcribed responses to this open-ended question were iteratively reviewed and organized into five main categories, with individual interviewees frequently identifying multiple categories of threats: (i) government regulations and environmental policies (85% of interviewees), (ii) conversion of rangelands to other, higher value land uses (34%), (iii) society’s negative perceptions of the beef industry (33%), (iv) climate and resource (e.g., land, water, forage) considerations (28%), and (v) economic considerations and costs of doing business (23%).

Consistent with other studies (e.g., Niles et al., 2013; Roche et al., 2015b), these livestock producers perceive socio-economic factors, in particular government regulations and environmental policies, as major threats to the future of their operations (85% of interviewees). In the category of government, interviewees mentioned regulations (e.g., environmental, transportation, labor) and, specifically, “overregulation” as the most significant threats to their operations. Perceived threats are often rooted in past experiences (Niles et al., 2013), as one producer remarked,

“I don’t know how you’re going to continue to raise cattle with all the environmentalists saying you can’t do this, you gotta fence your streams, you can’t use herbicides, you can’t do that.” (2)

Concerns surrounding environmental policies and agency oversight of privately owned rangelands were tied to the Endangered Species Act (ESA) and species-specific management considerations. The ESA is the primary law in the United States protecting imperiled species from extinction as a “consequence of economic growth and development untempered by adequate concern and conservation” (16 USC sec 1531). The law was written to protect both the species and the habitats upon

which they depend. Interviewees expressed concerns about how the ESA has already or would impact their ability to continue to operate in the future. Beyond ESA-listed species (e.g., coho salmon, gray wolf, California condor), producers also expressed concerns about non-ESA listed species that have become highly publicly visible (e.g., wild horses, tule elk, greater sage grouse) and have resulted in diminished producer flexibility and management capacity.

Producers who identified rangeland conversion (34%) as a major threat were particularly worried that residential development and intensive crop production would drive significant losses of open spaces and access to forage. Others have noted the economic marginality of ranching exposes these ecologically diverse landscapes to such conversion and development pressures (Sayre et al., 2013; Cameron et al., 2014). As discussed above, many of the interviewed producers related their operations were under substantial economic stress. For instance, those interviewees who derive limited income from their ranches still consider that income as essential are particularly vulnerable to these pressures. An interviewee who ranches near one of the state's most populous cities expressed,

"I guess you call it urban sprawl. More residential development moving into traditional grazing lands. There's going to be a point where some next generation inherits this piece of land and it's going to be just too much to say 'no' to developing it." (3)

The struggle to remain economically viable was also communicated by producers who cited economic considerations and costs (e.g., insurance, materials, labor, taxes, regulatory compliance) associated with doing business as a threat to their future (23%). These interviewees often reiterated concerns about pressures to convert rangelands to other more profitable uses. These land use changes also impact availability and per acreage costs of privately leased grazing lands, which are a critical forage component for a majority of operations in the state (Roche et al., 2015b). As one producer in the San Joaquin Valley's rich agricultural region commented,

"... we are losing more ground to other forms of agriculture than we are to houses. For example, that side of the ranch over there was given to my cousin and I used to lease it from him for my cows. But he has decided to lease it all out to strawberry farmers instead, for a lot more money. I lost that whole side of the ranch.... I lost the whole thing." (4)

"That's what it's coming down to. A lot of these grazing leases, especially in the San Joaquin Valley, those guys are losing ground right and left due to the almonds. You see it up in Sacramento. The irrigated guys are saying, 'Hey, let's rip out the irrigated [pasture] and put in trees.'" (4)

Producers also discussed inability to reach a minimum scale of production efficiency for economic viability due to exorbitant land costs resulting from competition from higher value commodities. One interviewee contended that this cross-commodity competition is a major threat to the sustainability of California's cattle ranches and rangelands,

"Right now a big threat is keeping viable when there's a lot of competition for ground. They're planting vineyards like crazy. It's insane. Walnut and almond guys are buying up all the grazing ground. Just finding ground, and enough of it to be an economically viable cattle operation, is a huge challenge." (5)

When discussing threats to the future of California's cattle ranches and rangelands, one-third of producers also mentioned negative public perceptions of the beef industry. The public dialog on meat production and consumption has intensified in recent years with some arguing meat alternatives and substitutes as the ultimate solution (Laestadius and Caldwell, 2015; Alexander et al., 2017). However, from the landowner viewpoint, rangeland livestock production is the only economically and ecologically sustainable use of these vast landscapes, and without income from traditional livestock market goods they argue these lands would be at great risk for conversion and degradation from more intensive land uses.

Cattle producers also voiced concerns about climate and drought, as well as related issues of forage and water availability. Drought brings substantial and recurrent ecological, economic, and social stresses to California's ranches, which are predominately reliant on rain-fed forages, and has been a formative force for most operations. Ranch management strategies for coping with drought have been adapted over time through multiple generations (Roche, 2016); however, recent extreme events, like the 2012–2016 California drought in which most of the state was under severe conditions, have pushed cattle operations to their limits. Climate and related resource impacts will increasingly challenge ranching operations as rising temperatures, greater precipitation variability, and more frequent and intense droughts are expected to continue (Pathak et al., 2018). Indeed, a majority (82%) of these interviewees have already noted their current strategies would be insufficient in the face of more frequent drought events (Macon et al., 2016). Moreover, recent work has suggested first generation producers are even more vulnerable to increasing climate variability and change due to their smaller networks, lower access to resources, and fewer available adaptation strategies than typical, large, multigenerational enterprises (Munden-Dixon et al., 2019).

Opportunities for Sustainability

We also asked cattle producers "What do you view as the major opportunities for California's ranches and rangelands?" Transcribed responses to this open-ended question were iteratively reviewed and organized into three main categories. Twenty-five percent of interviewees indicated they saw no future opportunities for ranching and rangelands in California. Conversely, 75% of interviewees indicated they did see future opportunities to: (i) improve livestock goods marketing strategies (28% of interviewees); (ii) enhance education and communication to improve consumer perceptions of the beef industry and producers' stewardship of rangelands (33%); (iii) conservation easements (11%); and (iv) PES (11%). An additional 36% of interviewees identified other miscellaneous opportunities

(e.g., accessing state and regional park lands for grazing, agro-tourism, mitigation banking). Fundamentally, these producer-identified opportunities generally relate to enhancing integration and connectivity between land stewards and society more broadly, as two interviewees expanded,

“I am optimistic. I think there’s a lot of opportunities for partnerships,... I believe livestock production is more beneficial than pretty much any other agricultural practice in enhancing soil quality and wildlife. I think there’s a lot of common goals for a livestock producer and some of the environmental organizations to put together.” (6)

“I do see opportunities. I’m having conversations with conservationists and other people today about the importance of ranching that are better than 15 years ago. I see that as an opportunity. How you actually turn that into something tangible I don’t know, but the conversations are happening. Most days I want to believe that public awareness is shifting a little bit too. That’s a good thing.” (7)

Producers who discussed improving marketing strategies pointed to opportunities for accessing niche markets and adding value to their cattle via programs focused on consumer values (e.g., organic, animal welfare certified, natural) that also increase livestock-derived revenues. Interviewees often associated “niche marketing” with direct-to-consumer sales or other sales avenues that increased their interaction with consumers (e.g., farmers’ markets). Through these streamlined sales channels facilitating direct communication, producers hoped that they would also improve consumers’ and society’s perspectives on ranching and rangeland stewardship. Niche markets are another avenue through which producers may be compensated for co-production of specific ecosystem services with their traditional livestock products (Goldstein et al., 2011). One interviewee who direct-markets to consumers discussed the messaging benefits of his grass-finished, locally raised beef operation,

“So I’m not going to go out and bash conventional business.... But there are some benefits to doing what we’re doing and if you want to think about cows grazing in green grass up until their last day of life, I can sell you the beef. The consumer votes with their dollar. They get to choose.” (8)

Direct engagement with, and education of, the general public was also at the forefront of interviewees’ minds when they considered future opportunities. This category of responses centered around the notion that if the public learned about the environmental benefits of ranching operations, then they would be more willing and able to internalize the positive externalities and place a value on them (i.e., recognize the ecosystem services they currently receive for free). These producers were optimistic that society would ultimately recognize they are supplying environmental benefits without compensation, and that this would create good will and possibly demand. One interviewee explains,

“Niche marketing. That’s the whole secret to success. You’d better be innovative. ... If you could convince all the people who want to buy

locally that there’s going to be less and less of local products. You have to support your local rancher.” (9)

Eleven percent of interviewees specifically identified conservation easements as an opportunity to enhance sustainability. Thirty percent of all interviewees indicated they already had a conservation easement in place on some or all of their property. Conservation easements are voluntary agreements between a landowner and another entity (e.g., government, and non-governmental organizations) where the landowner agrees to limit the development and/or conversion of land in perpetuity in exchange for a lump sum payment and estate tax benefits. Interviewees viewed conservation easement programs as a means to keep the ranch in their family (e.g., mitigate inheritance tax liability, manage estate planning issues, buy out ownership shares from family members), preserve open space, and maintain habitat for sensitive and endangered species. These one-time cash infusions into ranching enterprises may partially offset the positive externalities generated by these operations while guarding the land against conversion to alternative uses. As one producer in the process of establishing an easement agreement stated,

“I’m pretty excited about the fact that we’re going to put this ranch in the conservation easement. ... We don’t have any desire to split the ranch up for ranchettes or anything. We want to keep it in the family, want to keep it a viable working cattle operation. That kind of money makes a big difference. It’s going to change my life and change everybody’s in the family. It’s going to change the ranch for generations to come.” (10)

Finally, 11% of producers identified PES programs as potential future opportunities. Many who perceived opportunities in this area specifically mentioned payments for carbon sequestration, habitat for specific wildlife species, and maintaining open space. One interviewee indicated,

“The carbon credits and the wildlife enhancement stuff, those things can work right along with our crops and cattle.” (11)

Interest in Ecosystem Service Markets

Ecosystem service markets have been presented as pathways to socially, economically, and ecologically sustainable food systems (Figure 1C); however, only 11% of producers interviewed here organically identified PES programs when asked about possible opportunities to enhance sustainability. To elicit a better understanding of producer perspectives, we asked a series of questions about their interest and willingness to participate in ecosystem service-based markets if they existed.

All interviewees were asked if they would be interested in participating in a market in which they would receive payments for producing a specific ecosystem service(s). Nearly 13% indicated they would not consider participating in such a market, 45% were neutral, and 42% stated they would definitely consider participating. Regardless of their initial response, interviewees were asked the open-ended question, “Under what conditions would you be willing to participate in a market for ecosystem

services?” Broadly, interviewees stated they would need to have a trust-based relationship with the broker responsible for facilitating market transactions, and that they would be less willing to participate if there was governmental involvement. Many of the producers interviewed expressed specific concerns about broker identity,

“My main concern is who is this outfit and what are their ultimate goals? Why are they doing this, and what are they trying to gain?” (12)

“Yes, it [broker identity] makes a difference. I work for the government and I don’t trust it. I’m cautious.” (13)

“... everything we’ve ever done on our own properties has always been independent. We have never taken any government money to do any of it. You know there’s that little fine print at the bottom of those pages that says, ‘We reserve the right to come onto your property to check for wetlands and other stuff.’ Have you seen that? Plus, that’s right after you give them all your financials in a very large stack. You’d have to give them your whole life right there ... well, not us.” (4)

Many of the producers interviewed also expressed that their participation would depend on the specific requirements of the agreement, such as duration (Hansen et al., 2018). For example,

“I would be very open to something like that. But the problem I have most of the time is, these programs you get involved in, they give you the money up front and it’s done. If they had a program whereby it’s a yearly source of revenue to pay for sequestration or whatever it is, then you could utilize that revenue on a yearly basis. That lump sum stuff, it always sounds good but you’re running less animals and still trying to make a yearly chunk of revenue to make ends meet. The big chunk may last 10-12 years, then it’s gone. If you had a revenue source you could depend on that contributed to your annual operating costs, that would be wonderful.” (14)

“It might be worthwhile from the standpoint that you’d get paid for doing a lot less work. On the same token, you hear about these places that want to buy your forest service grazing allotment but it’s a one-time thing. They’re not going to pay you every year...It would have to be annually but also something you could get out of if you wanted to.” (15)

Interviewees also mentioned requirements that would diminish their independence and managerial control of their land and cattle operation would substantially reduce the likelihood of their participation. For example,

“I wouldn’t want it to become any sort of leverage tool by any agency for them to start dictating management of private land.” (16)

“It all depends on how much control they would have over me. I get kind of concerned about that sometimes. That would be a big sticking point.” (17)

Interviewees were asked what ecosystem services they would be willing to sell, assuming a market had developed. The majority of interviewees (78%) did not have specific services in mind. Interviewees were specifically asked if they would be willing to reduce production of livestock goods (and related income) in

order to increase overall revenue from the sale of non-bundled ecosystem services. Seventy-six percent of interviewees were positive, indicating maybe (54%) or yes (22%), but raised a list of conditions; interviewees specifically noted they would have to maintain managerial control and flexibility while engaging in these agreements and they would need to know and trust the broker. Twenty-four percent were not willing to trade any livestock-related revenue for revenue derived from non-bundled ecosystem services. Some indicated they are unwilling to trade livestock revenue because they strongly value their roles in the food supply system, and some believe their livestock management does not negatively impact other ecosystem services,

“I don’t think so. The whole idea of agriculture is to feed the world. So if you cut your numbers in half and every ranch cuts their numbers in half, how do we feed the world?” (18)

“Yeah, if you could tell me that what I’m doing is hurting the environment, but I am not. Why stop what I’m doing? I think the balance is already there. I think we coexist very well. I don’t think one [ecosystem] service suffers because of the other.” (19)

RECONCILING DEMAND AND SUPPLY FOR NON-BUNDLED ECOSYSTEM SERVICES

Rangeland-based cattle operations are facing substantial financial challenges that potentially threaten their long-term economic sustainability. While society expects the provisioning of non-bundled ecosystem services, the inability to exclude consumption to extract payment means that there is no economic incentive for a market to emerge where suppliers are compensated for their production (Wayburn and Chiono, 2010). Likewise, in cases where such markets are finding limited success, wealth disparity among potential consumers likely create food access challenges and social justice issues. Many economists believe that compulsory mechanisms (e.g., government instituted cap and trade regulations) are necessary to create demand and overcome free-riding of ecosystem services that are public goods (e.g., Jacka et al., 2008). This is why, to date, regulations (e.g., U.S. ESA, Clean Air Act) have been major drivers of environmental markets (Goldstein et al., 2011), while voluntary free-market based environments have languished, relying on consumer preferences and corporate responsibility and reputation to generate demand and value. These regulation-driven markets are not free markets; rather, they require substantial government involvement (a form of market failure), which can vary with shifting political agendas. Those who “demand” credits are compelled by governmental regulation or law to purchase the product to “mitigate” environmental harm they are creating via trade-offs associated with their economic activities. It is not likely that such markets would be broadly welcomed by the cattle ranching community in California and other states (Gosnell et al., 2011)—as willing suppliers—given they are in strong concurrence (85% of interviewees) that government and environmental regulations are actually substantial threats to their own livelihoods. It is ironically wicked that the greatest threat these producers see to their enterprises is the only current

means available to create a consumer base for the non-bundled ecosystem services that they do not have private property rights over but society expects them to provision. As one cattle producer summarized after their own investigation of the ecosystem markets available to them:

“I just don’t know about them, pretty much the only market I found was to governmental agencies, which is not okay with me. They [governmental agencies] create their own rules, force money out of someone else, and then they’re out trying to use those folks’ money to buy these things from me because of their own rules? They’ve created their own false economy.” (20)

CONCLUSIONS

The development of markets, and the success or failure of PES more generally, depends upon the political, social, economic, and institutional environments in which they operate (e.g., Muradian et al., 2013). True social, economic, and ecological sustainability on working rangelands will require partnerships between livestock producers and broader society. Unconstrained livestock production systems (**Figure 1A**) and compulsory programs to address trade-offs (**Figure 1B**) are not partnerships, and are not sustainable today or into the future. We assessed the potential for free markets for rangeland ecosystem services to arise as novel opportunities to facilitate partnership and balance ecological trade-offs associated with provisioning livestock goods (**Figure 1C**). We have identified fundamental obstacles on both supply and demand sides that cast considerable doubt on free markets as a panacea for sustainable working rangelands. Such markets will certainly be impracticable in settings such as California where extensive rangelands are at substantial risk of loss to higher value competing land uses, where the very regulations intended to conserve these lands are viewed by livestock producers as the core threat to their livelihoods, and where many producers see no opportunities for enhancing the sustainability of their enterprises (based upon our interviews of 100 ranchers and previous surveys, Roche et al., 2015b). Many rangeland livestock producers face significant socio-economic challenges to maintaining viable operations, and decisions (e.g., regarding rangeland conversion to highest value uses) made under these stressors can place the ecological sustainability of these complex and dynamic ecosystems at risk.

While livestock producers are not motivated by economics alone, there are significant financial impediments to enhancing non-bundled ecosystem services that need to be resolved. This is an essential challenge to developing sustainable food production systems on many of our most threatened rangeland ecosystems. We must solve this challenge together using a diverse set of tools to achieve socially, economically, and ecologically viable outcomes for producers and society. Producers do see opportunities for enhanced sustainability via improved value and marketing of livestock goods that are co-produced with bundled services, participation in conservation easements, and improved connections with society as a whole. These results highlight the continued importance of enhancing existing and new partnerships between producers and society to generate

a diversity of strategies to build more equitable food systems and sustain these critical rangeland ecosystems. Examples of successful partnerships to develop strategies to address ecological tradeoffs associated with livestock production can be found across most rangelands systems. The Malpai Borderlands Group in New Mexico and Arizona, USA (Sayre, 2006), the Bi-State Local Area Working Group in western Nevada and eastern California, USA (Duvall et al., 2017), the Thunder Basin Prairie Grasslands Ecosystem Association in Wyoming, USA (Haufler, 2001), the Blackfoot Challenge in Montana, USA (Hittesdorf, 2014), and the Idaho Rangeland Conservation Partnership in Idaho, USA (IRCP, 2020) serve as grass-roots examples of conservation partnerships among diverse stakeholders focused on solutions that address the interdependent social, economic, and ecological aspects of sustainability. Such partnerships employ an array of tools (e.g., incentive programs, in-kind contributions of resources between partners, technical support, research, niche marketing, regulatory relief) to accomplish shared goals (e.g., habitat conservation and restoration, profitable ranching enterprises). Such partnerships require investments by all partners and must be structured around mutual respect and trust, all of which take time, effort, and compromise to achieve and maintain. We suggest these partnerships and others—not false hopes for a rangeland ecosystem service market—are the path forward to sustainably intensify rangeland food production systems while conserving all aspects of these working landscapes and dependent communities.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because they are not publicly available due to confidentiality and consent terms for the study. Requests to access the datasets should be directed to Leslie M. Roche, lmroche@ucdavis.edu.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of California, Davis Institutional Review Board. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

LR and KT conducted interviews. LR, TS, and KT jointly conceived research idea and shared equally in all aspects of manuscript development, drafting, and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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