RESEARCH ARTICLE

Drivers and constraints of land use transitions on Western grasslands: insights from a California mountain ranching community

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Abstract

Context Land use change drives a host of sustainability challenges on Earth's grasslands. To understand the relationship between changing land use patterns, human well-being, and ecosystem services, research is needed into land use transitions on privately-owned grasslands. Such inquiry lies at the intersection of land system science, landscape sustainability science and environmental governance.

Objectives This study investigated land use change in a mountain ranching community in the Sierra Nevada, California. The research objective was to highlight factors influencing land use transitions and corollary ecological outcomes on privately-owned grasslands in the Western US.

Methods This mixed methods case study integrated participant observation, 30 semi-structured interviews, and analysis of land cover and real estate data. Interviews were conducted with ranchers, public agencies, and conservation and real estate industry

representatives, and analyzed with the constant comparison method using NVivo 12.

Results Land use transitions in the case study region include agricultural intensification, residential and solar development, and disintensification. These transitions were influenced by many factors including decreasing land access and water availability, amenity migration, intergenerational succession, and conservation policy.

Conclusions By highlighting factors influencing land use transitions on working lands, this study can be applied to improve the uptake of environmental policies. For the future, several approaches may support grasslands conservation: ensuring grazing lands access, income diversification, groundwater regulations, agriculture-compatible conservation easements, and land use policies supporting ownership transition to amenity purposes rather than low-density residential development.

Keywords Land use transitions · Ecosystem services · Social-ecological systems · Rangelands · Mental models

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Introduction

Global grasslands are experiencing significant land use change, particularly conversion to cropland and residential development (White et al. 2000; Asner et al. 2004). In the continental US, a third of

rangelands—landscapes dominated by grasses, forbs or shrubs—have been converted since European settlement (Rindfuss et al. 2007). While serving to meet growing human needs, conversion can degrade soils, deplete biodiversity (Lark et al. 2020), and reduce water quality and availability (Bourque et al. 2019). Habitat loss, particularly for residential development (Freedgood et al. 2020), has driven a 53% reduction in US grassland bird populations since 1970 (Rosenberg et al. 2019). Converted grasslands support significantly fewer plant species than old-growth grasslands and require hundreds of thousands of years to recover species richness (Nerlekar and Veldman 2020).

The pursuit of landscape sustainability, or long-term continuation of ecosystem services for human and environmental benefit (Wu 2013, 2021), requires understanding social-ecological drivers working across scales to shift land use (Lambin et al. 2001; Bürgi et al. 2004). Land system scientists and rangeland researchers have investigated global grassland conversion trends (e.g., desertification, land abandonment), yet further research is needed into the full suite of land use transitions taking place on privately-owned grasslands in developed economies. Unknowns remain regarding the impacts of recent grassland ownership changes on land use and the effectiveness of environmental policies in these new contexts. Land system science and environmental governance research can serve to deepen understandings of these factors to address two foundational questions of landscape sustainability science posed by Wu (2021): what socio-economic factors influence the “landscape pattern-ecosystem services-human well-being” nexus, and how can better understandings of that nexus inform environmental policy and landscape planning?

Identifying land use transitions

To analyze land use transitions, researchers have developed the land use transition pathways conceptual framework, identifying land trajectories from an undisturbed state to frontier usage, agriculture and eventually urbanization (DeFries et al. 2004). Decisions made by individuals, communities and governments drive land use decisions, based on trade-offs between meeting human needs and environmental impacts (DeFries and Eshleman 2004). Economic

development can drive land use change toward both intensification and disintensification, with disintensification often taking place when economic development brings a transition from depleting towards conserving resources, as with the creation of protected areas or outsourcing of agricultural production (Lambin and Meyfroidt, 2010). Land abandonment, or reduction and removal of agriculture from landscapes, is particularly prevalent in North America, the former Soviet Union, Asia, and the EU (Cramer et al. 2008; Plieninger et al. 2014).

An important transition underway in the American West is sale of rangelands to in-migrating hobbyist or “amenity” ranchers (Gosnell and Travis 2005; Gosnell et al. 2006; Epstein et al. 2019). Multi-functional agricultural landscapes like rangelands provide an array of non-commodity benefits to landowners, including socio-ecological, cultural and viewshed values (Renting et al. 2009), which amenity ranchers value more than property income potential. While most ranchers have historically been both consumption and production oriented (Smith and Martin 1972), amenity landowners are typically uninterested in personally managing their grassland properties for commodity production and often transfer responsibility to ranch managers, lease their land for grazing, or eliminate agricultural altogether (Gosnell and Abrams 2011; Lubell et al. 2013). Population movement into rural areas for lifestyle reasons—called the rural rebound (Ferranto et al. 2014) or rural gentrification (Gosnell and Abrams 2011; Abrams and Bliss 2013)—is predicted to continue across the American West as production ranchers subdivide their lands (Walker and Fortmann 2003; Plieninger et al. 2012). This rise in amenity ranchers can be described as landowners living ‘on the land, but not off the land.’

Factors driving rangeland transitions

Such changes in rangeland ownership result from endogenous and exogenous factors functioning across scales, from international markets to local cultural shifts. Societal developments like remote work, decreased transportation costs, expansion of digital and service-oriented industries, and the romanticization of rural life draw newcomers to rural areas (Jackson-Smith 2003; Gosnell and Abrams 2011). Other forces drive residents away from rural areas, such as government regulations and societal hostility

to ranching (Liffmann et al. 2000; Hurst et al. 2017). Landownership change is also driven by loss of intergenerational succession, influenced by political and financial factors like accessibility of grazing allotments, state and federal tax codes, land use planning, and incentive programs like conservation easements (Brunson and Huntsinger 2008; Haggerty et al. 2018).

Land use transitions on rangelands are a function of private landowner decisions. These rangeland management decisions are guided by livestock production goals, and social, economic, environmental, political and personal financial variables (Stuth et al. 1991; Roche et al. 2015; Wilmer et al. 2018) (see Fig. 1). Factors like wealth and age (Coppock and Birkenfeld 1999), property size (Huntsinger and Fortmann 1990; Lubell et al. 2013), dependence on ranch income and multi-generational engagement (Didier and Brunson 2004) influence conservation activities. Management decisions are also influenced by ranchers' need for flexibility over time and space, with ranchers utilizing

forage within their social networks, storing hay, and grass-banking to cope with climate, production and market related variability (Wilmer et al. 2018).

Outcomes of different land uses

Past research highlights expected ecological outcomes in different ownership contexts. In-migrating amenity ranchers introduce new mental models (Abrams and Bliss 2013), where mental models are how individuals perceive and interpret the natural environment and thus manage natural resources (Jones et al. 2011). Different types of range landowners have distinct goals, capital access and time availability (Coppock and Birkenfeld 1999; Didier and Brunson 2004), resulting in varied approaches to land use and conservation (Kennedy and Brunson 2007; Lubell et al. 2013; Roche et al. 2015; Yahdjian et al. 2015). In contrast to traditional ranchers, amenity landowners often earn most of their income from interest and rent, and are drawn to rural areas as places of natural beauty

Fig. 1 Landowner decision-making within rangeland social-ecological systems. This model aggregates factors influencing rancher decisions from studies by Gentner and Tanaka (2002), Kennedy and Brunson (2007), Didier and Brunson (2004), Sayre

(2004), Farley et al. (2017), Lubell et al. (2013), Brain et al. (2014), Roche et al. (2015), Wilmer and Fernández-Giménez (2015), Roche et al. (2016), and Aoyama and Huntsinger (2019)

rather than agricultural production (Walker and Fortmann 2003). These landowners tend to be more open to conservation-related grazing reductions and have fewer livestock-predator tensions compared to production-focused ranchers (Gosnell et al. 2006; Gosnell and Abrams 2011). Researchers have identified a hypothesized “drawbridge sustainability” phenomenon where new rural in-migrants often actively work to prevent further in-migration, in contrast to old-timers who generally support local economic growth (Epstein et al. 2019).

The target outcomes for which working landscapes should be managed varies significantly across interest groups (Walker et al. 2003; Walker and Fortmann 2003; Plieninger et al. 2012). In other words, whether landscapes are managed in a way that is “natural” depends on one’s goals (Behnke Jr. and Scoones 1993; Huntsinger et al. 2007, 2008; Huntsinger and Oviedo 2014; Behnke Jr. and Scoones 2017). Notwithstanding the popular notion that leaving landscapes alone is best for ecosystem services, biodiversity is in many cases compatible with extensive livestock operations (Mastrangelo and Gavin 2012; Grau et al. 2013). Grazing cessation can actually decrease soil organic matter, nitrogen, and water availability, in some cases resulting in rapid shifts in plant composition and wildlife habitat (Peco et al. 2006; Plieninger et al. 2014). Debate continues around the benefits of leaving nature alone versus actively managing it for biodiversity, as seen in the rewilding and anti-rewilding movements (Holmes et al. 2020). Most often, management lies somewhere in the middle of this spectrum. Although declining agriculture and subsequent urban development can threaten biodiversity, sometimes termed the “cows vs. condos debate” (Knight et al. 1995), landowner turnover does not necessarily harm environmental outcomes (Gosnell et al. 2006).

Ecological outcomes under different landowner types also vary based on conservation program participation. In California, traditional ranchers participate in conservation programs and implement environmental improvements at a significantly higher rate than amenity landowners (Cheatum et al. 2011; Ferranto et al. 2011; Plieninger et al. 2012). Beyond government programs, neoliberal environmental solutions have grown in popularity, including conservation easements and sustainability certifications. Many landowners participate in such programs, including those who prefer to avoid government-run

conservation programs (Cheatum et al. 2011). At the same time, neoliberal policy tools for private land conservation have drawbacks, particularly conflict between landowners and conservationists as landowners lose control over the management agenda (Gooden and ‘t Sas-Rolfes 2019). Conservation easements and market-based incentive programs shift decision-making authority to entities besides the landowner, particularly those that do not engage target communities in determining recommended management practices (Morris 2008; Serenari et al. 2016; Gooden and Moir 2019). Notwithstanding these critiques and the small percentage of land protected by conservation easements, these policies have been found to effectively prevent land cover change (Nolte et al. 2019).

Research objectives

This interdisciplinary study presents an in-depth case of land use transitions in a California cattle ranching community to investigate land use change on privately-owned rangelands and implications of shifting attitudes towards both agricultural production and landscape conservation. I engage land system science and environmental governance to answer the following motivating questions:

- (1) What land use transitions are taking place on privately-owned Western US grasslands?
- (2) What factors drive or constrain these transitions?
- (3) How do different landowner types produce distinct ecological outcomes?
- (4) What policies and policy actors influence conservation outcomes in this social-ecological context?

A landscape-scale case was selected due to the numerous human-environmental interactions taking place at this scale (Wu 2013). Two major contributions of this study are (a) identifying political, socio-economic and technological drivers and constraints underlying land use transitions; and (b) demonstrating how rigorous qualitative methods can contribute to landscape sustainability science. By integrating land cover data with social-ecological systems knowledge at the individual, household and community levels, this research highlights multifactorial influences on land use, with the end goal of improving the uptake and efficacy of working lands conservation policies.

Methods

Case study

This study engages a single case design (Flyvbjerg 2006) focused on Sierra Valley, California (Fig. 2), the largest alpine valley in the US (PFT 2011). Land system scientists use case studies to understand the socio-economic and political variables driving land use transitions (Lambin et al. 2001; Lambin and Geist 2008). Land use transitions on California's rangelands deserve attention due to their vast scale, their high level of biodiversity, and ongoing land use change (Cameron et al. 2014). Rangelands comprise half of California's land area (FRAP 2017), with almost every county grazed by cattle (UC ANR 2007).

Sierra Valley provides a strong example of social-ecological processes taking place in ranching communities across California and underlying drivers of land use change. Sierra Valley's landscape includes sagebrush scrub, grasslands, wetlands, and vernal pools covering approximately 49,000 ha (Audubon 2008).

California's grasslands are mostly privately-owned (FRAP 2017) and are recognized among the world's biodiversity hotspots for native species richness (Myers et al. 2000). The ecological values of private

lands are often greater than nature preserves and public lands due to better soils, water access, and low visitation rates (Maestas et al. 2003; Brunson and Huntsinger 2008), and also greater diversity of management practices (Schaich and Pleininger 2013; Petucco et al. 2015). On California rangelands, well-managed livestock grazing can support biodiversity, limit woody encroachment, and prevent the spread of invasive plant species (Huntsinger et al. 2007; Bartolome et al. 2014; Barry 2015; Spiegel et al. 2016). Although most ecologists agree on the negative effects of historic grazing activities, including waterway damage and impacted plant communities, disagreement remains around the current health of California's grazed rangelands and the role of grazing in conservation (Huntsinger and Hopkinson 1996; Starrs and Huntsinger 2012).

Sierra Valley began experiencing significant land use change in the mid-nineteenth century as European settlers claimed lands traditionally managed by the Maidu, Washoe and Paiute native tribes. As Sinnott (1976) describes, European settlers in the valley developed agricultural industries including hay, grains, dairy and beef. Clover and timothy grass were seeded for forage, replacing native plants like bunchgrass, buffalo grass and wild rye. Settlers installed fencing across the valley floor and removed sagebrush

Fig. 2 Case study site: Sierra Valley, California. Visualized with ggmap (Kahle and Wickham, 2013)

for grain production. Twentieth century railroad construction connected the valley to population centers, further fueling economic development (Sinnott 1976). Today, nearly the entire floor of Sierra Valley is covered in privately-owned ranches, with some large cattle ranches operated by absentee landowners. Cattle numbers have more than doubled in the region since 1860, according to USDA Census of Agriculture records (Haines et al. 2018).

Since European settlement, Sierra Valley has been a place of not only agricultural production but also recreation and leisure. Mid-nineteenth century visitors vacationed at the valley's still popular sulphuric hot springs, attended competitions at the local racetrack, visited nearby mountain lakes, and engaged in recreational game hunting. Sierra Valley continues to experience in-migration of amenity-focused residents, including commuters to nearby cities. In the 1970s, a recreational home development was built on the valley's edge, subdivided into small lots situated to provide residents with open vistas of the valley and mountains (Sinnott 1976). While the two counties encompassing Sierra Valley have experienced some population growth since the 1920s, Sierra County remains the second-least populated county in California (Manson et al. 2020; See Fig. 3 for historical farmland trends).

Data collection

Data collection included participant observation and semi-structured interviews with ranchers, public agency staff, conservation groups, and a real estate agent (Stanford University IRB #50991; see Supplement 3 for Interview Protocol). Rather than sampling members of the California Cattlemen's Association as other studies have done—which underrepresents amenity ranchers and landowners with distinct political values from the Association—sampling was purposed and multi-staged, informed by local organizations and study participants. Participants were selected for variation in rancher types, property sizes, socio-economic factors, and conservation easement experience. Most ranches were cow-calf operations, the first of three stages in US beef production where operations manage a herd of breeding cows whose calves are sold annually (McBride and Matthews Jr. 2011). Participating production ranches included individuals living full-time on the ranch and primarily occupied with agriculture, and absentee landowners with professional ranch managers running their operations. On the amenity side, some interviewees were independently wealthy and had strong conservation interests, yet their descendants prioritized production. Furthest toward the amenity end of the spectrum were

Fig. 3 Farmland trends in Plumas & Sierra Counties, CA (1880–2012). Data from the USDA-NASS Census of Agriculture (Haines et al. 2018). Plumas and Sierra counties have

retained their agricultural heritage since European settlement, with some fluctuation in farm numbers and farmland acreage

several operations that prioritized conservation over agriculture, with livestock present at significantly decreased rates. In several cases, a ranch manager or employee was interviewed rather than the landowner.

I conducted 30 interviews in 2019 and 2020, including 24 interviews with ranchers. Interviews lasted 1–2 h, were digitally recorded, and were conducted in the homes of interview subjects or by phone. Those interviewed prior to the COVID-19 pandemic received follow-up calls to ensure that the pandemic itself was not driving differences in perspectives surfacing in later interviews. Published interview quotes were anonymized to protect the identity of participants and are represented as “SV#”.

Data analysis

Qualitative methods were selected to enable identification of new themes and relationships that would not emerge from quantitative approaches. Semi-structured interviews better capture lived experiences because participants can share with greater depth and specificity the factors motivating their decisions, often resulting in new hypotheses (Corbin and Strauss 1990; Babbie 2016). This study follows a social constructivist epistemology, where perceptions inform individuals’ knowledge such that there can be multiple “knowledges” of a single situation depending on the observer’s cultural context (Willig 2013). This approach is critical as distinct social-ecological realities can drive very different land management decisions, producing distinct ecological outcomes.

I analyzed interview data using inductive thematic analysis (Willig, 2013), requiring close reading and coding of interview transcripts with the constant comparison method of grounded theory (Glaser and Strauss 1967; Charmaz 2014). Grounded theory provides a structured approach to analyzing interview data through iterative hypothesis development (Charmaz, 2014; Gooden and Grenyer 2019). I conducted thematic coding in NVivo 12, a Computer Assisted Qualitative Data Analysis Software, developing codes based on patterns perceived in initial interviews, which were then used to identify differences in perception and common themes in the data (Willig 2013). Throughout analysis, I wrote memos to explain the connections between ideas and codes, as coding and memoing form the analytic basis for conceptual

development in qualitative research (Emerson et al. 1995; Coffey and Atkinson 1996).

Given the heterogeneity and recent changes in California’s ranching communities, there may be no universals across ranchers. Yet it is through such “intimate knowledge” (Flyvbjerg 2006) of ranching communities that the processes underlying landscape transitions can become better understood. Factors and hypotheses generated by this study serve as a foundation for further exploration with other methodologies.

Results

Interviews and land cover data analysis revealed several land use transitions taking place in Sierra Valley: agricultural intensification, disintensification, and residential development.

Intensification

Based on the USDA’s CropScape dataset, a geo-referenced land cover map, alfalfa production in Sierra Valley increased 67% between 2007 and 2018 to cover almost 10% of the valley (Boryan et al. 2011; USDA-NASS 2019) (see Fig. 4). Participants described land conversion to center-pivot irrigated alfalfa hay since the 1990s: “We have developed a couple thousand acres [over 800 ha] of alfalfa and we put irrigation on almost all of it.” (SV25).

Alfalfa hay production is perhaps the most notable form of income diversification in Sierra Valley, particularly prevalent in the more mesic regions of the valley. Hay is an important source of roughage during mountain meadows’ dormant season (Holechek et al. 2003) and is also sold to dairies, feed stores, and equestrians. Alfalfa is grown on 2.8 million ha across the American West (Yost et al. 2020), with hay the second largest crop in California by land area (Zaccaria et al. 2017; CDFA 2019) (Fig. 5). Notably, alfalfa requires a high level of water input (Zaccaria et al. 2017). Beyond alfalfa, some interviewed ranchers had also converted pasture to irrigated specialty crops such as hemp and wine grapes.

Multi-generational production ranches appear to intensify land use over time, including expanding hay production, to respond to income volatility and meet the economic requirements of additional generations. As one participant explained: “There are four

Fig. 4 Increase in alfalfa production in Sierra Valley, 2007 and 2018. Data from Boryan et al. (2011) and USDA-NASS (2019)

Fig. 5 California leading agricultural products by land area, 2018. Data from CDFA (2019); images from Freepik

generations between my grandfather and my son living, contributing in their own individual ways ... we do cow-calf and the slightest amount of meadow hay, just enough to sustain our needs and sell a little bit for a little extra cash income for my old man's pocket." (SV29) In fact, household income is a determining factor in ranchers being able to remain on their land (Wetzel et al. 2012). Rangeland residents frequently draw income from sources outside of ranching, thereby decoupling their livelihoods from the land on which they live.

Production-focused ranchers highlighted the importance of diversification in making ranching financially sustainable. Ranching is a volatile and low-income business (Liffmann et al. 2000) that is mostly unprofitable when you consider the opportunity cost of investment (Andersen et al. 2002; Wetzel et al. 2012). As one producer described: "You have

stellar years where you make money and you are thinking, oh my God, I have to pay taxes. And then you have year after year where you do not break even." (SV36) Participants often reported making more money from diversified businesses like alfalfa than from cattle. As such, all interviewed ranchers had income outside of ranching, including alternative crops (e.g., hay, hemp, almonds, wine grapes), wool fiber, hunting clubs, vacation rentals, wedding venues, and off-ranch income. Most ranches were supported by full-time, off-ranch work by one spouse. One ranch had developed a 1.4 hectare solar array as a form of diversification, a trend across Western rangelands (Holecheck et al. 2015). Yet another source of diversified income is conservation easements: "We elected to put a conservation easement on that ranch to take the money and pay the ranch off." (SV14) The need for diversified income on mountain rangelands is hardly a new phenomenon; as rangeland researchers in the 1940s explained: "Employment in a single occupation, such as mining, lumbering, or agriculture, often brings too little income for family support, whereas integration of two or more sources of income may provide a living sufficient to maintain the local populations" (Weeks et al. 1943).

With expansion of irrigated agriculture, groundwater overdrafting has become one of the greatest environmental challenges on California's rangelands. Due to heightened overdrafting during drought times, the State of California issued the Sustainable Groundwater Management Act (SGMA) in 2014 requiring that groundwater basins cease overdraft. The Sierra

Valley sub-basin was highlighted as a medium priority basin within SGMA due to documented groundwater declines and resulting land subsidence (Bachand et al. 2020). Ranchers expect to be affected by SGMA and have responded in different ways. Some have invested in irrigation infrastructure: “They put a moratorium on any new ag wells. I could see that coming and I did an ag well.” (SV18) Others have reduced water use in anticipation of groundwater restrictions: “Now we are irrigating, but we are not trying to make hay, so we are able to pump a lot less water.” (SV46).

Ranch diversification is particularly important considering the expected impact of climate change on precipitation, forage availability, wildfire frequency, and long-term financial sustainability (Holechek et al. 2020). Yet many ranchers were skeptical about whether climate change is occurring. In response to questions about climate change, participants often cited variations in weather as a normal feature of the landscape: “I do not really believe in climate change. The climate changes every year. It is never the same.” (SV15) Only a small number of participants highlighted the importance of adaptation given the impact of climate change on water availability, using methods like planting alternative crop species that succeed under different temperature conditions.

Disintensification

Sierra Valley is also experiencing disintensification from amenity migrants purchasing ranches. Study participants noted the distinct cultures of amenity migrants, including prioritization of conservation over production agriculture: “We have an influx of people in our community who are non-agriculture based ... I have had interactions with people who are completely against our way of life...” (SV29) Another participant noted: “I have noticed that the community culture has become much more of a bedroom community.” (SV7)

Past studies have confirmed that in-migrating amenity landowners introduce shifts in land management (Abrams and Bliss 2013). Indeed, amenity landowners in this case prioritized the environmental health of their properties over production goals. These landowners had significantly lower levels of livestock grazing on their properties, leased their land for grazing rather than managing cattle themselves, and engaged evidence-based management and scientific

monitoring. Two ranches, for example, voluntarily paid a conservation non-profit to monitor wildlife populations, plant diversity, and soil health on their properties. These ranchers were less concerned than production ranches about conservation easement restrictions on grazing timing or infrastructure development. Irrigated alfalfa was mostly not present on amenity-focused properties included in this study, and those owners did not discuss the importance of building income-generating opportunities for the next generation. Notably, it is not uncommon for in-migrating landowners to purchase properties specifically for the purposes of conservation, and participants observed this taking place in Sierra Valley.

Residential development

Study participants described increasing numbers of second-home owners and commuters in Sierra Valley. Newcomers principally purchase smaller plots within one of the valley’s towns rather than larger ranches, and either commute to nearby cities or use their Sierra Valley property as a retirement home or vacation home. The decision to move to the Valley is partly driven by increasing housing costs in nearby cities, which have received growing levels of in-migration from higher density regions like the San Francisco Bay Area. Notwithstanding the Valley’s low housing inventory and dearth of infrastructure like medical facilities and grocery stores, participants and experts explained that the COVID-19 pandemic and expansion of remote work have expedited amenity in-migration, causing a surge in the real estate market. A real estate expert described recent in-migrants to Sierra Valley as being lifestyle-oriented: “They are looking to raise families there, but not necessarily be ranchers.” (SV50) Some ranchers expressed concern about in-migration leading to gentrification and increased housing prices: “There are people moving here from San Francisco ... they are kind of pushing out your average people ... for them to buy a house that is \$500,000, they would not bat an eye at that.” (SV13).

Given past concerns about urbanization of Sierra Valley (Lage 2005), I analyzed data from the California Department of Conservation’s Farmland Monitoring and Mapping Program to understand the extent to which development is occurring. These data reveal that less than 1% of Sierra Valley’s land area has been

converted to urban development, and under 80 ha were converted in the three decades before 2018. To understand the types of properties that might be developed in the future, I obtained sales data from the Plumas Multiple Listing Service, a local real estate sales database. Looking only at sold rangeland properties over 8 ha in size, over 5% of the valley's land area (approximately 2,680 ha) was sold in the decade before 2020. These properties included working cattle ranches, amenity ranches, meadows and timberland. Descriptions of these parcels provided by a local real estate agent highlighted their land use potential: "Can be split into 10 acre parcels"; "Used to grow hay"; "Pasture land ready to go for the entrepreneur to develop into an income producing property with a well, center pivots, and alfalfa seed."

Drivers and constraints on land use

Interviews revealed the identified land use transitions to be driven or constrained by several key factors: land access, water availability, conservation policies, and intergenerational succession.

First, increasing alfalfa production appears to be partly driven by the distal factor of decreasing land access at lower elevations. Like many livestock producers worldwide, Sierra Valley ranchers practice transhumance, utilizing rangelands in lower-elevation foothills for winter and springtime grazing. Transhumance supports the mountain ranching economy by reducing the cost of feeding cattle in winter months: "If you have cattle and you are not sending them down below to the valley to eat grass on some rented pasture or an allotment of some sort, you will be [using] a lot of hay." (SV12) Sierra Valley ranchers have lost access to winter grazing lands due to conversion of historically-used land at lower elevations. This decrease in forage availability puts pressure on production cattle ranches to convert mountain meadows for alfalfa production:

It is cutthroat to find winter ground because either it's going up in houses or it is getting burnt, or it is in almonds ... You could have a piece of ground tied up and the next year it is gone. (SV29)

Last year we lost a bunch of feed in the Chico fire ... We always have enough hay so that if we

have to, we can stay home ... leave that barn full, just in case. (SV25)

Local forage access has also been reduced as grazinglands come under the management of amenity ranchers and land trusts, with some of these lands leased to ranchers but grazing levels significantly reduced. At the same time, while in-migrants often reduce grazing levels on their properties, some participants hypothesized that in-migration could increase forage access if new landowners convey conservation easements and thus reduce land values. Some participants described forage availability as additionally impacted by recent declines in snowpack, which some scientists attribute to climate change (Gergel et al. 2017; Sun et al. 2019). As one participant explained: "Snowpack is our reservoir. If you get earlier melts, then you have to anticipate what will happen in August when you run out of grass." (SV11).

Declining forage availability is also the result of reductions in grazing on public lands grazing allotments due to environmental restrictions. Notably, rangeland research has found that reductions in grazing on public lands increases intensity of agricultural activities on private lands, particularly increased grazing and conversion to hay production (Runge et al. 2019). Both ranchers and some Forest Service staff expressed strong interest in expanding the use of public lands for grazing and streamlining the process for landowners. One participant spoke to the regulatory and financial burden of accessing public lands grazing allotments:

A Forest Service allotment was attached to this ranch. So three or four years ago, I spoke to one of the [Range Conservationist] guys at the Forest Service. And he says, oh yeah, it has not been active for 30 years. And I said, okay, great, what do I need to do to get that going? And he says, well about \$60,000 to start with for an environmental study and about four or five years from now, maybe we can do it, if everything goes well. (SV46)

A second factor that appears to have influenced land use conversion in Sierra Valley is increasing water availability due to regional water infrastructure development and modern irrigation technologies. Historic dam construction transformed land use in Sierra Valley from dryland farming to irrigated pasture, with

agriculture well drilling escalating in the mid-twentieth century as larger cattle operations moved to the valley and neighbors raced to augment water access (Sinnott 1976). With increased water availability, meadows were plowed and irrigated to augment hay production. Both production-focused and amenity ranchers expressed concern about conversion of native grassland to hay production. One expert noted the fine balance between resource use and conservation: “It is common knowledge that you can overtax the groundwater and it will affect wetlands. But at the same time, folks have to make a living.” (SV17) A production rancher also spoke to this tension: “Since the meadows did not produce much, they got plowed up, much to my dismay. I love the meadows. Since we had to make a living, that was the thing to do.” (SV26).

While irrigation technology developments allow for agricultural intensification, water and energy policies can have the opposite effect. Because of its high dependence on water, alfalfa production is significantly impacted by changing water and power costs: “A lot of our water comes from irrigation wells ... The power bill is exorbitant.” (SV14) Notwithstanding increasing irrigation costs, most participants did not report implementing water usage reductions. Some participants expressed concerns about future restrictions on water use from state groundwater policies limiting agricultural communities’ ability to produce food:

There is a double standard. Just take [Las] Vegas, for instance. How many hotels are out there that consume water? Showers, golf courses, swimming pools ... But they look at how the farmers take too much water. If they really stop us from farming and utilizing so much of this water, where’s the food going to come from? (SV42)

Participants pointed to water as one of the most significant factors influencing the future of the valley and possible land uses, given that irrigation enables alfalfa production and thus diversified income. Looking ahead, continued fluctuations in the alfalfa market and state restrictions on groundwater pumping may result in ranch operations investing in alternative crops to meet the financial needs of the next generation.

Thirdly, land use transitions in Sierra Valley are influenced by conservation policy, including policies focused on preventing urban development like County

General Plans, state farmland protection policy (e.g., California’s Williamson Act), and conservation easements. To prevent urban development, a number of ranches in Sierra Valley have conveyed easements to conservation organizations. Both amenity and production ranches with easements reported a high level of satisfaction: “We cannot grow a lot of stuff ... so our easement works out really well for us.” (SV20).

While conservation policies can prevent intensification and conversion, they can also be problematic for producers. Ranchers shared frustrations that site-specific or local factors were not often incorporated into state or national rangeland policies. This sentiment supports the recommendation that regulators work more closely with natural resource managers in policy development (Ostrom and Cox 2010). For example, the requirements necessary for producers to receive NRCS cost-sharing grants for conservation work are frequently a barrier to participation. NRCS conservation program participation could require that an archaeologist and biologist evaluate ranches for potential historical significance and endangered species. Many ranchers are wary of such requirements: “People still get hung up about not wanting to participate with NRCS because they still just do not know what will be done to them.” (SV6).

Given the importance of diversification to ranch sustainability, production ranches reported concerns about conservation policies or programs limiting their ability to run economically viable operations. Interviewed ranchers were particularly concerned about grazing limitations—whether relevant to grazing allotments or conservation easements. Seasonal grazing restrictions in conservation easements, often inserted for the purposes of protecting nesting birds, can cause ranchers to lose a significant portion of the summer grazing season. As participants explained:

These newer easements are a lot more strict than the first ones that basically just kept open spaces open. Now they have really strict grazing standards, and it reduces the number of cattle that can run and often you are grazing at a poor time for the cattle. (SV47)

It always seems to end up being July 15th when cattle can start grazing. Well, that is two months into your typical grazing season here. (SV20)

Production ranchers described grazing season delays required by some recently negotiated easements to be an impossible commitment for producers. This concern reflects the Western Sierra Nevada's cattle production cycle, with green forage waning in June and replaced by dry forage with inadequate protein content by late summer (Fig. 6).

Beyond concerns about grazing restrictions, some traditional ranchers feared that conservation easements limiting future construction may stymie the ability of future generations to diversify, innovate and develop new agricultural businesses. Ranchers were concerned that restrictions on grazing or hunting could also limit diversification. As one producer noted: "The problem with easements, there are a lot of hidden restrictions to them ... It is really tricky for keeping the ranch in agriculture." (SV10) Ranchers and experts participating in this study called for less of a top-down approach to land use governance and more flexibility: "The issue you deal with is a lot of the regulations are written by people who have no actual knowledge of what it takes to run an economically viable operation." (SV11).

Given the sentiments described above, the long-term potential for neoliberal conservation programs like conservation easements to be scaled and

successfully prevent land use change will be constrained by how well these concerns are addressed. While some organizations have worked to implement easements with fewer restrictions (e.g., The California Rangeland Trust was created by ranchers for this purpose), their implementation has been limited by lack of conservation funding available for less stringent easements.

Finally, while some ranches intensify land use to support additional generations, land use can also be impacted by loss of intergenerational succession. As one participant explained: "[The next generation] makes too much money in other jobs ... they just want to do it when they feel like having fun." (SV15) In many cases, the younger generation does not have the financial stability to support the family business once the ranch is passed down. When members of the next generation are no longer interested in ranching, ranches are at greater risk for subdivision and sale: "There were six of us kids and all of us got married and all of us have kids... It is hard for me to see that the land is not going to just be easier to sell than to work at it and to continue to preserve this family farm for future generations." (SV42)

Fig. 6 Fluctuations in herd demand and protein content on mountain meadows of the West Side Sierra Nevada. Conservation easements that limit spring and early summer grazing can be challenging for ranchers as the most nutritious forage is available in May and June. Lines represent herd demand for

protein content and bars represent protein content on mountain meadows. Source: University of California Agriculture and Natural Resources (George et al. 2001). Copyright © 2001 Regents of the University of California. Used by permission

Heterogeneity in landscape management

Sierra Valley landowners participating in this study held many common values for land management. Both amenity and production ranchers defined conservation as having to do with sustainable use of the landscape: “Conservation is a love of the land and trying to maintain and better it ... We are stewards of land.” (SV29) Landowners reported implementing a variety of conservation activities, including managing for native plants, pollinators and wildlife and protecting riparian areas. As other researchers have found both in Sierra Valley and other California ranching communities (Aoyama and Huntsinger, 2019; Lage 2005), both types of ranchers explained that rangelands need to be actively managed by humans to support ecosystem services. Without grazing, many believed that rangelands would turn into a “jungle” of invasive species and be poor habitat for wildlife: “If there were no cows here, this place would just be a big, wild mess. We have noticed since we have been grazing the cows out in the back, there is a lot of grass growing where it was not growing before. Keep the weeds down.” (SV15) Ranchers emphasized the role of grazing in supporting the health of the landscape, a concept widely supported by rangeland experts (Barry 2015; Bartolome et al. 2014; Huntsinger and Hopkinson 1996). In fact, some academics have hypothesized that increases in amenity landownership could result in reduced ecosystem health due to lower levels of active management (Plieninger et al. 2012). Participants also highlighted the importance of grazing for preventing catastrophic wildfires that diminish habitat: “Forest fires go through and it looks like the surface of the moon when they are done. You know what is better? Having some cattle and some loggers in there trying to manage it.” (SV46)

Notwithstanding these shared values, participants’ varying degree of focus on production agriculture appears to produce different habitat outcomes. On the one hand, agricultural activities can at times provide valuable habitat to species (Huntsinger et al. 2017; Lomba et al. 2020). For example, migrating birds are drawn to water on irrigated lands in the wet parts of the valley, and pronghorn have returned to Sierra Valley in numbers not seen in a generation, largely because of the irrigated alfalfa fields of production ranches. Mule deer, pronghorn, and migrating birds are generally accepted by production ranchers as a natural part of the

landscape, if competitors for forage. Participants explained that production agriculture can support wildlife in Sierra Valley by increasing water and feed availability:

Irrigating those meadows, which had gone unirrigated for so long ... it changed the vegetation and brought the meadows back to life. We used to see maybe a hundred geese and now we see a thousand. Right here, there were no deer ... Now they are back here. (SV18)

The wildlife is a byproduct of this ranch. We basically have a huge bird sanctuary here ... There are places in the valley that people really like to go bird watch, but they would probably do a backflip if they saw where all the birds really are. (SV47)

At the same time, some agricultural activities negatively impact wildlife, habitat, and groundwater, particularly when rangelands are converted for crop production. Some production ranchers reported removing beaver, muskrat, coyote, bear, and elk because of their negative impacts on agriculture. For example, elk can cause livestock stress due to their aggressive interactions with cattle: “Elk will herd those cows into a harem. Two years ago, an elk drove a calf away and killed it with his horns.” (SV18) Ranchers frequently remove beavers and muskrats because of their impact on water systems: “I had to tear a beaver dam out yesterday because he has blocked it all up.” (SV13) Wolves, documented in the area since the mid-nineteenth century (Sinnott, 1976), can impact ranches directly through predation of livestock and guardian animals, as well as indirect impacts on livestock weight gain from heightened stress. As one participant explained, “Compensation [for predation] is a tricky thing, because the real damage a wolf does is not the kill it makes, but the general health of the whole herd. Stress of rebreeding, weight gain ... and on the ranchers. I do not think people understand what it is like fearing that something is out there going to attack your herd.” (SV25) Some amenity ranchers who manage livestock also shared concerns about predator species returning to Sierra Valley: “There is that side of me where I understand the importance of wildlife and corridors and then there is that other side of me ... I want this impenetrable, fenced area where I know that our

animals are okay... It is an interesting conundrum for me.” (SV11).

Discussion

The three major land use transitions identified in this study can be mapped onto broader trends predicted by the land use transition pathways framework (Fig. 7). The land use transition pathways framework enables analysis of the trade-offs between land uses that support short-term human socio-economic wellbeing and long-term negative impacts of those land uses on ecosystem services (e.g., impacts on freshwater resources and wildlife habitat). This understanding is needed to improve the sustainability of land use practices and improve environmental policies by supporting both short- and long-term human wellbeing and ecosystem resilience on working landscapes (Foley et al. 2005). Solutions to supporting both human wellbeing and rangeland ecosystem services include grazing management that supports wildlife habitat and conservation easements, which diversify income without further converting grassland.

Several factors have been added to the framework in the context of Sierra Valley, including disintensification due to amenity landownership; extensive

grazing as an ongoing type of less intensive frontier land use; and solar development. Management by native peoples has also been added, as archeological evidence supports native tribes residing in the region for at least 5,000 years (Waechter and Norton n.d.) and being in California for at least 19,000 years (Klein 1995). It is important to note that sale of ranches can result in any of the three identified land use transitions—intensification, disintensification, or residential and commercial development—depending on the buyer and whether a property has a conservation easement.

Proximal and distal factors influencing land use transitions in Sierra Valley as highlighted by this study are summarized in Fig. 8. At a local level, proximal factors like zoning policies and conservation easements can constrain development. Other local factors can drive land use intensification, such as dam development, water competition, and demand for irrigated crops. Intensification is also driven by distal factors like forage losses at lower elevations and can be constrained by state policies (e.g., groundwater limitations).

Fig. 7 Land use transition pathways framework applied to Sierra Valley, California. The land use transition pathways framework applied to Sierra Valley, adapted from DeFries et al. (2004), Foley et al. (2005), and Mustard et al. (2007)

Opportunities for improving grasslands conservation policy

Given the distinct habitat provided by different ranch types, experts suggest that agricultural policies support heterogeneity on agricultural lands, including interweaving large areas of native ecosystems into working lands (Fischer et al. 2008). Thus a diversity of grazing management regimes as seen in Sierra Valley's mosaic of land ownership may support long-term landscape conservation and biodiversity (Fuhlendorf and Engle 2001; Peco et al. 2006; Grau et al. 2013). In other words, production agriculture supports some wildlife through increasing water and feed availability, while disintensified ranches and nature preserves provide valuable habitat to species that compete with or are detrimental to production agriculture. Well-managed cattle grazing will continue to offer important ecological benefits, including supporting biodiversity by preventing invasion of non-native grasses, shrub encroachment, and fragmentation. As human population growth into fire-prone areas makes traditional fire management regimes more difficult to implement, livestock grazing could aid in reducing vegetative fuel loads and preventing woody encroachment. At the same time, continued preservation of old-growth and restored grasslands is needed to support long-term biodiversity, particularly for native perennial grasses and forbs (Nerlekar and Veldman 2020).

Conservation policies could be upscaled across Western working lands if financial and policy issues are resolved. The financial burden that conservation policies often place on producers can be significant, such as when allotment management costs are placed on producers rather than the managing agency. For landowners who are economically dependent on the agricultural productivity of their ranches, conservation program participation is limited by perceived anti-agricultural framing (Merenlender et al. 2004; Kabii and Horwitz 2006; Cross et al. 2011). If conservation easements were more flexible to the production needs of traditional agricultural operations, and if adequate funding was secured from public and private sources, such conservation policies could be implemented more broadly.

Upscaling landscape sustainability solutions requires alignment across policy actors operating at different scales within the hybrid governance model

(Lambin et al. 2020). Conservationists interested in preventing grasslands conversion should consider the underlying drivers operating at both proximal and distal scales. Pressure on mountain meadows could be relieved by state policies supporting transhumance and grazing lands access—both on public and private lands—for cow-calf operations. From a science education perspective, the climate change skepticism documented in this study highlights the need to engage rural landowners on climate science and adaptation opportunities to mitigate potential impacts of climate change on cattle production. Beyond climate, groundwater overdraft is a growing issue that occurs because ranches operate at low margins with high income variability. Income diversification opportunities through innovative business models or payments for ecosystem services should be supported by policy-makers, private sector initiatives, and corporations.

Finally, in light of rural gentrification and remote work, there is a growing opportunity to engage amenity landowners individually and through collaborative initiatives. This public or privately-led engagement could focus on managing for specific conservation outcomes (e.g., rebuilding native ecosystems, preventing the spread of invasive plants, protecting old-growth and restored grasslands) and supporting the agricultural viability of landscapes by providing grazing access to production-focused ranchers. Future research is needed to document the particular plant and animal species supported by various land management activities. While amenity landowners utilize non-traditional capital resources to enable adaptive management, science-based decision-making by ranchers could be further supported through private initiatives providing low cost scientific monitoring.

Study limitations

Weaknesses of the case study approach include a high volume of data produced, uncertainty around the generalizability of identified relationships to other geographies, and the difficulty of conducting meta-analyses on studies of this nature as interview data must be kept confidential (Didier and Brunson 2004; Babbie 2016). In this study, I undersampled amenity and absentee landowners and so the data are likely biased towards more actively engaged members of the community. I endeavored to address this by contacting

Residential & solar development

Drivers

- **Ranch income diversification**
- **Landowner access to capital**
- **Amenity migration**
- Regulatory burdens on agriculture
- Renewable energy policy

Constraints

- **Land use planning** (e.g., county General Plans, state agricultural land protection policies)

Agricultural intensification

Drivers

- **Ranch income diversification**
- **Water development**
- **Landowner access to capital**
- Irrigation technology
- Forage loss at lower elevations (e.g., due to residential development, wildfire)
- Demand for irrigated crops (e.g., alfalfa hay)

Constraints

- **Land use planning** (e.g., local zoning)
- **Conservation easements**
- **Climate change perspectives**
- **Amenity migration**
- Public lands access
- State agriculture & water policy

Agricultural disintensification

Drivers

- **Amenity migration**
- Societal interest in conservation and rewilding
- Regulatory burdens on agriculture
- Endangered species policy

Constraints

- Pro-agriculture policies and programs

◀ **Fig. 8** Drivers and constraints of land use transition pathways in Sierra Valley. Proximal factors are shown in bold and distal factors in regular font. This figure builds on the land use transition pathways framework (DeFries et al. 2004; Foley et al. 2005; Mustard et al. 2007) and social-ecological systems frameworks developed by Ostrom and Cox (2010) and Charnley et al. (2018). Photo credits: Judy Gallagher@flickr, Freepik

new landowners identified in real estate sales data; however, this method was unsuccessful in securing interviews. Undersampling of absentee landowners in rangelands research is particularly concerning given recent rangeland ownership trends. Finally, study conclusions may be limited by sample size; yet this study captured the perspectives of one fifth of range landowners in Sierra Valley, accounting for 47.1% of the land area of the case study site. The interview campaign was discontinued when I reached an interview saturation point—with similar responses generated from each additional interview—signaling an adequate sample size for the purposes of this analysis (Glaser and Strauss 1967).

Conclusion

This study addressed two fundamental questions of landscape sustainability science: what factors influence the relationship between land use, ecosystem services, and human wellbeing, and how those factors can be better integrated into environmental policy and landscape planning. In response to these questions, I engaged qualitative methods to uncover the proximal and distal factors influencing land use change on private grasslands in the Western US and implications for ecological outcomes and policy development. Through an in-depth, mixed methods case study of a mountain ranching community, I identified several land use trends: intensification for alfalfa production; residential and solar development; and disintensification resulting from amenity migration. Key factors influencing these land use changes included decreased access to forage, changes in water availability, conservation policies, and intergenerational succession. I highlighted similarities in land management perspectives between traditional and amenity ranchers and areas where these mental models diverge between landowner types to produce distinct ecological

outcomes. Several factors appear critical to protecting the ecosystem services of privately-owned grasslands and should be considered in policy development: grazinglands access, income diversification opportunities, regulations that ensure groundwater recharge, agriculture-friendly conservation easements, and policies supporting transitions to amenity landownership rather than low-density development.

Rangelands are managed by humans for varied values and outcomes, whether agricultural production, cultural value, energy production, or habitat conservation. Public and private conservation programs can be designed with these goals and values in mind, and effective implementation is dependent on the mental models and decision processes of individual land managers. Future research should explore the efficacy of specific conservation policies and programs in shaping the management decisions of both production and amenity-focused range landowners, and the best process for community-engaged conservation of privately-owned landscapes.

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Declarations

Conflict of interest The author declares to have no conflict of interest.

Ethical approval Research methods were approved by the Stanford University Institutional Review Board (Protocol #50991).

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