

DISSERTATION

LINKED LIVELIHOODS, LAND-USE, AND IDENTITIES ON TRANSITIONING LANDSCAPES IN
NORTHEASTERN COLORADO: A SOCIAL-ECOLOGICAL STUDY

Submitted by

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ABSTRACT

LINKED LIVELIHOODS, LAND-USE, AND IDENTITIES ON TRANSITIONING LANDSCAPES IN NORTHEASTERN COLORADO: A SOCIAL-ECOLOGICAL STUDY

Rangeland social-ecological systems in Northeastern (NE) Colorado are undergoing linked land-use, livelihood, and identity transitions. Land change is a spatially and temporally complex process in which land-use decisions cascade through interconnected social and ecological spheres, affecting both humans and the environment. While a wealth of empirical research on land cover changes exists, multiscale, multilevel research on the causes and consequences of linked social-ecological change remains limited. To avoid oversimplification and craft system-appropriate policies in rangeland systems, we require in-depth and process-based knowledge of the causes and consequences of change. Moreover, we must build upon and advance theory to support the role of contextual research in advancing sound practical applications and future inquiry in related systems. Thus, this dissertation applies a theoretically informed multi-method approach to examine the interrelationships among livestock producers' shifting livelihoods, well-being, identities, and associated land change transitions in two rangeland-dependent communities in NE Colorado.

Social-ecological systems (SESs) theory serves as this dissertation's theoretical foundation, framing rangelands as systems in which humans are embedded within and affect ecosystems and vice versa. Within the broader SESs framing, this research advances existing livelihood and well-being theories and frameworks, a land change conceptual model, and identity theory. Moreover, the multi-method design acknowledges and addresses that knowledge from one method offers only a partial perspective of complex systems (i.e., the partiality of knowledge). This dissertation's multi-method methodology facilitates the convergence of multiple perspectives to assemble a meaningful

view of social-ecological change in rangeland systems. In so doing, it contributed to evolving social-ecological systems research methodologies.

Chapter 1 introduces this dissertation, providing an overview of the research questions, theoretical frameworks, and my positionality. Chapter 2 presents a systematic map that characterizes the North American rangeland social science literature by 1) the research objectives and questions; 2) who was studied; 3) the study location; 4) the theories, methodologies, and methods; and 5) how these research characteristics have changed from 1970 to 2017. This evidence map found the need for more North American research that 1) is informed by social theory, 2) applies a diversity of methods, 3) considers a broader diversity of stakeholders, and 4) draws from multiple social science disciplinary traditions. The subsequent studies address these identified research needs.

As rangeland-based livestock systems experience social and ecological change, producers make increasingly complex livelihood decisions for improved or sustained well-being. Understanding these decisions requires more holistic frameworks that capture livelihood decision-making pathways and associated human well-being outcomes so that support systems reflect producers' needs. Using a modified grounded theory approach based on 32 livestock producer interviews, Chapter 3 introduces the empirical foundation for an integrated, place-based livelihood and well-being framework with the potential to address these gaps in the theory and practice of rangeland sustainability. The results show that producers vary in access to cultural and political factors and emphasize diversification (adding ranch-based enterprises), extensification (purchasing or leasing more land or livestock), and contraction (selling land or livestock) as livelihood strategies. We propose that scholars and practitioners apply the resulting integrated framework to conceptualize social-ecological-emotional livestock systems in Colorado and the US more broadly.

Chapter 4 applies a multi-method approach combining remote sensing and qualitative interviews to examine the causes and consequences of land-use change in two agricultural communities in northeastern Colorado. This research found that both study sites experienced a decline in planted or cultivated land cover (i.e., approximately >20% of the vegetation is annual crops or pasture/hay) from 1984-2019, with 16.0% and 18.7% of each study site's total land areas transitioning out of cultivated cover. Most of the cultivated land transitioned to herbaceous/grassland cover (i.e., approximately >80% of the vegetation is non-intensively managed graminoid or herbaceous), with 10.3% and 18.4% of each study site's total land area transitioning to herbaceous/grassland cover from 1984-2019. This chapter identified the significant role of policies – specifically an open space conservation program in one community and the Conservation Reserve Program in the other – in driving the trends of decreased cultivated land and increased herbaceous cover. Participants also emphasized how shifting perceptions of agriculture affect their land-use decisions.

Chapter 5 examines how social-ecological change affects individuals, exploring livestock keepers' conceptualization of their occupational identities and the associated gender divisions in the context of rapidly changing North American rangeland systems. Analysis of participant interviews revealed that, while history often presents farmers and ranchers as distinct and conflicting identities, participants related their increasingly plural roles (including dual farmer-rancher roles) with the need to diversify their operations to preserve their way of life. Participants emphasized the significance of land and livestock to both their agricultural identities and financial well-being. These findings capture that while most participants perceived positive shifts towards greater acceptance of women in agriculture, women did not always receive public acknowledgment of their roles as farmers or ranchers. As livestock keepers restructure their identities in response to social-ecological change, opportunities open to support the increased inclusion of diverse identities in agricultural spaces.

This dissertation examines social-ecological change in NE Colorado through multiple theoretical lenses and methodological approaches, shedding light on the causes and consequences of social-ecological change in NE Colorado's rangeland communities. The findings illuminate the complexity of change, highlighting the need to avoid oversimplification in crafting policies and programs to support rangeland managers. Given some producers' concerns about impending system transformations, I recommend that future work engage these rangeland stakeholders to co-produce pathways to deliberate transformations for rangeland social-ecological systems.

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CHAPTER 1

INTRODUCTION

Globally, livestock grazing has supported human lifeways for 10,000 years. Worldwide, pastoral social-ecological systems face multiple challenges, leading to major transitions (Galvin, 2009). Northeastern (NE) Colorado shares such experiences of change as rangeland systems undergo linked land-use, livelihood, and identity transitions. Moreover, the 21st century propelled these grazing systems into a polarizing global debate focused on generic solutions (Steinfeld et al. 2006, Gerber et al. 2013, Glatzle 2014). If poorly informed on rangeland systems' complexity, decisions guided by oversimplified conceptions can force already challenged environments, food systems, and cultures over undesired tipping points (Briske et al., 2015; Brown & Thorpe, 2008). Thus, while researchers have studied land cover changes empirically, numerous dimensions of rangeland transitions remain unexplored. To avoid one-size-fits-all recommendations and craft appropriate land-use policies (Lambin et al., 2001), we must understand the causes and consequences of change in context. Thus, this dissertation investigates social-ecological change in NE Colorado by examining the interrelationships among shifting livelihoods and well-being, land-use patterns, and producers' identities. This research also contributes to the evolving methodology of social-ecological systems research by integrating qualitative and quantitative methods to analyze linked social and ecological changes in rangeland landscapes.

Social-ecological systems (SESs) are complex, adaptive systems interconnected and reciprocal across the social and ecological spheres (Folke, Biggs, Norström, Reyers, & Rockström, 2016; Holling, 2001). In this dissertation, I join a cohort of researchers that conceptualize and research rangelands as SESs (Brunson, 2012; Hruska et al., 2017; Huntsinger & Oviedo, 2014a; Ostrom, 2009; Sayre, 2017; Westley et al., 2011; Westley et al., 2013). Scholars struggle to research

SESS' multiscale and multilevel linkages, but given the dynamics of interconnected systems, we cannot understand SESSs at a single scale (Walker et al. 2004, Adger et al. 2005a, 2005b, Cash et al. 2006, Hruska et al. 2017). I address this significant research gap by applying a multi-method approach – including participant observation, interviews, and remotely sensed data analysis – to investigate change in rangeland SESSs. These multiple vantage points come together in this dissertation to construct a holistic view of NE Colorado rangeland social-ecological landscapes.

In Chapters 2-5, I research underexamined elements of rangeland SESSs, with a specific emphasis on the social sphere (Figure 1.1). This study focuses on North American agricultural producers that extensively graze livestock (i.e., livestock producers) as either a sole occupation or in-parallel with other work (e.g., off-operation employment, cultivated cropland, and agritourism). Moreover, this dissertation moves between theory and empirical data, iteratively drawing upon each other to develop both theoretical and empirical contributions. Chapter 2 is a systematic evidence map of the rangeland social science literature, situating this dissertation within this growing area of inquiry. Chapter 3 is a constructivist grounded theory study in which I developed a novel framework that integrates livelihoods and well-being. Chapter 4 builds upon Chapter 3's findings to analyze the social-ecological causes and consequences of land change in NE Colorado. Chapter 5 examines livestock producers' occupational and gender identities, outlining associated behaviors, symbols, and adaptations. Specifically, this dissertation addresses the following research questions:

1. What is the state (i.e., patterns and trends) of the North American rangeland social science literature (Chapter 2)?
2. What are the knowledge gaps and future research directions in the rangeland social science literature (Chapter 2)?
3. How do NE Colorado livestock producers/keepers conceptualize their livelihoods and livelihood strategies (Chapter 3)?

4. What is the link between NE Colorado livestock producers'/keepers' livelihoods and their well-being (Chapter 3)?
5. How has land cover changed in NE Colorado from 1984-2019 (Chapter 4)?
6. How do livestock producers'/keepers' livelihood strategies (Chapter 3) and driving forces of change interact to influence land change trends in NE Colorado from 1984-2019 (and vice versa) (Chapter 4)?
7. How do NE Colorado livestock producers/keepers occupationally identify, and what behaviors, symbols, and adaptations link to these identities (Chapter 5)?
8. How do gender roles affect access to and experiences of agricultural occupational identities (Chapter 5)?

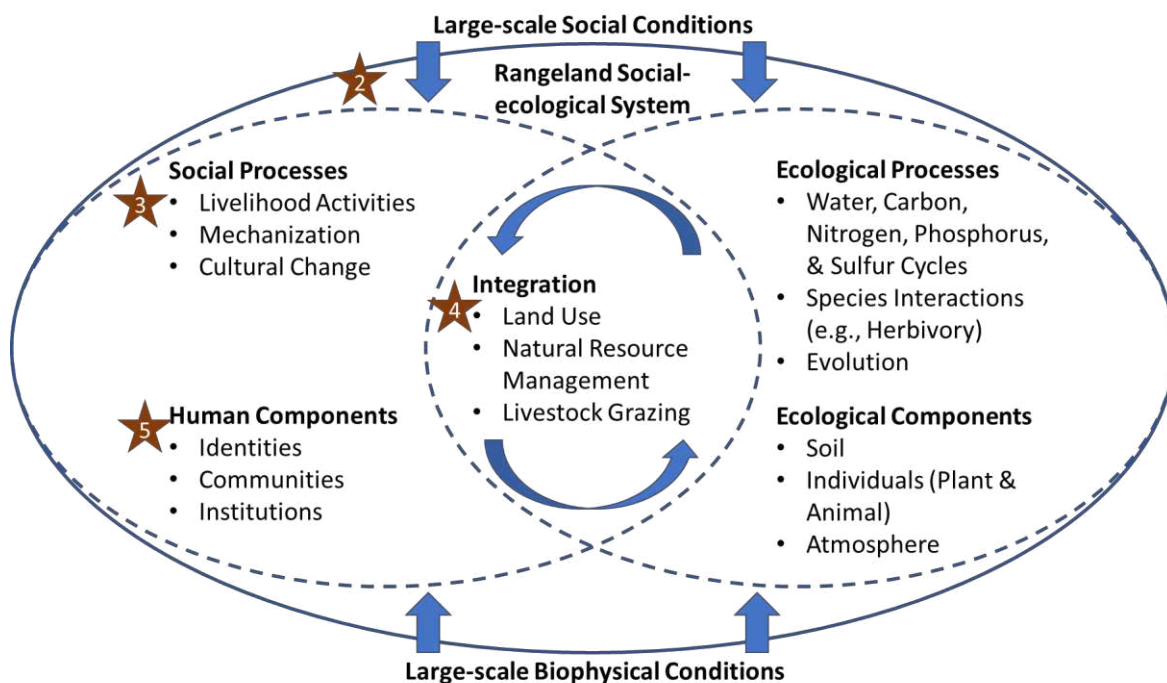


Figure 1.1. Rangeland social-ecological system (SES) diagram adapted from Virapongse et al. (2016). The left circle represents the social sphere, and the right circle depicts the ecological sphere. The overlap of the two represents the nexus of the integration of the social and ecological. The central arrows represent the reciprocal feedback between the social and ecological. The external arrows represent the large-scale social (i.e., socio-cultural and economic) and biophysical (i.e., abiotic and biotic) conditions that influence the SES. Chapters 3 and 4 (orange stars indicate chapter numbers) contribute knowledge of the social processes (Chapter 3 on livelihoods) and the

human component (Chapter 5 on identities). Chapter 4 (land change) examines the integration of the social and ecological spheres over time.

This introductory chapter briefly reviews the significant theories and literature that this dissertation draws on and advances. I then outline the methodological approach and structure of the dissertation. This chapter closes with a statement of my positionality in relation to the research topic and communities.

1.1. THEORETICAL FRAMEWORKS

This dissertation's theoretical foundation is SESs theory. The conceptualization of SESs stems from a diversity of disciplines and continues to stretch across disciplinary boundaries (Herrero-Jáuregui et al. 2018). Inquiry into human-environment (Grossman 1977) and people-nature (Sayer 1979) relationships offered early insights into the interconnectedness of humans and the environment (Judkins et al. 2008). Simultaneously, ecology spawned resilience thinking (Holling, 1973), which evolved out of general systems theory to integrate further the following concepts: feedback, boundaries, emergent properties, hierarchies, interaction, and self-organization (Steedman and Regier 1987, Turner et al. 1990). By the 1980s, the fields of political economics, ecology, and complexity science began to explore concepts of complex, coupled SESs (Schoon and van der Leeuw 2015), laying much of the groundwork for the connection of Ostrom's (1990) work on institutions into SESs thinking (Ostrom 2007, 2009). While the study and application of SESs have grown, these systems' complexity makes it difficult to meaningfully measure and integrate social and ecological variables (Fox et al. 2009, Binder et al. 2013, Herrero-Jáuregui et al. 2018). Thus, social-ecological researchers draw on many disciplines to study diverse systems across varying spatial extents and timeframes (Gunderson & Holling, 2002; Holling, 1973; Ostrom, 1990, 2007, 2009).

This research builds upon and contributes to a growing literature body that conceptualizes rangelands as SESs (Brunson, 2012; Hruska et al., 2017; Huntsinger & Oviedo, 2014; Ostrom, 2009;

Westley et al., 2011; Westley et al., 2013). In socio-environmental grazed systems, human decisions and actions affect ecosystem functions and vice versa, with outputs cascading through feedback loops to affect human well-being and local environments (Hruska et al. 2017). Analogous to the structure of a double helix, we conceptualize socio-environmental grazed systems as inherently and inseparably integrated between the social and ecological spheres, with outputs cascading through feedback loops to affect human well-being and local environments (Figure. 1.2).

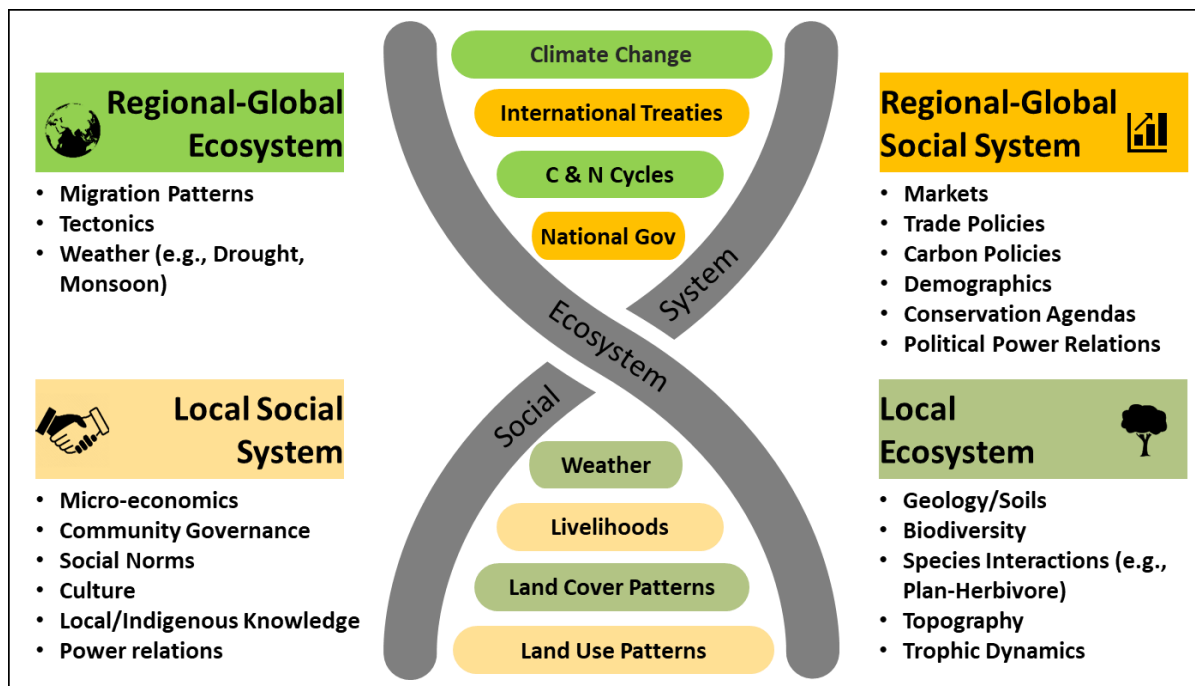


Figure 1.2. Rangeland socio-environmental systems conceptual diagram. The social and ecological run parallel, twisting together and interrelating at multiple levels.

While SESs theory has gained currency in interdisciplinary scholarship and the social sciences, some scholars have critiqued the lack of depth and completeness of the *social* in SESs scholarship (Stojanovic et al. 2016). A central critique emerges from critical theory, which examines power relations in society with a normative goal of advancing equitable power and social relations (Tyson 2006). Critical theorists argue that current SESs theory and empirical research depoliticize the social (Smith and Stirling 2010, Glaser and Glaeser 2011, Mackinnon and Derickson 2012,

Fabinyi et al. 2014, Welsh 2014). Failure to consider power dynamics is problematic when SESs scholarship often aims to identify appropriate governance structures and regimes. Thus, if we fail to consider power, SESs research and its practical applications may reinforce systems that marginalize people. Another critique is that SESs focuses on the material and institutional with limited attention to culture (Crane 2010). The focus of SES theory on the material, structural, or collective action can fail to consider individual agency – our ability to make decisions relatively autonomously and creatively – presenting individuals as passive entities instead of agents of change (Coulthard 2012, Stojanovic et al. 2016). Overall, SES research can focus on quantifiable variables and structures, leaving elements of the subjective life unexamined and, ultimately, unintegrated into decisions regarding natural resource management (Crane 2010, Glaser and Glaeser 2011). Moreover, the rangeland social science literature mirrors many of the critiques of SESs theory, which I demonstrate in Chapter 2's systematic evidence map.

1.1.1. Livelihood and Well-being frameworks

This dissertation examines the often underexplored social sphere, conceptualizing the social-emotional through integrating well-being with the livelihoods framework. Binder et al. (2013) analyzed ten SES frameworks, identifying the sustainable livelihood approach as most appropriate for considering the macro-social and ecological effects on the micro-social scale. The concept of livelihoods first emerged from international development and extension research, especially in agriculture (Solesbury 2003). Researchers and development practitioners conceptualized the livelihoods framework as an alternative to "disciplinary reductionism" (Chambers and Conway 1991, p. 3) and the exploitation of rural people and places (Solesbury 2003). Chambers and Conway (1991, p. 6) define livelihoods as "the capabilities, assets (stores, resources, claims, and access) and activities required for a means of living." Researchers and practitioners (among others) have diagramed the livelihoods framework in various configurations with slight variations in the capitals represented. The framework incorporates the reciprocal and

adaptive interaction between the context (e.g., drought and society) and structures/processes (e.g., governance and policy) (Hussein 2002). The frame presents livelihoods with no singular phase or pinnacle but, instead, with the environment and human systems continually interacting with livelihood outcomes to shape future livelihoods and vice versa.

As the western US rapidly transitions, fluctuations such as population growth and urban expansion influence significant social and ecological change in rangeland systems (Huntsinger et al. 1997, Liffmann et al. 2000, Nelson 2001, Smith and Krannich 2009). Binder et al. (2013) present the sustainable livelihood approach as an action framework to analyze and consider natural resource decision-making in transitioning communities. Yet, the overwhelming majority of livelihoods research is focused on Africa and Asia (e.g., Kydd et al. 2004). Moreover, the current framework offers limited consideration of how livelihood strategies affect human well-being (and vice versa). Thus, Chapter 3 contributes to theory-building by constructing a coupled livelihoods and well-being framework from NE livestock producers' lived experiences.

Whereas livelihoods have been central to conservation and development since the early 1990s, well-being applications in these fields and specifically within an SES framing are nascent. The concept of well-being draws heavily from human development while integrating concepts from diverse study areas, such as livelihoods (McGregor and Sumner 2010). The World Health Organization developed the 5-item World Health Organization Wellbeing Index (WHO-5) in 1998. While the health sector widely adopted the framework, fields such as conservation and development have historically considered livelihoods and poverty alleviation as indicators of the social system, often failing to examine the role of well-being (Topp et al. 2015). More recently, conservation practitioners have started to directly research human well-being (Agarwala et al. 2014, Fry et al. 2017). Consequently, researchers and practitioners recognize the need to move beyond only economic and environmental framings towards the inclusion of the subjective (Biedenweg et al. 2017). In the social-ecological context, Armitage et al. (2012, p. 3) modify

McGregor's (2008) definition to define well-being as "a state of being with others and the natural environment that arises where human needs are met, where individuals and groups can act meaningfully to pursue their goals, and where they are satisfied with their way of life."

While there exist multiple well-being indices, researchers and practitioners have begun to converge on a well-being framework's shared principles. Well-being is the multi-dimensional interplay of the material (i.e., "what you have"), relational (i.e., "what you can do with what you have"), and the subjective (i.e., "how you feel about what you have and what you can do") (McGregor and Sumner 2010, Beauchamp et al. 2018). For instance, an individual can have material well-being (i.e., wealth), but their well-being could be relatively low due to how they feel about their situation (i.e., subjective) and poor social relationships (i.e., relational). Like livelihoods, there is not a pinnacle of well-being; but instead, well-being is ever-evolving. The proposed framework in Chapter 3 integrates well-being within a SESs framing, novelly capturing how well-being and livelihoods interrelate within a system.

1.1.2. Land Change

Chapter 4 builds from our advanced understanding of livestock producers' adaptive strategies, examining the interrelationship among driving forces, livestock producers, and land change patterns (Hersperger et al. 2010). Land change science acknowledges and examines the interactions between the biophysical (Chase, Pielke, Kittel, Baron, & Stohlgren, 1999) and human systems (Vitousek et al. 1997). For instance, research has captured how rapid transitions, especially urban expansion, drive significant social and ecological change in rangeland systems (Gosnell & Travis, 2005; Huntsinger, Buttolph, & Hopkinson, 1997; Knight, Wallace, & Riebsame, 1995; Liffmann, Huntsinger, & Forero, 2000; Nelson, 2001; Riebsame, Gosnell, & Theobald, 1996; Smith & Krannich, 2009). Moreover, land-use change is a spatially and temporally complex process as historical and contemporary events drive multiscale transitions (Lambin & Meyfroidt, 2010). As

such, Lambin et al. (2001) call for research that recognizes global factors, the social and ecological, and place-based dynamics through time.

To date, land change science does not have a dominant theory (Lambin, Geist, & Rindfuss, 2006). Lambin et al. (2006) suggest that a synthesis of theories might best address land change science's complexity. Moreover, Hersperger, Gennaio, Verburg, and Bürgi (2010) highlight the significance of and need to advance conceptual models in land change science, emphasizing that meaningful conceptual models and theory development are reciprocally reinforcing. Therefore, within the theoretical framing of complex adaptive SESs, I draw upon and contribute to Hersperger et al.'s (2010) conceptual model of land-use change that links causes, actors, and land change. In the select conceptual model, forces of change and actors (i.e., ranchers) interact. This interaction influences land change, which feeds back to the interplay between actors and drivers of change. Chapter 4 builds from Chapter 3 to examine and theorize how interacting driving forces and rancher and farmer adaptive strategies influence land change trends in NE Colorado from 1984-2019.

1.1.3. Identity Theory

Additionally, as livelihoods (Chapter 3) and landscapes (Chapter 4) transition, so too do identities (Green, Marcouiller, Deller, Erkkila, & Sumathi, 2010; Hansen et al., 2005; Hansen et al., 2002; Nelson, 2001; Smith & Krannich, 2009). For example, as market pressures drive land sales, ranchers may lose their livelihood strategy of extensive livestock production and their sense of rural identity (Huntsinger et al. 1997, Burton 2004b). In this dissertation, I apply identity theory, which considers the interplay between identities and society (Burke & Stets, 2009). In identity theory, the self is a dynamic accumulation of roles, such as rancher, mother, and wife (Stryker & Burke, 2000; Stryker & Serpe, 1982). A role is how one defines themselves in society (e.g., rancher) and the expectations connected to the social position (e.g., hardworking). Identity is the self-categorization of being a rancher, but also, there is an interplay between roles and decision-making

(i.e., decisions a rancher makes) (Burke, 1997). Moreover, we use symbols and social interactions to verify that our behaviors align with the identity (i.e., what a rancher *ought* to do) (Mead 1934, Stets and Burke 2000).

While some rangeland social scientists have defined rancher decision-making as a dynamic process influenced by social factors (Huntsinger et al., 1997; Liffmann et al., 2000; Smith & Martin, 1972; Wilmer & Fernández-Giménez, 2015), rangeland social science literature shows scant attention to socio-cultural factors such as identity. Despite empirical evidence that identity significantly influences farmer decisions, agricultural researchers have considered attitude as the determinant of behavior, often overlooking the influence of cultural constructs such as identity (Allison 1996, Burton 2004a, 2004b). Sorice et al. (2012) is one of the few rangeland studies that considers identity. Still, their Likert-type scale does not capture the socio-cultural and multi-faceted nature of identity. Thus, Chapter 5 applies identity theory (Burke & Stets, 2009) as an organizing framework to examine how livestock producers conceptualize and adapt their occupational identities within their changing landscapes. Chapter 5 offers a foundational understanding of rangeland identities, which we posit will support future identity integration into decision-making models.

1.2. PHILOSOPHY OF SCIENCE

The philosophy of science – philosophical assumptions about the nature of reality (ontology) and how we can know it (epistemology) – underpinning this dissertation asserts some semblance of a reality independent of our minds (i.e., my ontology = critical realism) with humans constructing a perceived reality (i.e., my epistemology = constructivism) (Moon and Blackman 2014). Realism asserts that a reality exists independent of the human mind. Yet, as a critical realist, I believe that we never perfectly understand reality given its complexity and human inquiry limitations. As such, my constructivist epistemology posits that while reality is independent of the

human mind, humans construct knowledge of the world (Crotty 1998). Thus, constructivism does not seek an objective truth of an object or topic but, instead, an understanding.

Aligned with the demands of critical realism and the acknowledgment that there is no single truth, this dissertation employs a diversity of conceptual approaches and methods to support critical and broad examination of social-ecological change (Bhaskar et al. 2010). The idea that any source of knowledge can only offer a partial perspective (i.e., partial knowledge) drives this dissertation's multi-theory and multi-method methodology (Haraway, 1988; Nightingale, 2003). Methodology is the researcher's choice of how to apply the identified methods, integrating ontology and epistemology (Gay & Weaver, 2011; Sprague, 2016). Moreover, acknowledging the partiality of knowledge is especially salient when examining complex, adaptive SESs as these systems come into better focus as researchers layer multiple perspectives that converge and conflict (Nightingale 2003, Janssen et al. 2011, Preiser et al. 2018). Therefore, this dissertation employs a multi-method approach – including participant observation, interviews, and remotely sensed data analysis – to assemble multiple, partial vantage points into a relatively holistic understanding of how change shapes livelihoods, landscapes, and identities in NE Colorado rangeland systems.

1.3. ORGANIZATION OF THE DISSERTATION

This dissertation is comprised of four research chapters. Chapters 2-5 serve as stand-alone, peer-reviewed journal articles, introducing some repetition in the literature reviews and methods for some chapters. Moreover, I use the first person singular when discussing the dissertation's totality and transition to the first-person plural in the research chapters to recognize co-authors' contributions.

Chapter 2 is a systematic evidence map of the rangeland social science literature, which serves as the academic lineage for this dissertation. Rangeland science emerged from concerns about land degradation due to increased livestock grazing (Ross 1984), placing questions of land condition at the center of this applied field. Since the 1990s, however, social science research about

rangelands has become increasingly prominent, as scientists and practitioners recognize that human decisions underlie many ecological impacts of and responses to environmental change. However, these works had not been systematically reviewed to assess the state of rangeland social science in North America or to identify research gaps. Chapter 2 presents a systematic map that examines and advances this growing body of social science literature on rangeland systems. I characterize this literature by 1) the research objectives and questions; 2) who was studied; 3) where the research was conducted; 4) which theories, methodologies, and methods were applied; and 5) how these research characteristics have changed from 1970 to 2017. The research gaps identified in Chapter 2 guided the conceptualization of the remainder of this dissertation, enabling this work to build upon and contribute to the growing body of social science research in rangeland systems.

Chapter 3 presents the empirical foundation for an integrated livelihood and well-being framework with the potential to address gaps in the theory and practice of rangeland sustainability. As rangeland-based livestock systems experience social and ecological change, producers make increasingly complex livelihood decisions for improved or sustained well-being. Understanding these decisions requires more holistic frameworks that capture livelihood decision-making pathways and associated human well-being outcomes so that support systems reflect producers' needs. This research offers a framework that Extension, policymakers, and researchers can use to design and promote more equitable and human-centered support systems for livestock producers in the western US and beyond.

Chapter 4 applies a multi-method approach to examine the causes and consequences of social-ecological land change in the two study sites in NE Colorado. A random forest land classifier is used, analyzing 36 years of satellite imagery to investigate land cover trends. Moreover, interviews with livestock producers examine how drivers of change and livestock producers' adaptive strategies interrelate to influence land cover trends. These analyses are integrated,

constructing a rangeland change conceptual model that illustrates the interrelationship among driving forces, livestock producers, and land change patterns.

Chapter 5 addresses the gap that little research examines identities in the context of rapidly changing North American rangeland systems. This study applies and builds upon identity theory to examine how livestock producers conceptualize their occupational identities and the associated gender divisions. As livestock keepers are restructuring their identities in response to social-ecological change, this research identifies opportunities to support the increased inclusion of diverse identities in agricultural spaces. This more nuanced understanding of agricultural identities and their relationship to behavior can support Extension staff, researchers, and policymakers to develop strategies appropriate for the shifting needs of increasingly pluralizing rangeland stakeholders. Chapter 6 summarizes the findings across the multiple vantage points – the academic literature, livestock producers' experiences, and remotely sensed data – presented in Chapters 2-5.

1.4. POSITIONALITY

"Do modern sciences advance social progress? How one answers this question depends upon what one counts as science and as social progress." (Harding, 2006, p. 1)

I reflect on my positionality to clarify my motivations, relationships to the participants, and epistemology or theory of knowing (Sprague, 2016). An explicit statement of positionality is essential because humans construct science. Therefore, personal experiences and emotions affect our research. Moreover, one way to ensure rigor is to examine how these biases may influence my work reflectively.

It was twenty-one early mornings and over seven hundred boxes into the harvest season, and I was working my way up the row. The row terminated at the edge of US Route 1, and I swung my rake with a twelve-year-old's eagerness for lunch and anticipated completion. A few feet away from lunch, I looked up at Route 1 to see a woman viewing me through the lens of a camera. Her lens focused on me, moved to my grandfather hunched over with sixty years of work, swung across

the field to my mother, lagging in row eleven, and panned out to capture the field and my community. I became aware of the power dynamics of observation.

In subsequent years, I started working in research, primarily in Ethiopian livestock systems. Our research focused on engaging stakeholders in the livestock sector, including farmers, to identify and resolve sector-level challenges. Early in our project, scientists and farmers agreed that vaccinating livestock would improve livelihoods. Yet how could a farmer with five animals be expected to purchase a vaccine sold in 250-dose or 1,000-dose vials? We collaboratively identified a problem, but it has taken years of ongoing engagement with the public and private sectors to advance change. I realized that stakeholder engagement is not a silver bullet. While our project successfully engaged farmers in the research process, there remained a chasmic disconnect between people's needs and current systems.

My community on display made me aware of observation's power dynamics. My work in Ethiopia helped me understand that stakeholder engagement intersects with and can be constrained by existing systems, including politics and the private sector. Therefore, I brought to my Ph.D. research a commitment to engaging with farmers' and ranchers' lived experiences and acknowledgment that my work is nested within a historical-cultural context. Still, my Ph.D. has grappled with and illuminated the relational nature of the research process.

In Colorado, my membership in a diversity of epistemic communities and subcommunities makes me both an insider and an outsider among livestock producers (Naples 1996, Tuana 1996). Together, participants and I negotiated these boundaries. My dominant role as an outsider positioned me as a learner, creating space to ask for clarification and for participants to offer detailed explanations. For instance, interviewees often predicated long explanations of their experiences with statements such as "Do you know what that is?" Yet, my lived experience of growing up in a rural community and natural resource-dependent household often enabled me to relate to participants' sentiments and emotions.

From these experiences, I have assembled and built my identity and ethics as a researcher. My personal epistemological views have come from a place where we can measure reality, but my experiences and observations have led me towards awareness of the influence of the dynamic of social constructs and the understanding that these social dynamics are always in transition. In addition to an epistemological shift, I view research as a process that is nested within a historical-cultural context and relationally shaped among stakeholders.

Moreover, it is significant that I wrote this dissertation in 2020-2021 amid significant change, including (but not excluding) a global pandemic, political unrest, racial injustice, economic instability, and a climate crisis. While I wrote this dissertation, over two million people died of COVID-19. A police officer murdered George Floyd over an allegedly counterfeit 20-dollar bill. While a black man was murdered over 20 dollars, billionaires enjoyed net worth growth in 2020. Yet, I was often drawn back into this dissertation by acknowledging that understanding people's lived experiences and examining complex issues are needed skills to combat such injustices. This year has also brought further conviction that my future research needs to integrate advocacy and deliberate change to current systems.

CHAPTER 2

THE LANDSCAPE OF NORTH AMERICAN RANGELAND SOCIAL SCIENCE: A SYSTEMATIC MAP

2.1. INTRODUCTION

Rangelands are social and ecological landscapes that seemingly defy a singular, standard definition. The spatial extent of rangelands extends from a 40-acre ranch to 30%-50% of Earth's ice-free land area (Sayre, 2017). From the Sahelian Acacia savanna to the shortgrass steppe, rangelands are all lands that are not forested, cropland, ice-covered, or inhabited as cities (Sayre, 2017). Rangelands are also cultural and social landscapes that often transcend ecological and political boundaries. The sociocultural extent of rangelands can extend from one individual's source of recreation (e.g., Brunson & Gilbert, 2003) to the central source of a community's livelihoods (e.g., Coles & Scott, 2009). Researchers have advanced our understanding of these complex systems through the study of the ecological dynamics and management practices, but the equally complex social factors on North American rangelands have been historically understudied. As the rangeland science paradigm in North America shifts towards a complex systems and social-ecological focus (Briske, 2017), there is an opportunity to fully integrate and centrally locate the social sciences into the more holistic study of rangelands as complex social and ecological landscapes (Sayre, Carlisle, Huntsinger, Fisher, & Shattuck, 2012; Sherren & Darnhofer, 2018).

The inception of rangeland science is intertwined with North America's colonial history and associated normative policies on rangeland assessment and use (Sayre, 2017). While Indigenous peoples lived on and managed North American rangelands for thousands of years (Mcadoo et al. 2013), with European colonization and migration came the rapid expansion of livestock production. As livestock and rangeland systems changed rapidly and significantly in the late 19th and early 20th centuries, land degradation emerged as a principal policy concern (Sayre, DeBuys, Bestelmeyer, &

Havstad, 2012). The policy and research responses to this land degradation, including the Taylor Grazing Act of 1934 and the Soil Conservation and Domestic Allotment Act of 1936, are often viewed as the inception of rangeland science (Rasmussen, 1985; Ross, 1984; Sayre, 2017). This urgent need shaped an early production-oriented rangeland science paradigm into which social science was later integrated, often in an auxiliary role. These ecological findings and paradigms have been reviewed and synthesized in various papers (Briske, Fuhlendorf, & Smeins, 2003; Briske et al., 2011; Fleischner, 1994; Milchunas & Lauenroth, 1993).

Social science is the study of people and groups of people, such as households, societies, economies, and cultures (Bhattacharjee 2012). The uniting characteristic of the social sciences is the study of the social life of humans, and the diversity of social science includes the investigation of the individual to the study of society, including anthropology, political science, geography, sociology, economics, psychology, and a diversity of other disciplines and fields. While anthropologists such as Evans-Pritchard (1940) studied global pastoralists (Dyson-Hudson and Dyson-Hudson 2003), there was comparatively less focus on social factors on North American rangelands in the early 20th century. Early social research on rangelands in North America, such as Smith and Martin (1972) and Buys (1975), came later in the 20th century, more intermittently, and explored social factors of behaviors and attitudes, often in the disciplinary context of ranch economics. In parallel with the broader emergence of interest in interconnected human-environment systems (Ostrom, 1990; Scoones, 1999; UN General Assembly, 1972; United Nations, 1992; Zimmerer, 1994), both social and ecological scientists began to recognize the importance of integrating the social sciences into the study of North American rangelands. With the development of social theories relevant to applied fields like agriculture, such as diffusion of innovation theory (Ryan and Gross 1943, Rogers and Shoemaker 1971, Rogers 2003) and Ajzen's (1985, 1991) theory of planned behavior, rangeland researchers inquired about the motivations and perceptions of rangeland stakeholders in an effort to shape behaviors towards adoption of "best practices" and

innovations (van Kooten et al. 2006, Martin et al. 2013, McClaran et al. 2015). The rise of fields such as political ecology (Escobar 1996), social-ecological systems (Liu et al. 2007a, Ostrom 2009), and the study of pastoralism internationally (Dyson-Hudson and Dyson-Hudson 2003), offer new theories and methodological approaches to further diversify inquiry (Jeffrey 2003, Aboelela et al. 2007, Lang et al. 2012). Just as early advances in rangeland ecology contributed to assessment and management of rangelands, further advances in rangeland social science can and should contribute to more equitable development of and service delivery for individuals, communities, and societies who depend on rangelands. For example, a greater understanding of who does and does not have access to natural resources, and how access is gained, is foundational knowledge for the development of more equitable and sustainable systems of natural resource management (Ribot and Peluso 2009). The primary objectives of this paper are to systematically collect and analyze North American rangeland social science studies, map patterns across the literature, and identify gaps to inform future research (Arksey & O'Malley, 2005; Colquhoun et al., 2014; Miake-Lye, Hempel, Shanman, & Shekelle, 2016).

2.2. METHODS

2.2.1. Systematic Map Methodology

Systematic methodologies to inform evidence-based decision-making have been extensively applied in the health service sector, but the application of such research approaches has only recently increased in the field of conservation and environmental management (Pullin and Stewart 2006, Berrang-Ford et al. 2015). Systematic approaches, such as systematic reviews and maps, apply rigorous, transparent, and objective processes to minimize bias (Colquhoun et al., 2014; Higgins & Green, 2011). Unlike systematic reviews, systematic maps do not address specific questions but rather collate and synthesize diverse evidence on a high-level topic or area of study (Randall and James 2012, James et al. 2016, Miake-Lye et al. 2016). We chose to conduct a systematic map given that the rangeland social science literature had not been previously collated

and synthesized, since the methodology can be applied across heterogeneous studies, and to identify specific questions for deeper review. To capture the breadth of the literature we defined rangeland social science broadly, encompassing a range of literature from articles that integrate social science with biophysical research to work that is solely social science (Sherren and Darnhofer 2018). This definition allows for the inclusion of a diversity of academic fields that conduct social inquiry in relation to rangelands and recognizes the value of both integrated and stand-alone social science. Additionally, areas of study such as history, feminist studies, and anthropology span the social sciences and humanities, but to create a comprehensive and systematic map of rangeland social science, we chose to include these fields. We offer this systematic map both to acknowledge the contributions of rangeland social science to date and as a tool to inform future research. While we broadly and systematically examined the rangeland social science literature, in our analysis we chose to highlight the largest research gaps and those that we perceived to have the greatest impact on the advancement of the field.

2.2.2. Research Questions, Protocol Development, and Inclusion Criteria

The overarching goal of this systematic map is to describe the state of social science research on North American rangelands. More specifically, we aimed to determine what kinds of social science research questions have been asked, how these questions have been researched, and the major and impactful research gaps. Following standards for systematic methods, we first developed the review protocol (Figure 2.1). The objective of an *a priori* protocol is to enhance rigor, reduce bias, and create a transparent process that can be both tracked and scrutinized by the reader (James et al. 2016).

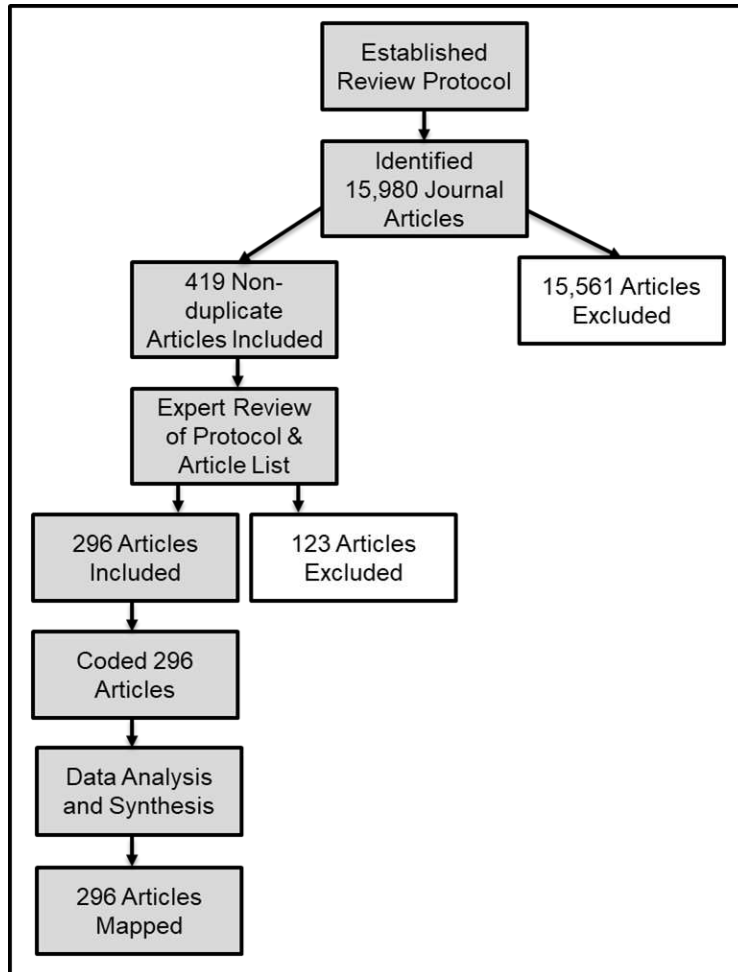


Figure 2.1. Overview of the review process from protocol development to synthesis executed from September 2017 to November 2018.

In the protocol we outlined the research objectives and detailed methods, and we used the protocol to guide the research process. Additionally, we established the following criteria for the inclusion of research: 1) a geographic focus on North America, 2) a social science component, 3) focus on rangeland or ranching systems, and 4) a scientific article published in a peer-reviewed journal from 1970 to 2017 in English or Spanish. These criteria were applied to determine the inclusion of research throughout the review process and are subsequently referred to as the *inclusion criteria*.

2.2.3. Article Search and Expert Review

In the systematic map protocol, we included a list of search terms developed to identify all relevant information while maintaining a necessary level of specificity (Table 2.1) (Pullin and Stewart 2006). To identify potential articles, we searched all permutations of the *Primary* and *Secondary* keyword terms joined with the Boolean operator *AND* in the Web of Science database (Table 2.1). For example, we searched ("Grass* landowner" AND Survey) and ("Grass*landowner" AND Interview). To identify the initial search terms, we reviewed the keywords listed in major rangeland social science publications, and we continued to add keywords until the results yielded only redundancies, indicating data saturation (Saunders et al. 2018). Three of the authors (E.D., J.B., K.J.)¹ screened the abstracts and titles of the resulting articles against the inclusion criteria.

Table 2.1. Keyword terms searched with all permutations of the *Primary* and *Secondary* terms joined with the Boolean operator *AND* (e.g., "Grass* landowner" AND Survey) in Web of Science from approximately October 2017 to February 2018. The use of an asterisks (*) with the root of a search term returns all forms of the word (e.g., range* returns range, ranges, rangeland, and rangelands).

Primary	Secondary
"Grass* landowner"	Survey
Rangeland	"Focus group"
Livestock producer	Interview
Permittee	Extension
Landowner	Decision*
Rancher	Motivation
Range* manager	"Native American"
Agency employee*	"American Indian"
Ranch*	"African American"
Range* operator	"Asian American"
	Race
	Ethnicity
	Value*

¹ Elena G. Dosamantes (E.D.), Jasmine E. Bruno (J.B.), Kevin E. Jablonski (K.J.)

Perception
Attitude*
Planning
Behavior
Policy
Knowledge
Gender
Hispanic
Innovation*
Adoption
Collaboration †
Indigenous †

† Indicates that the term was added in a second round of keyword searches based on stakeholder feedback.

After the completion of the first phase of keyword searches, we consulted multiple rangeland social science experts on the review protocol and the identified citations (Pullin and Stewart 2006). These materials were physically and electronically disseminated at the *Rangeland Social Science Gathering 2018*, a meeting of rangeland social scientists during the 2018 Society for Range Management Annual Meeting in Sparks, Nevada. The approximately 20-25 attendees were recruited for expert debrief of the keyword terms, the identified literature body, and the overall review protocol. Attendees identified omissions related to concepts of collaboration and Indigenous peoples, and due to this feedback, we included additional terms in a second round of keyword searches that resulted in the inclusion of additional articles. This process improved the content and construct validity of the systematic map (Sampson et al. 2009).

The complete keyword search identified 15,980 articles. We applied the inclusion criteria at the title and abstract level and identified 2,016 articles. Lastly, we eliminated duplicates, identifying 419 articles for full-text review. We retrieved and downloaded, as pdfs, 419 articles through open access means or university subscription services. We used a Google Form (Appendix A) for data

extraction and coding, creating the systematic map database in Microsoft Excel (version 1808). We tested our coding protocol with a sample of ten articles to train all reviewers, confirm the inclusion and exclusion criteria, and finalize the data collection tool. Questions with a low level of agreement between reviewers were either discarded or reworded and/or labeled with further clarification.

2.2.4. Full-text Review and Coding

The first four authors of this paper (C.J., E.D., J.B., K.J.)² completed the full-text review of the articles and were trained to exclude articles conservatively and to indicate papers that required a second review, which was completed by a different reviewer. If there were discrepancies between the two reviewers, the third reviewer was engaged in the final inclusion decision. During full-text review we excluded an additional 123 articles based on the inclusion criteria, and coded and analyzed data from the remaining 296 papers (Appendix B).

In the systematic map database, each item has a unique record including basic article characteristics such as author, title, and year of publication. We extracted the authors' stated research questions, objectives, and hypotheses and indicated whether they were implicit or explicitly stated. We coded for geographic area studied, academic field and journals, study populations and unit of analysis, data collection and analysis methods, integration of collaborative and participatory approaches, theoretical and methodological frameworks, and how these research elements have changed over time. We defined methodology as the researchers' choice, integrating philosophical and fundamental assumptions, of how to apply their selected methods (Gay and Weaver 2011, Sprague 2016a). We coded a binary response for methodology, selecting yes only if the authors were explicit about the application of a methodology. Otherwise, we did not attempt to deduce the methodology, and rather, indicated that it was not explicit. We followed an identical coding scheme for theoretical frameworks, and applied Strauss and Corbin's (1998) definition of

² Chantsallkham Jamsranjav (C.J.), Elena G. Dosamantes (E.D.), Jasmine E. Bruno (J.B.), Kevin E. Jablonski (K.J.)

theory as "a set of well-developed concepts related through statements of relationship, which together constitute an integrated framework that can be used to explain or predict phenomena."

The dominant academic field was first determined by the nature of the journal. If the academic field of the journal was not explicit, the theories applied in the research, the literature cited, and the first author's department were used to identify the dominant academic field, and if no single field could be discerned as dominant, the reviewers selected *interdisciplinary*. When relevant we identified an applied field, such as range science or human dimensions of natural resources. Otherwise, we coded for a discipline such as *ecology* or *anthropology*. Throughout this paper, we generally refer to both applied fields and disciplines as *academic fields*.

We also had an *a priori* interest in which populations are engaged as research participants or subjects, and the degree to which rangeland social science addresses questions related to individual or intersecting social identities and power relationships (Crenshaw 1989, 1997, Nash 2008). Thus, we coded if and how the research considered the individual attributes/identities of gender, race or ethnicity, age, and education, and ranch operation characteristics of income and operational scale. If one but only one of the identities or characteristics listed above (e.g., gender) was considered, we coded the paper as *considers attributes/identities or operation characteristics as singular and stand-alone*. Next, if two or more attributes/identities or characteristics were considered, we coded papers as considering attributes/identities or operation characteristics as *multiple, simultaneous, and intersecting or multiple, intersecting, and marginalizing within structures of power*. By identity we mean the self-categorization of an individual's role in society, such as one's gender, occupation, and race (Stets and Burke 2000, Stryker and Burke 2000). Social location denotes how a person's identities define their position in history and society, such as the historical influence of gender on women's engagement in labor markets (Anthias 2012). In total, we extracted 48 data fields, with 27 close-ended categories and 21 open-ended fields. The data are publicly available in Mountain Scholar: <http://dx.doi.org/10.25675/10217/195227>.

2.2.5. Analysis

After data cleaning, we analyzed and visualized the qualitative data in R 3.5.1 using the `ggplot2` and `RColorBrewer` packages (Neuwirth, 2005; R Core Team, 2019; Wickham, 2016). First, we calculated descriptive statistics (frequencies) on all closed-ended categorical data items (e.g. studied population, research method). Second, to assess changes over time in studied populations and research methods, we compared the relative frequency of response types by decade. Third, to understand and display the geographical locations of social science research over time, we used Python with packages `Matplotlib`, `NumPy`, and `Pandas` to conduct a spatial-temporal analysis and produce maps (Oliphant 2006, Hunter 2007, Mckinney 2010).

Fourth, to identify trends in research objectives across our sample and over time, we conducted a content analysis on the research objectives text (Elo and Kyngäs 2008). If no research objective was identified, we analyzed text describing the research question. We used content analysis because this method considers spatial and temporal trends and is both systematic and replicable (Stemler 2001). We coded text describing research objectives using a combination of *a priori* codes, or codes predetermined before examining the data, and emergent codes, codes that were identified from and through the reading of the data (Denzin and Lincoln 2008). Given our familiarity with the rangeland social science literature, we were aware of the prevalence, both explicit and implicit, of innovation theory (i.e., adoption or diffusion of innovations). Therefore, we created the following *a priori* codes to allow a more nuanced understanding of studied predictors or drivers of adoption of innovations: *attributes as predictors/drivers of adoption*, *perceptions and attitudes as predictors/drivers of adoption*, and *social dynamics/power as predictors/drivers of adoption*; we recoded all articles related to adoption into these categories (Rogers, 2003; Everett M. Rogers & Shoemaker, 1971). We also coded the text of research objectives for all papers using emergent codes and grouped these codes into categories: *adoption*, *conservation*, *collaboration*,

management behavior, project/program design and evaluation, history of ranching and rangelands, adaptation and decision-making, economics and agribusiness, identity, and social context.

Lastly, we used VOSviewer (van Eck and Waltman 2010) to conduct a bibliometric citation analysis to explore the network patterns among journals that have published rangeland social science literature. In the selected analysis, VOSviewer represented each journal with a circle sized relative to the number of articles published in the journal. We used VOSviewer to determine the relatedness of journals by the number of times they cite each other, and VOSviewer visualized these cross-journal citations through clusters and links, with tightly clustered and linked journals indicating a high number of relative citations (van Eck and Waltman 2010).

2.3. RESULTS

2.3.1. Spatial and Temporal Trends in North American Rangeland Social Science

The literature review process resulted in a total of 296 rangeland social science journal articles published between 1970-2017. With three articles published between 1970-1979, three articles from 1980-1989, 46 articles from 1990-1999, 86 articles from 2000-2009, and 158 articles published between 2010-2017, there is an upward trend of published rangeland social science literature in North America from 1970-2017 (Figure 2.2).

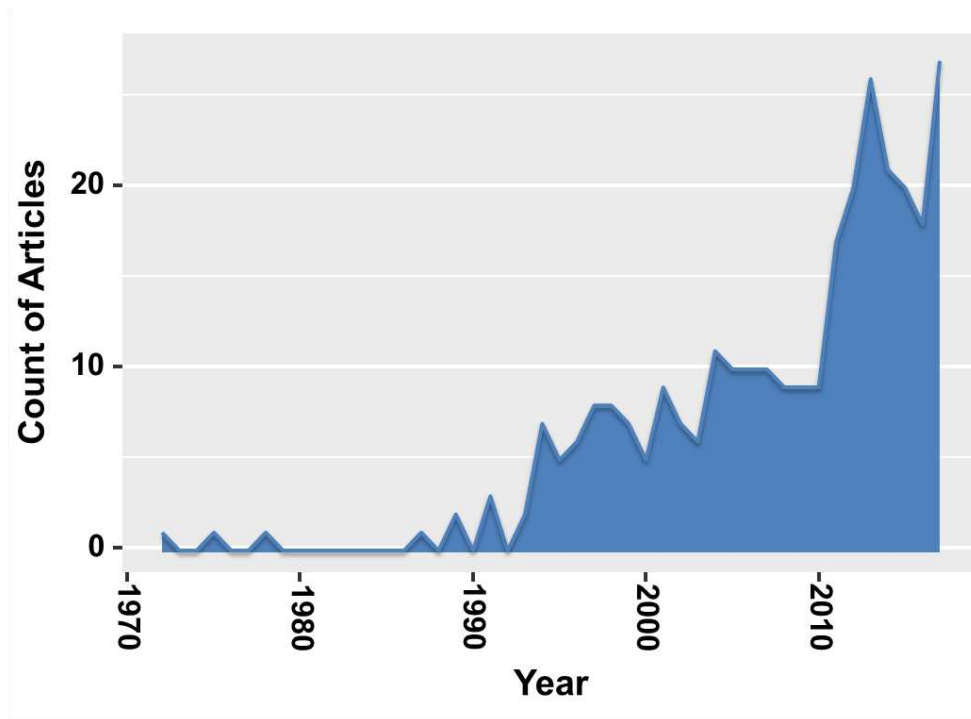


Figure 2.2. Plot of count of North American rangeland social science journal articles by year published from 1970-2017 (n=296 articles).

The literature body spans 21 academic fields across the social sciences, biological sciences, and humanities with rangeland science (34%) and human dimensions of natural resources (12%) contributing the most articles (Table 2.2). Accompanied by the trend of increased publications over time is a geographic expansion of the study location. For a full three decades, early rangeland social science publications were based on populations and topics based in the United States with research focused on Canada and Mexico not emerging until the 2000s (Figure 2.3 a-e).

Table 2.2. Academic fields represented in the article sample with the academic field identified first by the journal and if unclear, the disciplinary approach, literature cited, and the first author's department.

Academic Field	No. of articles	% of articles
Rangeland science	100	34
Human dimensions of natural resources	35	12

Economics	30	10
Ecology (social focus)	25	8
Agriculture/Animal science	24	8
History	15	5
Geography	13	4
Anthropology/Ethnobotany	10	3
Sociology	5	2
Education and Extension	5	2
Ethics and philosophy	5	2
Wildlife	5	2
Social psychology	4	1
Interdisciplinary	4	1
Conservation	4	1
Organizational science	3	1
Veterinary medicine	3	1
Public health/Human development	3	1
Political science	1	<1
Engineering	1	<1
Humanities-English	1	<1

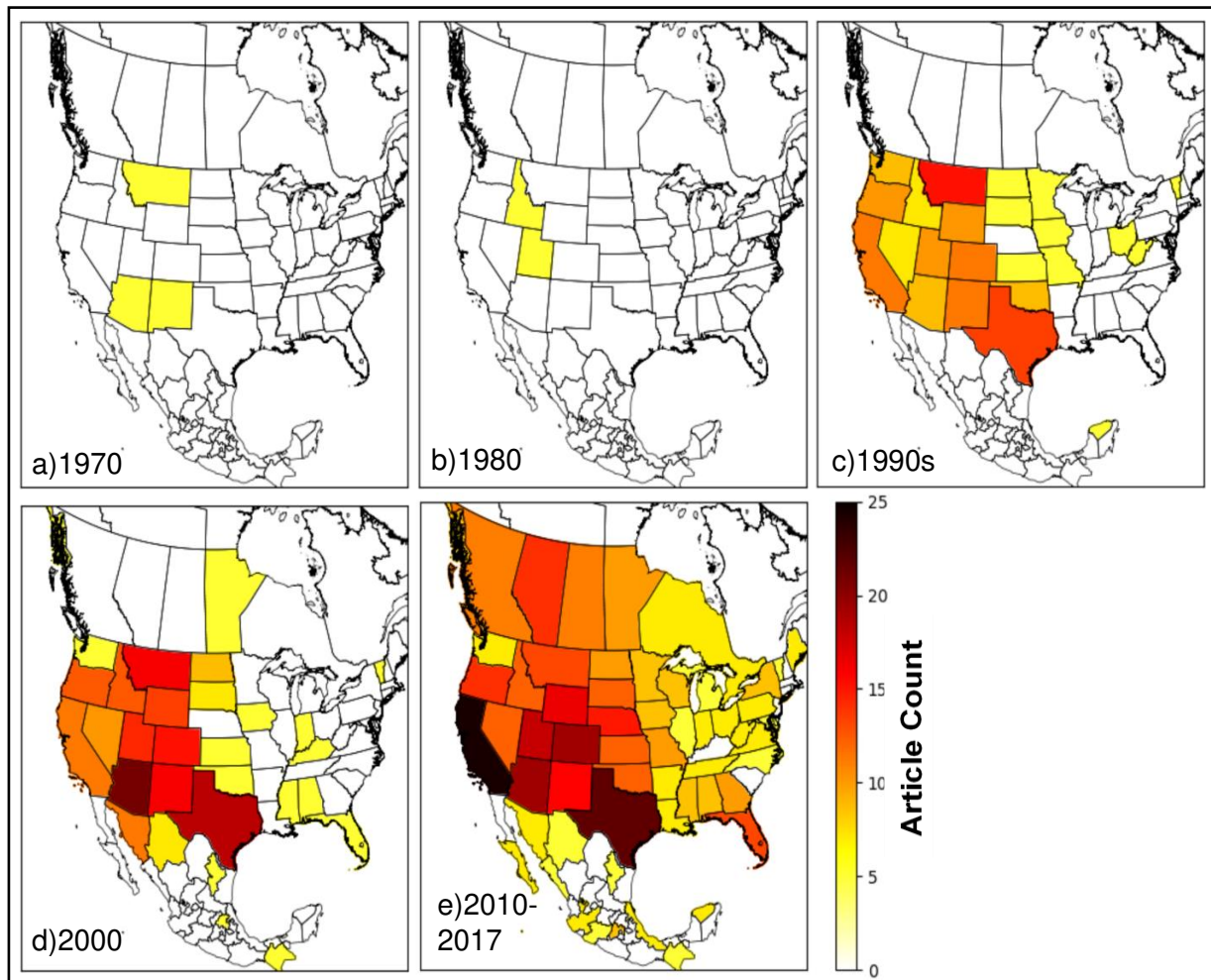


Figure 2.3 a-e. The count of the geographic location of the people and topics studied in the rangeland social science literature by state or province in the a) 1970s, b) 1980s, c) 1990s, d) 2000s, and e) 2010-2017.

2.3.2. Citation and Journal Trends

The bibliometric citation analysis by source examined the relatedness of journals by the number of times they cite each other (van Eck and Waltman 2010). The citation links, indicated by lines between circles, represent citations between journals. With 71 out of the 296 journal articles in *Rangeland Ecology & Management* (REM), it is the most prominent journal in our rangeland social science literature sample with 1,121 citation links to a wide diversity of 121 other journals in the literature body. *Society & Natural Resources* and *Wildlife Society Bulletin* are the second most

prominent journals, each publishing 15 articles with a total of 333 citations and 345 citations, respectively. The size of the circles in Figure 2.4 represents the relative count of the articles, showing the prominence of REM, even though only 25% of articles were published here. Of the 121 journals, 64 journals are clustered based on the high number of citations across journals. Relatedness was calculated based on citation occurrence using the association strength similarity measure (van Eck and Waltman 2007). Fifty-seven journals are external to the central clusters. The full list of journals are in Appendix C disaggregated by external and internal to the citation clusters, accompanied by the associated number of articles and citations by journal.

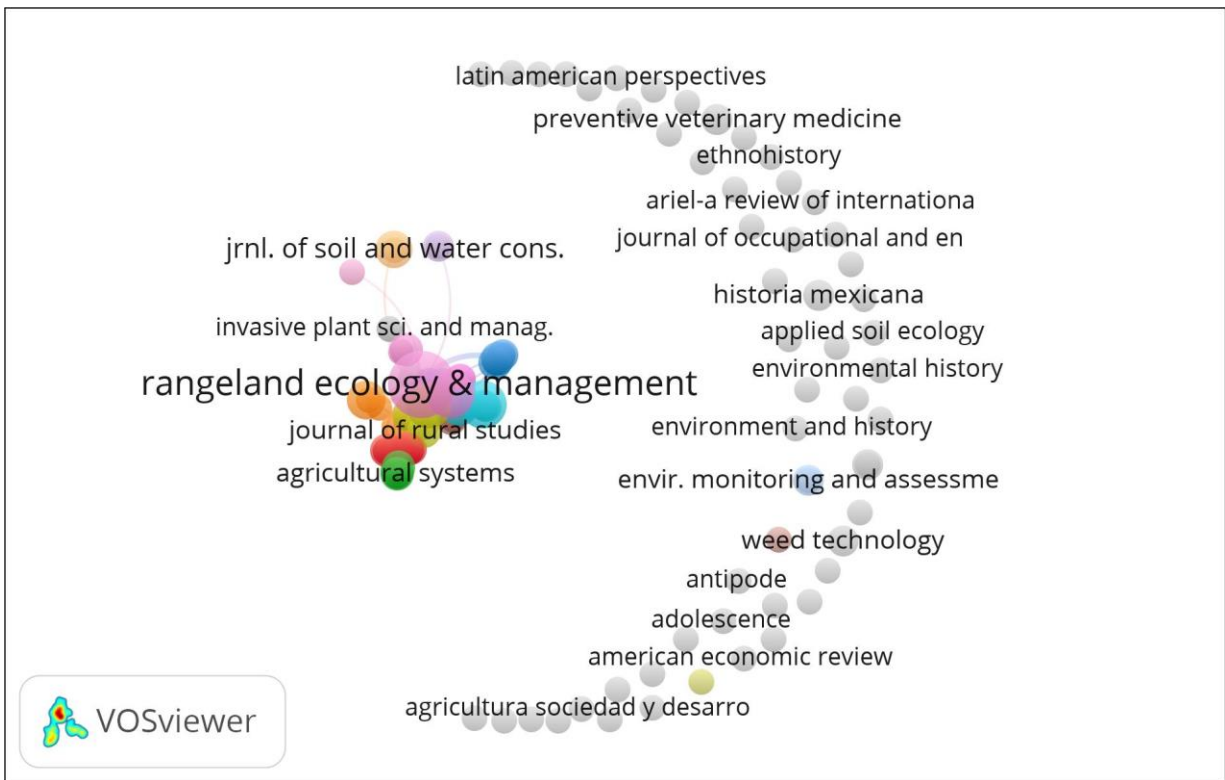


Figure 2.4. Citation network map by journal. The central rangeland social science clusters, determined by citations across sources, present high relatedness across 64 journals (Appendix C). The crescent of unconnected nodes displays 57 journals with low relatedness by citation to the central clusters. The sizes of the circles represent the relative count of the articles, showing the prominence of *Rangeland Ecology & Management* (largest, central circle).

2.3.3. Study Populations and Research Methods

In the 296 papers that met our criteria, we found that 81% of rangeland social science papers were centered on ranchers (66%), farmers (22%), or landowners (22%). Less consideration has been given to land managers (14%), rangeland organizations (e.g., grazing associations) (11%), the general public (10%), Indigenous communities (3%), scientists/researchers (3%), stakeholders such as youth (2%), other resource users such as hunters (2%), and Extension professionals (1%) (Table 2.3).

Table 2.3. Data collection method, data analysis method, study population, and unit of analysis for the selected 296 articles. Category totals are non-cumulative with some articles classified into multiple non-exclusive categories.

Data collection method	No. articles	% of articles	Unit of analysis	No. articles	% of articles
Survey	154	52	Individual	202	68
Interview	99	33	Group	76	26
Literature review	49	17	Household/Operation	63	21
Archival/Document	28	9	Community	33	11
Focus group	15	5	Agency/Org.	16	5
Participant observation	15	5	Ecological unit	12	4
Ecological/Ag.	15	5	Literature/Doc.	5	2
Workshop	9	3	Project	3	1
Social media	2	1	Other	4	1
Other	10	3	Unclear	10	3
Unclear	8	3			
Data analysis method	No. articles	% of articles	Study population	No. articles	% of articles
Descriptive statistics	182	61	Ranchers	196	66
Inferential statistics	132	45	Farmers	64	22
Multivariate statistics	28	9	Landowners	64	22
Noncomp. case study	27	9	Land managers	40	14
Economic model	26	9	Org(s)/Group(s)	33	11
Doc/Archival analysis	18	6	General public	31	10
Thematic/Content	16	5	Indigenous Peoples	10	3

Grounded theory	13	4	Ecological/Ag.	10	3
Literature review	13	4	Literature or project	9	3
Comp. case study	8	3	Scientific community	9	3
Model	7	2	Resource users	7	2
Simulation model	5	2	Cattle producers	6	2
Narrative analysis	4	1	Youth	6	2
Policy	1	<1	Extension	3	1
Other	23	8	Other	12	4
Unclear	4	1			

When disaggregated by decade, the trend of ranchers as the dominant study population persists (Figure 2.5). The literature body remains skewed towards the study of ranchers, but the diversity and abundance of populations increases through time with six populations studied between 1970 and 1989 and 13 populations considered between 2010 and 2017.

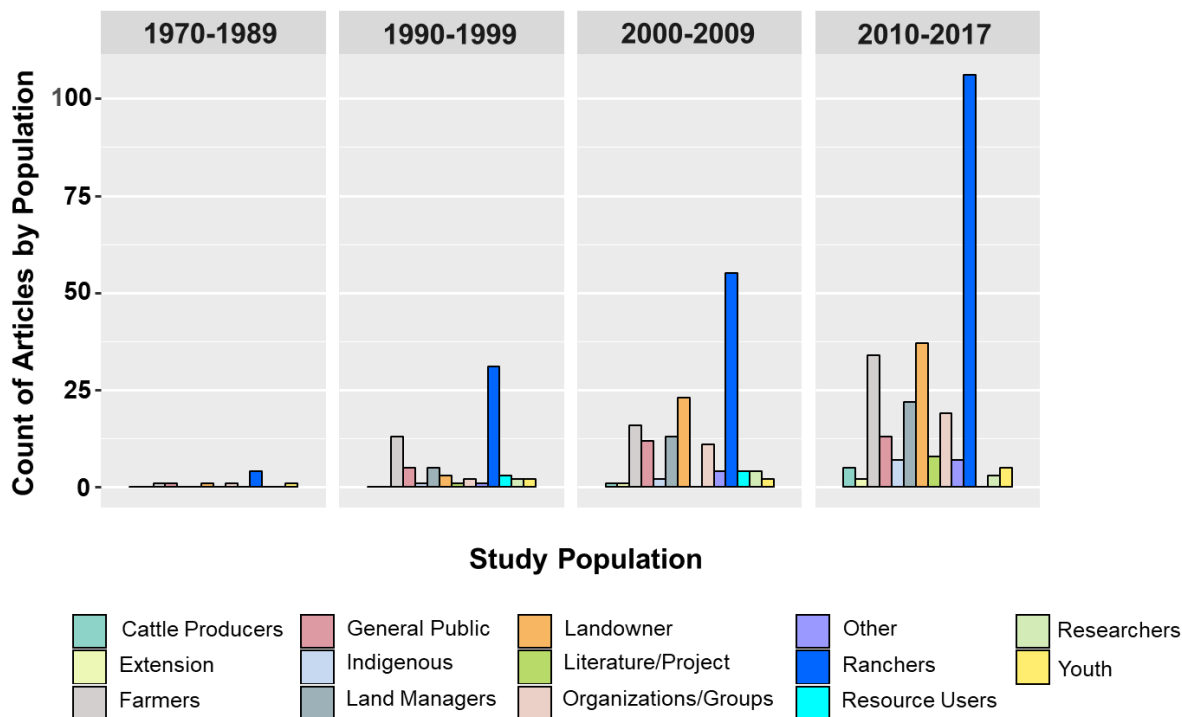


Figure 2.5. Article counts by decade with the bar color indicating the human population studied (ecological/agricultural populations not included). Category totals are non-cumulative with some articles classified into multiple non-exclusive categories. For instance, we coded Indigenous ranchers as both *Indigenous* and *ranchers*.

The most frequently used research methods are surveys (52%) and interviews (33%; Figure 2.6). The category totals for data collection methods are non-cumulative with some articles coding to multiple categories. For example, if a survey of predetermined questions was administered but it was preceded by exploratory interviews or had a standalone structured interview section, the article would be coded for both *survey* and *interview*. When temporally disaggregated, the dominance of survey and interview research remains consistent through the decades, but like with the study population, there is a greater diversity of data collection methods over time. Moreover, only 34% of the rangeland social science literature has been presented as grounded in a theoretical framework (Table 2.4). Forty-two percent of the selected articles explicitly named a collaborative partner, but only 8% of articles include a participatory element.

Table 2.4. The percent of the selected articles that state a research objective, question, hypothesis, and collaborative partner, and the percent of articles that employ a theoretical framework, methodological framework, and participatory methods. For all questions, 296 articles were coded, and responses were dichotomous with either *yes* or *no*.

	No. articles	% of articles (yes)
Research objective stated	289	98
Research question stated	80	27
Research hypothesis stated	207	70
Methodological framework considered	48	16
Theoretical framework considered	102	34
Collaborative partner explicitly mentioned	123	42
Participatory research component	23	8

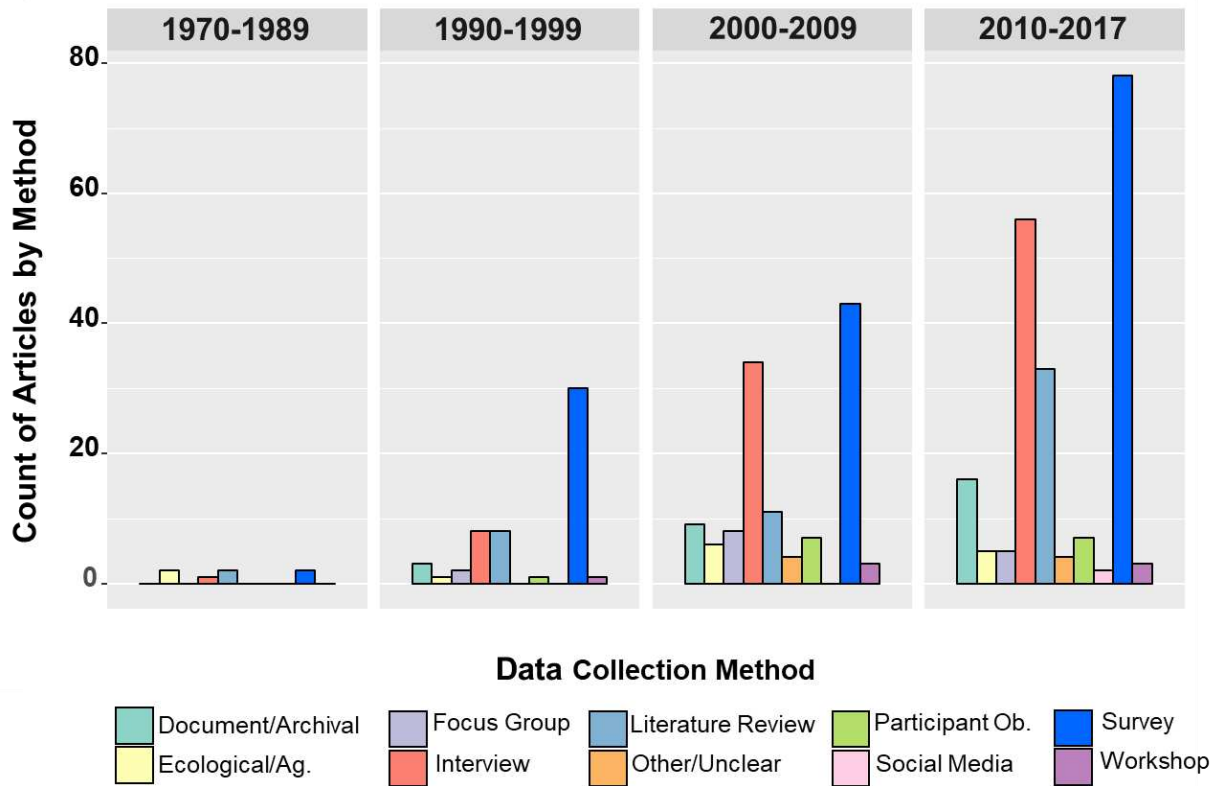


Figure 2.6. Article counts by decade with the bar color indicating the data collection method used. *Ecological/Ag.* serves as an overarching category to account for any biophysical data collection method (e.g., soil samples, precipitation measures) used in studies with both ecological and social research. Category totals are non-cumulative with some articles classified into multiple non-exclusive categories.

2.3.4. Content Analysis of Research Objectives and Questions

A content analysis of the research objectives highlights the prevalence in the literature of concepts related to adoption of technologies or conservation/management (53%). Within the subset of the literature on adoption, many papers consider management behavior (40%). The research in the adoption sub-set is often focused on attributes of sampled individuals or operations (63%), such as rancher attributes/identities (e.g., age, education) and operation characteristics (e.g., operational type and scale), that are associated with or predict adoption of innovations. While 38% of articles researched perceptions and attitudes regarding a technology or practice, only 17%

considered factors additional to attributes and perceptions, such as power, politics, and historical context. In addition to adoption, conservation (21%) and collaboration (13%) emerge as prevalent concepts, with the first paper coded to collaboration appearing in 1991.

2.3.5. Attributes and Identity

Both the content analysis of the research objectives and the close-ended coding applied to the full-text identified operation characteristics, such as operational scale and income, and their relationship to rancher attitudes or practices as the dominant focus of the literature (Table 2.5; Figure 2.5). In contrast, race or ethnicity (not mentioned in 82% of articles) and gender (not mentioned in 72% of articles) are the least considered attributes/identities. Additionally, only 5% of the articles consider power dynamics or marginalized social locations (e.g., women, racial or ethnic minorities, youth) in the rangeland social science literature. The below evidence gap map displays attribute/identity or operation characteristics on the x-axis and the dimensions for how attributes/identities or operation characteristics are considered on the y-axis (Figure 2.7). Figure 2.7 graphically highlights gaps where few articles exist and where there is a concentration of research. For instance, while a relatively high number of articles consider age (128 articles), only five papers examine how age intersects with other attributes/identities to marginalize individuals (e.g., succession challenges of older, low-income producers).

Table 2.5. The level of consideration of individual attributes/identities (e.g., gender, race or ethnicity), operation characteristics (e.g., operational scale), and dynamics of power and social location. For all questions, 296 articles were coded, and responses were dichotomous with either *yes* or *no*.

	No. articles	% of articles (yes)
Consideration of gender		
Used in analysis	38	13
Sample described	35	12
Mentioned	11	4
Not mentioned	212	72

Consideration of race or ethnicity		
Used in analysis	31	10
Sample described	7	2
Mentioned	15	5
Not mentioned	243	82
Consideration of age		
Used in analysis	64	22
Sample described	49	17
Mentioned	15	5
Not mentioned	168	57
Consideration of education		
Used in analysis	54	18
Sample described	41	14
Mentioned	23	8
Not mentioned	178	60
Consideration of class, socio-economic status, or income		
Used in analysis	93	31
Sample described	44	15
Mentioned	38	13
Not mentioned	121	41
Consideration of operational scale		
Used in analysis	96	32
Sample described	54	18
Mentioned	47	16
Not mentioned	99	33
Consideration of power and identity		
Power & intersecting marginalized social identities	16	5
Simultaneity of interacting social identities	47	16
No consideration	233	79

Dimension of consideration	Attribute/identity or operation characteristic					
	Operational scale	Class, socio-economic status, or income	Age	Education	Sex and gender	Race and ethnicity
Singular and stand-alone	152	122	87	74	52	23
Multiple, simultaneous, and intersecting	34	40	36	35	25	17
Multiple, intersecting, and marginalizing within structures of power	11	13	5	9	7	13

Figure 2.7. Evidence gap map for the rangeland social science literature. The numbers indicate the count of articles that research the attribute/identity or operation characteristic on the x-axis and the associated dimension of how these attribute(s)/identity(s)/characteristic(s) are considered on the y-axis. The color gradient represents the count of articles, with white representing a low count (0-25 articles) and increasing article counts represented by darker shades of blue.

2.4. DISCUSSION

While rangeland science conceptually acknowledges the connection between environmental concerns and social processes (Brunson, 2012; Hruska et al., 2017; Ostrom, 2009; Stoddart, 1965; Watson, 2005), the volume of rangeland social science literature in North America remains relatively small when compared to the associated rangeland ecology literature. For example, Sherren and Darnhofer (2018) analyzed REM and found that one out of 61 published papers in 2016 was social science and five out of 77 papers published in 2011 were social science. Furthermore, our results indicate that rangeland social science has focused predominately on ranchers, with limited consideration of gender, race, or ethnic identities. While a diversity of 121 journals published studies in the literature body, the majority was survey research from applied natural resource fields. In view of this relatively untapped potential, we focus our discussion of the preceding results on how rangeland social science can evolve to more equitably and effectively address pressing topics, rather than a critical appraisal of specific articles or questions.

2.4.1. Reaching Beyond Ranchers in Rangeland Social Science

The majority of the articles study ranchers, with less frequent investigation of other rangeland stakeholders such as natural resource management agency employees, ranch workers including guest workers, and the general public, for example. While ranchers are a critical population to engage as they have made and continue to make significant contributions to rangelands, there exists an opportunity to diversify the study populations engaged in our research. This research gap may link to knowledge gaps of how diverse rangeland stakeholders perceive new technologies, how they make decisions, and their attitudes towards rangelands. While many populations remain understudied, Barry 's (2014) research on the public's perception of rangelands on social media and Plunkett, Carolyn, and Knaub's (1999) gender-disaggregated research of farm and ranch adolescents undergoing family transition both begin the work of integrating a diversity of voices and viewpoints into rangeland science. To understand the diversity of management decisions on rangelands, we recommend more comprehensive consideration of all rangeland stakeholders. Research methods and methodologies such as stakeholder mapping (Bryson 2004) could support rangeland decision-makers, researchers, and Extension agents to better understand the varied social and economic systems of North American rangelands. Stakeholder mapping is used to identify participants in a system and understand factors such as their needs, level of engagement, and interests. In North American rangeland systems, we propose that stakeholder mapping could support our understanding of the diversity of people engaged in rangeland systems, their needs, and how they could be effectively engaged in future research.

2.4.2. Social identities and dynamics on rangelands

The existing rangeland social science literature has contributed significant knowledge related to adoption of innovations, but seldom considers how gender, race, or ethnic identities influence such decisions. Additionally, our results indicate that few studies consider class, or the intersection of multiple social identities (e.g., Indigenous women), and how these factors may affect

an individual's access to and management of resources. The content analysis of the research objectives and questions revealed that adoption of innovation and management behavior are the most frequently studied concepts in the North American rangeland social science literature. While operation characteristics (e.g., operation type or scale) and specific individual attributes/identities (e.g., age, education, income) are linked to concepts of adoption (Parente and Prescott 1994, El-Osta and Morehart 1999, Fernandez-Cornejo et al. 2007), the lack of research on topics such as gender, class, race, or ethnicity limit the research and Extension communities' understanding of diverse needs in rangeland communities. Moreover, an individual's relationship to the research process often affects their level of influence or perceived credibility, and the exclusion of people of color, women, youth, and groups of lower socio-economic status as research subjects or co-researchers can reinforce existing power dynamics (Harding 2006). While there is limited research that considers gender, ethnicity, or race, McCurdy and Kwan's (2012) study of ethnic and gender differences in rural youth and Arnold and Fernandez-Gimenez's (2007) grounded theory approach to collaboration on tribal rangelands serve as examples of works that consider these factors.

Beyond the inclusion of concepts of race, class, gender, and ethnicity, there is a need to consider how these identities interrelate. Rangelands as social-ecological systems exist within complex cross-scale political, ecological, economic, and social systems (Hruska et al., 2017; Huntsinger & Oviedo, 2014; Sayre, 2017). Gender, class, and race relate to dynamics of power within such systems, and rangeland social science's minimal consideration of these dynamics limits our understanding of how diverse stakeholders make decisions on the landscape. While Sayre et al. (2013) serves as an example of research that considers concepts of power, there remains an opportunity for rangeland social scientists to more broadly and deeply address how diverse identities, social locations, and power shape rangeland management and its outcomes. This gap could be addressed by engaging diverse researchers, such as feminist scholars, who focus on issues of inequity of gender, race, ethnicity, and class (Sprague 2016a). For example, intersectionality is a

feminist theory that considers the interactions between marginalized identities such as race, gender, and class (Crenshaw 1989, 1990, Davis 2008, Nash 2008, Sprague 2016a). Rangeland literature has explored the experiences of women (e.g., Wilmer & Fernández-Giménez, 2016) and Indigenous communities (e.g., Garcia-Bernal, 1994) on rangelands, but an intersectional framework would consider the unique experience of being an Indigenous woman, for example. Additionally, as the average age of manager populations increases, rangeland social science could build a better understanding of the experiences and challenges of range managers and ranchers throughout decision-makers' lifetime, and through various levels of physical ability, that address issues of ranch succession. For example, Fischer and Burton (2014) documented endogenous cycles of farm succession in Scotland, describing the co-creation of a 'succeedable' farm and a successor over time to better explain barriers to farm succession. We encourage rangeland social scientists to identify such knowledge gaps related to identity and power in rangeland systems. However, to address such gaps, the rangeland research community must also deepen collaborations with researchers from other fields, such as feminist and critical race studies. Just as economists and human dimensions researchers contributed to early rangeland social science, scholars from other social science fields and the humanities have the potential to contribute quality research that deeply explores and critically analyzes the social complexity and diversity of North American rangelands.

2.4.3. Diverse Social Sciences on Rangelands

Rangeland science (34% of the 296 articles) and human dimensions of natural resources (12%) represent the two most common academic fields in the sample, reflecting the prominence of integrated natural and social science research (Sherren and Darnhofer 2018). Specific to the social sciences, the following academic fields contribute three or more articles to the sample: economics (10% of the 296 articles), history (5%), geography (4%), anthropology and ethnobotany (3%), sociology (2%), education and extension (2%), social psychology (1%), and organizational sciences (1%). Social science is an overarching category of academic disciplines, and there are several

prominent social science disciplines or fields that are either under-represented or not found in our sample. The lack of prominent areas of study such as ethnic studies, communications, women's studies, and community development is notable. Research by rangeland scientists reviewed in this paper have popularized social inquiry on rangelands, such as the study of livelihoods (e.g., Coles & Scott, 2009), social-ecological services (e.g., Huntsinger & Oviedo, 2014), and cultural resilience (e.g., Wilmer & Fernández-Giménez, 2016). But, as rangeland demographics change (Sheridan 2001, Sagoff 2003), recreation continues to expand on public lands (Miller et al. 2001, Taylor and Knight 2003), and social and political change affects agricultural markets (Archer et al. 2008), rangeland social science will likely need to diversify to cope with such dynamic changes.

Peterson and Horton's (1995) use of mythic criticism of rancher discourse and Sluyter's (2015) analysis of Africans' impacts on cattle ranching in the Americas are examples of social questions, theories, and methods that are underrepresented in the rangeland social science literature. Peterson and Horton's (1995) use of critical theory on public policy discourse contributes knowledge on rancher perceptions and identity and serves as an example of the application of innovative social science approaches and methods. Additionally, only 5% of the rangeland social science articles are historical research, but this sub-set contains works that research Indigenous communities and the history of North American colonization (e.g., Garcia-Bernal, 1994; Sanderson, 2011). In a literature body often focused on the individual and applied management questions, such works contribute significantly to concepts of social dynamics and the historical context of rangelands. Further inclusion of more diverse epistemologies, theoretical frameworks, methodologies, and methods could expand how we study and understand rangelands as historical, cultural, and social-ecological landscapes. At the *Rangeland Social Science Gathering 2018*, leading scholars brainstormed that the implementation of rangeland social science curricula, the recruitment of social science faculty in rangeland departments, social science editors for REM, and interdisciplinary collaborations with social science principal investigators are actionable ways

to diversify and further develop rangeland social science (personal communication, January 26, 2018).

2.4.4. Opportunities for Interdisciplinary Research

The identified rangeland social science articles span at least 22 different academic fields and 121 journals from both the social sciences and natural sciences, suggesting the importance of rangelands to a diversity of social and natural science researchers. We also found significant contributions to the rangeland social science literature from the natural sciences, notably agriculture and animal science (e.g., Hendrickson, Sassenrath, Archer, Hanson, & Halloran, 2008; Laforge, Anderson, & McLachlan, 2017; Turner et al., 2016) and wildlife management (e.g., Irby, Saltiel, Zidack, & Johnson, 1997; Parks & Messmer, 2016; Stronen, Brook, Paquet, & McLachlan, 2007). In addition, the bibliometric citation analysis displays a high number of journals (57 journals) with low levels of citation by and of the central clusters (64 journals) of rangeland social science. This indicates that many researchers and academic fields are doing social research on rangelands but remain disconnected from the central rangeland social science literature body. Opportunities exist to cultivate broader research and perspectives through interdisciplinary research that integrates multiple academic disciplines (Tress et al. 2005). Such interdisciplinary work can extend our ability to address dynamic social-ecological challenges, such as climate change (Yung et al. 2015, Havstad et al. 2018), land-use change (Huntsinger and Fortmann 1990, Huntsinger et al. 1997, 2010b), and rapid demographic changes in the Western US (Lorah and Southwick 2003).

2.4.5. Diverse Methods for Diverse Inquiry

Survey (52% of the 296 articles) and interview (33%) research have made significant contributions to the rangeland social science literature (e.g., Brunson & Steel, 1996; Fernandez-Gimenez, McClaran, & Ruyle, 2005; Huntsinger, Forero, & Sulak, 2010; Lynn Huntsinger, Buttolph, & Hopkinson, 1997; Huntsinger, Johnson, Stafford, & Fried, 2010; Kreuter et al., 2005; Kreuter,

Amestoy, Ueckert, & McGinty, 2001; Liffmann, Huntsinger, & Forero, 2000; Meador, Meiman, Hild, Taylor, & Thompson, 2011; Sorice, Kreuter, Wilcox, & Fox, 2012). As our research questions change, it is likely that our methods will also diversify. For example, as we seek more knowledge on the subjective lived experience, an ethnographic or oral history study may be most appropriate. Additionally, a strength of the sample is that 42% of the literature listed the name of a collaborative partner, but only 8% of the research was evidently participatory. This demonstrates that while our research often involves collaboration, there is an opportunity to apply participatory methods when appropriate. The combined emphasis on lived experience, reflection, and reflexivity of participatory methods and methodologies could further contribute to our need for more inclusion, diversity, and consideration of power in rangeland systems (McTaggart 1991, Baum et al. 2006). In addition, much rangeland social science is not explicitly framed by a theory. We hypothesize that this gap is linked to the applied nature of the field. While this applied management approach has contributed significantly to range management, the use of theory enables researchers to build from and onto existing knowledge. For example, Toledo, Kreuter, Sorice, and Taylor (2014) explicitly apply social exchange theory (Cropanzano and Mitchell 2005) and Waage (2001) draws from the theory of nation-building (Anderson 2006), contributing to the application and development of theory in rangeland social science. Given the historical focus of rangeland science on applied questions, we have the opportunity to explore the complementary relationship between applied research and theory, using applied research to test theory and theory to guide applied inquiry (Hawkins 1978). In addition, greater theoretical contributions could further foster the application of social science theories, methodologies, and methods to the critical questions of rangeland science and other adjacent social science fields (Sherren and Darnhofer 2018).

2.5. IMPLICATIONS

2.5.1. Research Implications

Given the recent increase of peer-reviewed North American rangeland social science, this systematic map takes stock of what has been done and highlights knowledge gaps for researchers, funders, and practitioners. We speculate that social science on North American rangeland systems has been historically constrained by the limited rangeland social science curriculum and few opportunities for cross-disciplinary exchange. We propose that greater inclusion of social sciences in rangeland curricula and recruitment of social scientists into rangeland departments could contribute to the expansion of social inquiry in rangeland science and management. An analysis of rangeland curricula across North American universities could identify education gaps and illuminate opportunities for deeper integration of rangeland social science scholarship. Further, *Rangeland Ecology & Management* is the most prominent journal related to rangelands, but the identified rangeland social science literature spans 121 journals. This diverse distribution of rangeland social science suggests an opportunity to connect more broadly with researchers and fields that share a common interest in rangelands. While this research is focused on North America, future research could extend this systematic map and bibliometric research to the international rangeland science literature. We speculate that opportunities for collaboration and interdisciplinarity would emerge, most notably across the research traditions of the Global North and South.

A major gap revealed by this review is the relative paucity of North American social science research on rangeland stakeholders other than ranchers, landowners, and farmers, such as the general public and rangeland recreational users, to name a few. Thus, there are opportunities for future research, such as stakeholder mapping, that explore the diversity of rangeland stakeholders and their social, economic, and conservation networks. We posit that diversifying the research populations will lead to a shift in the research questions, and with this shift, there will likely be a

need to employ a wider breadth of research methods, methodologies, and theories. As rangeland science starts to engage more diverse populations and considers social identities and dynamics on rangelands, there are opportunities to learn from and collaborate with diverse social sciences such as feminist and ethnic studies. Finally, we propose that a next step of this map is a systematic review of the findings from the research body, especially on the large sub-set of adoption of innovation literature. Research questions could include: What factors are studied as predictors to or correlated to adoption, which have been significant predictors of adoption and how much of adoption behavior do they explain? What do we know about effective processes for promoting adoption? Just as the rangeland ecology paradigm strives to incorporate the complexity of rangelands at scale, rangeland social science must also capture the diversity of social settings to effectively contribute to sustainable and equitable resource management.

CHAPTER 3

AN INTEGRATED LIVELIHOODS AND WELL-BEING FRAMEWORK TO UNDERSTAND NORTHEASTERN COLORADO RANCHERS' ADAPTIVE STRATEGIES

3.1. INTRODUCTION

Rangelands cover 40% of Earth's terrestrial surface and are critical to approximately one billion peoples' livelihoods, predominately through livestock production (Sayre et al. 2013). Both globally and in northeastern (NE) Colorado, United States (US), rangelands – land on which the indigenous vegetation is dominated by grasses and shrubs but existing communities can include both native and introduced plants – are undergoing linked social and ecological transitions and transformations (Brown et al. 2008, Briske et al. 2015). In this context of social-ecological change, ranchers make increasingly complex livelihoods decisions (Wilmer et al. 2019). Still, mirroring critiques in social-ecological systems (SESs) thinking more broadly, decision-making frameworks in agriculture have yet to deeply integrate social and emotional factors – such as culture and well-being (Burton 2004a, Prokopy et al. 2019, Bruno et al. 2020). This study further theorizes the SESs sustainable livelihoods approach (SLA) by examining ranchers' subjective lived experiences, focusing on the social and emotional dimension of human well-being.

While rangeland scientists, among others, have conceptually and empirically linked social and ecological processes on rangelands, the need remains to deepen our consideration of social concepts and the interrelated emotional sphere (Brunson, 2012; Hruska et al., 2017; Huntsinger & Oviedo, 2014b; Ostrom, 2009; Westley et al., 2011; Westley et al., 2013). SESs are complex, adaptive systems of interconnected social and ecological relationships, where human decisions and actions affect ecosystem functions and vice versa (Ostrom 2007). Inquiry into human-environment (Grossman 1977) and people-nature (Sayer, 1979) relationships offered early thought on the

interconnectedness between humans and the environment (Judkins et al. 2008). Subsequently, the emergence of resilience (Holling, 1973) and systems thinking integrated concepts of feedback, boundaries, emergent properties, hierarchies, interaction, and self-organization (Steedman and Regier 1987, Turner et al. 1990, Liu et al. 2007b, Meadows 2008). While the study and application of SESs have grown, these systems' complexity continues to challenge researchers to measure and integrate both social and ecological variables across varying spatial extents and timeframes.

The simplification of the complex integration of the social and ecological dimensions in SES models facilitates shared understanding. Yet, models of culturally and place-bound processes, such as household and individual decision-making, must capture lived experiences at a higher resolution. SESs research struggles to match scales across the social and ecological spheres, often resulting in an aggregated examination of the social (Elsawah et al. 2020). Critiques of SESs emphasize the limited attention to culture, the political, and peoples' agency (i.e., our ability to make decisions autonomously and creatively) (Crane 2010, Coulthard 2012, Stojanovic et al. 2016, Schlüter et al. 2019, Elsawah et al. 2020). Thus, elements of the subjective life, especially concepts within the emotional sphere such as well-being, remain underexplored in natural resource decision-making, especially in rangeland systems (Crane 2010, Glaser and Glaeser 2011). Therefore, this study uses livestock producers' lived experiences from two communities in NE Colorado to further theorize existing SESs decision-making frameworks.

This paper uses qualitative data from interviews and participant observation to theorize the link between ranchers' livelihood decisions and their well-being, offering a framework to conceptualize social-ecological-emotional livestock systems. We then apply our proposed framework to illustrate ranchers' prominent adaptive strategies, examining the linkages between livelihoods and well-being.

3.1.1. Theoretical Frameworks

We initiated this research with existing knowledge of and interest in adapting the SLA to the context of NE Colorado. The focus on well-being emerged during the study and became a second critical framework for our data interpretation. We propose that the well-being framework and SLA are not substitutions but, rather complementary, with the SLA capturing micro-scale decision pathways and well-being considering the associated human outcomes. While SLA and well-being share several conceptual tenets (e.g., place-based), their implementation histories differ. We suggest that integrating the SLA and well-being frameworks could enhance both approaches.

3.1.1.1. *The sustainable livelihoods approach (SLA)*

As an alternative to "disciplinary reductionism" (Chambers and Conway 1991: 3) and the exploitation of rural people and places, researchers and development practitioners in the 1990s aimed to position rural perspectives at the center of knowledge and innovation development (Solesbury 2003). Sustainable livelihoods were conceptualized and subsequently incorporated into the United Nations' Earth Summit 1992 (Perrings 1994). We follow Chambers and Conway's (1991: 6) definition of livelihoods as: "the capabilities, assets (stores, resources, claims, and access) and activities required for a means of living." Inherent in this definition is the understanding that resilience (i.e., the ability to cope with and recover from shocks) and sustainability (i.e., benefits to the next generation) are critical aspects of livelihoods.

Researchers and practitioners have diagrammed the livelihoods framework in a diversity of configurations with slight variations in the capabilities/assets/capitals represented. For example, the United Kingdom's Department for International Development (DFID) depicts livelihoods as a pentagon of the five interrelated capitals of financial (e.g., income), natural (e.g., land), and social (e.g., community), human (e.g., labor), and physical (e.g., infrastructure) (Hussein 2002). The frame focuses on the impacts of macro-social and ecological dynamics on the micro-social scale (Binder et al. 2013). Aligned with the overarching critiques of SES theory, gaps remain in consideration of the

social sphere, most notably the limited attention to well-being, culture, political power, and self-identity. While community-level frameworks, such as the community capitals framework, include consideration of culture and politics, these dimensions among others remain underexamined in individual and operation-level decision-making frameworks (Emery and Flora 2006).

The overwhelming majority of livelihoods research focused on Africa and Asia (e.g., Kydd et al. 2004). Yet, we suggest that the livelihoods framework is a potentially valuable approach to understand a diversity of SESs, including in the Global North. Coles and Scott (2009) provided a notable exception as they applied the SLA in Arizona, US, using narrative analysis to reveal the interconnectedness and compounding effects of factors that influence livelihoods and explored alternative adaptive strategies of marginalized groups. While they conducted a livelihoods analysis for a specific social group, Coles and Scott (2009) stopped short of constructing a framework that could have broader applications. The current SLA framework fails to capture the nuances of US livestock producers' livelihood strategies. We posit that the SLA's lack of contextualization to the Global North contributes to the framework's limited use in the US. This research addresses this incompleteness by constructing a livelihoods and well-being framework from NE Colorado livestock producers' lived experiences. Such context-specific models offer applications in analogous systems and illuminate context-specific factors' effects in broader theory (Hong et al. 2014).

Lastly, previous research used the terms *assets* or *capitals* to refer to elements identified as having value by the participants. We argue that value can extend beyond monetization and that a diversity of valuation systems exists (Scholte et al. 2015, Jacobs et al. 2016). For many, factors such as family, faith systems, one's agency, morals and ethics, a sense of belonging, and friends provide value that extends beyond what economic systems can capture or those elements of our lives that are "invaluable." To reflect this understanding, we refer to *factors*, whether financial, social, or otherwise, that contribute to constructing one's livelihood. Also, we consider livelihoods

sustainable only when the health of both people and the natural system are maintained or improved long-term (Chambers 1992, 1995).

3.1.1.2. The well-being framework

The concept of well-being draws heavily from the field of human development while integrating concepts from diverse areas of study, such as livelihoods (McGregor and Sumner 2010). While multiple well-being indices exist, conservation and development practitioners and researchers have begun to converge on shared well-being principles. This conceptualization of well-being that captures the multi-dimensional interplay of the material (i.e., "what you have"), relational (i.e., "what you can do with what you have"), and the subjective (i.e., "how you feel about what you have and what you can do") has gained momentum (McGregor and Sumner 2010, Beauchamp et al. 2018). For instance, within this framing, an individual's high wealth levels (i.e., material) coupled with an inability to leverage this wealth to achieve their goals (i.e., relational and subjective) can result in low well-being overall.

Moreover, researchers increasingly acknowledge the effects of environmental management changes on human well-being (and vice versa) (Agarwala et al. 2014, Topp et al. 2015, Fry et al. 2017). With a SESs framing, Armitage et al. (2012: 3) modified McGregor's (2008) definition of human well-being as, "A state of being with others and the natural environment that arises where human needs are met, where individuals and groups can act meaningfully to pursue their goals, and where they are satisfied with their way of life." Dawson and Martin (2015) integrate well-being into an ecosystem services analysis to overcome social-ecological reductionism or a failure to acknowledge multiscale change, power, and the social sphere's complexity. Conceptualizations of well-being advance SESs thinking by acknowledging the differences in people's well-being, offering a more in-depth examination of the social sphere, specifically of emotional factors (McGregor & Sumner, 2010). For instance, individuals' well-being goals, pathways to well-being, and capabilities to pursue well-being differ (McGregor & Sumner, 2010). Beauchamp et al. (2018) examined this

heterogeneity of well-being in three communities in Cambodia, identifying how unique land-uses in each site influence peoples' well-being conceptualizations.

Despite the momentum of well-being in conservation and development work, much of the empirical well-being research in natural resources to date has positioned well-being as an outcome of human-environment interactions (Biedenweg et al. 2017, Beauchamp et al. 2018, Woodhouse and McCabe 2018). For instance, research programs consider how interventions can contribute to well-being improvements in human systems (Wongbusarakum et al. 2014). For example, the Puget Sound Partnership researchers, a coordinating body for the Puget Sound recovery in Washington, cocreated and integrated well-being indicators into an ongoing recovery program (Biedenweg et al. 2017). Research has less often considered well-being's role in initiating changes in human-environment reactions – our systems framing addresses this gap, examining how well-being outcomes feedback to livelihoods.

3.1.2. Study Areas

NE Colorado provides the context for this study. We selected two sites to contextualize the framework within the region (Figure 3.1). We defined the study area to include a site in northeastern (NE) Larimer County in the rapidly growing Front Range Urban Corridor (running north-south between Cheyenne, Wyoming and Pueblo, Colorado) and one more rural site in northcentral (NC) Weld County.

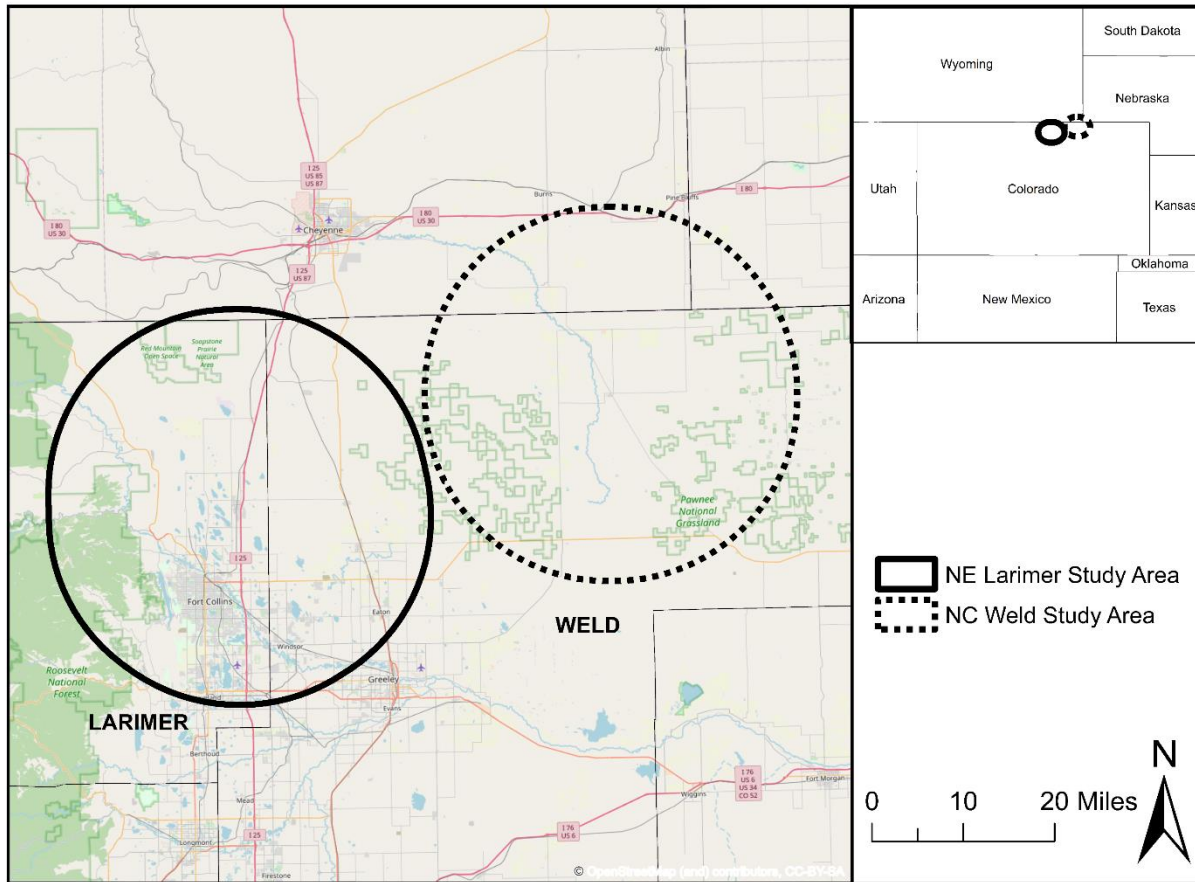


Figure 3.1. The study sites in northeastern Larimer County and northcentral Weld County, Colorado (ESRI 2011). The study area symbols indicate the average extent of participant agricultural landholdings.

Both sites lie within the semiarid region of the central grasslands of North America. The shortgrass steppe dominates the eastern extent of the NE Larimer site, transitioning westward into shrublands and, ultimately, forest in the foothills of the southern Rocky Mountains. The NC Weld site consists of shortgrass steppe punctuated by the iconic Pawnee Buttes (Milchunas, Lauenroth, & Burke, 1998). Following the forced removal of the Indigenous inhabitants in the late 19th century, the communities share livestock grazing histories on native vegetation, with cultivated land serving as the secondary land-use (Lauenroth et al. 2008).

The two study sites experienced divergent development trajectories at the start of the 21st century, however. In the Larimer study site, the population boomed 135.4% from 2000 to 2010 (United States Census Bureau n.d.). Larimer County and associated cities have worked to balance exurban growth with conservation goals (Resnik et al. 2006, York et al. 2011). In comparison, the NC Weld County study site experienced a -10.5% change in population from 2000 to 2010, and some neighboring communities were abandoned (United States Census Bureau n.d.). Moreover, while agriculture has remained central to many Weld County towns, several communities are increasingly economically dominated by the oil and natural gas industry, including our study site (Davis 2012). We selected these two adjacent sites with divergent development trajectories to capture the diversity of agricultural communities in NE Colorado.

3.2. METHODS

3.2.1. Methodology

We used an iterative methodology informed by constructivist grounded theory (Charmaz 2006, 2008). Grounded theory is a systematic methodology that analyzes contextual data to integrate or develop broader theory (Guetterman et al. 2019). Our initial analysis began using inductive methods. Because constructivist methodology acknowledges *a priori* knowledge, as some themes emerged, we acknowledge the alignment of our initial themes with existing frameworks. Thus, we used a deductive approach to relate emergent themes with existing frameworks' terminology when relevant. Using inductive analysis allowed us to identify unexpected and novel themes that described participants' perceptions and how they construct a living or livelihood, and deductive analysis enabled us to relate our proposed framework to the existing literature. Our iterative methodology of both inductive (identifying patterns) and deductive analyses (understanding patterns) facilitated ongoing scrutiny of the data and interpretations (Figure 3.2). This study offers an early contribution to theory, and we encourage applications and adaptations to new sites and systems, advancing the generalizability of the proposed framework (Firestone 1993).

3.2.2. Data Collection

The first author collected data through participant observation and 26 semi-structured interviews with 32 producers in the summer and fall of 2018 and 2019. (Figure 3.2). We collected all data under Colorado State University human subjects Institutional Review Board protocol 040-19H. Participant observation is a means of observing daily life from the participants' standpoint (Goffman 1989, Sprague 2016b). The first author engaged in participant observation on one participant's ranch for two weeks, conducting daily chores, recording field notes, and memoing throughout the experience. The first author met community guides during participant observation who introduced her to research participants and invited her to introduce this study at a community meeting. The first author continued to participate in workdays on multiple operations throughout the study period.

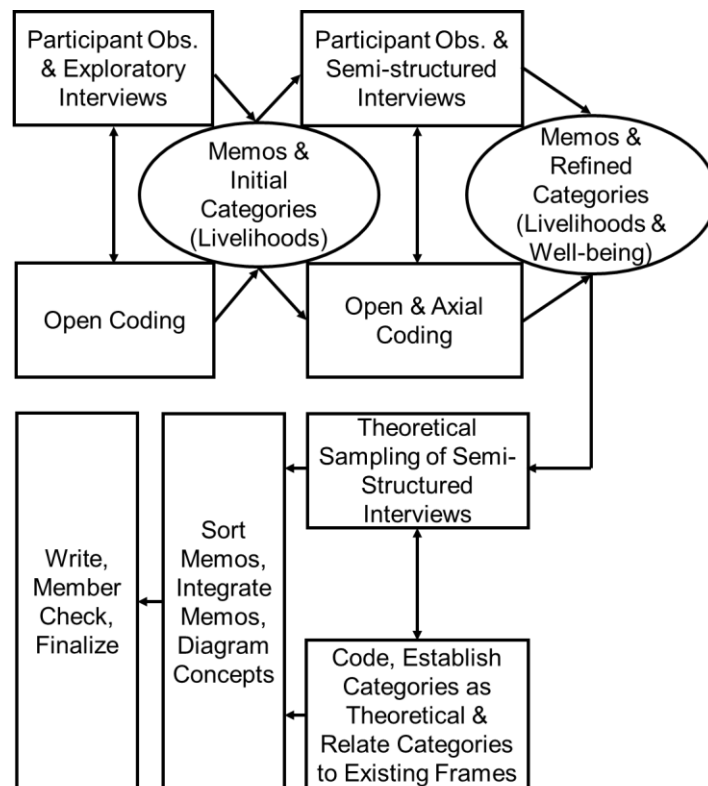


Figure 3.2. Diagram of the iterative research process from which we derived an integration of the sustainable livelihoods approach (SLA) and well-being (WB) framework (adapted from Charmaz 2006).

All 32 interview participants identified agriculture as an occupation and reared livestock, including cattle, sheep, and goats (Table 3.1). While most participants also had cultivated crops, we use the term *rancher* throughout this chapter as all interviewees had extensively grazed livestock. Participants ranged in age from 37 to 90, including both first-generation and multi-generation producers. While race and ethnicity are critical to experiences and social factors, we do not disclose participants' race and ethnicity to ensure anonymity.

Table 3.1. Characteristics of interview participants.

Characteristics	Participants (n=32)
Gender	
Women	13
Men	19
Geography	
Northeastern Larimer	15
Northcentral Weld	17
Interview Mode	
Individual	20
Couples	12
Production Status	
Retired	5
Active	27

The first author conducted all interviews, with interviews averaging 100 minutes and often involving a tour of the operation. At the start of the research, we used snowball sampling or the recruitment of subjects by existing participants (Johnson 2014). Our initial interviews were exploratory with prompts such as, "How did you become a rancher or farmer?" and "Can you walk me through your typical day?" As inductive data collection and analysis progressed, we framed our semi-structured interview instrument around livelihoods. As the concept of well-being emerged, we modified the interview protocol to address well-being outcomes further (Appendix D). To support

the emergence of theory, we transitioned from snowball to theoretical sampling (i.e., selecting participants to support theory development) (Coyne 1997, Breckenridge and Jones 2009).

3.2.3. Data Analysis and Trustworthiness

The first author coded the interviews and participant observation memos using the constant comparative method (Strauss and Corbin 1994, Charmaz 2006, 2008) in RQDA (Huang 2014, R Core Team 2019). Using inductive analysis, we explored what concepts were significant and frequent, then collapsed these into axial codes before determining how themes related to one another (Strauss and Corbin 1998, Charmaz 2006, 2008). We conducted theoretical memoing, clustering, and selective coding during subsequent analyses, during which we integrated preliminary findings into late-stage interviews to facilitate discussion with participants. The data collection cycle and analysis continued until we achieved categorical saturation, allowing us to construct our grounded theory (Saunders et al. 2018). In diagramming our integrated theory, we deductively drew parallels to naming conventions of existing frameworks when appropriate. For instance, we collapsed *on-operation labor* and *personal attributes* and deductively labeled the category *human factors* to align with existing conventions.

We applied Lincoln and Guba's (1986) criteria to ensure the trustworthiness of our analysis. The iterative, multi-method design facilitated prolonged engagement with participants, supporting understanding, trust, iterative questioning, and triangulation. Additionally, we maintained an audit trail with the first author engaged in reflective commentary through memoing and peer debriefing. We achieved theoretical saturation, seeking counterexamples throughout the analysis, and lastly, we presented the research findings to producers (member checking) and revised them when appropriate.

3.3. FINDINGS

First, we present our integrated framework and ground the components of the proposed framework in our data. Specifically, we share findings of the seven livelihood factors (i.e., financial,

natural, social, human, physical, political, and cultural). Second, we outline well-being outcomes (i.e., material, relational, and subjective). Next, we present livestock keepers' framing of the study sites' broader social and ecological context. Lastly, we employ our framework to illustrate the following three adaptive livelihood strategies (i.e., producer decision pathways in the face of change): contraction, expansion, and diversification (Table 3.2).

Table 3.2. Overview of the livelihood input factors, livelihood strategies, and well-being outcomes. Given our inductive approach, all components emerged from our data, and we subsequently explored their presence in the literature.

Livelihood Input Factors	Livelihood Strategies	Well-being Outcomes
<p>Financial Economic resources (e.g., savings, investments, income, cattle, land, home equity) (UNDP 2017)</p>	<p>Contraction Reduction of business activity and operation scale (e.g., sale of animals or land)</p>	<p>Material Assets, income, ecosystem services, health, and wealth (Armitage et al. 2012)</p>
<p>Natural Natural stocks that people can draw on (e.g., land, forests, and water) (Scoones 1998)</p>	<p>Expansion Increase in economic activity and growth of operation (e.g., purchase of animals or land)</p>	<p>Relational Social resources and relationships that contribute to identities and personal action (e.g., social, political, cultural) (Armitage et al. 2012)</p>
<p>Social Social resources (e.g., family, community, cooperatives, and grazing associations) (Scoones 1998)</p>	<p>Diversification Variation of the range of products or areas of operation either on-operation (e.g., vertical integration within the beef sector, conservation easements) or off-operation (e.g., a family member's job in town)</p>	<p>Subjective Self-reported quality of life, aspirations, and emotional health (e.g., happiness, security, satisfaction) (Armitage et al. 2012)</p>
<p>Human Individual attributes (e.g., work ethic), knowledge, and physical capabilities (Scoones 1998)</p>		
<p>Physical Human-made objects (e.g., infrastructure, technology, tools) (Serrat 2017)</p>		
<p>Political Access to power, organizations, or individuals that influence</p>		

governance and resource management (Ribot and Peluso 2003, Flora et al. 2004)

Cultural

Way of life, heritage, and beliefs that create shared meaning for a social group (Flora et al. 2004, Pretty 2011)

3.3.1. Integrated SLA and Well-being Framework

The emergent integrated SLA and well-being framework illustrates how livestock owners draw upon seven factors to assemble livelihood strategies for improved well-being (Figure 3.3). The framework captures the influence of social and ecological change (e.g., drought and market downturns) on producers' livelihood factors and well-being. In turn, these changes drive livestock keepers to adapt their strategies to maintain or increase their well-being outcomes. Impacts on the livelihood factors flow through the system to influence the well-being outcomes and vice versa.

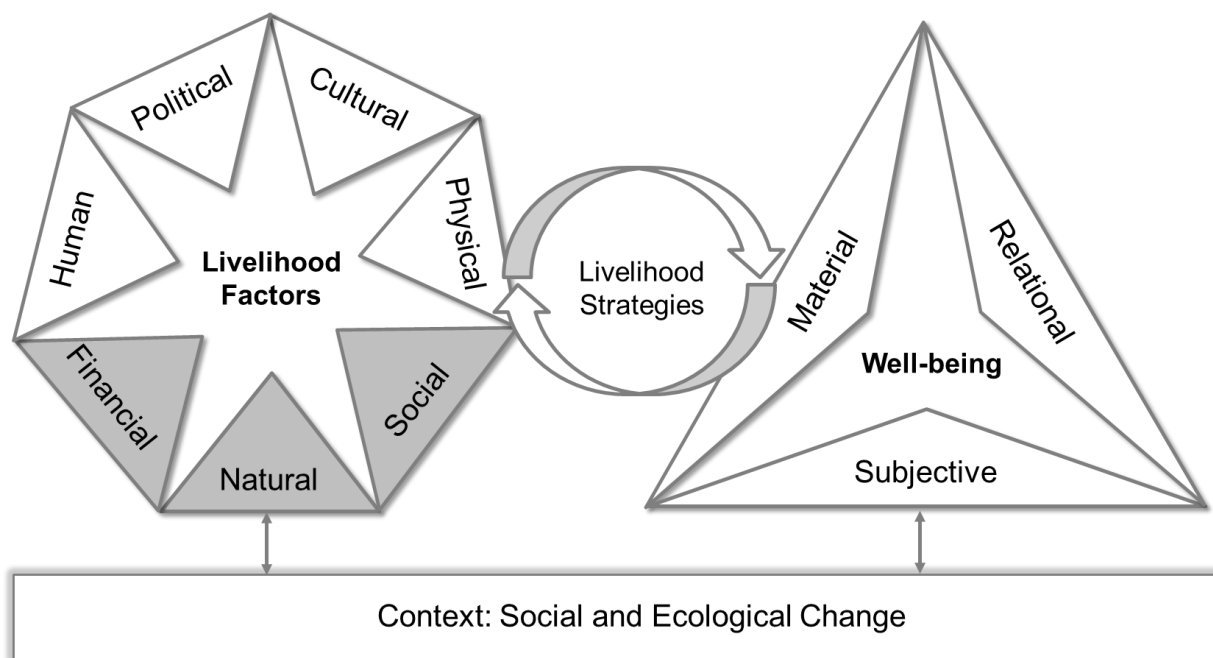


Figure 3.3. The integrated sustainable livelihoods approach and well-being framework for northeastern Colorado livestock producers. Within the context of rapid social and ecological change, livestock producers interrelate these seven livelihood factors (i.e., financial, natural, social,

human, physical, political, and cultural) to create strategies to improve their material, relational, and subjective well-being. Financial, natural, and social factors are represented in grey as foundational factors or those essential to how producers conceptualize their livelihoods. Feedbacks between well-being outcomes and livelihood factors facilitate cycles of accumulation or loss.

3.3.2. The Foundational Livelihood Factors (Financial, Natural, and Social)

Livestock keepers identified financial, natural, and social factors as foundational, or essential, to how they conceptualized their livelihoods. Participants recurrently emphasized the significance of these factors. Ranchers presented finances as foundational to the existence and future of their operation. For most, livestock is what "brings in the money, so you have to figure out a way to pay for everything with them" (R11). One Weld County couple identified financial strategies as differentiating rural, family-owned businesses from multinational companies like the meat processor JBS. They explained:

[Making money in the middle is] generally rural America's attitude, and then, JBS is a Brazilian-owned company and purely a corporate-owned structure, and that is very, very money-driven. Of course, we are money-driven too. That is the name of the game. You need to make money. It is the management in the middle that we really concentrate on. (R1)

The couple continued to articulate that rural US producers deviate from multinational corporations' "cookbook formula." They clarified that "we try to make our strengths where their weaknesses are, and that has been our success" (R1). They perceived large companies as "volume" driven, while the money in rural America is made "on management" (R1). Wilmer et al. (2019) found that ranchers were "managing for the middle," or mitigating risk and variability by employing management practices that strike a balance between competing responsibilities. Similarly, we found that instead of focusing on a singular strategy (e.g., large cattle numbers), ranchers made a series of management decisions to balance their gains and losses across different factors (i.e., "management in the middle"). Moreover, the below rancher expressed the significance of the financial to other factors:

If you are successful financially, it will help things a lot to keep the peace [in the family], so to speak. It's not near as hard to keep everybody focused and keep things going well if

you're making enough money for people to be comfortable. So, I have strong emphasis on the financial and also a strong emphasis on everybody getting along. (R29)

There is not always a clear distinction between financial and natural resources in US farming and ranching (Vitiello and Wolf-Powers 2014). For example, private land or grazing privileges (e.g., public land grazing leases) can function as financial assets (and liabilities), often serving as collateral for annual operating loans. Our proposed framework recognizes this fluidity while also acknowledging the unique roles of natural and financial factors in shaping livelihood strategies and supporting well-being. One northeastern Larimer producer captured this need to balance the interplay between natural and financial factors:

It boils down to managing your limiting functions. And so, in general, when you look at it from a resource perspective, the limiting functions are soil, water, sun, and money ... How do you manage all this stuff in a way that you can be a steward of your resources, utilizing them in a reasonable way, but also have the money to do so? (R10)

Despite participants' emphasis on strategies that cultivate balance, especially between financial gains and the longer-term management of natural resources, they still experienced the vulnerability of natural resource-dependent livelihoods. Below, one rancher captured the inherent but tenuous relationship between nature and her well-being:

I am dependent upon whatever falls from the sky, so there are some years where we are in better shape than others because we had a wet year, etc. When it is a dry year, not only am I dry, but that means that hay is short. (R3)

Social factors are also foundational and interrelated with financial and natural elements, but participants stressed that rural, agricultural communities' social context is changing. Interviewees discussed how social change affects their relational well-being, with some producers experiencing a shift towards more social factors and others less. Aligned with this disparity of experiences, producers related ownership of scarce and high-value natural resources – such as oil, water, and land – to political and social factors that influence power dynamics. One rancher stated, "Owning [water] gives some clout; you sell it, you lose the clout" (R8). Here, we draw upon Ribot and Peluso's (2003: 154-155) framing of "access as bundles and webs of powers that enable actors to

gain, control, and maintain access." Through this lens, the ownership of scarce water rights in the context of high urban and industrial demand for water in much of the western US affords access to social and political factors, which in turn facilitate further access to power and resources. Yet, as SESs shift, the valuation of resources change, altering access and, in turn, social dynamics (Ribot and Peluso 2003).

Moreover, participants emphasized that as operators of family-owned ranching businesses, their businesses' and families' well-being are tied to their social relationships. For instance, one couple discussed how other local producers contribute to their operation, and therefore, they reciprocate support to enable the future of local business:

Our main source of income is cattle feeding, and our land is geared towards feed crops to support our feedlots, but all of our neighbors sell cattle to us. So, if they are experiencing a drought, we will move up our timeline on when we purchase our calves to when they are running out of feed. Or we will take some of our irrigated land and sell them some of our feed so that they can get through the drought times. A lot of that comes through the church because a lot of the people that we deal with go to the same churches. (R1)

Participants emphasized how strong community relationships through institutions such as schools, churches, and associations enable producers to support each other's adaptive capacity. Yet, despite the significance of social factors, one Weld County farmer shared:

During the last election, I've seen our country spread apart further than I'd ever seen in my life, and that really bothers me. And it was almost getting to the point that when you go to a social event, are you going to sit with a Democrat or are you going to sit with a Republican? Because [if] we sat with a Republican, the tension is a little bit higher than what it is if you sat with a Democrat. (R19)

Above, the farmer illuminated how county-level change has negatively affected his and other peoples' social factor, specifically their social networks (Cash et al. 2006).

3.3.3. Human and Physical Factors

Juxtaposed to the necessity of financial, natural, and social factors in establishing and maintaining a livestock operation, participants presented human and physical factors as those used to grow their operations further. In many cases, livestock keepers discussed human and physical factors as substitutes for one another. For instance, changes in technology (a physical factor) have

reduced labor needs (a human factor). One producer shared how, unlike his father's generation, he comfortably and efficiently drives out "in a heated cab with a radio going, and feed[s] 350 head of cows, and it takes 20 minutes" (R25).

Participants emphasized that the human factor – attributes, knowledge, and physical abilities –required to ranch and farm have changed over the years. One producer stated, "Years ago when my poor father started ranching, why it was a lot of physical labor. Now it's much more management, administrative" (R29). More than expertise and labor, interviewees emphasized the significance of personal attributes required for success, such as morals and resilience. When asked about the essential elements of being a rancher, one producer stated:

I think you need to be well-read. I think you need to be able to communicate well with the outside world and with the people around you. There's just a whole bunch of things I guess I'd have to say that are important. You need to be able to roll with the punches. You need to be able to handle adversity, handle disappointment, handle change. Handling change is a very key component of virtually any business, I think. Being able to take a situation that's foreign to you and keep moving on in spite of the problems. (R29)

As seen above, participants expressed that personality and life skills are critical to one's resilience as a rancher or farmer.

In terms of physical factors, participants discussed how technology has decreased labor demands, often increasing their subjective well-being. For some, technology, such as cameras, enabled them to "just roll over in bed and look at my phone" (R21) to check the calving barn. Yet, technological advances may not be accessible for all producers, and as one participant shared, "I could see a lot of, just technology being the future. If you don't embrace it, I'm afraid it'll run over you" (R21). Interviewees also shared concerns about overinvesting because all the equipment has to "pay their own way" (R25).

3.3.4. Political and Cultural Factors

While researchers and practitioners rarely integrate political and cultural factors into the SLA, this study supports Baumann's (2000) proposed inclusion of political factors. Participants identified access or "the ability to benefit from a thing" as central to political and cultural factors

(Ribot and Peluso 2003: 153). One participant outlined his use of political factors to inform resource governance:

A dispute with the neighbor over surface water has forced us to form groundwater management districts, which are governed by the people within the district. The people that gave us the most support are the ones that are still giving us support, and they will be the directors of the groundwater management district. (R1)

Aligned with Ribot and Peluso's (2003) theory of access, the above farmer leveraged his social network to negotiate resource governance that maintains his access to water. Participants' framing of social factors as foundational aligns with the theory of access' claim that power emerges from social relations (Ribot and Peluso 2003, Peluso and Ribot 2020).

In contrast, other participants expressed limited access to political factors, especially political power. Several participants felt that their rural identities limited their access to political influence, citing a lack of representation for rural people and places at the national, state, and in some cases, the county levels (Ribot and Peluso 2003). One participant articulated that national and state-level politicians "don't understand the concept of rural America. Yeah, it doesn't really get heard. If you live in the flyover states, that's exactly what you are" (R18). Most participants expressed that they feel more meaningfully engaged in local-level politics. For example, one participant voiced contention with national-level policies but support for state and county-level staff of the national Farm Service Agency (FSA) because they "actually live" (R18) in the communities and can make changes. Several participants served on the local school board, the County Agriculture Council, numerous conservation initiatives, and several other local efforts. While participants discussed the adverse effects of federal and global policies and institutions on their material well-being, they dedicated years of primarily unpaid work to local institutions to support the social and cultural aspects of life that contribute to their relational and subjective well-being.

For some participants, cultural factors, such as their family's history on the land, supported their commitment to agriculture. While sharing her relationship to her family's pioneer history, one

producer said, "You cannot live out here with the wind and not feel [that connection]" (R3). But, as a retired Larimer County producer shared, this way of life is changing for many:

Culture? I have seen a lot of change, like going from horses to tractors to all this modern equipment, you know. The elimination of labor, computers running, tractors running, the evolution of irrigation. You know? Farmers today do not irrigate like I did. I used to shovel. These people use a computer and a pad. You know? I was still of that generation. The culture, it's real. To me it is upsetting because the owners of the land are detached from it. The farmers that operate it just own equipment. (R4)

Above, the farmer reflected on how shifts in the practice of agri-culture affect peoples' relationship to the land, capturing the linkage of natural and cultural factors (Flora & Thiboumery, 2006; Pretty, 2011). Such disconnection from the land can drive declines in cultural factors, cascading to affect identities, livelihoods, and well-being (Pretty 2011).

Yet, some participants viewed cultural shifts as an opportunity for advancement (Little 2013). For instance, when asked if he experienced policy constraints, a first-generation Larimer rancher said, "I think social expectations probably have limited me and limited more people than politics do." He continued:

Well, I think we tell ourselves time and time again that you can't walk on the moon, right. You'll never be an astronaut. Well, as soon as you start telling yourself that – as soon as you let society tell you that's just impossible, that just doesn't happen – you start believing in it, and then it's done. It's gone. And I think that's more powerful than any law would ever be. (R10)

For the first-generation producer above, his lack of multi-generational history in agriculture allowed him to work "outside the margins" (R10). Below, one Larimer rancher shared his response to his community's changing demographics:

I try to understand people and then deal with it in a positive attitude. Because I mean, things aren't like the good ole days, are they? So, you just have to understand that. So, when the lady drives in here and says, "Your cow is dying." You just kind of look at them like this is a teaching moment. "Would you and your little girl like to go out there and watch her have her baby calf?" (R16)

Above, the participant shared his livelihood strategy that supports his cultural resilience in response to change (Crane 2010). He acknowledged his experience of cultural loss while also adaptively responding to change by educating community members about his way of life.

3.3.5. Well-being Outcomes (Material, Relational, and Subjective)

Well-being consists of three interrelated dimensions: material, relational, and subjective. When producers discussed shorter-term decisions in response to episodic challenges, such as drought, they focused their livelihood strategies on maintaining their material well-being. One couple described how the ability to maintain the material well-being of their business drives their decision to continue their operation, which in turn contributes to their identities as businesspeople:

[We are] mostly economically driven. I don't like that idea that we are farmers because that is what we want to be. We do it because we make money. We run it as a business. And of course, we like what we do, but we wouldn't do it if we didn't make money. (R1)

The connection between identity and the material outcomes (i.e., we are not farmers; we are businesspeople) emphasizes the importance of material well-being to other facets of participants' livelihoods. For instance, although material well-being is easy to articulate and often a short-term priority, the material has implications for relational and subjective well-being.

While producers frequently focused on material outcomes in response to near-term perturbations (e.g., extreme weather and economic downturns), they often oriented their longer-term decisions around the relational dimension of well-being. Producers especially emphasized that family was the core of their complex social webs. From stories of parents driving through the night to help with calving season to a son unwilling to sell the operation because it is his mother's home, producers presented family as a driving force behind their long-term livelihood decisions. In addition to family, many producers expressed gratitude and a sense of well-being as they recounted community support during tornadoes, family losses, and illnesses. Still, in the context of rural change, older participants expressed losses to their relational well-being. For example, some struggled with the loss of "neighboring" culture or close community bonds. One retired participant shared, "In the old days, I think, that the farmers talked, and they associated with each other when I was growing up. But then in the 80s, it was starting to break-up" (R4). He believed that the challenges of the economic downturn created divides. Instead of fostering support through

community social networks, people said, " I am not in that group, and I don't want to know about your problems" (R4). Moreover, when asked about change in his community, one Weld resident shared:

[Community change] upsets me. We had a bowling alley in [place name] [that] they built in 1960 or so, and during my lifetime, I'd go [to] that bowling alley. In the back, they had a roller-skating rink. A lot of the people in the community bowled, and it was just a central community entertainment deal. This one guy bought it, and he didn't keep it up. People got mad, and they wouldn't come and stuff like that. So, I told him how I felt about it, and he said, "What the hell? It's mine. You don't need to tell me about how to run this business." Well, I do because this has been a source of my entertainment for lots of years, and you're screwing it up and it's pissing [me] off. Well, there's nothing in [place name] now. (R19)

This participant shared how the loss of rural public spaces can negatively affect well-being.

As the last quotation captures, the subjective dimension of well-being is interrelated with the material and relational. While participants often led with the importance of finances, the conversation frequently transitioned to reflective dialogue about people's relational and subjective well-being. For example, as we stood outside during a cold fall night next to a producer's favorite animal, she shared, "We live out here because we want our skies" (R13). Here, the producer captured how a connection to place and the environment (natural factor) contribute to some people's subjective well-being. She shared how nature's role in her relational and subjective well-being drives her and her husband's major life decisions, including their occupations.

Alternatively, another producer shared how the challenges of livestock production can negatively affect subjective well-being:

We always talk about management and things like that. But, how do you deal with the stressors of what you do? Because we look at the business side of it, and in normal industries, you get to leave. When I bail out of bed, I'm at work. When I go to bed, I'm still at work. How do you deal with constantly being bombarded? (R11)

The producer positioned ranching outside of "normal industries," suggesting a need for tailored support for people engaged in farm and ranch work. Some producers expressed interest in education and programs around communication skills, fostering a sense of community, and mental health. The above producer identified a need for facilitated peer-to-peer discussions about

ranching's personal and management struggles, cultivating space for dialogue and connection among people with shared experiences.

While participants shared the challenges of ranching, they also conveyed their appreciation for their way of life. One producer said, "I go out there and ride through [the fields] with the four-wheeler every day. I enjoy that. I really enjoy that, talking to the cows." He goes on to say, "Well, I'm already living the dream. Yeah, with a little bit of oil and stuff. I took a picture for my mom, and it's a picture of ... ten oil tanks and an oil well, and there's cows on green grass" (R17). This producer's subjective well-being and access to oil income help mitigate some of his challenges, such as political disempowerment. Still, he shared that these challenges were manageable given his close relationships with other community members (i.e., relational), financial security (i.e., material), and appreciation for his way of life (i.e., subjective well-being). A different Weld County producer reflected on how his money went to his family, which created a life worth living:

When we had \$1,700, I said, "That's a wonderful number." [My wife] said, "What's so wonderful about that?" I said, "Well, geez, look at it like this." I said, "When you and I got married in 1971, we had \$1,700. We raised two kids, our house is paid for, and we still got the \$1,700. We sent them to college; we still got the \$1,700. What more could you ask for?" (R19)

Above, the participant shared how his balance across the triad of material, relational, and subjective outcomes created a resilient state of well-being.

3.3.6. Social and Ecological Change in Northeastern Colorado

When asked to discuss their histories as livestock producers, participants recurrently shared the significance of change. Yet, participants often expressed different sentiments regarding change. For instance, one Weld County producer explained the progressive abandonment of eastern Plains communities:

There are other towns that I knew about when I was a kid. A town called [place name] that is completely gone - you just find foundations there. And you go on down the road, there's a little town called [place name], and it's got some empty buildings there, but nobody lives there. And you go on to Highway 14, and you come to a little town called [place name], and it's gone. (R19)

One retired Larimer farmer predicted a system transformation:

I think in this area agriculture will die. As Florida gets deeper and deeper into the water, they are going to move up here to stay dry, and we are going to farm Iowa and Nebraska and places where there is more productive land than this. We are going to put houses here. (R4)

While the above farmers shared past and projected future losses due to change, one multi-generation rancher reflected that technology changes have positively facilitated "the coming together of the rural and urban societies" (R29). He continued to explain how these changes, specifically those that have increased communication and mobility, have positively affected the ranching community's subjective well-being and agricultural productivity:

I think agriculture in general, because of [advancements in technology], is more able to take advantage of opportunities, is better managed than it ever used to be. I guess that's the best way I can put it. I just think that people are happier out there, and they perform better, and the ranches are more successful. That they exist has been a great consolidation of our issues. But, in general, the whole ranching business is much more able to survive when they know what the rest of the world is doing. (R29)

The above rancher emphasized the interconnection of ranching to larger economic systems that drive change at the local level. Given the context of change, a common question remained: How do producers use their resources to develop adaptive strategies to shape desired livelihood and well-being outcomes? For example, after learning about predicted shifts in native plant communities in response to increased carbon dioxide levels, one Weld producer inquired, "How will I adapt to the new plant community?" (R7). Similarly, a Larimer producer asked, "As urban sprawl occurs, is society going to be welcoming to traditional agriculture? Are they going to be expecting agriculture to look different?" (R10).

3.3.7. Adaptive Livelihoods and Well-being Strategies

Below, we use our integrated livelihoods-well-being framework to illustrate four cases of producer decision-making in response to social or ecological change. The first case depicts a cycle of decline. In contrast, each of the other three cases illustrates a distinct strategy used to maintain or increase well-being during shocks like drought or economic downturns.

3.3.7.1. Cycle of decline

Livestock producers identified shocks and stresses such as extreme weather, family health crises, urbanization, and severe economic downturns as events that drive a cycle of decline, as the Weld producer in Figure 3.4 narrates. Some livelihoods research frames such exoduses from agriculture as a livelihood strategy of migration (e.g., Scoones 1998). We observed migration out of agriculture not as a strategy but as a forced transition in which producers have restricted agency.

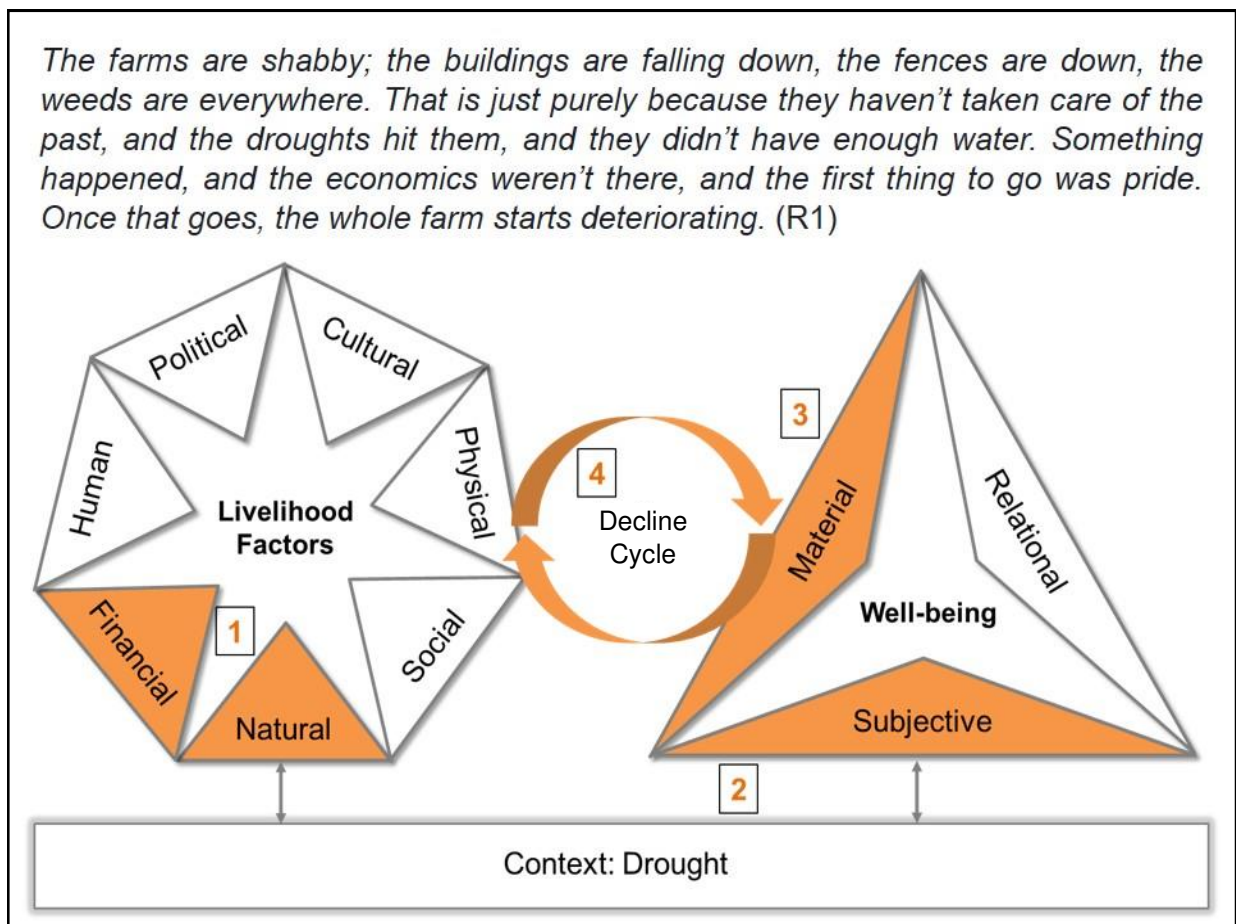


Figure 3.4. The integrated sustainable livelihoods approach and well-being framework for northeastern Colorado livestock producers capturing a multi-factor cycle of decline, with orange depicting losses. (1) First, the operation was hit with drought, further challenging the financial factor. (2) The financial and natural losses influenced a loss of pride or subjective well-being. (3) This loss of financial, natural, and subjective well-being affected a decline of material well-being. (4) Lastly, these losses sparked the system transforming decline cycle and migration out of agriculture.

3.3.7.2. *Avoiding the cycle of decline through contraction, expansion, or diversification*

While livelihood strategies are complicated and specific to the operation's context, we identified three broad livelihood strategies that producers used to avoid cycles of decline when challenged: contraction, expansion, and diversification.

For one small-scale Larimer rancher, limited resources require contraction in response to challenges:

I try to figure out what is the minimum that I can deal with ... I have sold a lot of lambs this year that I might have kept otherwise, and I probably have another load, probably 10 to 20 more, that needs to go. I have sold all of the older ones and such. And now it is time to start thinking about selling lambs, which is sad because they are going to take you forward. R3

Others shared this rancher's contraction strategy, some drawing heavily on one resource to preserve another, such as temporarily overgrazing to reduce cattle sales. In more extreme situations, producers sold parts of their operations. Moreover, a Weld producer explained a long-term strategy of selling commercial cattle to preserve grazing land and registered animals (Figure 3.5). As the drought progressed and destocking cows from the commercial cow-calf pairs were insufficient, the producer used his physical infrastructure to maintain calves in the feedlot. These combined strategies preserved his high-value resources, enabling the producer to rebound from the drought effectively.

The drought in 2002 took care of all the commercial cows. In fact, the drought of 2002, breeding groups went out for a month. And then everything got weaned in the feed yard in July. And that's where everybody stayed. All commercial cows got weaned early. The cows went to town, and the calves just stayed in the feed yard. The registered cows got to stay, but they didn't get turned out until probably October, after it froze, so there was no real huge impact from cattle on the ground. (R11)

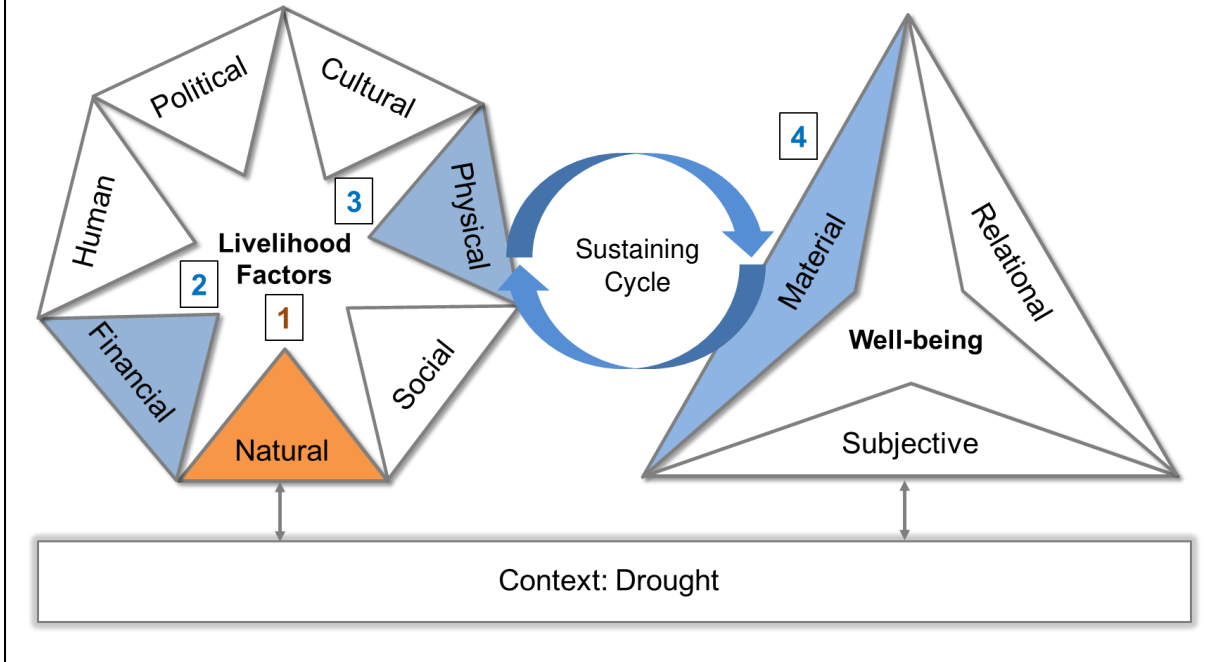


Figure 3.5. The integrated sustainable livelihoods approach and well-being framework for northeastern Colorado livestock producers illustrating a contraction strategy, with orange depicting losses and blue indicating elements that gained or maintained. (1) First, severe drought negatively impacted the natural factor. (2) To maintain the high-value natural factor, the producer leveraged his financial factor in the form of commercial cattle to reduce grazing. (3) As the drought progressed and the commercial animals' reduction was insufficient, the producer utilized the physical infrastructure to maintain calves in the feedlot. (4) These combined strategies preserved the high-value resources of grazing land and registered cattle, enabling the producer to rebound from the drought effectively.

In contrast to the cases above, the couple below found opportunity for expansion in economic downturns:

And in [a cow's] 12-year lifespan, her value is going to go up and down, up and down. Well, most ranchers never take advantage of the up or the down ... In a 12-month period, cow prices are up, we're selling cows, we're selling our most overpriced cows that we own, and then we're replacing them with lower value ... So, we're taking advantage of [market changes], and what we like to see in the cattle market is movement. We like the market to go up, and we really like the market to go down because we've learned how to generate a

tremendous amount of cash flow from the top and the bottom and maintain our inventory ... We've learned to manage this total dollar amount of our inventory so if [cattle prices] get too high, we sell back to this base level. When it drops way below that base level, we have that money to buy more head. (R28)

These ranchers leveraged their human factor in the form of knowledge, finances, and social network to purchase cattle in a market downturn. They move their cattle inventory quickly to capture profit through market gains. Similarly, some producers, such as the one in Figure 3.6, purchase more land during market lows. The below producer's expansion strategy likely contributed to his role as a community leader and growth to 12,000+ acres and 50,000+ head of cattle.

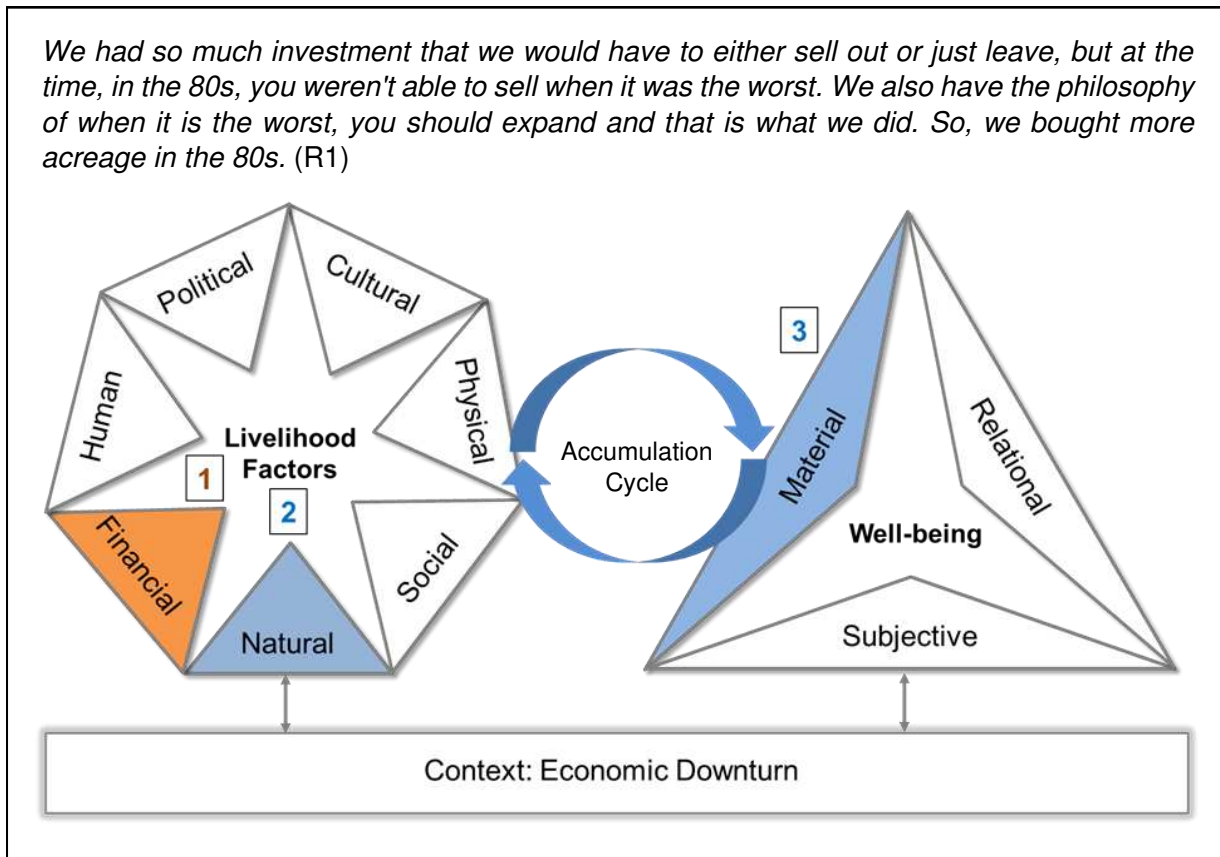


Figure 3.6. The integrated sustainable livelihoods approach and well-being framework for northeastern Colorado livestock producers illustrating a strategy of expansion when challenged, with orange depicting losses and blue indicating elements that gained or maintained. (1) First, the economic downturn in the 1980s left the producer unable to sell-out. (2) In response to financial challenges and limited access to other livelihood strategies, the producer invested in acreage when the market was low. (3) Due to their ability to increase property despite challenges with financial

institutions, the producer maintained their industry through the 1980s downturn, and today, they are a large-scale operator.

We identified diversification as a critical strategy to smooth income, optimize equipment, and mitigate risk. Producers discussed diversification as both an adaptive and coping response, like one Weld producer's use of multiple diversification strategies in extreme drought (Figure 3.7). The producer's decision to diversify across sectors and vertically integrate within the cattle industry, such as investing further into a feedlot, sustained his operation through the drought. Livestock owners shared how they leveraged their existing wells of livelihood factors to assemble these adaptive strategies – contraction, expansion, and diversification – to maintain or enhance their well-being and livelihood factors in the face of rapid social and ecological change.

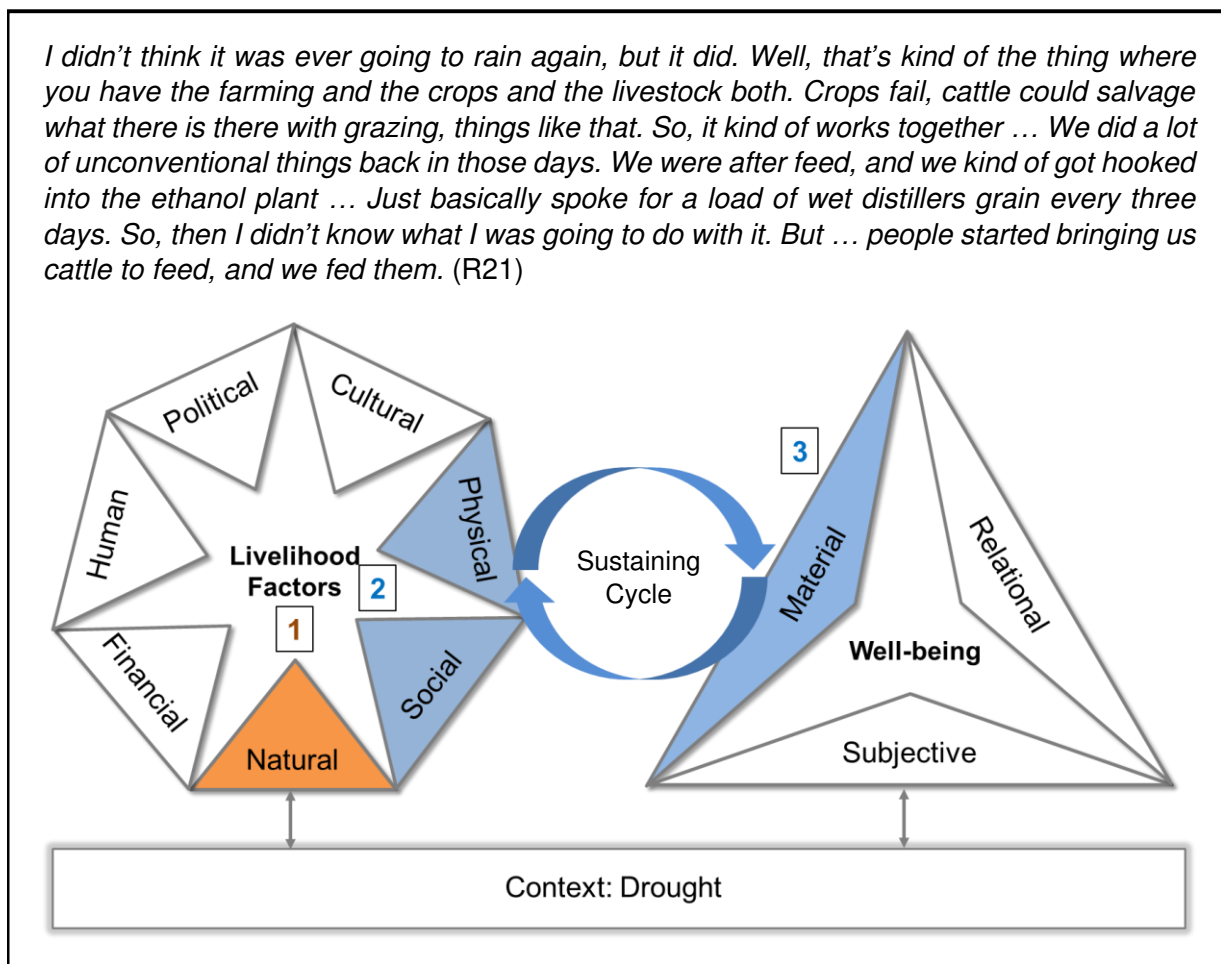


Figure 3.7. The integrated sustainable livelihoods approach and well-being framework for northeastern Colorado livestock producers illustrating a strategy of diversification, with orange depicting losses and blue indicating elements that gained or maintained. (1) First, drought hit the operation, and as a result, the natural factor was reduced, eliminating crops and reducing grazing. (2) Given the loss of natural resources, the producer used his physical factor of a feedlot and his social network to custom feed local producers' cattle. (3) Despite the loss of grazing resources and crops, the producer's vertical integration strategy in the cattle industry enabled his ability to maintain his material well-being.

3.4. DISCUSSION AND IMPLICATIONS

Grounded in our analysis of NE Colorado livestock producers' lived experiences, we proposed and applied an integrated SLA and well-being framework that sheds light on the interplay between ranchers' livelihood decisions and well-being (Delmar 2010). Below, we discuss this framework's contribution to social-ecological-emotional systems' conceptualization and advocate for continued theorization. We also offer that the integrated framework can support the incorporation of human well-being into producer outreach programs. As such, this study offers further research directions in rancher decision-making and, more broadly, in sustainable livelihoods and well-being.

3.4.1. Theoretical Advancements

We propose that scholars and practitioners apply this integrated framework to conceptualize social-ecological-emotional livestock systems in Colorado and the US more broadly. The significance of subjective well-being (i.e., the emotional sphere) to livelihood strategies emerged from this empirical qualitative study, addressing the need to examine subjective lived experiences in SESs research (Coulthard 2012, Stojanovic et al. 2016, Schlüter et al. 2019, Elsayah et al. 2020). Moreover, this work addresses a lack of livelihoods research in the Global North rangelands, contextualizing a holistic livelihoods approach of "a living" to producer decision-making in NE Colorado. This framework is an early contribution to theory, which we expect will continue to evolve through the dynamic and adaptive process of theory-building. For instance, applications to other sites and systems will expand this study's insights beyond Colorado to widely

support the development of socially, ecologically, and emotionally sustainable livestock systems (Firestone 1993). Moreover, this contextualized framework offers insights to the broader livelihood and well-being frameworks (Hong et al. 2014). Future research could examine if the proposed integration of livelihoods and well-being extends to a diversity of SESs, such as other rangeland/pastoral settings, fisheries, forest-based or farming systems, to name a few.

Our proposed framework captures the social, ecological, and emotional dimensions of change. For instance, the framework enriches our understanding of the effects of well-being – such as feelings of pride – on livelihood factors and, in turn, adaptive strategies. As such, well-being is not framed as a static outcome but as one of the many critical elements in complex adaptive systems. Well-being is also highly personal, and therefore, our integrated framework leverages the capacity of the well-being approach to capture some of the heterogeneity among ranchers and farmers (Deneulin and McGregor 2010). The proposed framework does not assume that all people in a system have the same goal (e.g., financial gains). For instance, while some producers' might feel a sense of subjective well-being from a connection to their heritage, others within the same system may not garner well-being from cultural factors. Instead, the integration of well-being supports researchers in understanding peoples' differing goals and associated strategies. For example, aligned with the place-attachment literature (Lewicka 2011), our findings indicate that some peoples' goal is to maintain their subjective well-being by continuing to live at home – whether defined by the dwelling, land, or community. Thus, these individuals are willing to adapt their livelihood strategies to achieve this goal. We posit that applications of this framework may guide researchers in identifying such previously unconsidered influences of human well-being on adaptive strategies.

Moreover, this research adds qualitative depth to the predominately quantitative literature on rancher decision-making (Bruno et al. 2020). In this analysis, both political and cultural factors emerged in our integrated livelihoods and well-being framework, reflecting a central critique that

SES scholarship depoliticizes the social (Smith and Stirling 2010, Glaser and Glaeser 2011, Mackinnon and Derickson 2012, Fabinyi et al. 2014, Welsh 2014). Specific to rangelands in the western US, research has identified ranchers as having high degrees of political factors and cultural significance (e.g., Donahue 1999). Yet, this research found that some ranchers and farmers lacked access to political and cultural factors. Aligned with Ribot and Peluso's (2003) theory of access, we found that natural and social factors mediated access to political factors. This finding raises questions about who has access to political and cultural factors on western rangelands. We posit that rangeland social science's limited consideration of diverse stakeholders on North American rangelands has left issues of access disparity of political and cultural factors underexamined (Bruno et al. 2020). In the future, researchers could apply this framework to examine disparities in access to political and cultural factors in North American rangelands.

3.4.2. Extension and Outreach Implications

In practice, similar to the recommendations of Woodhouse et al. (2015) and Biedenweg et al. (2017), our findings highlight the importance of social well-being support in natural resources outreach, such as in drought response planning and programs. The systems framing leads us to speculate that continued failure to address human well-being in most natural resources and agriculture programming could negatively influence livestock keepers' adaptive capacity. Therefore, we emphasize continued support for outreach and Extension initiatives focused on producer well-being, such as the University of Maine's *Farm Coaching* program (The University of Maine n.d.) and Holistic Management programming (e.g., Holistic Management International) (Savory and Butterfield 2016). Further, natural resources programs could consider the expanded use of peer networks, such as those created in the Women, Food and Agriculture Network (WFAN) (Wells 1998), to support producers' relational and subjective well-being.

Our findings also offer insight into livestock keepers' adaptive livelihood strategies – diversification, contraction, and expansion. We found that diversification was the most widespread

livelihood strategy employed by ranchers in the face of challenges, highlighting the opportunity for Extension and outreach programs that support off- and on-operation diversification. Its pervasiveness in both our data and the broader literature (Barbieri et al. 2008, Barbieri and Mahoney 2009, Gutwein and Goldstein 2013) indicates producer eagerness to explore diversification. Barbieri and Mahoney (2009) demonstrate how diversification is an effective farm or ranch restructuring strategy in response to change. Similarly, Lin (2011) found that crop diversification that increases structural (i.e., agroforestry) and ecological (i.e., incorporation of wild varieties) complexity can increase farmers' resilience to climate change. Despite its potential as an adaptive strategy, policies, markets, uncertain land tenure, and the limited capacity of the land to support differing land-uses may hinder diversification (Herrick et al., 2012a; Sayre et al., 2012). Given that management "panaceas" are non-existent (Ostrom 2007), we advocate for "toolbox" approaches to diversification (i.e., a set of opportunities that producers can select and adapt to their context and needs).

In contrast to diversification, producers held divergent views of expansion and contraction as livelihood strategies. While some producers found opportunities during challenges, others were forced to reduce their assets or operations, often to preserve their highest value resources. We speculate that the co-occurrence of contraction and expansion strategies in shared geographies may facilitate the loss of family-owned operations. As some producers are forced to sell land or animals, others buy them up, consolidating holdings into a few large-scale, often corporate-owned operations. Further research might consider how access to livelihood factors influences producers' decisions to expand or contract. Additionally, a land-use change analysis could explore how both expansion and contraction strategies during socio-economic or ecological downturns affect a region (e.g., Knapp 2008).

3.5. CONCLUSIONS

We present an empirical foundation for an integrated livelihoods and well-being framework grounded in NE Colorado livestock producers' experiences. The framework theorizes reciprocal relationships between livelihood decisions and human well-being outcomes. We also applied our framework to illustrate a cycle of livelihood and well-being decline and three adaptive strategies that improved well-being: contraction, expansion, and diversification. We advocate for applying this framework to other sites and systems, expanding these research insights on the interplay between livelihoods and well-being beyond northeastern Colorado to widely support the development of socially, ecologically, and emotionally sustainable livestock systems.

This study also emphasizes the significance of well-being and resource access to producers' livelihood decision-making. As such, we suggest that outreach and research involving livestock producers are likely to achieve greater success when programming addresses human well-being and resource access inequities. Lastly, our findings highlight the importance of diversification to ranch adaptation. Therefore, we recommend continued Extension and outreach programming that supports farmers' and ranchers' on- and off-operation diversification strategies.

CHAPTER 4

A SOCIAL-ECOLOGICAL LAND-USE CHANGE MODEL: A MULTI-METHOD STUDY OF CHANGE ON WORKING RANGELANDS IN NORTHEASTERN COLORADO FROM 1984 TO 2019

4.1. INTRODUCTION

Global rangelands are undergoing rapid social and ecological change (Herrick et al. 2012, Reid et al. 2014). People have historically viewed these seemingly "residual" lands as available for "productive" use (i.e., cultivated or developed uses) (Herrick et al. 2012, Sayre 2017). Sayre (2017, p 2) writes that "what unites rangelands is less what they are than what they are not," with rangelands an aggregation of all land types that do not fit into other land cover classes (Sayre et al. 2013). Yet, rangelands are social-ecological systems (SESs) where humans are embedded within and affect ecosystems and vice versa (Holling, Berkes, & Folke, 1998; Hruska et al., 2017; Ostrom, 2007). Rangeland SESs encompass vibrant cultures, often politically marginalized societies, and globally essential and imperiled hotspots of biodiversity (Sayre et al. 2013). Thus, land-use decisions cascade through these interconnected systems, affecting both humans and the environment.

Turner, Lambin, and Reenberg (2007) define land change as transitions in terrestrial ecosystems driven by human and environmental interactions. Land change is a spatially and temporally complex process, with historical and contemporary and endogenous (i.e., local knowledge) and exogenous (i.e., global markets) factors driving change (Lambin and Meyfroidt 2010). For instance, the decision to use fences on western United States (US) rangelands drastically changed both the ecosystem and social systems (Sayre 2006). Today, this historical transition continues to influence contemporary landscapes (Sayre 2017). Thus, to avoid oversimplification and craft appropriate land-use policies, land change analyses must acknowledge the complexity of

land change, including consideration of global factors, the social and ecological, and place-based dynamics through time (Herrick et al., 2012; Lambin, Turner, Geist, Agbola, Angelsen, Bruce, Coomes, Dirzo, Unther Fischer, et al., 2001; Lambin & Geist, 2008).

Land-use and land cover change analyses have become essential tools in studying global environmental change (Agarwal et al. 2002). While remote sensing approaches are valued tools in these approaches (e.g., van Vliet et al., 2012; Weng, 2002; Ziegler et al., 2012), issues of data availability and processing demands have limited applications, often constraining analyses to a few timesteps (Kennedy et al. 2014, Young et al. 2017). Yet, more recently, researchers can achieve a closer approximation of continuous change due to the National Aeronautics and Space Administration (NASA)/United States Geological Survey's (USGS) open-access archive of Landsat imagery and open-source algorithms that automate image preprocessing (Woodcock et al. 2008, Kennedy et al. 2018, Wulder et al. 2019, Zhu et al. 2019). Moreover, with these advancements, the availability of remotely sensed data no longer dictates a study's temporal and spatial bounds, advancing the needed "integration of quantitative and qualitative data" (Magliocca et al. 2014, p. 224). Such data and methodological advancements offer new opportunities for both how and what we research on transitioning landscapes.

In this study, we examine drivers of land-use change in qualitative interviews with 32 ranchers. Second, we apply open-source algorithms and develop a land classification model to analyze 36 years of land cover trends over a spatial extent corresponding to the interview data. We integrate the qualitative and quantitative data to model rangeland land-use change conceptually. This research contributes conceptual and methodological advancements to land change science.

4.1.1. Theoretical and Conceptual Framing

Over a decade ago, Lambin, Geist, and Rindfuss (2006, p. 7) stated that "[t]he time is getting ripe for one or more overarching theories of land change to emerge, theories that incorporate insights from multiple social and natural sciences, and theories that explain change in the behavior

of people as well as land-cover/use change.” We join the growing cohort of land change (e.g., Rindfuss et al., 2008) and rangeland (e.g., Hruska et al. 2017) scientists that conceptualize rangelands as complex adaptive SESs (Preiser et al. 2018). Complex adaptive SESs are interconnected and reciprocal across the social and the ecological spheres, or effects in the ecosystem flow through to the social system and vice versa (Holling, 2001). This interconnection drives adaptation of the system, making it more resilient to increasing change (Folke et al. 2016).

Moreover, we also draw on the land change literature to parse Hersperger et al.'s (2010) forces of change into *Direct Causes* (i.e., factors that directly influence actors' land-use decisions) and *Underlying Driving Forces* (i.e., fundamental processes that drive direct forces). The literature categorizes forces of change into proximate or direct causes (i.e., local-level human decisions or factors that directly affect land-use) and underlying or distant driving forces (i.e., fundamental social processes that can occur at different levels and support proximate or direct causes) (Geist and Lambin 2002, 2004, Meyfroidt et al. 2013). To integrate this terminology into our conceptual model, we disaggregate actors' decisions from direct forces of change (i.e., *Ranchers' Adaptive Strategies*) to acknowledge humans as active agents and their decisions as complex processes (Rueda et al. 2019). Moreover, we argue that the term *distant* is incompatible with the conceptualization of interconnected and adaptive systems. Thus, our use of the term *Underlying* integrates distant drivers or “the interconnections between social-ecological system” (Meyfroidt et al. 2013, p. 438).

Examining complex adaptive SESs requires diverse conceptual and methodological approaches that acknowledge their dynamic network of interactions (Nightingale 2003, Campbell et al. 2005, Preiser et al. 2018). Thus, within the theoretical framing of complex adaptive SESs, we draw upon and contribute to Hersperger et al.'s (2010) conceptual land-use change model (Figure 4.1). In the conceptual model, forces of change and actors' (i.e., ranchers) adaptive strategies interact and influence land change. Yet, we adapt Hersperger et al.'s (2010) model by replacing

unidirectional arrows with double-headed arrows, indicating the feedback among the complex adaptive system components. For instance, in our adapted model, land change outcomes feedback to the interaction between actors and change drivers.

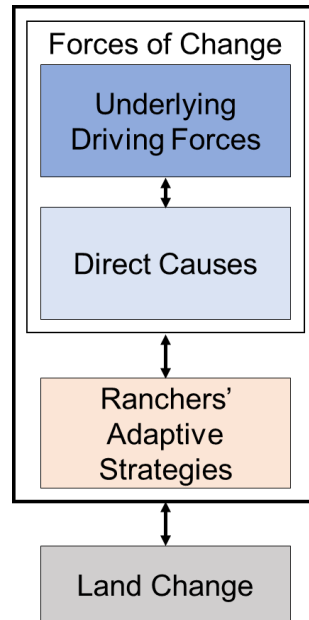


Figure 4.1. A land change conceptual model in which the interaction between change factors – underlying and direct – and ranchers’ adaptive strategies influence land change (and vice versa) (adapted from Hersperger et al., 2010).

Hersperger et al. (2010) state that to examine how interacting driving forces and actors’ decisions influence land change trends, “it is necessary first to analyze the question about how driving forces influence actors in their decisions and how these decisions feedback on driving forces.” In Bruno, Fernandez-Gimenez, & Balgopal (2021), we outline how change forces influence ranchers’ decisions, identifying three prominent adaptive strategies around land-use, contraction, diversification, and expansion. Thus, this study builds upon this previous research (Bruno et al. 2021a) and Hersperger et al.’s (2010) conceptual model to examine how the interaction of forces of change and actors’ adaptive strategies shape land change patterns (and vice versa) in two rangeland communities in NE Colorado.

4.1.2. Study Sites

We focus this study on two communities, one centered in northeastern (NE) Larimer County and the other centered in northcentral (NC) Weld County. We conducted the interviews in and around the two communities and analyzed land cover trends for the entire area within the 20-mile buffers to capture the extent of participants' agricultural landholdings (Figure 4.2). Thus, the study sites are 922,505 acres (1,441 square miles) and 847,548 acres (1,324 square miles) in the NE Larimer and NC Weld sites, respectively (Figure 4.2).

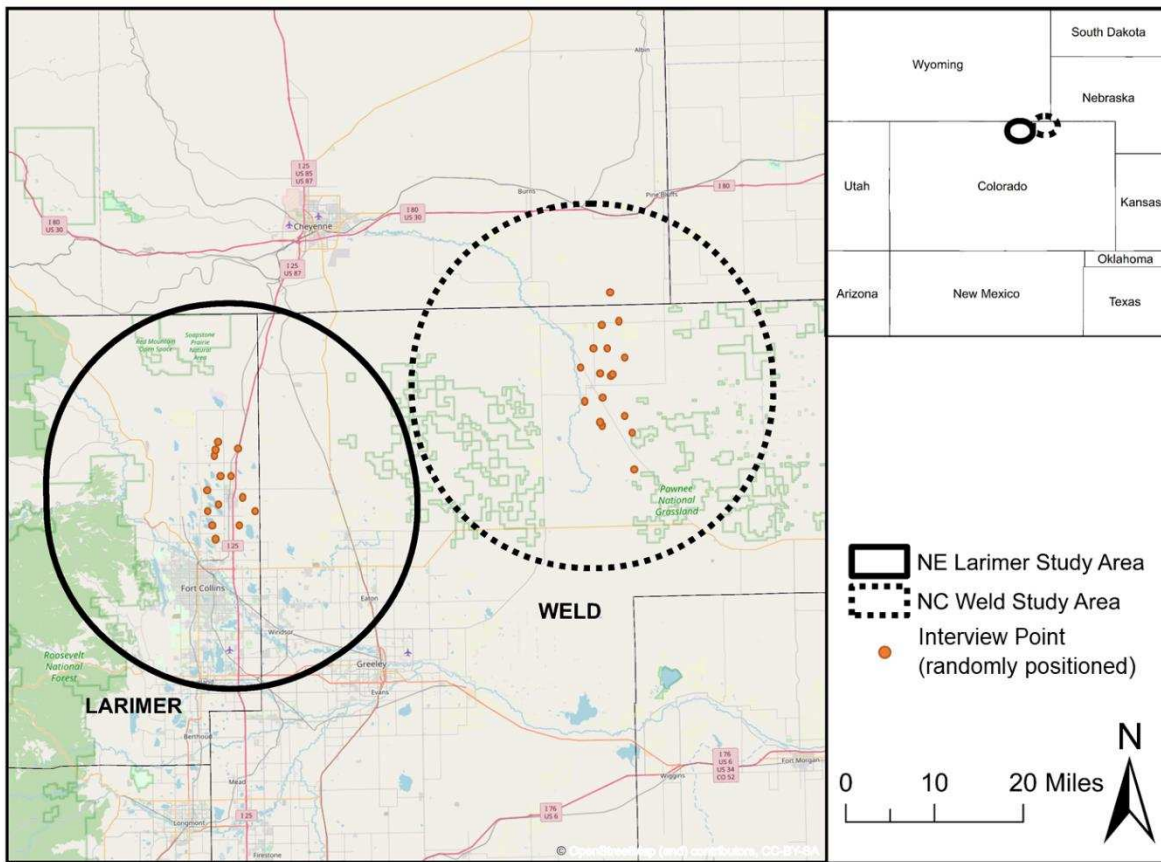


Figure 4.2. The two adjacent study sites, one centered in northeastern (NE) Larimer County and the other in northcentral (NC) Weld County, Colorado (ESRI 2011). Randomly positioned points fall within the area of the interviews, and the circles indicate the area analyzed for land cover, 922,505 acres (1,441 square miles) and 847,548 acres (1,324 square miles) in the NE Larimer and NC Weld County sites, respectively.

The two sites sit adjacent to each other and within the North American central grasslands' semiarid region. The NE Larimer site is dominated by the shortgrass steppe in the East, transitioning westward to the foothills of the southern Rocky Mountains into shrublands and, ultimately, forest. The NC Weld site consists of shortgrass steppe punctuated by the iconic Pawnee Buttes. The warm season grasses blue grama (*Bouteloua gracilis* [Willd. ex. H.B.K.] Lag. ex. Steud.) and buffalo grass (*Bouteloua dactyloides* [Nutt.] Engelm.) dominate the shortgrass steppe, accompanied by the cool season grasses western wheatgrass (*Pascopyrum smithii* [Rydb.] A. Love) and needle and thread (*Hesperostipa comata* [Trin. & Rupr.]) and a variety of perennial and annual forbs and subshrubs (Lauenroth et al. 2008). Today, the shortgrass steppe's primary land-use is livestock grazing on native vegetation, with cultivated land serving as the secondary land-use (Lauenroth et al. 2008). Here, we outline the history of the two sites for our study period from 1984-2019, with Bruno et al. (2021) providing an overview of the sites from the late 19th century into the middle of the 20th century.

The 1980s' farm financial crisis greatly affected NE Colorado's agricultural communities and US agriculture more broadly. A cascading series of policies from the New Deal into the 1970s' Farm Boom increased operation size and production (Barnett 2000, Rosenberg and Stucki 2017). Yet, entering the 1980s, high production and an export decline forced down prices for agricultural goods, and policies to reduce high interest rates caused agricultural lands to devalue (Barnett 2000). While many families – often from communities historically underrepresented in US agriculture – were forced to exit the sector in the decades leading up to the financial crisis, the 1980s was a period of painful restructuring that deeply affected many producers' well-being (Meyer and Lobao 2003, Rosenberg and Stucki 2017).

The 1980s also brought the Conservation Reserve Program (CRP) launch in 1985, which is the largest federally run private-land retirement program in the US (Stubbs 2014). Administered by the US Department of Agriculture's Farm Service Agency (FSA), the CRP pays farmers to halt

agricultural production on environmentally sensitive land to lower the commodity supply and support environmental objectives. The CRP determines payment amounts by the average local rental rates for cropland/pastureland and soil productivity (Stubbs 2014). More recently, the 2014 farm bill expanded CRP lands' uses to include emergency harvesting and livestock grazing for new farmers and ranchers. In Weld County, farmers and ranchers enrolled 6,347 acres in 1986, 171,988 acres in 1996, 224,174 acres in 2006, and 219,046 acres in 2016. In Larimer County, ranchers and farmers enrolled comparatively fewer acres, with 2,321 acres in 1996, 637 acres in 2006, and 527 acres in 2016 (no Larimer County acres enrolled in 1986) (USDA Farm Service Agency 2021).

Emergence out of the agricultural recession and into the 1990s brought a wave of globalization to agriculture, leading to increased US agricultural imports and exports (Dimitri et al. 2005). At a regional scale, the Rocky Mountain West became the fastest-growing region in the US in the 1990s (Vias and Carruthers 2005). In Colorado, increased in-migration, especially exurban growth, in the 1990s and previous decades significantly influenced the social and ecological landscape (Riebsame et al. 1996). The 1972 passing of the Colorado Senate Bill 35 – which exempts lots larger than 35 acres from subdivision approval processes – supported exurban growth. For example, in Colorado's East River Valley (southwest of our study sites), Theobald, Gosnell, & Riebsame (1996) found that the trend of increasing ranch size reversed in the 1990s, with ranch sizes decreasing for the first time in a century. They also found that single households on 35 to 45-acre parcels, commonly referred to as ranchettes, held 20% of private land (Theobald et al. 1996).

The turn of the century brought a 395-week drought to NE Colorado from October 30th, 2001 to May 19th, 2009 (National Integrated Drought Information System n.d.). Moreover, the increasing growth and associated resource demand of municipalities increased water and land prices. In parallel, conservation efforts, often initiated in the 1980s and 1990s, gained momentum (Larimer County Department of Natural Resources 2015). For instance, the Mountains to Plains

Project launched in 2004 (Resnik et al. 2006, York et al. 2011). Today, this collaborative conservation effort between Larimer County, the City of Fort Collins, The Nature Conservancy, and other partners has enrolled 60,000 acres through open space development (i.e., undeveloped land open to the public) and conservation easements on private ranches (i.e., mutual agreements between landowners and land trusts or governments that limit land uses for conservation) (Larimer County Department of Natural Resources 2015). Many of these programs support the concept of working landscapes – balancing social, ecological, and economic objectives – that support livestock grazing but often at lower than historical stocking rates (Resnik et al. 2006, Huntsinger and Sayre 2007).

Today, our two study sites, despite their proximity, demonstrate divergent development trajectories. In the NE Larimer site, the population grew 135.4% from 2000 to 2010 (United States Census Bureau n.d.). In comparison, the NC Weld site experienced a -10.5% decrease in human population from 2000 to 2010, and some neighboring communities were abandoned (United States Census Bureau n.d.). Moreover, while agriculture remains central to both areas, many Larimer County communities, especially those close to Fort Collins, have become increasingly suburban, including some parts of our study area. Also, many Weld County communities are increasingly dominated economically by the oil and natural gas industry, including our study site (Weld County Government n.d., Davis 2012). In this paper, we examine 36 years of linked social-ecological change in these two NE CO communities.

4.2. METHODS

4.2.1. Methodology

This research applies a multi-method design, integrating qualitative and quantitative traditions to explore land change in NE Colorado (Johnson, Onwuegbuzie, & Turner, 2007). We integrate the analyses of interview data and remotely sensed land cover data (Figure 4.3). Our

integration of methodological traditions affords us multiple vantage points from which to examine land change's complexity.

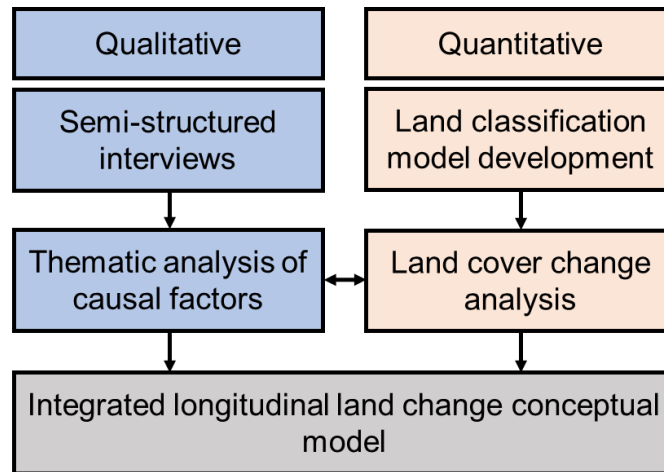


Figure 4.3. The multi-method research process used to examine social-ecological land change in northeastern Colorado.

4.2.2. Qualitative

4.2.2.1. Data collection

We collected data through participant observation and 26 semi-structured interviews with 32 producers in the summer and fall of 2018 and 2019. Members of our social networks facilitated introductions with community guides, and we collected all data under Colorado State University human subjects Institutional Review Board protocol 040-19H. We interviewed 20 participants alone, with the remaining 12 interviewed as couples. Fifteen people resided in NE Larimer and 17 in NC Weld. All 32 interview participants identified agriculture as their occupation and produced livestock, including cattle, sheep, and goats. Interviewees ranged in age from 37 to 90, including first- and multi-generation producers. Thirteen participants identified as women and 19 as men.

Interviews averaged 100 minutes and often involved a tour of the operation. At the start of the research, we used snowball sampling (i.e., recruiting future subjects via participants' suggestions and social networks) (Johnson, 2014). Our initial interviews were exploratory with

prompts such as, "How did you become a rancher?" and "Can you walk me through your typical day?" We also asked about livelihoods and well-being, but social and ecological change arose in all the interviews. Therefore, as the interviews progressed, we modified the interview protocol to further explore the causes and consequences of change.

4.2.2.2. *Data analysis*

We conducted an initial phase of open coding in RQDA (Huang 2014, R Core Team 2019), identifying significant and frequent concepts. Next, we collapsed the codes into categories and recoded all data, conducting a thematic analysis (Braun and Clarke 2012). We applied Lincoln and Guba's (1986) criteria to ensure the trustworthiness of our analysis. The iterative, mixed-method design facilitated prolonged engagement with participants. Additionally, we conducted reflective commentary through memoing and peer debriefing.

4.2.3. **Quantitative**

4.2.3.1. *Imagery preprocessing*

We collected data from the USGS/NASA archive in our study sites from 1984 to 2019, preprocessing these data using open-source algorithms and packages. First, we applied a subset of the LandTrendr algorithm in Google Earth Engine to access NASA/USGS Landsat Surface Reflectance Tier 1 datasets (i.e., TM, ETM+, and OLI) from June to October of 1984 to 2019 (Gorelick, Hancher, Dixon, Ilyushchenko, Thau, & Moore, 2017; Kennedy et al., 2018). These Landsat data are available in individual scenes, and LandTrendr spatially and spectrally linked these data. The resulting output is a time-series of image band stacks with fourteen bands each year (Table 4.1).

Table 4.1. The codes and full names for the fourteen spectral bands (Kennedy et al. 2018).

Code	Name
NBR	Normalized Burn Ratio
NDVI	Normalized Difference Vegetation Index

NDSI	Normalized Different Snow Index
NDMI	Normalized Difference Moisture Index
TCB	Tasseled-Cap Brightness
TCG	Tasseled-Cap Greenness
TCW	Tasseled-Cap Wetness
TCA	Tasseled-Cap Angle
B1	Thematic Mapper-equivalent Band 1
B2	Thematic Mapper-equivalent Band 2
B3	Thematic Mapper-equivalent Band 3
B4	Thematic Mapper-equivalent Band 4
B5	Thematic Mapper-equivalent Band 5
B7	Thematic Mapper-equivalent Band 7

We completed the remaining preprocessing steps and developed the land classification model using Python 3.7 (Van Rossum and Drake 2011). We downloaded a Shuttle Radar Topography Mission void filled at one arc second (60 meters by 60 meters) Digital Elevation Model (DEM) from Earth Explorer ([http:// earthexplorer.usgs.gov](http://earthexplorer.usgs.gov)). We projected the processed time-series images and the DEM to Albers Conical Equal Area to match the MultiResolution Land Characteristics (MRLC) consortium National Land Cover Database (NLCD) (Homer et al. 2020). Next, we clipped the images and DEM to the bounds of the combined 100-mile buffers around each study community for data preparation. We resampled the image and the DEM to the NLCD pixel structure and derived slope (in degrees) and aspect from the DEM. To reduce edge effects, we clipped the resulting outputs to the bounds of the combined 50-mile buffers around each study community. Upon completing these preprocessing steps, all processed time-series images, slope, aspect, and elevation data had the same geographic extent, cell size, and coordinate reference system. We used these data as inputs for the land classification model developed below.

4.2.3.2. *Land classification model*

Next, we trained a random forest model using the available NLCD data to classify land cover in northeastern Colorado (Breiman 2001). We selected a random forest model because it effectively

handles high-dimensional and unbalanced data (Gislason et al. 2006). Random forest classifiers are also relatively robust to outliers and non-linear data (Breiman 2001). Furthermore, researchers have successfully used random forest models for land classification (Rodriguez-Galiano et al. 2012, Young et al. 2020).

To improve the quality of the model predictions in our study area, we simplified the 16 NLCD land cover classes in our study area through reclassification to eight classes (i.e., water, developed, barren, forest, shrubland, herbaceous/grassland, cultivated, and wetlands) (Anderson et al. 1976). We constructed an array of the 14 bands (Table 4.1), elevation, aspect, and slope. We created a mask of the array's valid data (with invalid data predominately assumed to be due to clouds). We applied this mask to the NLCD data to extract pixels where the array has valid data. To parse this valid array and NLCD data into either training data (used to build the classification model) or test data (subsequently used to test the model), we conducted a train-test split (Pedregosa et al. 2011, Bronshtein 2017). Next, to remove outliers, we applied a neighborhood cleaning rule with eight neighbors and a threshold of 0.20 to the training data (i.e., we keep data points that share a classification with more than 20% of their neighbors) (Laurikkala 2001, Lemaître et al. 2017). Then we conducted random undersampling to limit the training data to at most 1.7 million pixels in each class for each year. We repeated the above process for all NLCD years and combined the results. On the combined results, we ran a neighborhood cleaning rule with five neighbors and a threshold of 0.35 (Laurikkala 2001, Lemaître et al. 2017) and conducted random undersampling to limit the training data to at most three million pixels in each class.

Upon completion of data preparation, we fit the random forest classifier. We applied the model to the processed time-series images, slope, aspect, and elevation data from 1984 to 2019 to create land classification rasters. We calculated a 20-mile buffer from each study community, combining the communities and buffers to establish our study sites (Figure 4.2). We removed pixels

from the dataset if there was no data for any of the years, analyzing 922,505 acres (1,441 square miles) and 847,548 acres (1,324 square miles) in Larimer and Weld, respectively.

4.2.3.3. *Model performance and analysis*

To assess model performance for each cover class, we calculated the class-wise F1-score (1). The F1-score seeks a balance between precision (i.e., true positives over total predicted positives) and recall (i.e., true positives over the number of true positives plus the number of false negatives) (Sasaki 2007). We selected the F1-score because the metric performs well despite imbalanced class distribution (e.g., the herbaceous cover area is more than one order of magnitude larger than the developed cover area). We also calculated Cohen’s kappa (2) to show the extent to which the model outputs agree with the NLCD classes (Artstein and Poesio 2008). Cohen’s kappa statistic also effectively handles multiple and imbalanced classes. The F1-score and kappa are optimum at 1. A kappa score of 1 indicates a perfect prediction agreement of the classifier, and an F1-score of 1 indicates perfect precision and recall. We also present a confusion matrix and accuracies in Appendix E (Story and Congalton 1986).

$$F1_{score} = 2 * \frac{Precision * Recall}{Precision + Recall} \quad (1)$$

$$kappa = \frac{observed_{accuracy} - chance_{agreement}}{1 - chance_{agreement}} \quad (2)$$

Using the raster package in R (Hijmans and van Etten 2012, R Core Team 2019), we converted pixels to acres and aggregated areas for each class for each study site for each year. Next, we calculated rolling three-year medians for each land class by study site to reduce short-term fluctuations in the data. Throughout this article, we report the three-year median using the middle year with subscript *M*. For example, we report 1985_M to represent the three-year median for 1984

to 1986. We examined the year-to-year change among cover classes and the overall change trajectories of each cover class. We calculated and reported the net change area and change magnitude for each site over the study period. Below, we focus our analysis on the four classes – cultivated, developed, herbaceous, shrubland – that ranchers discussed in the interviews and covered the largest land area across the two sites (Appendix F). Aligned with the NLCD, cultivated areas are >20% annual crop or pasture/hay vegetation, developed areas are >20% human-constructed materials, herbaceous/grassland areas are >80% non-intensively managed graminoid or herbaceous vegetation, and shrubland areas are >20% shrub cover (Anderson et al. 1976).

Next, we integrated the qualitative and quantitative findings to examine how forces of change and ranchers interact and affect land cover patterns. We used the qualitative findings to identify forces of change and conceptually relate these to our land cover findings. We constructed a conceptual model of rangeland land-use and cover change for NE Colorado.

4.3. FINDINGS

The land cover classification model performed well as per the F-1 scores (Table 4.2) and the Cohen's kappa scores (Table 4.3), especially given the number of classes and a spatial extent that included both the shortgrass steppe and the Rocky Mountains. Aligned with Landis and Koch's (1977) characterization, Cohen's kappa scores (2) demonstrate substantial agreement of our classifier (Table 4.3). Below, we integrate the qualitative and quantitative data to present land cover trends for cultivated, herbaceous, shrubland, and developed land classes from 1984-2019 in both study sites (i.e., land cover change). Next, we examine the forces of change – direct causes and underlying driving forces – and their relationship with land cover changes among land classes. This work builds upon previous research on NE Colorado ranchers' adaptive livelihood strategies (Bruno et al. 2021a).

Table 4.2. The class-wise F1-scores of the land classification model on the dataset (i.e., the bounds of the combined 50-mile buffers around each study community).

Land Cover Class	F1-score
Water	0.83
Developed*	0.49
Barren	0.57
Forest	0.93
Shrubland*	0.68
Herbaceous/grassland*	0.86
Cultivated*	0.76

*indicates classes that we focused on in the analysis

Table 4.3. Cohen’s kappa scores for the classifier’s agreement with the National Land Cover Database (NLCD) classifications for the two study sites by year (i.e., the two 20-mile buffers around the study communities).

Year	Weld Site	Larimer Site
2001	0.66	0.65
2004	0.69	0.65
2006	0.64	0.61
2008	0.62	0.66
2011	0.72	0.69
2013	0.67	0.63
2016	0.70	0.64

4.3.1. Land Cover and Use Patterns

The model output demonstrates that in both the NE Larimer and NC Weld sites, cultivated land cover decreased and herbaceous cover increased from 1984-2019 (Figure 4.4a-4.4b). In 1985_M, NE Larimer had 338,491 acres of cultivated land (36.7% of the total study area), which declined to 190,941 acres of cultivated land (20.7% of the total study area) by 2018_M. This change represents a transition of 16.0% of the total NE Larimer site out of cultivated land (-147,550 acres or a 43.6% decrease of cultivated cover) from 1985_M to 2018_M. The NC Weld site had a median of 288,225 acres of cultivated land (34.0% of the total area) in 1985_M, with a median of 129,609 acres

(15.3% of the total study area) by 2018_M. This change represents a transition of 18.7% of the total NC Weld study area out of cultivated land (-158,616 acres or a 55.0% decrease of cultivated cover) from 1985_M to 2018_M. From 1985_M to 2018_M, 10.3% of the total Larimer study area and 18.4% of the Weld study area transitioned to herbaceous cover (+94,926 acres and +156,474 acres of herbaceous cover in the Larimer and Weld study sites, respectively). Moreover, in NE Larimer, between 1985_M and 2018_M, 4.80% of the total area transitioned to shrubland (+44,614 acres of shrubland cover), and 1.83% of the total area transitioned to developed cover (+16,896 acres of developed cover). In NC Weld, between 1985_M and 2018_M, 0.572% of the total area transitioned to shrubland (+4,850 acres of shrubland cover), and 0.183% of the total area transitioned out of developed land (-1,583 acres of developed cover).

The identified trend of decreased cultivated cover conflicts with findings in the literature. Hu et al. (2020) found that cropland in the US increased slightly between 2000 to 2010, and other researchers (e.g., Herrick et al., 2012) predict continued conversion of rangelands to croplands. Yet, many of these studies examine a larger land area over a shorter time (Herrick et al. 2012, Cameron et al. 2014, Byrd et al. 2015, Hu et al. 2020). Participants below questioned the sustainability of solely agricultural operations in NE Larimer:

The question is, should you even try [agriculture] in Larimer County, and some of us are trying. An example of how to make [agriculture] sustainable is dude ranching or farm experiences and charging for that. Say [the operation] has two components, an agricultural component and an entertainment component. The two fit together in a holistic way, in fact. If you're going to farm in Larimer County, maybe you have to have an enterprise of that sort to go with [the farming]. That's not necessarily bad. You may say, well, is it agriculture? (R8)

It is done. [Agriculture] will never be back, and of course, there are people that say that is just the way it needs to be, and we just need to move agriculture 25 miles east and figure out how to get water to them. Well, that is getting harder and harder to do. (R3)

Yet, as one Weld County farmer shared, ranchers and farmers 50+ miles east of the Larimer study site also struggle to maintain their operations:

The farms are shabby, the buildings are falling down, the fences are down, the weeds are everywhere. That is just purely because they haven't taken care of the past, and the

droughts hit them, and they didn't have enough water. Something happened, and the economics weren't there, and the first thing to go was pride. Once that goes, the whole farm starts deteriorating. (R1)

The above livestock producers identified direct and underlying forces that drive land-use changes and potentially land cover change in both the NE Larimer and NC Weld sites.

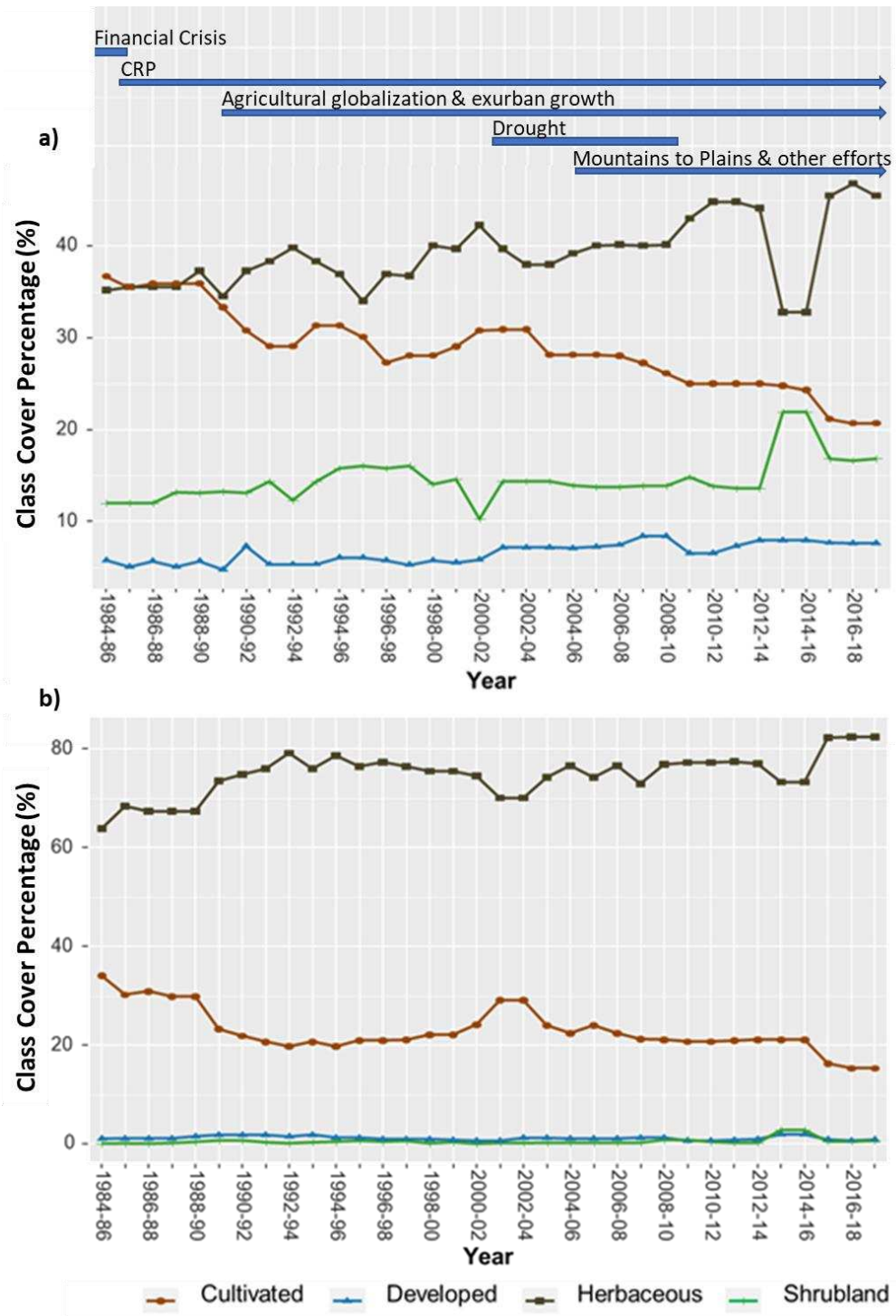


Figure 4.4a-b. Three-year medians of the proportions (%) of the total land area of cover classes – cultivated (i.e., planted vegetation), developed (i.e., human-constructed materials), herbaceous (i.e., grasslands), and shrubland (i.e., shrubs) – graphed along with critical events in northeastern Colorado in the (a) northeastern Larimer County, Colorado study site (922,505 acres) and the (b) northcentral Weld County, Colorado study site (847,548 acres) (Anderson et al. 1976) from 1984-2019.

4.3.2. Direct Causes

While Geist and Lambin (2002, p. 143) define proximate or direct causes as “human activities or immediate actions at the local level, such as agricultural expansion, that originate from intended land-use and directly impact [land] cover,” we disaggregate actor decisions from direct causes. Thus, we define direct causes as factors that directly influence actors’ land-use decisions. Aligned with findings in other systems, we identify multiple direct factors that interrelate to drive change (Geist and Lambin 2002, 2004, Ling Lim et al. 2017).

4.3.2.1. *Direct causes in the northeastern Larimer site*

The NE Larimer site lies within the rapidly urbanizing Front Range corridor that extends from southern Wyoming to Pueblo, Colorado. Participants emphasized the significant influence of urbanization on their communities and decisions about their operations. While only 1.83% of the total area (16,896 acres) transitioned to developed land in the past 36 years – predominately converting cultivated and herbaceous land – this reflects a 31.7% increase in developed land in the Larimer site (Figure 4.5). One rancher shared how increased developed land cover feeds back to influence drivers of change:

So, when we built this house, it was \$250,000 or \$275,000, something like that. And now they want to tax us for \$750,000. So, my wife and I talked about it. It's a nice problem in that our property has gone up in value, but now we want to stay in agriculture. As the people drive by and they see our little calves out here, and they come up and tell us our cow is dying. No, she's lying on her side because she's having a calf. I mean, it's nice to have urban here. But it's encroachment. So, can we stay in agriculture with what's going on here? Because now our taxes go from \$1,500 a year to \$4,500 a year. So, you say, "Well, yeah, but your land..." We didn't build this to sell it ... I'm trying to make a living in agriculture, and my taxes have gone from \$1,500 a year to \$4,500 a year. I mean, in the whole scheme of things, it doesn't break me. But now we're talking taxes, we're talking [a] different kind of fencing, it changes it... and Larimer County says it wants to be agriculture friendly. Does it? (R16)

Aligned with Bruno et al.'s (2021) findings, the above rancher expressed how urban pressure does not always drive a rapid exit from agriculture. Rather, demographic changes directly affect an increase in developed land cover, which feeds back to regional and local level policies (e.g., taxes and regulations) and economies (e.g., cost of agricultural inputs). For instance, as regional

economies and demographics restructure, demand for water and land from municipal buyers rises, increasing resource values (Brookshire et al. 2004). These rising costs of water and land decrease their uses as agricultural inputs, creating barriers to entry, expansion, and, in some cases, the maintenance of an existing agricultural operation. Such challenges can drive producers to diversify or contract their operations (Bruno et al. 2021a).

Figure 4.6 illustrates a general trend that the majority of land transitioned out of cultivated land shifted to herbaceous cover from 1984-2019 in the Larimer study site. The Larimer rancher below shared how regional and local policies and programs have directly shifted land-use:

You have to be careful with [open spaces] because [the creation of Soapstone Prairie Natural Area] has taken some of [the land] out of agriculture. In other words, we used to run 1,200 cows, and now we run 600 cows. So, it's cut the productivity of that in half. On the other hand, Larimer County's working with producers in Larimer County, so I mean we've got a great relationship with them. Is it exactly how we would run it? Nope. On the other hand, I never let a biker pass, or a hiker pass, or a guy riding horses pass without talking to them. Hey, here's an opportunity to tell them about cattle, or agriculture in Larimer County, or the history of this place. Because we owned it for 30 years, and I mean, it's very seldom that it turns into anything but a positive discussion. (R16)

Another Larimer County rancher shared how state policy allowing sub-division to 35-acre parcels (SB 35, 1972) affects the local culture and land-use patterns:

We do a lot of grazing on national forests, and we have these cattle drives and so on. The ability to do that has changed markedly over the last 20 years, 30 years. It's just that there [are] twice as many people, twice as many 35-acre parcels. You know the 35-acre conundrum in Colorado ... The people are getting less knowledgeable and flexible about grazing and so on. (R8)

Since the regions' transformation to Euro-American agrarian society, the dominant use of rangelands has been livestock grazing, with cultivated land the secondary use (Lauenroth et al. 2008). The first rancher explained how conservation programs (e.g., Mountains to Plains Project) have maintained livestock grazing on some rangelands but not at historical intensities (i.e., lower stocking rates), while also supporting multi-use landscapes (e.g., recreation, education, and conservation). Such transitions from private ranchland to open space align with Gosnell and Travis' (2005) findings on local land tenure trends, including increased ranchland ownership by

conservation organizations as a rapidly growing form of ranching in the Rocky Mountain West. The second rancher's quote aligns with Theobald et al.'s (1996) finding that ranches' division into ranchettes (i.e., 35-acre parcels) is a dominant shift in Colorado's land-use. Such low-intensity development and exurban migration may have a limited influence on land cover trends while drastically affecting the social (i.e., cultural change) and ecological spheres (Riebsame et al. 1996, Theobald et al. 1996, Gosnell and Travis 2005). For instance, researchers have linked ranchettes in Larimer County to increased landscape fragmentation and weedy, invasive species (Knight et al. 1995, Miller et al. 1996, Mitchell et al. 2002).

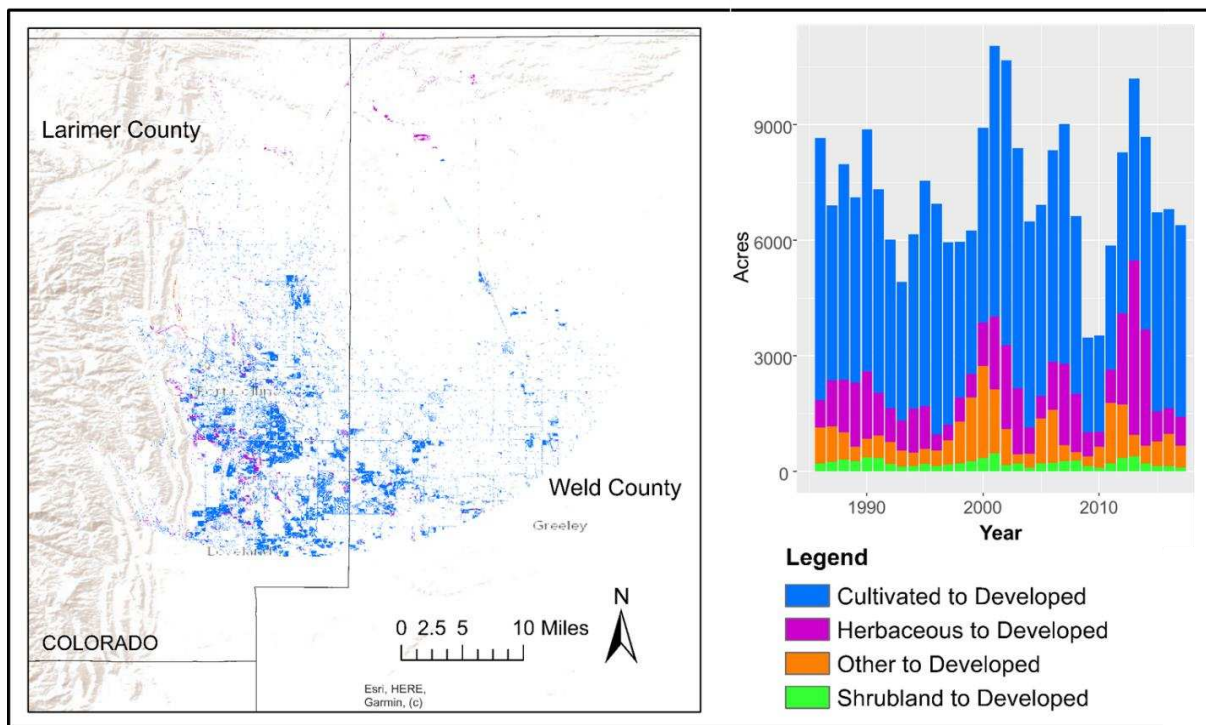


Figure 4.5. The map illustrates the transition of cultivated, herbaceous, other (wetlands, water, barren, forest), and shrubland to the developed land cover class from 1985_M (three-year median of 1984-1986) and 2018_M in the northeastern Larimer County, Colorado study site. The stacked bar graph depicts the acres transitioned from 1985_M-2018_M.

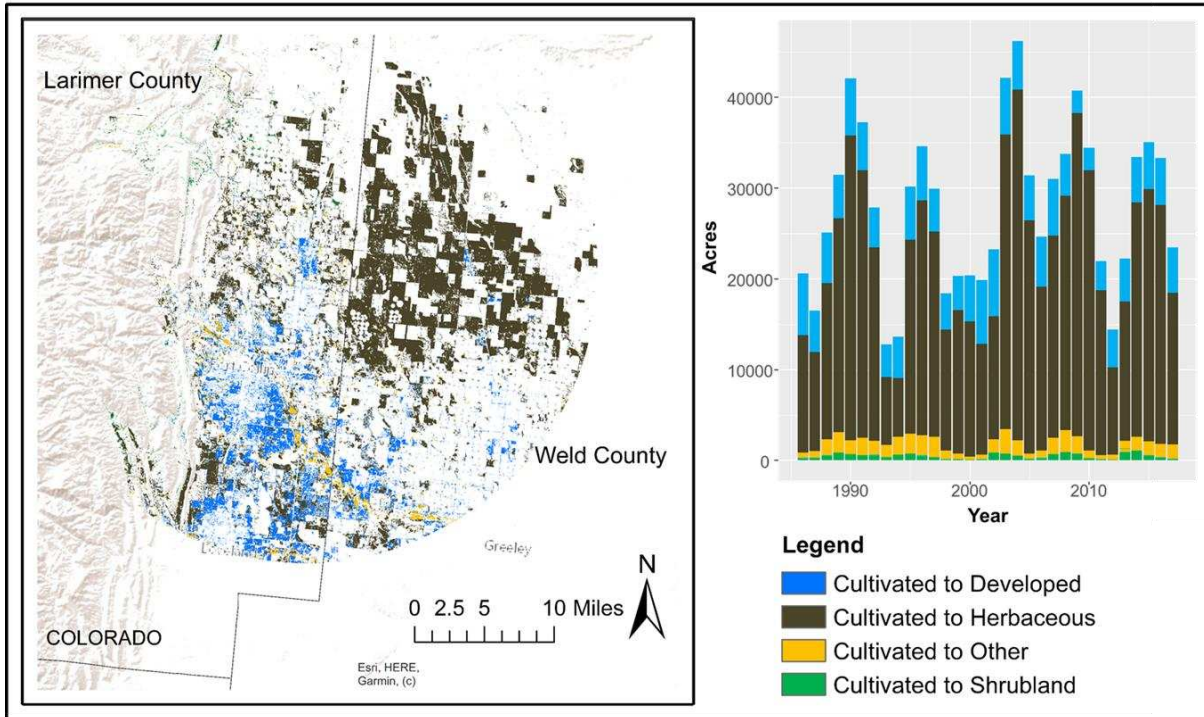


Figure 4.6. The map illustrates the transition from the cultivated land cover class to developed, herbaceous, other (wetlands, water, barren, forest), and shrubland classes between 1985_M (three-year median of 1984-1986) and 2018_M in the northeastern Larimer County, Colorado study site. The stacked bar graph depicts the acres_M transitioned from 1985_M-2018_M.

4.3.2.2. *Direct causes in the northcentral Weld site*

The dominant land cover trends in the NC Weld site are decreased cultivated cover and increased herbaceous cover. Cultivated cover predominantly transitioned to herbaceous cover in the NC Weld site (Figure 4.7). Drawing parallels to the conservation programs in Larimer (i.e., Mountains to Plains Project), Weld participants discussed the federal CRP's influence on land cover and use trends, directly driving a transition from cultivated land to herbaceous. One Weld County farmer shared:

[The CRP] put millions of acres to the wayside. And the reason they did it was because our crops have always been a political tool within the whole world. And we just got way over-produced and [there were] so many crops that weren't going to [be harvested]. So, they said they'd take all of [the lands that became the CRP] out of production, and then it balanced out a little bit. So maybe there was a good thought there. They were supposed to be 10-year programs, and they'd be over with. But during that time, we had the, for lack of a better

word, we had the do-gooders out there [that extended the program to] 40-years. The CRP is really good for wildlife, and it's good for the birds ... And it had nothing to do with commodities. And it didn't work for the commodity deal because I thought when this many acres went into it, the price of wheat would soar higher, and [it] didn't. [They] actually went down. So, it didn't work for that. Then we kept it going. It's still going today. And we kept it going because of the preservation of wildlife. I just don't know if the taxpayers are paying that much money to keep a sharp-tailed grouse alive. Is that important? (R19)

The above farmer enrolled in the CRP, which effectively transitioned cultivated land to herbaceous cover, but above, he questions the underlying and seemingly transitioning motivations for the federal policy.

Technology (e.g., mechanization) and oil and gas production are two factors that participants identified as driving land-use change in Weld County (Bruno et al. 2021a). For instance, investment in new technologies and diversification are often mutual strategies, with diversification spreading equipment capital (e.g., tractors and cameras in the calving barns). Oil and gas also enabled multiple participants to maintain their ranches and, in many cases, expand (Davis 2012). While participants emphasized the role of oil and natural gas in maintaining and expanding their ranching operations, they also shared their struggles with an industry that brings pollution (e.g., dust) and traffic while making few contributions to the local culture. One ranching couple captured the complex role of the oil industry in rural communities in the West:

Husband: Oh yeah. As a ranch, we benefited from the damages. We have a way better surface amount of damage every month than most people. We're just using that as one more way for this ranch to generate income. We'll just take that money and put it somewhere where it will generate income down the road.

Wife: Like it helped buy the ranch in Texas.

Husband: So, if our kids need to sell something – which they will – the place down the river can sell, and it'll be worth a lot of money.

Wife: And the oil and gas, we're not negative toward it. We have to live with it, so you might as well.

Husband: We've benefited ... We had a ranch that was basically a state park. We had very few roads through it, we could hardly ever drive a pickup in the pasture, four-wheelers, or side by side, and we don't have trails. It's one big, continuous chunk, and we locked the gates.

Wife: Used to. (R27)

Husband: Used to, and now we might have 300 vehicles on our ranch in a day. (R28)

The couple above allude to a “split estate,” where property ownership splits between the mineral rights (e.g., oil and gas) and the surface of the land (Davis 2012). As a result of payments for damages or surface disturbances, the above ranchers can maintain and expand their rangeland-based cattle operation, keeping acreage in herbaceous cover. Yet, while the operation remains in herbaceous cover, the land-use has diversified in a way that significantly alters the social-ecological landscape.

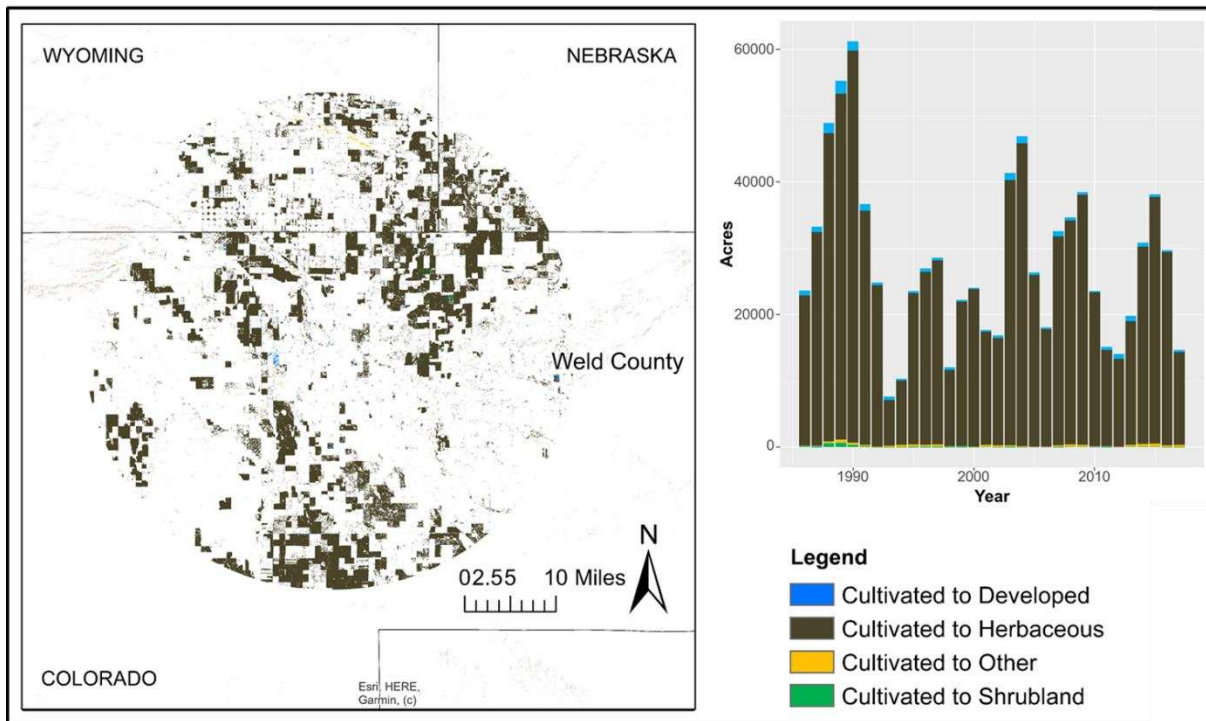


Figure 4.7. The map illustrates the transition from the cultivated land cover class to developed, herbaceous, other (wetlands, water, barren, forest), and shrubland classes between 1985_M (three-year median of 1984-1986) and 2018_M in the northcentral Weld County, Colorado study site. The stacked bar graph depicts the acres transitioned from 1985_M-2018_M.

4.3.3. Underlying Driving Forces

In this study, we use Geist and Lambin's (2002) terminology of *underlying driving forces*. Yet, we conceptualize our study system as a complex adaptive SES. Thus, we expand upon the definition of underlying driving forces to include social-ecological interactions as underlying

driving forces of change. Moreover, we frame these factors as underpinning direct drivers while also directly influencing actors.

Participants presented socio-cultural and climate change as underlying drivers of system changes. In this study, we define culture as the unique customs, beliefs, and knowledge that have shared meaning for a group of people (Wright 1998, Mulcahy 2006). Moreover, ranchers discussed federal policies as both underlying and direct change drivers, sometimes directly influencing their land-use decisions as presented above while also underpinning direct factors. For instance, while participants positioned the CRP as a direct driver that influences their adaptive strategies, they also discussed how the federal program underpinned direct change factors, such as local demographics.

One Weld County rancher shared:

Well, the CRP program, which it's had positive and negative effects on the community on both sides. It just kind of depends where you sit there. [The CRP has] enabled [my parents] to retire, more or less ... The check just came to the mailbox. You didn't have to worry about a crop or anything, but then on the other side of that, they didn't have to go out and buy any fertilizer or parts or diesel. You see what I mean? ... It was a good investment, so a lot of absentee owners bought a lot of CRP land at banks. That draws quite a bit of money out of the community. So, CRP has been good, bad, both, [it] just depends [on] how it affected you. So, I don't know. I've got some CRP land [of] my own. So, it's neither here nor there. It's been good and bad both. It just depends how you want to look at it. (R21)

The rancher's statement echoes Smith and Martin's (1972) and other researchers' findings (Johnson & Lichter, 2019; Johnson & Rathge, 2006; Lu & Paull, 2007; Nickels & Day, 1997) that the viability of local ranches and the associated rural communities are linked. Smith and Martin (1972) emphasized that the link is more than economic, with ranching contributing to regional and community culture and demographics. The rancher's quote captures how the CRP program underpins local economies and demographics in the NC Weld study site.

In both study sites, interviewees emphasized the significance and driving force of socio-cultural change, especially regarding public perceptions of agriculture. For example, one Larimer County rancher explained how increasing social heterogeneity influences cultural change:

So, I drive down the road, and we've got cattle in the trailer, and the people from California that move here don't understand that we go 45 miles an hour in a 50 mile an hour zone, and

they do 70. When they go by here, they wave, not with all their fingers, if you get what I'm saying. So, the real encroachment is, I mean ... that I don't mind people who want to move out in the country, as long as they want to move out in the country, but they want to move out in the country and change it to where they came from. So, the little rural towns change, and then they want to annex the little rural towns. (R16)

The above rancher identified socio-cultural change as "the real encroachment" (R16). Exurban migration (i.e., shifts in demographics and economies) and socio-cultural change reinforce each other, driving rapid and significant change. Above, the interviewee positions cultural encroachment as exogenous to agriculture. Yet, interviewees also identified socio-cultural changes within agriculture, including shifting political views in rural communities (Bruno et al. 2021a).

Participants shared diverse viewpoints regarding climate change and changing weather patterns (e.g., increased extreme weather events), which aligns with broader research on peoples' perceptions of climate change (Saad 2014). Yet, there was consensus on the dynamism, complexity, and persistent influence of extreme weather events, which some linked to climate change. Participants shared lived experiences of the impacts of extreme weather events, such as drought, on direct causes (e.g., local demographics and economies) and land-use decisions, affecting land cover. One Weld County couple shared how drought forced people to sell their cows, forcing a transition from a cow-calf to yearling operation:

Husband: [Drought] changes the way everybody does business. Some of the people had to liquidate their [cows], so they would no longer be a cow-calf but a yearling operator. We have had to raise different crops. We used to raise sugar beets. We had shares in Western Sugar. We were part of that co-op and were owners of that company. We had to sell [because] we didn't have enough water to raise sugar beets. We had to decide if we were going to stay in the cattle business or if we were going to be cash farmers with beets. So, it forced us to liquidate [the beet] portion of the business. It has caused some major changes with the communities. It has caused a lot of people to move out. There are a lot of empty houses now. (R1)

Wife: Right, we have definitely seen a decline. (R2)

Below, another rancher shared:

So, we hit another drought in the 1980s [and] things change dramatically. [The] whole system changed, and I even went to a meeting. There were bankers, farmers, everybody. It was a big crowd of people, and they were trying to explain to us that things were going to be different, but they didn't tell us what we were going to have to do. It was like, "We know what we're going to do. We're going to eat you like you're just raw meat." And they did. A lot

of farmers took a fall quick. I was able to hang on, and I came down to the point I had \$60,000 in debt ... Now, at that time, I had over 2,000 acres of grassland, the best water, good fences, good equipment, [and] the knowledge. They wanted to foreclose. Now, you got to think about that, for \$60,000. (R30)

The rancher above framed drought within a complex adaptive SES, capturing how the extreme weather event underpinned direct change drivers.

4.4. DISCUSSION

This multi-method research examines the causes and consequences of social-ecological land change in NE Colorado. We analyzed 32 rancher interviews and 36 years of remotely sensed imagery in our two NE Colorado study sites. Below, we integrate these qualitative data focused on change forces and quantitative data on land cover change patterns to develop a rangeland use change model. Our rangeland change model builds upon existing conceptual work (Hersperger et al. 2010) and our previous research on ranchers’ adaptive strategies (Bruno et al. 2021a) (Figure 4.8).

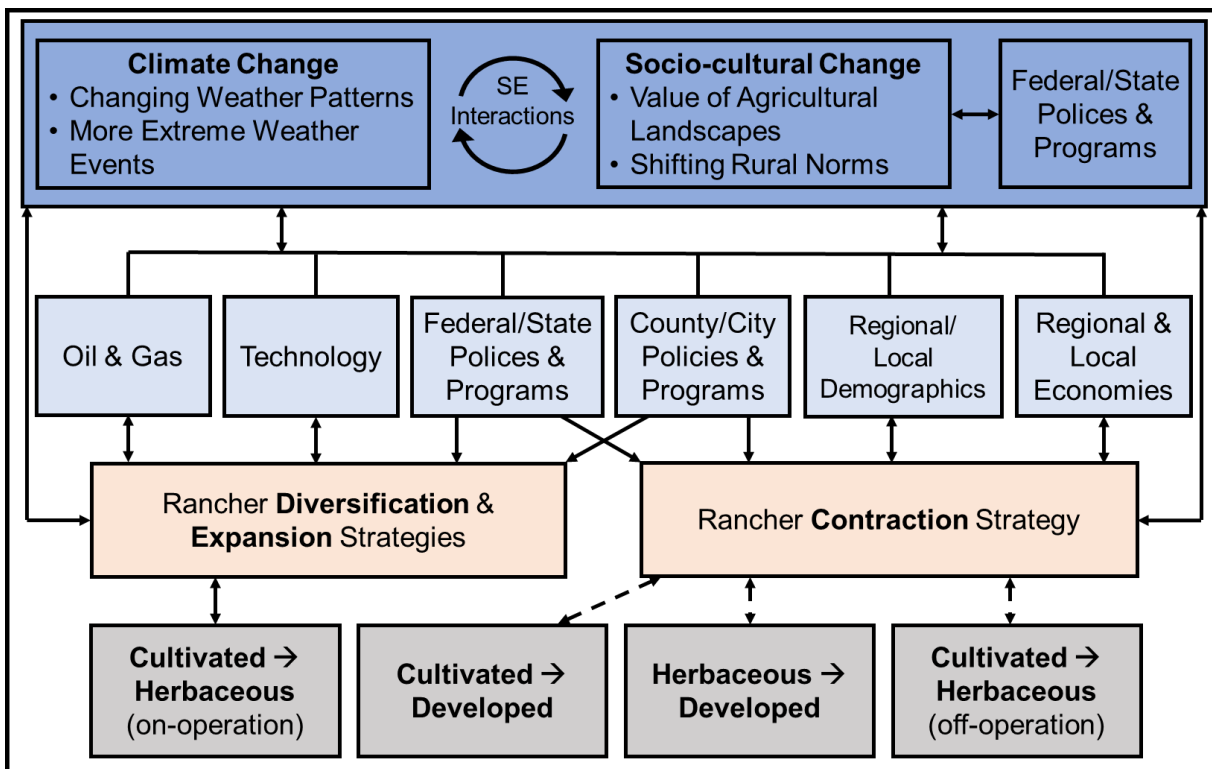


Figure 4.8. Social-ecological rangeland use and cover change model. The model captures how forces of change – underlying and direct forces of change in dark and light blue, respectively – and ranchers’ adaptive strategies around land-use (depicted in orange) (outlined in detail in Bruno et al.

[2021]) interact to affect land cover change (depicted in gray) in northeastern Colorado. The dashed arrows indicate ranchers' limited influence on the land change outcomes.

Out of the four major land cover classes in our study sites – cultivated, herbaceous, developed, and shrubland – we omitted shrubland in the above rangeland change model because ranchers did not discuss the land class in interviews. We posit that this is due to participants conceptually linking shrubland with herbaceous cover and observing little change in shrubland cover. The western portion of the NE Larimer site transitions into mixed shrubland, primarily mountain mahogany (*Cercocarpus* spp. [Kunth]), and herbaceous foothills used for extensive grazing (Mitchell 1993). In the NC Weld site, some of the prominent shrubs, such as Fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.), are palatable to livestock (and wildlife) (Vavra et al. 1994). Thus, we posit that participants in both sites may have conceptually grouped shrubland with herbaceous cover, with ranchers' references to rangelands, grazing lands, and pasture representing the aggregation of herbaceous and shrubland cover. Moreover, research in Weld County has identified a positive relationship between shrubs and sandy topsoils over medium-textured subsoils in the shortgrass steppe (Sala et al. 1997, Dodd et al. 2002). Thus, given this association between shrublands and soils unsuitable for agriculture (and often for development), we posit that shrublands are less likely to transition to crop or developed cover. We speculate that participants did not observe and thus did not discuss significant transitions to shrubland cover. We suggest that further research examine if and how land change patterns specific to shrublands incorporate into our proposed rangeland change model.

4.4.1. Land Change Patterns: Cultivated to Herbaceous Cover

Research in rangeland systems has identified trends of rangelands put to “productive” use (i.e., developed or cultivated land) (Herrick et al. 2012). The cultivation of crops on these often marginal lands, such as parts of the shortgrass steppe, can force systems over ecological thresholds (i.e., transitions among stable states) with varying reversibility potential (Briske et al. 2005, 2006).

Yet, in both sites from 1984-2019, the most considerable net losses were to cultivated land and the largest net gains to herbaceous cover. Our findings indicate that the trend of rangeland conversion can be reversed or mitigated, at least on a scale relative to our study area. Interviews discussed the role of programs and policies, such as the CRP, in reverting cultivated land back to herbaceous cover. Also, efforts, such as those led by Larimer County and the City of Fort Collins, mitigated the conversion of rangelands, maintaining herbaceous cover.

Much of the acreage affected by these programs and policies have become working landscapes, often supporting livestock grazing (Resnik et al. 2006). The CRP is the exception, but more recently, the program introduced limited forms of grazing under the 2014 Farm Bill. The 21st century propelled grazing systems into a polarizing global debate focused on generic solutions (Donahue 1999, Steinfeld et al. 2006, Gerber et al. 2013). The who, what, why, and when of livestock grazing are context-specific and complex. Yet, on the shortgrass steppe in NE Colorado, seventy-five years of grazing treatments have demonstrated that grazing as a land-use – even many years of heavy grazing – is unlikely to push the system over a threshold (Holechek, Galt, & Khumalo, 2006.; Milchunas, Lauenroth, Chapman, & Kazempour, 1990; Milchunas, Lauenroth, ..., & 2008; Porensky, Derner, Augustine, & Milchunas, 2017). Moreover, research has shown that the blue grama-dominated shortgrass steppe experiences limited species composition change under long-term light, moderate, and in some cases, heavy grazing (Milchunas et al., 1990). Given observed land cover trends in conjunction with grazing as a land use, this research offers a landscape-level case of rangeland conservation.

4.4.2. Ranchers' Adaptive Strategies

The land change literature frequently aggregates actors' land-use decisions with direct drivers of change (Geist and Lambin 2002, 2004). In this study, we disaggregate actors from forces of change, acknowledging that interactions between actors and other direct drivers of change affect land change patterns (Rueda et al. 2019). Bruno et al. (2021) found that NE Colorado ranchers and

farmers employ three prominent adaptive strategies of diversification (adding enterprises), extensification (purchasing or leasing more land or livestock), and contraction (selling land or livestock). Our findings captured above in the rangeland change model indicate that these adaptive strategies are influenced by intersecting direct and underlying forces of change. Livestock producers' diversification and expansion strategies influence on-operation transitions of cultivated to herbaceous cover. Moreover, livestock producers' contraction strategies (e.g., selling land) can drive land cover transitions from cultivated to herbaceous cover in areas with conservation programs/policies (e.g., open space programs) and the transition of cultivated and herbaceous land to developed cover. While agricultural producers have a high level of control over their initial decision to reduce their operation size through land sales (contraction), this strategy decreases their influence over future land-use decisions (depicted by dashed arrows). The system components — underlying driving forces, direct causes, producers' adaptive strategies, and land change patterns – interrelate and feedback to shape and adapt the SESs.

Ranchers have been called the West's keystone species (Knight 2007), and as such, their land-use decisions are critical, especially in regions with significant private landholdings. Yet, this study and previous research have found that the sale of ranchland is a frequently employed adaptive livelihood strategy in Colorado and the Rocky Mountain West more broadly (Theobald et al. 1996, Gosnell and Travis 2005, Leonard and Gutmann 2006, Bruno et al. 2021a). Moreover, our findings highlight how decreased cultivated land can negatively affect local economies, often leading to local demographic changes in rural communities (i.e., depopulation). Land tenure dictates who makes decisions about using and managing land and connected resources (Reid et al. 2014), and this study indicates that current land-use trends are reducing livestock producers' influence on natural resource management. Thus, we suggest that future research build upon our proposed rangeland change model by incorporating actors who have increasing influence in this study system, such as prominent conservation organizations and public officials at the county and

city levels. Moreover, as discussed in more detail below, these land tenure shifts have socio-cultural implications that require further study.

4.4.3. Direct Driving Forces of Land Change Patterns

Our findings found that some forces of change identified as underlying in the literature directly affect land change in our study sites (Geist and Lambin 2002, 2004). For instance, participants shared that policies, such as the USDA CRP, are significant and often direct drivers of their decisions. By 2019, Weld County producers had enrolled 41,562 acres in the CRP. In Larimer County, the City of Fort Collins, the county government, and partners have transitioned 60,000 acres into either open spaces or conservation easements. Such programs and policies have directly affected land change patterns, which underlie ecological outcomes, such as increased wildlife habitat (Resnik et al. 2006, Stubbs 2014). Moreover, in NE Colorado on the shortgrass steppe, Burke, Lauenroth, & Coffin (1995) compared fields with native vegetation, those abandoned from cultivation 50 years prior, and areas recently cultivated, finding that fields with native vegetation had the highest soil organic matter and silt.

Yet, other direct drivers can mitigate herbaceous conversion while negatively affecting the SES system. For instance, there remains a debate on the higher environmental impacts of many ranchettes with less livestock per operation versus the impacts of large ranches (Gosnell & Travis, 2005; Harner & Benz, 2013). Ranchettes have a relatively small development (house and road) footprint while maintaining a parcel size of at least 35-acres. Yet, Mitchell et al. (2002) longitudinally compared large intact ranches and ranchettes in Larimer County from 1957 and 1994, finding that ranchettes had significantly higher landscape-level fragmentation. While both Larimer and Weld Counties have large tracts of protected areas, Knight et al. (1995) posit that rural subdivisions abutting protected areas present challenges, including liability and public relations. Also, subdivisions can increase the spread of nonnative, weedy species (Knight et al. 1995) and road infrastructure (Miller et al. 1996).

Demographic shifts are another direct driver that can mitigate herbaceous conversion while negatively affecting the SES system. As demographics shift, demand for urban and industrial water increases, raising the value of water rights and leases (Brown 2006). In addition to land tenure shifts, water ownership structures are also central to land change, especially in semi-arid and arid landscapes where water dictates land-use. For instance, producers can earn more by selling or leasing water rights than using water as an agricultural input (Brookshire et al. 2004). We also speculate that the “buy and dry” trend may influence reduced cultivated land and increased herbaceous cover. This trend is when municipalities or others purchase farmland primarily for water rights and let the land lie fallow or revegetate naturally (often becoming invaded with weedy species, which would still show up on remote sensing as herbaceous cover) (Devine 2015).

4.4.4. Underlying Driving Forces of Land Change Patterns

Participants identified climate change, socio-cultural change, and high-level policies/programs as underlying driving forces of land change. They discussed these elements as underpinning direct drivers, and in the case of culture, shaped by system feedbacks. Socio-cultural change in NE Colorado is well documented, with changing regional economies and demographics driving increased social heterogeneity and cultural change (Riebsame et al. 1996, Theobald et al. 1996, Gosnell and Travis 2005, Kennedy and Brunson 2007). While heterogeneous communities can experience conflict over resource use (e.g., agricultural production versus conservation) (Yung et al., 2003), this study offers insights that such social heterogeneity has and can continue to contribute to natural resource management (Chapin and Knapp, 2015). For instance, in our study areas, multiple collaborative efforts, such as the Mountains to Plains Project, have worked to balance multiple and sometimes divergent social and ecological goals across complex systems (e.g., Resnik et al. 2006, Fernández-Giménez et al. 2019).

While land cover trends indicate gains towards local and regional ecological objectives, participants shared concerns about cultural resilience. In other research, we found that livestock

producers identified the significance of local culture on their adaptive livelihood strategies (Bruno et al. 2021a) and their ability to verify their identities as farmers and ranchers (Bruno, Fernandez-Gimenez, & Balgopal, *forthcoming*). For instance, NE Colorado livestock keepers expressed how their family histories in ranching supported their continued commitment to agriculture (Bruno et al. 2021a). Despite this significance, participants expressed little sense of agency or influence over any of the underlying forces, including socio-cultural change. This study emphasizes that land change is a social and ecological phenomenon. As such, future research could more deeply examine how agricultural producers conceptualize themselves within an SES, explicitly their perceived influence on climate, socio-cultural change, and high-level policies. We posit that such work may increase livestock producers' sense of influence while also informing outreach efforts, especially climate change messaging. We also suggest that existing and future conservation efforts may need to expand upon cultural resilience programming, especially those lacking a collaborative component such as the CRP.

4.5. CONCLUSIONS

This study applied a multi-method approach to holistically examine the causes and consequences of land-use change in rangeland SESs in NE Colorado. Previous research on land cover in rangelands has often used a limited number of timesteps and consequently struggled to match the temporal and spatial extent of qualitative data. As a result, landscape-level research on rangeland change has often focused on either land-use decisions or land cover trends. This study developed a random forest land classifier that enabled us to align the land cover analysis's temporal and spatial extent with participants' lived experiences. We integrated these analyses, constructing a rangeland change conceptual model that illustrates the interrelationship among direct and underlying forces of change, livestock producers' adaptive land-use strategies, and land cover change patterns. We found that both study sites experienced a decline in cultivated land cover from 1984-2019, with most of the cultivated land transitioned to herbaceous/grassland cover. Our

qualitative analysis identified the significant role of conservation programs and policies, especially the Conservation Reserve Program and open space programs, in driving the trends of decreased cultivated and increased herbaceous cover. We also found that despite the relatively small number of acres transitioned in and out of developed cover, participants emphasized how demographic and socio-cultural changes affect their land-use decisions and, ultimately, land cover patterns. This research offers insights that prominent global trends of rangeland and grassland conversion can be reversed or mitigated, promoting the conservation of these vibrant, essential, and imperiled SESs.

CHAPTER 5

OCCUPATIONAL AND GENDER ROLES IN AGRICULTURE: APPLYING IDENTITY THEORY TO THE EXPERIENCES OF LIVESTOCK RANCHERS AND FARMERS IN NORTHEASTERN COLORADO

5.1. INTRODUCTION

Throughout the world, rangelands are undergoing linked land-use, identity, and livelihood transitions (e.g., Galvin, 2009). Rangelands are commonly defined as ecosystems with native vegetation dominated by grasses, forbs and shrubs. Here, we expand this definition, considering rangelands social-ecological systems (SESs) in which humans are embedded within and affect ecosystems and vice versa (Holling et al. 1998, Ostrom 2007, Hruska et al. 2017). Rangelands support approximately one billion peoples' livelihoods, predominately through livestock production (United Nations n.d., Sayre et al. 2013). Thus, we conceptualize rangelands as inseparably coupled with these individuals, communities, and economies. Today, as intersecting climatic and societal changes challenge rangeland SESs, researchers have empirically studied the effects of change on the land (e.g., Olexa and Lawrence 2014) and rangeland stewards' management decisions (e.g., Roche et al. 2015). Yet, the effects of change in rangeland SESs on people's identities and, in turn, their livelihood strategies and well-being remain understudied. To address this research gap, we apply identity theory (Stryker and Serpe 1982, Burke and Stets 2009) to examine how northeastern (NE) Colorado livestock keepers conceptualize and adapt their occupational identities within changing landscapes. We also explore how gender affects conceptualization of and access to agricultural identities.

Humans have long grappled with our identities or “[t]he set of meanings that define who one is when one is an occupant of a particular role in society, a member of a particular group, or claims particular characteristics that identify him or her as a unique person” (Burke and Stets 2009,

p. 3). From Aristotle, Bernard Williams, and John Locke to today's scholars, our preoccupation with *who we are* and *what it means* is evident in the diversity of theoretical approaches to identity. These include identity theory in sociology (Stryker and Serpe 1982, Stryker and Burke 2000, Burke and Stets 2009) and social identity theory in psychology (Abrams and Hogg 1988, Hogg 1993). Moreover, the study of identity in environmental and agricultural contexts has grown, including increased research on place attachment (Lewicka, 2011) and environmental identity (Kempton and Holland 2003). Research has also examined how identities affect environmental decisions (Clayton and Opatow 2003, Devine-Wright and Clayton 2010). This study contributes to this growing literature on identity and its effects on behavioral and social change in the context of social-ecological transitions.

Here, our objective is to apply sociological identity theory to examine livestock producers' occupational identities (Stryker and Serpe 1982, Stryker and Burke 2000, Burke and Stets 2009). We also aim to examine how gender roles affect access to and experiences of occupational identities. Drawing from both identity theory and feminist geography (e.g., Brandth, 2002a), we consider occupational and gender identities concepts formed by humans that can change over time (i.e., social constructs). We present how this more in-depth understanding of occupation and gender identities can support social change and outreach in rural communities in Colorado and beyond. As such, our work contributes to rangeland social science and, more broadly, rural studies.

5.1.1. Identity Theory

Identity theory considers the interplay between identities and society (Burke and Stets 2009). Stryker and Serpe's early thought on identity theory draws heavily upon symbolic interactionism (Stryker 1980, Serpe and Stryker 1987, 1993, Stryker and Serpe 1994), which theorizes that we understand our social world and exchange meaning through symbols or elements with implied shared meaning (Mead 1934). These symbols are formed through human interactions, varying across social groups, and changing over time (Burke and Stets 2009). For example, cows

are significant to both Hindus and Maa-speaking pastoralists. Yet, they are a sacred symbol of life for many Hindus (Korom 2000) while representing social status for many Maasai people (Volpato and King 2019). In identity theory, the self is an accumulation of roles, such as rancher, mother, and wife (Stryker and Serpe 1982, Stryker and Burke 2000). A role is the self-categorization of an individual in society (e.g., rancher) and the expectations connected to the social position (e.g., hardworking). We use symbols and interactions to place ourselves and others into these roles (Mead 1934, Stets and Burke 2000).

In Figure 5.1, we adapt Burke and Stets' (2009) identity model. In identity theory, identities have a connected set of meanings or the *Identity Standard* (i.e., how a rancher “ought” to be). We attempt to align our *Social Behavior* to the identity standard (i.e., decisions a rancher makes) (Burke 1997, Simon and Klandermans 2001). Based upon our behaviors and connections to symbols, we receive feedback from others (i.e., *Reflected Appraisals*), and these appraisals from others shape how we see ourselves (i.e., *Perceptions*). Next, we consider if our perceptions of ourselves match the identity standard. If we determine that there is little discrepancy, we verify that we are “successful” in the identity (i.e., identity verification). If we perceive ourselves as deviating from the identity standard, we might modify our behavior or feel disconnected from the identity. For instance, an individual may feel that others do not consider their small acreage operation a “real” ranch, and thus, they may no longer feel comfortable identifying as a rancher. Finally, identities can change over time in response to change (i.e., *Disturbances*).

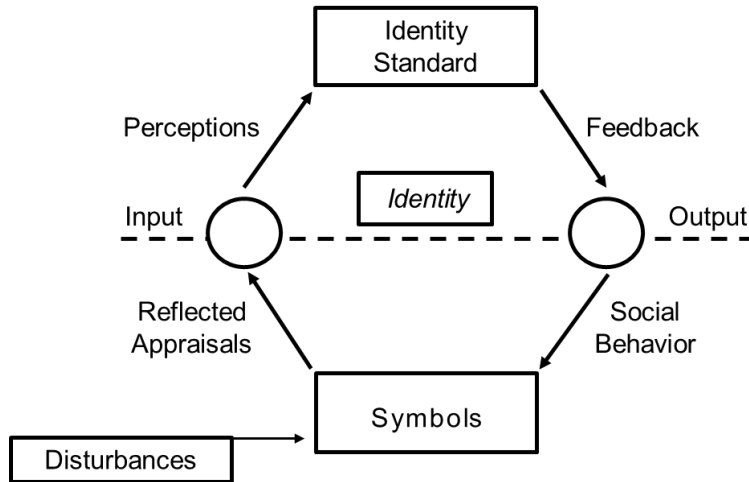


Figure 5.1. Identity theory model adapted from Burke and Stets (2009, p. 134).

Moreover, identity theory acknowledges that we can claim multiple identities (Stets and Burke 2000, Stets and Harrod 2004). For instance, an individual can simultaneously hold the roles of mother, rancher, and farmer (among others). These multiple identities are hierarchical (e.g., mother dominant to rancher and rancher dominant to farmer) and often context-specific (e.g., home versus a public space). An identity's prominence or salience is linked to how critical a role position is to an individual's social assets (i.e., social capital). In this hierarchy, occupational identities and gender are often very salient, given their centrality to everyday life (Burton 2006, Shortall 2014). Also, we negotiate these role identities in relation to counterroles or counteridentities. For example, a rancher identity can take on additional meaning in relation to that of a farmer (White and Burke 1987). Here, we use Burke and Stets' (2009) identity model as an organizing framework to examine livestock keepers' role identities, specifically the relationship between occupational identities and gender roles.

5.1.2. The Study of Identity in Agriculture

Feminist geographers, rural sociologists, and critical development scholars have extensively explored identity in agricultural systems. Early feminist and critical research, much of which

emerged from the Global South, aimed to understand the contributions and challenges of historically underrepresented groups in rural and agricultural spaces (e.g., Boserup, 1989; Bukh, 1979; Sachs, 1983; Whatmore, 1988). For example, Bukh (1979) illuminated the role of Ghana's colonial economy and patriarchal structures in inhibiting women's access to land, labor, education, capital, and agricultural outreach. Other fundamental questions driving this body of research are what it means "to be" a farmer and who has access to these agricultural identities (e.g., Peter et al. 2009, Babers 2014). More recently, research has considered conceptualizations of masculinity in agricultural systems (e.g., Saugeres 2002, Barlett and Conger 2004, Pilgeram 2007). Peter et al. (2009) found that men most often claim and are seen as fulfilling the role of farmer despite women's significant contributions in Iowan agricultural communities. In addition to gender and occupational roles, research has also explored the meanings and contributions of other identities in agriculture, including black (e.g., Babers 2014) and queer (e.g., Leslie 2019) identities, among others.

While there has been extensive work on identity in agriculture, little research in agriculture draws upon and contributes to the extensive and well-developed literature on identity theory. This limited work includes Shortall's (2014) application of identity theory to explore how women's off-farm work affects men's gender and agricultural identities. Shortall (2014) found that as women transitioned to more off-farm work, men experienced increased loneliness and a sense of lower status due to less identity verification from their spouses. Applying identity theory, Brasier et al. (2014) found that women farmers in the northeastern United States (US) had two prominent identities – farm operator and farm partner – that emphasize women's prominent agricultural roles. Burton (2004a, 2004b), later echoed by Prokopy et al. (2019), identified a need to integrate self-identity concepts into prominent behavioral approaches in agricultural research. Finally, Burton (2004b) emphasized the importance of cultural factors, especially self-identity, in the future of agriculture. He posits that changes in what people perceive as symbolic of a "good" farmer will

shift farmers' agricultural practices. For instance, if rangeland heterogeneity symbolized success, rancher adoption of practices that support heterogeneity, such as grazing and fire (and the interaction of the two), may increase (Fuhlendorf et al. 2009).

Much of the research on identity in agriculture has focused on cultivated systems, with scant work on grazing lands and animal agriculture in the Global North. Moreover, while there is a significant body of literature on gender, youth, and ethnic identities in pastoral and agro-pastoral systems (e.g., Coppock et al., 2013; Flintan, 2010), only a few studies consider identity in ranching systems (e.g., Opatow and Brook, 2003; Wilmer and Fernandez-Gimenez, 2016). Instead, much of the rangeland social science literature is focused on understanding rancher management decisions, emphasizing decision-making as a dynamic process influenced by sociocultural factors (e.g., Smith and Martin 1972, Huntsinger et al. 1997, Liffmann et al. 2000, Wilmer and Fernández-Giménez 2015). Yet, the influence of such sociocultural variables, including identity, on decision-making remains underexplored. Sorice et al. (2012) apply identity theory to consider the relationship between identity (i.e., farmer versus rancher roles) and a person's intention to enroll in a voluntary incentive program in central Texas. While Sorice et al. (2012) 's work reflects the emergence of identity theory applications in rangeland social science, the study applies a Likert-type scale to quantify farmers' and ranchers' role salience. Such survey research leaves factors such as identity symbols, meanings, and multiple roles underexamined. These gaps highlight the need for more qualitative research to consider the complexity of rangeland stakeholders' identities.

5.1.3. A Brief History of Agriculture in Northeastern Colorado

We focused this study on livestock producers in two NE Colorado communities, one in northeastern Larimer County and one in northcentral Weld County. Both study sites have long histories of change. The Ute, Arapaho, Cheyenne, Lakota, Apache, and Comanche were some of the many Indigenous groups that lived and hunted in NE Colorado for generations. While trappers, traders, and other Europeans and Euro-Americans came to NE Colorado seeking resources, the

Colorado gold rush of 1859 instigated a rapid influx of permanent or semi-permanent settlers (Mehls and Mehls 2006).

As Colorado became a state in 1876, the Desert Land Act (1877) was appended to the Homestead Act (1862) (the act did not include Colorado until 1891), attracting more people to the arid and semi-arid West (Ganoe 1937). The Homestead Act awarded land to any adult citizen who had not borne arms against the US government and pledged to settle and farm the land. With the 1862 act, women could own land, and the Civil Rights Act of 1866 enabled Blacks to homestead (i.e., Exodusters) (Williams 2000). In 1878, driven by demand for resources – timber, gold, land – the US government forcibly removed Indigenous communities, including the Ute, Arapaho, Cheyenne, Kiowa, Comanche, and Apache, from their homes and hunting grounds in NE Colorado (Burriss 2006).

With the government's forced removal of Indigenous peoples and agriculture promotion, NE Colorado transitioned to a predominantly sedentary, agrarian society. The influx of people and even more livestock into NE Colorado realized Major Stephen F. Long's vision of one large pasture on Colorado's eastern Plains (Mehls 1984). Small Plains towns, including our study sites, popped up across NE Colorado with the railroad, the boom of the "Beef Bonanza," demand for wool, and people's desire to own land. Distinctive communities emerged. For instance, Oliver Toussaint Jackson created Dearfield, a black agricultural settlement, in 1910 in Weld County, Colorado (Armitage et al. 1977, Moore 1993). In addition to animal agriculture, NE Colorado became the largest sugar beet producer in the early 20th century. This booming beet industry employed German-Russian immigrants at the turn of the century and, by the 1920s, Mexican and Mexican American families (Chase 2011).

In the deflated post-WWI economy and Dust Bowl of the 1920s and 30s, people abandoned many of these small, often geographically isolated, agricultural communities established in the first two decades of the 20th century. New Deal era policies and the Agricultural Adjustment Act drove

significant restructuring of US agriculture (Rosenberg and Stucki 2017). For instance, the Taylor Grazing Act of 1934 and efforts such as the Bankhead-Jones Land Utilization Act of 1937 transitioned arid and semi-arid lands unsuitable for crop production out of cultivation, promoting conservation (Mehls and Mehls, 2006). Yet, in turn, 14 percent of US farmers left agriculture from 1930 to 1950, including 37 percent of Black crop and livestock farmers (Reynolds 2002, as cited in Rosenberg and Stucki 2017).

A cascading series of policies from the New Deal into the 1970s, including accelerated depreciation schemes, drove unprecedented agricultural production (Barnett 2000, Rosenberg and Stucki 2017). By the 1970s, interest rates increased, and farm income decreased (Barnett 2000). The highly leveraged agriculture sector was thrown into upheaval, spurring the 1980s farm crisis, deeply affecting producers' mental health and well-being (Meyer and Lobao 2003). While farmers with high debt loads (often large-scale landholders) were significantly affected by the financial farm crisis in the 1980s, today, large operations dominate US agricultural production and economics. The median total income for all farm households was \$83,111 in 2019. In comparison, only 3% of all farms are large-scale family farms, but these operations produce 44 percent of the nation's value of production and have a median household income of \$350,373 (USDA ERS 2020). Another contemporary shift is the acknowledgment of women's agricultural roles, with 1.2 million women identified as agriculture producers in the 2017 census of agriculture, including 42% of Colorado's producers (USDA NASS 2019a). Furthermore, livestock grazing accounts for half or more of the market value of sales on almost half of all operations run by women (Hoppe and Korb 2013).

Our study sites demonstrate divergent trajectories for rangeland-based agricultural communities in the West. In Weld County, agricultural restructuring is reflected in the County's 193,060-acre Pawnee National Grasslands and ghost towns like Dearfield dotting the Plains. Many Weld County communities, including our study site, are increasingly economically dominated by the oil and natural gas industry (Davis 2012). In Larimer County, the contemporary landscape is a

mosaic of small-scale agriculture and housing developments (Bruno et al. 2021a). In comparison to Weld, urbanization and the expansion of protected areas, including both publicly accessible protected areas and privately owned ranches under conservation easements (both grazed at lower than historical stock rates), have increasingly altered northeastern Larimer County (Resnik et al. 2006, York et al. 2011). Our previous research found that livestock keepers in both sites adapt their livelihood strategies in response to demographic change (e.g., urbanization and depopulation), climate change (e.g., extreme weather), and economic recessions (Bruno et al. 2021a). We examine livestock keepers' lived experiences in these two NE Colorado sites to study agricultural identities in this context of social-ecological change.

5.2. METHODS

To examine identity – a concept formed through human interactions – we employed a constructivist epistemology or a theory about the nature of knowledge. Constructivism holds that the world exists external to the human mind but that people create knowledge through experiences and social interactions (Packer and Goicoechea 2000, Tuli 2010). Therefore, we initiated this research with exploratory inquiries and an iterative methodology informed by constructivist grounded theory, which applies a systematic and inductive approach to form a concept or idea of research participants' lived experiences (Charmaz 2006, 2008). Moreover, we applied gender as a sensitizing lens or a concept that the researcher uses to parse data and examine relationships (Charmaz 2003, Bowen 2006). As the significance of identities emerged from our data, we transitioned to a thematic analysis (Braun and Clarke 2006, 2012, 2013) using identity theory to deductively analyze the interview transcripts (Stryker and Serpe 1982, Burke and Stets 2009). Thus, this study uses Burke and Stets' (2009) conceptual identity model as an organizing framework to examine NE Colorado livestock keepers' work roles and how gender identities relate to these occupational practices.

5.2.1. Positionality

We acknowledge the influence of the researcher on the knowledge generated. The authors all work at Colorado State University in Fort Collins, Colorado, the lead author as a doctoral graduate assistant and the second and third authors as tenured faculty members. We all reside in northern Colorado but do not live in either study site or come from ranching backgrounds. This dominant role as outsiders positioned us as learners, creating space to ask for clarification and for participants to offer detailed explanations (Naples 1996, Tuana 1996). For instance, since we were clearly in learning mode, participants often preceded long explanations with clarification questions like “Do you know what that is?” Yet, our roles as outsiders posed a challenge to gaining entrance into the study sites. The multi-year timeframe of doctoral research alleviated this constraint, supporting sustained engagement with community members. Moreover, many participants expressed interest in supporting student work.

In addition to our dominant outsider roles, our membership in a diversity of communities established a degree of insiderness with some interviewees (Naples 1996, Tuana 1996). For instance, the first author shares the lived experience of growing up in a rural community and natural resource-dependent household with many of the participants. Similarly, the second author grew up in a small Midwestern town, worked on farms as a teen, and later as a ranch hand in Colorado and sheepherder in Wyoming. Her doctoral research involved extended participant observation with Mongolian herders, and her current research continues to place her in an outsider inside role as an action researcher with and advocate for pastoralists and extensive livestock production. The third author grew up in a Midwestern town. Although her immediate immigrant family was not engaged in farming, parts of her extended family is. She studied agriculture in college and graduate school, worked on feedlot, in a small dairy goat operation, and as an extension entomologist with intentions of working in international agricultural development. Her current research includes understanding the professional identities of science educators and

communicators in rural communities. We acknowledge that our degree of insiderness creates a bias towards the value of rural, agricultural communities. Yet, our differing personal and professional experiences and roles enable us to question and challenge one another throughout this research. For instance, the student and mentor relationship between the first and subsequent two authors encouraged iterative and critical debriefings of preliminary findings.

5.2.2. Data Collection

The first author collected data through participant observation and 26 semi-structured interviews with 32 livestock keepers in the summer and fall of 2018 and 2019 (Appendix D). Members of our social networks facilitated introductions with community guides, and we collected all data under Colorado State University human subjects Institutional Review Board protocol 040-19H. Participant observation is a means of observing daily life from the participants' standpoint (Goffman 1989, Sprague 2016a). During participant observation, the first author engaged in tasks on two livestock operations, memoed throughout these experiences, and attended a community meeting to introduce this research (Figure 5.2).

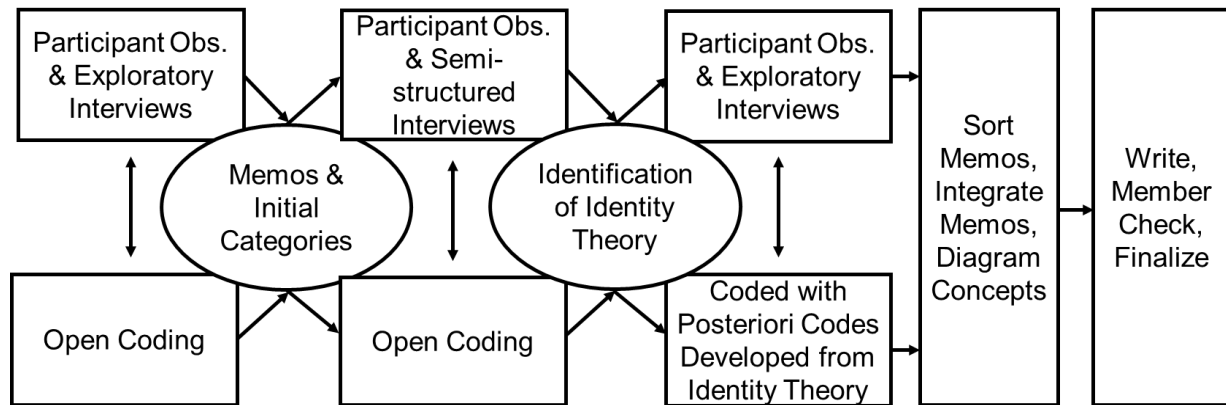


Figure 5.2. Diagram of the iterative qualitative research process (adapted from Charmaz 2006).

Interviews were audio-recorded, averaged 100 minutes, and often involved a tour of the operation. At the start of the research, we used snowball sampling or the recruitment of subjects

through existing participants (Johnson 2014). The initial interviews were exploratory with prompts such as, “Can you walk me through your typical day?” These early interviews included preliminary questions about identity such as, “What are your name and the name of your ranch/farm/operation?” and “Do you identify as a rancher, farmer, business/agribusiness operator, etc.?” As our first inductive and iterative data collection and analysis progressed, the significance of identity emerged. Thus, we drew on identity theory to frame our semi-structured interview instrument around the concept of occupational identities. In the Appendix D, we bolded the questions added throughout the research process to the initial interview script.

5.2.3. Demographics

Out of the 32 interview participants, 15 were from the northeastern Larimer County site, and 17 were from Northcentral Weld County. The interviewees included 13 women and 19 men, and we interviewed 12 participants as couples. Three women interviewees were widowed, with two identifying as sole operators and one co-running the farm with her son. All participants identified agriculture as at least one of their occupations and produced livestock. The respondents span a diversity of beef, sheep, agribusiness producers, and five retired participants. Interviewees’ ages ranged from the mid-30s to mid-90s. While race and ethnicity are critical to experiences and social factors, we do not disclose participants’ race and ethnicity to ensure anonymity.

5.2.4. Data Analysis and Trustworthiness

The first author conducted an initial phase of open coding in RQDA (Huang 2014, R Core Team 2019), identifying frequent and significant concepts. Once the concept of identity emerged, we constructed *a priori* codes based on identity theory (Stryker and Serpe 1982, Burke and Stets 2009). The first author coded all data, conducting a deductive, theory-driven thematic analysis (Braun and Clarke 2006, 2012, 2013). The deductively derived codes included *farmer identity standard*, *rancher identity standard*, *identity symbols*, *adapting identities*, *gender roles*, and *counterroles*.

We applied Lincoln and Guba's (1986) criteria to ensure the trustworthiness of our analysis. We considered credibility (i.e., the ability of the research to capture the desired phenomena) and confirmability (i.e., the emergence of the findings from the data) as the most critical measures of trustworthiness for this study (Shenton 2004). The iterative, multi-method design facilitated prolonged engagement between the first author and participants, supporting understanding, trust, iterative questioning, and triangulation. Due to the onset of the COVID-19 pandemic, we presented the research findings to producers (member checked) using ongoing email and phone conversations. Additionally, we maintained an audit trail with reflective commentary through memoing and peer debriefing among the authors.

5.3. FINDINGS

In Figure 3.5, we adapt Burke and Stets' (2009) conceptual model to illustrate livestock keepers' multiple identities, identity standards, and identity symbols. Moreover, this research is part of a more extensive study of livestock producers' adaptive strategies (*SES Behavior*) under SES change (*SES Disturbances*). Therefore, the components of the model shaded in grey concerning SES disturbances and behavior (i.e., *SES Disturbances* and *SES Behavior*) are integrated with the findings in this paper but discussed in detail in (Bruno et al. 2021a). Lastly, we explore the role of historical narratives in identity formation and how livestock keepers remold their identities in response to SES change.

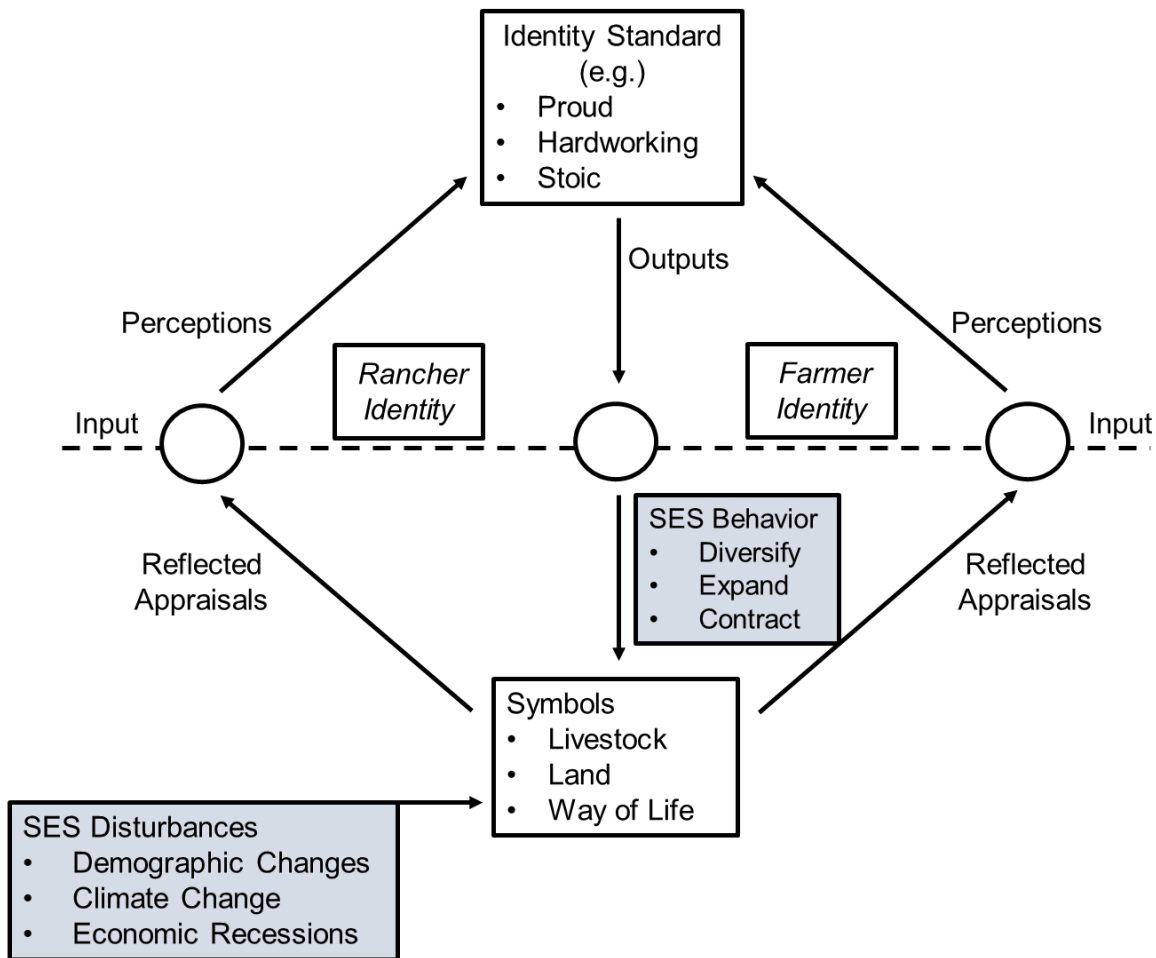


Figure 5.3. Model of the multiple identities of livestock keepers in northeastern Colorado rangeland social-ecological systems (SESs) (adapted from Burke and Stets [2009]). Multiple identities interrelate (i.e., rancher and farmer), impacting *SES Behavior*. *SES Behavior* and *SES Disturbances* (discussed in detail in Bruno et al. [2021]) influence identity *Symbols*. Based upon behaviors and connections to symbols, one receives *Reflected Appraisals* (i.e., feedback from others) and processes this feedback (indicated by the open *Input* circles), informing *Perceptions* (i.e., how one sees oneself). Next, one compares *Perceptions* and the *Identity Standard* (i.e., how a person with the identity “ought” to be). If there is a high discrepancy between *Perceptions* and *Identity Standard*, the *Outputs* might influence one to modify their behavior or feel disconnected from the identity.

5.3.1. Adapting Identities

5.3.1.1. Multiple identities

While *farmer* and *rancher* are often positioned as polar ends of a spectrum differentiated by cultivated crops or livestock (e.g., Sorice et al., 2012), participants’ experiences challenged this

dichotomy. When asked if they predominately identified as a farmer, rancher, businessperson, etc., participants often answered, “All of the above” (R1) and “Kind of all three” (R26). One participant explained how his multiple occupational identities are hierarchical, “I’m a rancher as a major, but the degree is investor” (R7). Some participants pushed back on our narrow list of occupational roles, stating identities such as “grass farmer” (R30), “solar farmer” (R10), “water manager” (R11), and “agritourism” (R3). Outlined in Bruno et al. (2021) and the above *Introduction*, contemporary livestock keepers in NE Colorado have experienced significant social-ecological change. Reflecting Burke and Stets’ (2009) emphasis on multiple roles within the self, participants shared how their increasingly multiple identities are an adaptive strategy to change:

I think the world just gets more complicated in all ways. The changes are more frequent. The world around you just changes so fast. It's way different than it used to be ... I'm not going to minimize what they did years ago, but they didn't evolve [like we do] today. I'd say it's much different in that respect, but there are some similarities, as far as working with animals and that type of thing. (R29)

If you look at it from a historical perspective, we get into a ranch, and we run cows, and that's it. But we forget so much about the business side of it. I spend more time in [my office] than I do out [working cattle]. And it's because [the ranch] is a business. The things that I do in here impact our bottom line more than me going and chasing cows. I really like to go see cows and do all that, but that is not what we get paid for. (R11)

[W]e have to cover so many things. You can't put a category. We have to be a mechanic; we have to be a psychologist; we have to be a veterinarian. Better be a doctor in the house ... You got to be able to step up to the plate. (R30)

5.3.1.2. *Women's access to agricultural identities*

Mechanization has driven change in NE Colorado operations and beyond (Bruno et al. 2021a). While past research found that mechanization subverted women's roles in some agricultural systems (e.g., Saugeres 2002), interviewees expressed opinions that aligned more closely with Riley's (2009) finding that women supported the decision to mechanize. Yet, unlike Riley's (2009) finding that women supported mechanization because it enabled them to transition away from farm labor, our participants (both women and men) felt that technology supported women to engage in physically demanding labor. While participants agreed that mechanization

expanded women's agriculture roles, many interviewees categorized farm and ranch labor aspects as masculine. For instance, one participant shared, "'That is a man's work.' I don't have to fix the mower. I don't have to pull calves on my own. Ranching is hard work and, it just chews women up and spits them out" (R6). The participant identified physically demanding ranch tasks as masculine, desiring work congruent with her feminine gender identity (e.g., off-operation work).

Participants emphasized women's contributions in agriculture, whether off-operation employment, ranch or farm labor or community engagement. Yet, many interviewees shared experiences where women were not acknowledged publicly for their roles as farmers and ranchers. These findings align with research that illuminates the invisibility of women's contributions in agriculture (e.g., Sachs 1983, Little and Panelli 2003, Riley 2009). One Larimer County man shared:

I came here in the '70s. We used to have a Larimer County Stock Growers meeting, and it was all ranchers. So, now when we have a Larimer County Stock Growers meeting, [members] want to know what we are going to have at the next dance and what's the rodeo going to be like. So, us guys with cows get off in a corner and talk about cows, and there's only a half a dozen of us. So, when I was President, I said, 'Why do the women go in the kitchen?' 'Well, it's the cattlemen, and they're supposed to talk about recipes.' And I said, 'That sucks.' I said, 'Some of the women own just as many cattle as the men do. If you want to talk about recipes, do that at another time. Those women need to be in here talking about cattle. The [family name] girls own as many cattle as we do. [Individual's name] owns as many cattle as we do.' So, we combined it. So, it's not the cattlemen talking about recipes. We've broke down a lot of walls. (R16)

The above interviewee shared how women were historically not acknowledged as ranchers (i.e., cattlemen). Yet, the positioning of women with cattle against group members without cattle (or limited interest in livestock) promoted women into higher-status public spaces. This man's statement highlights that women are increasingly receiving public access to agricultural identities through cattle ownership (i.e., livestock as an identity symbol) but that these roles remain elusive.

Despite a lack of public acknowledgment for their roles as ranchers and farmers, women participants celebrated and expressed pride in their agricultural lives. Yet, aligned with research that highlights barriers to women's access to agricultural resources (e.g., Sandhu et al. 2012, Sachs

et al. 2016), women interviewees, such as the one below, experienced additional burdens due to their gender:

A woman in agriculture lives in a man's world ...You're competing constantly. And you've got to learn how to hold your own. And if you can, you're okay. And don't let them bother you too much. Just go do your thing ... A woman in agriculture can make it if she's got a tough mind, but you got to do more than a man has to. The bankers that I have always dealt with, you had to be a step ahead of them if you could be, or at least kind of know what they're thinking. And bankers aren't going [to] like to hear that. Well, it's reality. And a man could go in, with one paper while a woman had better go in with five or six, and she's going to have to have all her *Is* dotted. (R30)

5.3.2. Identity Standards

5.3.2.1. *Agricultural identity standards*

To understand identity and, in turn, behavior linked to identity, we must grasp the meanings individuals and cultures link to the roles (Stets and Burke 2000). One participant shared, “Generally, they’re pretty good people. They’re ranch people” (R22). Captured in this statement is a shared understanding of what it means to be “ranch people.” Aligned with Little's (2002) findings, struggle is central to the rancher identity standard. One Weld county rancher shared, “[Grandma] said a louse couldn’t make a living here. I think she’s right” (R31). Linked to this struggle are elements of pride and isolation, both physical and social. One rancher shared:

You know, ranchers are pretty proud people. I mean, they don’t, myself included, ask for help. At the time, the kids were growing up, and I probably made the kids work harder, but you don’t ask for help. I mean, for right or for wrong, ranchers are pretty stoic people, and self-included, you just probably keep it in ... I mean, you don’t want to tell anybody you didn’t get a loan. That’s embarrassing. It isn’t [embarrassing] today because the financial statement looks a lot better. But at the time, you’re going through a divorce, your financial situation is, well, it’s half of what it was, and it wasn’t very good before. (R16)

Identity theory posits that we generate meaning from our “status (esteem and respect) and power (control of resources)” (Stets and Burke 2005, p 10). Incongruities between perceptions of people, including their status and power, and the identity standard (i.e., how a rancher “ought” to be) create tension. Despite participants’ ability to hold the dual roles of farmer and rancher, interviewees shared that ranchers have a relatively higher social standing, often making ranchers

the dominant public-facing role. Participants discuss the higher power and status of the ranch identity standard, especially when positioned relative to the lower status and power of a farmer:

There's something about owning and operating a cattle operation that has more caché than owning a farm. Although we do own lots of farms, not lot of farms, but we do own farms in Nebraska and Iowa. Being a rancher just is more sexy, if you want to use that term. (R6)

I guess that it's just a little more glorious to be a rancher than what it is a farmer. And I don't know why, but it's always been like that. And now I find my brother when we wanted to split this up, he was always liked being on a horse and not on a tractor. He hated tractors, and so he wanted all the cattle. And so, he took all the cattle, but I have no idea why that is. (R19)

5.3.2.2. *Producers versus women producers*

A mismatch between how one is perceived (i.e., reflected appraisals) and the identity standard creates conflict, driving people to abandon the identity or shift their behavior to align with the standard (Burke and Stets 2009). Below, a participant shared her frustration when her identity as a woman was deemed incongruent with the farmer identity standard (i.e., a woman farmer versus a farmer):

Several years [ago] I just went in and wrote out my \$250 premium [for crop insurance] ... I went in [and the] gal said, 'What are you doing?' 'I'm writing the check, is it raised?' 'No,' she said, 'You don't owe anything.' I said, 'What? The government doesn't give stuff away.' She says, 'Yeah, you are a woman. You are considered underprivileged. So, [the government] has said, "Give it to the ladies."' I was furious. I was furious. Underprivileged? (R30)

When asked why the term underprivileged felt inappropriate, she responded, "Didn't you hear what I said, that I am an American, white, throw-in proud, farmer" (R30). This participant expressed feelings of distress and frustration when her farmer identity was unverified by the government.

One participant, when asked if he had any questions, critically reflects on what external factors had changed his perceptions towards women's roles in agriculture:

I will ask you a personal question, how do you feel about it? About the gender thing? Do you feel like it's a women's lib thing, or do you feel like it is society just finally deciding, yeah, females are capable of doing the same work that males are capable of doing? We don't have to have two different jobs (R1).

Here, the above participant openly and vulnerably struggles with the root of subjugation. He first insinuates that physical ability is the source of difference, but he also questions society's role in oppression. Ultimately, he claims that “we” (i.e., men and women), personally positioning himself, no longer need to have different jobs or identity standards.

5.3.3. Identity Symbols

To further understand the meaning connected to agricultural identities, we explore identity symbols. For ranchers and farmers, livestock and land are vital, functioning as both identity symbols and financial resources without which they could not perform their agricultural identities. We also posit that land and livestock's material and symbolic roles are mutually reinforcing, financially and culturally supporting people's way of life. One participant explained, “He's expanding, but he is not a rancher anymore but under [the] disguise of ranching. His true income is coming off the water development” (R7). His statement emphasizes that livestock and land are currently essential to the verification of the rancher identity. Yet, given the adaptive nature of identity and the rapidly changing SESs (Bruno et al. 2021a), significant factors for ranching and farming in the new context – such as water and oil – may become symbols of agricultural identities.

5.3.3.1. Livestock

Participants discussed both the material and symbolic value of livestock. For many, animal care serves as a ritual, or “formal, significant, symbolically intended and complex action” (Gellner 1999, p. 135), connecting the individual to their identity meaning. For example, one Weld County producer shared:

I guarantee you, when I'm calving, I don't have calves freeze to death. I'm out there. If it's cold, they go to the barn. I'm just not made that way ... I treat them more like I'd like to be treated. (R26)

Here, the participant expressed how his livestock care behavior demonstrates who he is. When we asked the above participant if he thought more about the welfare of the land or livestock, he shared his philosophy that “[t]he livestock come first. They can die. Take care of them first; then you take

care of the land” (R26). This farmer’s connection with livestock prompted us to ask if he ever struggles to sell livestock. He responded:

That’s part of the business I don’t like. But it is what it is. You can’t raise them all and keep them all. I get attached to them. I background [grow animals from weaning until they enter the feedlot] my calves. I’ll wean them in October, and I background till January. Feed them through weaning and get them ready to be finished. A matter of fact, this last year [feedlot name] bought them and they didn’t even [feed] them the warmup things [conditioning ration for weight gain]. They just took them straight to their finishing things.

The above farmer shared his complex relationship with his cattle. His sense of attachment drives him to prioritize animal care. Yet, the livestock are also a significant financial factor in his business and livelihood (Bruno et al. 2021a), enabling him to sell the animals. Similar to Burton’s (2004b) finding that the appearance of crops indicates a farmer’s success, the recognition of the quality of the farmer’s cattle generated a sense of pride. Other interviewees echoed the above farmer’s enjoyment from working with cattle and cattle’s role as symbols of their quality as farmers and ranchers. One participant’s motto is, "If you like our bulls, tell your neighbor. If you don't like our bulls, tell me. I'm the only one that can do anything about it" (R16).

Yet, some ranchers challenged this centrality of livestock. For instance, one Weld County rancher stated:

I’m not married to cows; I’m married to my wife, kind of a deal. To me, ranchers give to the point where they’re in love with their cows. And, yes, I like my cows, but at the end of the day, bankers want [to be] paid back, and employees want [to be] paid, funny how that works. (R11)

When asked to expand on this idea, the participant continued:

You pour so much blood, sweat, and tears into the operation, your time into it. But at the same notion, for sanity reasons, you have to be able to separate the two. Some days are better than others. Okay? Cows are not named, typically. They have names, but that’s for registration purposes. But for me, it’s about numbers. I know, like the older cows, I know exactly what they’ve done for us and things like that. The younger cows, they have to prove their own way. They will in time. (R11)

This rancher grapples with livestock’s significance, voicing the importance of his (and his family’s) well-being over the livestock. Yet, he also presents a relational connection with the cattle, acknowledging reverence for the animals contributing to his family’s well-being.

The tax system has also adopted and formalized livestock as an indicator of an agricultural operation. One Larimer County smallholder explained:

[The County] sent out letters, and then all of a sudden, 'Oh, well, I've got six cows out here now.' And so, they're raising cows. And so now they're agricultural because they have a couple cows that are out there. That's not agricultural. You know? (R13)

When asked what differentiates agriculture, she said, "The amount of work that we put in" (R13).

The participant clarified that while people have access to identity symbols (i.e., livestock and land), they do not match the farmer and rancher identity standards (i.e., hardworking and able to endure struggle). As a smallholder in an increasingly urbanizing community, the participant expressed concern that the government would categorize her with these "hobbyists," compromising her identity verification and agricultural tax status. In addition to the personal conflict of identity nonverification, she would also experience significant financial consequences.

5.3.3.2. *Land*

The significance of livestock was ubiquitous among participants, but many interviewees also felt a sense of connection to the land. One Larimer producer recognized the land type as the factor that differentiates the two identities, "It's just [that] the ground's different. [My land] is kind of a pasture. Where we [used to] live, it was more of a farm. There's a difference between a farm and the ranch" (R20). For another Weld County livestock keeper, the land is why he is a rancher, "I love this ranch, and I want to make it the best landscape possible." (R28). When asked if they would move, the above producer said, "No, we love living out here. We would never move again" (R28). He followed by clarifying that they would adapt their livelihood strategies, such as transitioning to providing recreation opportunities, if that is what they needed to do to stay living on the land. Here, the participant identifies the land's multiple roles, clarifying that the material significance is in service of maintaining his and his family's connection to the land.

One participant grew-up on a large farm in Larimer, but the farm crisis in the 1980s and subsequent challenges significantly affected his family. He farmed throughout his adulthood, but

the family slowly sold off acreage. Having sold the last portion of the farm months before our interview, he shared, "I talk about love of the land ... and the family farm and the family tradition. You know, probably my life would have been happier if it was a feasible operation in these areas" (R4). The farmer continued by clarifying that the farm was not financially feasible, and he felt disconnected and not supported by the local community as he navigated financial challenges. He went on to share his feelings of disconnection from "the culture," frequently questioning his identity as a farmer. Here, we observe a livelihood double bind. His livelihood was unsustainable. Yet, to exit a cycle of decline (Bruno et al. 2021a), he had to sell his land, severing his connection to his identity and culture.

5.3.3.3. *Way of life*

Livestock and land span the symbolic and material, and both are critical to forming a *way of life*. Participants' expression of a way of life aligns with the anthropological sense of culture defined by unique customs, beliefs, etc., that have shared meaning for a group of people (Wright 1998, Mulcahy 2006). One older Larimer County participant reflected on how way of life is central to her survival:

We've been over this little bit with one of my family members. I said to her, if you want me to die, let me move to town. I said every ranchman or woman that has [moved to town has died]; this is their way of life. You make them move to town, and less than two or three months, they die. It's something I have observed where people have moved to town after they have been out in the country. (R20)

When asked why she thought people died when they moved to town, she responded, "Probably because they're not happy. Maybe it's the stress. I don't know. Either the stress or it's so different. I think it's too that they realize that their life is over" (R20). Similarly, another multi-generational producer explained how his love for the way of life verifies his agricultural identity and supports his well-being:

We're doing something we like to do. We're not in it because we were forced into [ranching] by our parents. We're not into it because it's the only thing we can do. We're into it because we actually love [ranching]. We love to get up in the morning and jump out of bed, eager to get to it. We love being able to raise our kids in this lifestyle. We love the freedom of not

having to answer to the boss or anybody. We love the freedom of, if we want to take the day off, we can, if we want to work until 8 o'clock at night, we can. There's just aspects to the lifestyle that are attractive to most of us and kind of keeps us doing it. When we think about something else we'd rather do, in almost all instances, it just doesn't have the appeal. Outside of financial, which has been fine, plenty fine, I think the fact that we enjoy what we do keeps us going. (R29)

5.3.4. Influences of Historical Narratives and Social-ecological Change on Identity

McAdams (2001, p. 101) described identity as “an internalized life story” that is self-defined and evolving. These narratives are authored through reconstructions of the past and anticipation of the future (McAdams 2001). Likewise, many participants shared the significance of historical narratives to their identity. One interviewee shared:

A lot of it's history. Ranchers came into this country; cowboys came into this country; money guys came into this country. Put a bunch of your land together, and [Ranchers, cowboys, and money guys] had it for themselves ... [The US government] did the Homestead Act; you'd come in and get 160 acres. Well, the only way you could make it pay was farming, and that was busting up the big ranchers. So, the farmers, that was a hateful word to a lot of ranchers at that point. But now, there's some that do both, and then you have just farmers, and you have just ranchers. So, on the side of the rancher, [he] relies on the farmer for his feed in the wintertime. And the farmer relies on the rancher to sell his feed to make money that way. (R24)

We create identity through human interactions, and thus, historical narratives about identity formation are not just a story of the self but a broader reflection of sociocultural norms. The above participant framed his agricultural identity within a settler colonialism story. The narrative began with the arrival of livestock and foreign capital into what appears to be “nobody's land” (i.e., *terra nullius*), with no mention of existing Indigenous communities. The story progressed with fears of government control, framing the Homestead Act as a dividing force between ranchers and farmers. Yet, the participant transitioned the narrative, emphasizing that contemporary identities both grew out of and grew beyond this problematic history. One Weld County rancher questioned, “But [Indigenous communities] didn't try to conquer the land. As Anglo-Saxons, we think we can conquer the land.” He goes on to question, “[We] go overboard to defend [the land], but what are you defending?” (R7). Underlying this participant's question is the acknowledgment that land holds both material and cultural value. Therefore, ranchers and farmers are protecting a resource that

provides both financial security and identity verification. He also questioned the utility of Euro-American beliefs around the land, suggesting the value of an alternative way of being.

Agricultural identities sit at the intersection of a violent history and contemporary change. As outlined in Bruno et al. (2021), NE Colorado ranchers are diversifying, contracting, and expanding their operations in response to change. While these adaptive strategies are responses to social-ecological change, they offer an opportunity to redraw identities. Peter et al. (2009) examined agricultural masculinity, identifying industrial producers as having more monologic masculinity (i.e., gendered norms and more control of nature) and sustainable farmers as demonstrating more dialogic masculinity (i.e., increased social openness and less control of nature). While participants shared management practices aimed at controlling nature (i.e., monologic masculinity), participants also shared strategies oriented towards working with or within nature (i.e., dialogic masculinity). For instance, when asked what factors were critical to keeping his operation running, one rancher said:

Part of me because I think that's more of the world that you can have some control over. A lot of the things that happen to you in life you don't really have as much say or control over. Or you just kind of are at the mercy of some outside functions, but the internal stuff you can do something about. There's no way to control the outside world, but you can control what happens to [you] and how you react to it. So, I think probably if you take care of the internal stuff, you've gone a long ways towards success. I think, at least you're doing all you can.
(R29)

The participant acknowledged his limited control over factors external to himself and demonstrated self-reflexivity. This presentation of dialogic masculinity reflects Peter et al.'s (2009) claim that animal agriculture is humbling, cultivating dialogic masculinity. Yet, this participant's focus on “outside functions” – weather, drought, storms, market ups and downs – suggests that the environment played a critical role in molding his perspectives.

Other participants explored moments in which they were challenged by and adapted to rapid social change. One Larimer County rancher shared:

[Protected area development] has taken some of [the land] out of agriculture. In other words, we used to run 1,200 cows, and now we run 600 cows. So, it's cut the productivity of

that in half. On the other hand, Larimer County's working with producers in Larimer County, so I mean we've got a great relationship with them. Is it exactly how we would run it? Nope. On the other hand, I never let a biker pass, or a hiker pass, or a guy riding horses pass, without talking to them. Hey, here's an opportunity to tell them about cattle, or agriculture in Larimer County, or the history of this place. Because we owned it for 30 years, and very seldom does it turn into anything but [a] positive discussion. And they say, 'Well, who are you? It says no dogs here, and you've got a dog.' Well, and I say, 'It's a working dog, and we get to bring ours.' 'Oh, that's cool.' We usually have a good discussion before it's over. (R16)

Above, the rancher shared the cost of conservation efforts on his operation while also capturing how his adaptability enabled him to verify his rancher identity and support positive social-ecological change.

5.4. DISCUSSION

Geertz (1973, p. 452) wrote, "The culture of a people is an ensemble of texts themselves ensembles, which the anthropologist strains to read over the shoulders of those to whom they properly belong." In this qualitative research, we peer over NE Colorado farmers' and ranchers' shoulders to outline their adapting identities, identity standards, and identity symbols using identity theory (Burke and Stets 2009). Moreover, we draw connections to our previous research (Bruno et al. 2021a) to examine the link between producers' shifting identities and adaptive behaviors in the context of SESs change. For rangeland social scientists and rural sociologists, this more in-depth understanding of producers' self-concepts is a missing link to the large body of literature on understanding ranchers' and farmers' decision-making strategies (e.g., Huntsinger et al., 2010; Liffmann et al., 2000; Wilmer and Fernández-Giménez, 2015).

5.4.1. Land, Livestock, and Way of Life

5.4.1.1. Land and livestock

Land and livestock are central to livestock keepers' identities and livelihoods. Land and livestock production values function as financial factors (i.e., financial capital) (Bruno et al. 2021a). Yet, land and livestock are also symbols, functioning as representations of identity. Aligned with Burton's (2004b) findings, the quality of care, especially for livestock, demonstrates producers'

skills and success. Therefore, land and animal losses can be devastating to both livelihoods (Bruno et al. 2021a) and identities.

One outreach specialist focused on grassland conservation shared that he felt that “[livestock producers] usually are bad at the business side of things because they care too much about the cattle and waste a lot of time and effort and money on them” (Grassland Conservation Ecologist, May 12, 2020). While this statement parallels some participants’ opinion that the business should be the priority, it also fails to acknowledge the multiple vital roles of land and livestock. Livelihood strategies require consideration of more than financial factors alone (Bruno et al. 2021a). Land and livestock can facilitate access to other critical resources and identities with higher status and power. As participants shared, cattle ownership can grant access to cultural factors, agricultural tax exemptions, verification of agricultural identities, and the public acknowledgment of women’s roles as farmers or ranchers.

This finding has important implications for engaging producers in conservation behaviors and the adoption of innovations. These results highlight the need to speak to all valued symbols – livestock, land, and way of life – when promoting behavior change among ranchers and farmers. For example, outreach and conservation specialists should emphasize the benefits of adoption for the land and livestock, which support the continuation of the ranching way of life. While these benefits may not be direct, a social-ecological systems framing could serve as a tool for conveying indirect benefits and feedback loops to valued elements in the system. This recommendation follows Brunson and Huntsinger's (2008) finding that conservation on private ranchlands has over-focused on ecological concerns, failing to address ranchers’ desires to maintain their ranch (i.e., way of life).

5.4.1.2. *Way of life*

The significance of people’s way of life or a ranching subculture emerged (Didier and Brunson 2004, Maloney 2004). Moreover, participants expressed how both the material aspects of ranching, such as carefully bred livestock, and the nonmaterial aspects, such as livestock care,

shape the ranching way of life. Analogous to the roles of a cross and prayer to Christian religious life, the symbols and practices of ranching convey the ideas, beliefs, and norms of the way of life. Thus, the sale of land and livestock in response to challenges (i.e., drought, economic downturn) (Bruno et al. 2021a) or lack of a successor (Leonard and Gutmann 2006) could compromise a producer's ability to perform the land and animal care rituals symbolically central to their way of life. This, in turn, could lead to an inability to verify their identity (Burke and Stets 2009). Furthermore, in addition to an unverified identity, losses of livestock, land, and way of life also present financial challenges.

Both the inability to verify one's identity and lost livelihoods can decrease farmers' and ranchers' well-being (Bruno et al. 2021a). One producer shared her struggles to stay on her working ranch as she aged, feeling like she would die if she left the land and lost her way of life. Another retired participant felt that the sale of his land decreased his well-being. The relationship between way of life and human well-being aligns with findings in our previous research (Bruno et al. 2021a) and work on place-based meaning and identity (e.g., Alcamo and Bennett 2003, Williams and Patterson 2008). These findings emphasize the importance of maintaining ranchers' and farmers' connections to livestock, land, and way of life. In a sector where the average age is 58, our findings emphasize the need for infrastructure and education to support aging in place in rural areas (USDA NASS 2019b). For instance, while most cattle-related deaths are with workers above 65 years of age (Langley and Hunter 2001), outreach and education efforts (USDA NASS n.d., eXtension 2012) can improve safety.

5.4.2. Shifting Identities

5.4.2.1. Farmers and ranchers

Our findings align with Bryant's (1999) observation of a move from "traditional," often singular, occupational identities towards plural, untraditional identities in South Australia's farming systems. While the historical settler colonialism narrative establishes farmers and ranchers

as counterroles, participants presented identity meanings, such as hardworking and stoic, shared across the farmer and rancher identities. Moreover, many participants simultaneously identified with farmer and rancher roles. These findings suggest that the addition of a farmer-rancher typology would contribute to well-established nomenclatures of farm identities (e.g., Ploeg 1994, Bryant 1999, Vanclay et al. 2006). The prevalence of mixed crop-livestock operations suggests the utility of outreach programs that explore synergies between crop and livestock systems (e.g., grazing crop residue) (Kumar et al. 2019). Many participants had a family history in solely crop or livestock production, with recent events driving diversification. Therefore, opportunities for farm to ranch (and ranch to farm) field days could support knowledge exchange and contribute to power-sharing across historically hierarchical identities. The one difference that participants identified was that ranchers hold more social "clout" than farmers. Future research could examine the factors that influence this power difference between ranchers and farmers.

Moreover, this research illuminates how adaptive strategies in response to change, most notably diversification (Bruno et al. 2021a), have influenced (and sometimes necessitated) increasingly plural identities. For instance, participants reported holding multiple roles, including those of businessperson, mechanic, veterinarian, and even grass farmer. Research has long struggled to identify rancher motivations (Smith and Martin, 1972; Torell et al., 2001). This study offers that one challenge may be that the long-used categorizations of *rancher* and *farmer* aggregate a wide diversity of contemporary producers. Moreover, research indicates that alternative food systems, such as organic, sustainable, and local agriculture, are emerging spaces where women are more accepted in their roles as farmers (Sachs et al. 2016). As one participant shared, present-day producers have needed to adapt rapidly to their changing context, and we posit that such change may offer opportunities for women. Thus, further qualitative research could build from this study to parse more nuanced identity categories of livestock producers, including a deeper consideration of emerging roles in alternative food systems. We posit that integrating such granular typologies

into behavioral models may shed light on unique motives and behaviors across more granular producer identities.

5.4.2.2. *Social change*

Aligned with Pilgeram's (2007) identification of the masculine as the "de facto gender" in agriculture, women participants shared the struggle of living in a "man's world" in agriculture. Women participants shared their challenges with oppressive structural systems, such as the financial sector. While most interviewees acknowledged increased acceptance of women in agriculture and women's critical contributions to on- and off-operation work, women did not always receive public acknowledgment of their roles as *farmers* or *ranchers*, sometimes labeled as *women farmers/ranchers*. Future research could consider if some people self-identify as and celebrate the roles of *woman rancher/farmer*, or if gender identity as a modifier unverified the occupational identity.

We ended all the interviews by asking participants if they had any questions. One participant reflexively asked why the first author thought perceptions of women in agriculture have changed. He continued with his self-reflection, tentatively acknowledging the role of feminist movements in changing perceptions and behavior. Many women (in and out of agriculture) are reluctant to identify as feminists, including participants in this study (Brandth 2002b). Yet, agricultural communities are nested within the broader social discourse in which identities are forged and affirmed, and therefore, change at higher social levels influences individuals' identities, and vice versa (Burke and Stets 2009). In this participant's reflection, we observe an acknowledgment of social justice movements' contributions to peoples', especially women's, lives in agriculture.

CHAPTER 6

CONCLUSION

6.1. CONCLUSIONS

This dissertation investigates the causes and consequences of change in complex, adaptive rangeland SESs in NE Colorado. I approached this research with dual and iterative aims of advancing theoretical SESs frameworks and examining the phenomena of change. SES theory serves as this dissertation's foundational theory (Berkes and Folke 1994, Holling 2001, Liu et al. 2007a, 2007c). Yet, despite the prominence of SESs theory, elements of the social sphere – such as culture, power, and actor agency – remain underexamined (Stojanovic et al. 2016). This dissertation's theoretical and conceptual contributions to these deficiencies leverage and advance the livelihoods (Chambers & Conway, 1992) and well-being frameworks (Armitage et al., 2012) (Chapter 3), Hersperger et al.'s (2010) conceptual land change model (Chapter 4), and identity theory (Burke & Stets, 2009) (Chapter 5). This dissertation also advances research on rangeland social science as an emerging applied field, livestock producers' increasingly complex adaptive strategies and identities, and land change trends in NE Colorado in its empirical contributions. Moreover, I acknowledge the partiality of knowledge (Haraway, 1988; Nightingale, 2003), assembling multiple vantage points – the academic literature, livestock producers' lived experiences, and remotely sensed data – into the holistic view of NE Colorado rangeland systems presented in this dissertation. Below, I reflect on learnings for researchers and practitioners from Chapters 2-5.

6.1.1. Summary of Findings and Their Implications for Research and Engagement

Chapter 2 systematically maps the emerging and growing body of social science inquiry on North America's rangeland systems from 1970 to 2017. Chapter 2 found that most (81%) of North

American rangeland social science has studied ranchers, farmers, and/or landowners, with limited consideration of other stakeholders (e.g., ranch workers, youth). Although the literature often considers age (43% of the studies) and education (40%), other attributes/identities, such as gender (28%) and race or ethnicity (18%), are less frequently included. The most commonly used research method is surveys (52%), and much of rangeland social science does not make explicit connections to either specific methodological or theoretical frameworks. The limited application of theories, methodologies, and a lack of diverse methods has potentially constrained who and what research has studied in North America. The limited consideration of gender and race in rangeland social science is echoed in the limited number of studies that have accounted for the effects of social identities and power relationships on people's connection to and management of rangelands.

Chapter 2 offers insights to rangeland researchers and educators. Notably, Chapter 2 highlights the need for more North American research that considers a broader diversity of stakeholders. This limited understanding of all rangeland stakeholders may also link to knowledge gaps of how diverse rangeland stakeholders perceive new technologies, how they make decisions, and their attitudes toward rangelands. I posit that diversifying the research populations will lead to a shift in the research questions. With this shift, there will likely be a need to employ a wider breadth of research methods, methodologies, and theories. I speculate that social science on North American rangeland systems has been historically constrained by the limited rangeland social science curriculum and few cross-disciplinary exchange opportunities. Thus, Chapter 2 suggests a need for increased social sciences inclusion in rangeland curricula and social scientists' recruitment into rangeland departments. As an early-career scholar, Chapter 2's research gaps informed my conceptualization of Chapters 3-5.

Chapter 3 emerged from my previous work as a development practitioner in which I used the livelihoods framework to inform community engagement and project design (Chambers, 1995; Chambers & Conway, 1991; Ian Scoones, 2009). Chapter 3 presents the empirical foundation for an

integrated livelihood and well-being framework that addresses gaps in the foundational frameworks, especially in applications to rangeland systems in the Global North. Seven factors emerged as main inputs for producers' livelihood strategies: financial (e.g., income), natural (e.g., land), social (e.g., community), human (e.g., labor), physical (e.g., infrastructure), political (e.g., access to policymakers), and cultural (e.g., way of life). Livestock producers described a dynamic process of interrelating these input factors to develop three primary livelihood strategies to avoid migration out of agriculture: contraction, expansion, and diversification. Through these livelihood strategies, producers increase or maintain their material (i.e., "what you have"), relational (i.e., "what you can do with what you have"), and subjective (i.e., "how you feel") well-being.

Chapter 3 offers a framework that captures the feedback between livestock producers' livelihood decisions and human well-being outcomes. The study also emphasizes the significance of well-being and resource access to producers' livelihood decision-making. As such, this study suggests that outreach and research involving livestock producers are likely to achieve greater success when programming addresses human well-being and resource access inequities. Thus, Extension, policymakers, and researchers may find the proposed framework helpful in designing human-centered support systems for livestock producers in the western US and beyond. Moreover, Chapter 3 offers an early conceptualization of social-ecological-emotional systems to the broader SESs literature.

In Chapter 3, participants shared rapid social and ecological change experiences and the associated threats to working rangelands and their livelihoods. Chapter 4 emerged from these lived experiences, applying a multi-method approach to examine the causes and consequences of land-use change in two NE Colorado ranching communities. Chapter 5 found that both study sites experienced a decline in cultivated land cover from 1984-2019, with 16.0% and 18.7% of total land areas transitioning out of cultivated cover in sites A and B, respectively. Most of the cultivated land transitioned to herbaceous/grassland cover, with 10.3% and 18.4% of total land area transitioning

to herbaceous/grassland cover from 1984-2019 in each site, respectively. The qualitative analysis identified the significant role of conservation policies, especially the Conservation Research Program and open space initiatives, in driving the trends of decreased cultivated and increased herbaceous cover. Moreover, the study found that 16,896 acres (1.83% of the total area) transitioned to developed land in the Larimer site and 1,583 acres (0.183% of the total area) transitioned out of developed cover in the Weld site. Despite the relatively small number of acres that transitioned to and from developed land cover, participants emphasized how demographic and cultural changes reduce the public's acceptance of agriculture.

Chapter 4 presents a rangeland-use change conceptual model that illustrates the interrelationship among driving forces, livestock producers, and land change patterns. This conceptual model reconciles qualitative and quantitative social and ecological findings, offering a tool for understanding the multiscale and multilevel phenomena of change in rangeland systems. Chapter 4's findings of decreased cultivated cover and increased herbaceous cover suggest that conservation efforts can challenge trends of uncultivable rangelands transition to "productive" use (i.e., developed or cultivated land) (Herrick et al. 2012). Yet, while broad land cover trends aligned with the ecological objectives shared by numerous stakeholders (i.e., Larimer County and the City of Fort Collins), Chapter 4 also highlights the need for research and outreach that examine and support cultural resilience of agricultural stakeholders in NE Colorado. Finally, the pieces (code) to develop the random forest classifier are publicly available on GitHub for future applications in the analysis of geospatial archives: <https://github.com/jasmineandjake/random-plains-class>.

Chapter 5 addresses the limited consideration of socio-cultural factors, such as identity, in rangeland social science (Bruno et al., 2020; Chapter 2) and SESs theory (Stojanovic et al., 2016). To address this gap, I used identity theory to deductively analyze livestock keepers' conceptualization of their occupational identities and the associated gender divisions (Burke & Stets, 2009; Sheldon

Stryker & Burke, 2000; Sheldon Stryker & Serpe, 1982). Chapter 5 found that, while history often presents farmer and rancher identities as distinct and conflicting, participants described their roles as becoming increasingly plural (including dual farmer-rancher roles) in response to social and ecological change. Participants emphasized the significance of land and livestock to their agricultural identities, financial well-being, and way of life (i.e., culture). This study also found that while most participants discussed the increasing acceptance of women in agriculture, women have not always received public acknowledgment of their roles as farmers or ranchers.

Chapter 5 offers insights to researchers and practitioners. Given the significance of land, livestock, and way of life, this study suggests that outreach and conservation efforts can use a social-ecological system framing as a tool to support behavior change, outlining the benefits of change on livestock care, rangeland health, and cultural resilience. As livestock keepers are restructuring their identities in response to social and ecological change, this study highlights opportunities to support the increased inclusion of diverse agriculture identities. This more nuanced understanding of agricultural identities and their relationship to behavior can support researchers and practitioners in developing strategies that meet rangeland stakeholders' shifting needs. Moreover, this study contributes to rural sociology's expanding interest in agricultural and rural systems' socio-cultural factors.

6.1.2. Future Research Directions

As a whole, this dissertation moves between theory and empirical data analysis, iteratively drawing upon each other to develop both theoretical and empirical contributions (Charmaz 2006, 2008). My positionality influenced my decision to orient this research around livestock producers' lived experiences. In a kitchen drinking coffee, I learned how diversification helps balance the challenges of harsh winters and dry years on the eastern Plains. In another kitchen filled with horses' pictures, a rancher shared her years of environmental activism, fighting Uranium extraction and participating in Ranchers for Peace. In a smaller kitchen closer to the mountains, an 88-year-

old rancher shared her belief that she will die if she leaves her ranch and way of life. I moved from this contextual data to the adaptation and development of frameworks and models. Such emergence of social theory is a dynamic and adaptive process, and therefore, future research can expand this dissertation's contributions beyond NE Colorado. I advocate for applying the frameworks and models from Chapter 3 (an integrated livelihoods-well-being framework), Chapter 4 (a rangeland change model), and Chapter 5 (an adapted identity theory/model) to other sites and systems, expanding this dissertation's insights to support the development of socially, ecologically, and emotionally sustainable livestock systems in NE Colorado and beyond.

Moreover, Nightingale (2015) advocates for research that works from the community and their existing material relationships to support people in realizing their self-determination. Chapter 4 and, to some degree, Chapter 3 contribute to our understanding that rural, natural resource-dependent communities are significantly, and often disproportionately, altered by social and climatic change (Dasgupta et al. 2014). While the resulting land changes can contribute positive benefits (e.g., increased food production and livelihoods), forced changes often bring unintended negative consequences, such as land degradation and lost lifeways (Herrick et al., 2012; Liffmann et al., 2000). These findings align with a growing body of literature that identifies the significant and often unplanned transitions in rangeland systems (e.g., Hansen et al., 2002; Huntsinger, Buttolph, & Hopkinson, 1997; Liffmann, Huntsinger, & Forero, 2000). Also, The Intergovernmental Panel on Climate Change (IPCC) identified the need for socially just and environmentally sustainable transformations in extensive global ruminant systems (Mbow et al. 2019).

As such, for many SESs, self-determination may require a deliberate transformation. Yet, pathways to such sustainable transformations for extensive livestock systems and linked communities remain understudied. Also, the transformability of SESs remains undertheorized (Hruska et al. 2017). Thus, this dissertation speaks to the need for researchers, local policy makers, Extension, and conservation organizations to work with ranching communities in Colorado and

beyond to conceptualize and theorize deliberate transformations with a normative goal of equitable outcomes for the environment and human communities.

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APPENDICES

APPENDIX A

Table. A.1. Rangeland social science systematic map data collection tool.

Question	Response Codes
Reviewer	
Author	
<i>Last Name, First Initial/Middle Initial (e.g., Bellamy, J.A, Brown, J.R.)</i>	
Title	
Full Citation	
<i>Rangeland Ecology & Management Citation Format example: Bestelmeyer, B.T., Okin, G.S., Duniway, M.C., Archer, S.R., Sayre, N.F., Williamson, J.C., Herrick, J.E., 2015. Desertification, land-use, and the transformation of global drylands. Frontiers in Ecology and the Environment 13, 28–36.v</i>	
Keywords	
<i>Copy and paste key words if listed in the paper. If no key words listed, write NA.</i>	
Inclusion Criteria	
<i>Check all that apply. Must meet first 3 criteria for inclusion.</i>	1=North America, 2=Ranching or Rangeland System, 3=Social Science, 4=Paper Excluded, 5=Other (Specify)
Exclusion Criteria	
<i>Check all that apply</i>	1=Not Focused on North America, 2=Study Focus Not People, 3=Not Ranching or Rangeland System, 4=Paper Included, 5=Not a Scientific Journal Article (i.e., No Book Chapters, Theses, Proceedings), 6=Other (Specify)
Dominant Academic Field	
<i>Check one based on 1) journal, 2) theories, 3) literature cited, 4) author's department. If no single academic field can be identified, check interdisciplinary.</i>	1=Economics, 2=History, 3=Law, 4=Sociology, 5=Ecology (Social Focus), 6=Social Psych, 7=Anthropology, 8=Geography, 9=Human Dimensions NR, 10=Political Science, 11=Range Science,

Data Collection Method

Check all that apply

Data Analysis

Check all that apply

Geographic Location of Study

Be as specific as possible

Study Population

Check all that apply. If organization or group selected, also check "other" and specify the group or org.

Unit of Analysis

Using the abstract and conclusion, consider what unit of analysis the author(s) are drawing inference about. If the primary focus is on individual opinions, check "individual." If the primary focus is on ranch level outcomes from sampling individuals, check both "individual" and "household/firm." If unclear, check most relevant option and "unclear."

Sample Size

For each data collection method selected, specify the sample size and unit of analysis (Example: Survey=24 Households, Ethnography=43 Individuals).

12=Education and Extension,
13=Organizational,
14=Ethics and Philosophy,
15=Agriculture,
16=Interdisciplinary,
17=Other (Specify)
1=Survey, 2=Focus Group,
3=Interview,
4=Ethnography, 5=Review,
6=Participant Observation,
7=Ecological/Agricultural Data Collection, 8=Other (Specify)
1=Descriptive Statistics,
2=Conventional Inferential Statistics, 3=Economic Model, 4=Simulation Model, 5=Multi-variate Statistics, 6=Comparative Case Study, 7=Non-comparative Case Study, 8=Narrative Analysis, 9=Modified Grounded Theory, 10=Bayesian Statistics or Model Selection, 11=Other (Specify)

1=Ranchers, Range Livestock Producers,
2=Farmers, 3=Other Landowners, 4=General Public, 5=Organization or Group, 6=Land Managers (Agency or Non-Profit), 7=Other (Specify)
1=Individual,
2=Household/Firm/Ranch or Farm Operation,
3=Group,
4=Agency/Organization,
5=Community, 6=Unclear,
7=Other (Specify)

Is there a clear research objective?

Yes, explicit-Authors clearly state research objective(s), purpose, or goal; Yes, implicit-author(s) present information that reflects the research objective(s) but not clearly stated early in the paper; No, not explicit or implied-research objective not stated and unclear

1=Yes, explicit, 2=Yes, implicit, 3=No, not explicit or implied, 4=Other (Specify)

Research Objective

Cut and paste or state in your own words the implied or explicit research objective.

Are there clear research questions?

Yes, explicit-Authors clearly state research question; Yes, implicit-research questions are implied through the research objectives or information in the article; No, not explicit or implied-no research question stated

1=Yes, explicit, 2=Yes, implicit, 3=No, not explicit or implied, 4=Other (Specify)

Research Question(s)

Cut and paste or state in your own words the implied or explicit research question(s).

Is there a clear hypothesis?

Yes, explicit-Author's clearly state hypothesis; Yes, implicit-information is presented that indicates expected result; No, not explicit or implied-experimental design with no expected relationship articulated

1=Yes, explicit, 2=Yes, implicit, 3=No, not explicit or implied, 4=Other (Specify)

Hypotheses

Sex or Gender Considered?

Used in Analysis (Independent, dependent, or covariate variable in the statistical analysis); Sample Described (Used to describe the sample, e.g., descriptive statistics or demographics); Mentioned (Concept is mentioned in the paper but no data is collected and/or reported); Not Mentioned (No mention of the concept in the paper)

1=Used in Analysis, 2=Sample Described, 3=Mentioned, 4=Not Mentioned

Race/ethnicity Considered?

Used in Analysis (Independent, dependent, or covariate variable in the statistical analysis); Sample Described (Used to describe the sample, e.g., descriptive statistics or demographics); Mentioned (Concept is mentioned in the paper but no data is collected and/or reported); Not Mentioned (No mention of the concept in the paper)

1=Used in Analysis, 2=Sample Described, 3=Mentioned, 4=Not Mentioned

Age Considered?

Used in Analysis (Independent, dependent, or covariate variable in the statistical analysis); Sample Described (Used to describe the sample, e.g., descriptive statistics or demographics); Mentioned (Concept is mentioned in the paper but no data is collected and/or reported); Not Mentioned (No mention of the concept in the paper)

1=Used in Analysis, 2=Sample Described, 3=Mentioned, 4=Not Mentioned

Education Considered?

Used in Analysis (Independent, dependent, or covariate variable in the statistical analysis); Sample Described (Used to describe the sample, e.g., descriptive statistics or demographics); Mentioned (Concept is mentioned in the paper but no data is collected and/or reported); Not Mentioned (No mention of the concept in the paper)

1=Used in Analysis, 2=Sample Described, 3=Mentioned, 4=Not Mentioned

Class, Socio-economic Status, or Income Considered?

Used in Analysis (Independent, dependent, or covariate variable in the statistical analysis); Sample Described (Used to describe the sample, e.g., descriptive statistics or demographics); Mentioned (Concept is mentioned in the paper but no data is collected and/or reported); Not Mentioned (No mention of the concept in the paper)

1=Used in Analysis,
2=Sample Described,
3=Mentioned, 4=Not
Mentioned

Operational Scale Considered?

Used in Analysis (Independent, dependent, or covariate variable in the statistical analysis); Sample Described (Used to describe the sample, e.g., descriptive statistics or demographics); Mentioned (Concept is mentioned in the paper but no data is collected and/or reported); Not Mentioned (No mention of the concept in the paper)

1=Used in Analysis,
2=Sample Described,
3=Mentioned, 4=Not
Mentioned

Intersectional Perspective?

1=Consideration of Political
or Power Dynamics Related
to Intersecting
Marginalized Social
Identities/Positions,
2=Simultaneity of
Interacting Social
Identities/Characteristics,
3=No Consideration

Independent or Explanatory Variable(s)

If not applicable, insert NA

Dependent or Response Variable(s)

If not applicable, insert NA

Measured or Observed Covariates/Effect Modifiers

Note: Included in empirical work (e.g. gender, education, risk orientation, weather patterns, market access, etc.). If not applicable, insert NA.

Key Findings/Results

Relationship between independent and dependent variables or key findings

Do the conclusions and key findings/results match?

1=Yes, 2=No

Abstract

Insert Abstract

Did the author(s) state research needs?

1=Yes, additional research
needs stated, 2=No, no
research needs stated

Author(s) stated research needs

Please cut and paste the text directly from the article. If not applicable, insert NA.

Did the author(s) state management implications?

1=Yes, management
implications stated, 2=No,
no management
implications stated

Author(s) stated management implications

Please cut and paste the text directly from the article. If not applicable, insert NA. Also, if implications merge policy and

management, include the text in both answers.

Did the author(s) state policy implications?

1=Yes, policy implications stated, 2=No, no policy implications stated

Author(s) Stated Policy Implications

Please cut and paste the text directly from the article. If not applicable, insert NA. Also, if implications merge policy and management, include the text in both answers.

Did the author(s) state outreach and education implications?

1=Yes, outreach and education implications stated, 2=No, no education and outreach implications stated

Author(s) Stated Outreach and Education Implications

Please cut and paste the text directly from the article. If not applicable, insert NA. If not applicable, insert NA.

Methodological Framework

Only select if explicit. Otherwise, select "Not Mentioned." General Definition: Methodology is the systematic, theoretical analysis of the methods applied to a field of study. The researchers' choice of how to use a method (e.g., survey) constitute their methodology (Sprague, 2016). That is, a methodology works out the implications of a specific epistemology for how to implement a method.

1=Post-positivist Survey, 2=Grounded Theory, 3=Not Mentioned, 4=Other (Specify)

Theoretical Framework

Check all that apply. If there is no explicit framework, but a theoretical framework is implied, check "no explicit framework" AND "implied framework" AND Other (specify) to specify the implied framework. If there is an explicit framework that is not one of the checkboxes, use Other (specify).

1=Theory of Reasoned Action, 2=Adoption of Innovation, 3=Common Pool Resource Theory, 4=Adaptive Governance, 5=Social Capital, 6=Livelihoods, 7=Institutional Analysis and Development, 8=Resilience Theory, 9=Social Ecological System Theory, 10=No Explicit Theoretical Framework, 11=Implied Theoretical Framework (specify if Other), 12=Other (Specify)

Funders

If explicit, list funders (e.g., NSF, USDA)

Is the research participatory?

1=Not Participatory Research, 2=Participatory (e.g., co-production, collaborative research, community-based research), 3=Author(s)

Indicate Research
Participatory but
Participatory Methods Not
Used, 4=Other (Specify)

Collaborative Public or Private Partners

If explicit, list any non-university collaborative partners. This could include agencies or NGOs. The collaboration could be as a co-author, funder, partner, field support, etc.

Is this stand alone social science?

Integrated social and ecological science: Collect, analyze, and discuss social and ecological data in relation to one another.; Social ecological systems: Includes reciprocal feedback loops between social and ecological systems. Must include how the social system influences the ecological system and how the ecological system influences the social system. Stand alone social science is defined here as studies of human perceptions, values, behavior, etc. that do not include any ecological data.

1=Yes, stand alone social
science, 2=Integrated social
and ecological science,
3=Social ecological
systems, 4=Other (Specify)

Notes

If not applicable, insert NA

APPENDIX B

CHAPTER 2: LIST OF REVIEW ARTICLES

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APPENDIX C

Table. C.1. Output from the bibliometric citation analysis listing the 121 journals in the rangeland social science literature body disaggregated by journals included in the citation clusters (64 journals) and journals not included in the citation clusters (57).

Journals (64) in citation clusters	Journals (57) not included in citation clusters
Agricultural History	Adolescence
Agricultural Systems	Agricultura Sociedad Y Desarrollo
Agriculture and Human Values	Agrociencia
Agriculture, Ecosystems & Environment	American Journal of Industrial Medicine
Agroecology and Sustainable Food Systems	Animal Welfare
Ambio	Annals of the New York Academy of Sciences
American Behavioral Scientist	Antipode
American Journal of Agricultural Economics	Applied Soil Ecology
Annals of the Association of American Geographers	Ariel-a Review of International English Literature
Biological Conservation	Botanical Sciences
Bulletin of the American Meteorological Society	California History
California Agriculture	Cuadernos De Desarrollo Rural
Climate Research	Disability and Health Journal
Climatic Change	Ecological Modelling
Computers and Electronics in Agriculture	Ecosystem Services
Conservation Biology	Environment and Behavior
Ecological Applications	Environment and History
Ecological Economics	Environmental Conservation
Ecology and Society	Environmental History
Ecosphere	Environmental Monitoring and Assessment
Environmental Management	Ethnohistory
Environmental Science & Policy	Food Policy
Forest Policy and Economics	Hispanic American Historical Review
Frontiers in Ecology and the Environment	Historia Agraria
Geoforum	Historia Mexicana
Global Environmental Change	Historical Methods
Growth and Change	Human-Wildlife Interactions
Human Ecology	Interciencia
Human Organization	Journal of Agribusiness in Developing and Emerging Economies
Invasive Plant Science and Management	Journal of Agricultural and Environmental Ethics
Journal of Agricultural and Resource Economics	Journal of Agriculture, Food Systems, and Community Dev.

Journal of Animal Science	Journal of Agromedicine
Journal of Applied Ecology	Journal of Fish and Wildlife Management
Journal of Applied Meteorology	Journal of Occupational and Environmental Hygiene
Journal of Arid Environments	Journal of Political Ecology
Journal of Environmental Management	Journal of Sociolinguistics
Journal of Environmental Planning and Management	Journal of the American Veterinary Medical Association
Journal of Rural Studies	Landscape Research
Journal of Soil and Water Conservation	Latin American Perspectives
Land Economics	Mathematical Social Sciences
Land Use Policy	Natural Resource Modeling
Mitigation and Adaptation Strategies for Global Change	Natural Resources Journal
Natural Hazards	Preventive Veterinary Medicine
Natural Resources Forum	Public Health Nursing
Oryx	Range Management and Agroforestry
Outlook on Agriculture	Restoration Ecology
Plant Ecology	Revista Cientifica-Facultad De Ciencias Veterinarias
Political Geography	Revista Mexicana De Ciencias Pecuarias
Quarterly Journal of Speech	Revista Ra Ximhai
Rangeland Ecology & Management (Journal of Range Mgt.)	Scientific Reports
Renewable Agriculture and Food Systems	Sociological Inquiry
Review of Agricultural Economics	Urban Ecosystems
Risk Analysis	Water Alternatives
Rural Sociology	Water Resources Management
Society & Natural Resources	Weed Technology
Sustainability	Wildlife Research
The Canadian Geographer / Le Géographe canadien	
The Professional Geographer	
The Rangeland Journal	
The Social Science Journal	
Weather, Climate, and Society	
Weed Science	
Wildlife Society Bulletin	
Written Communication	

Table. C.2. Output from the bibliometric citation analysis listing the 121 journals in the rangeland social science literature body, the number of articles published in each journal, and the number of citation linkages for each journal.

Number of documents	Journal(s) (number of citations in the literature body)
71	Rangeland Ecology & Management (1121)
15	Wildlife Society Bulletin (345)
15	Society & Natural Resources (333)
11	Ecology and Society (150)
6	Agricultural History (7)
5	Journal of Soil and Water Conservation (34); Journal of Environmental Management (60); Conservation Biology (136)
4	Journal of Agricultural and Resource Economics (59); Environmental Management (39); California Agriculture (30)
3	Weather Climate and Society (37); Rural Sociology (45); Renewable Agriculture and Food Systems (33); Professional Geographer (53); Journal of Rural Studies (117); Human Organization (41); Ecological Economics (35); Climatic Change (47); Agricultural Systems (74)
2	Written Communication (9); Weed Technology (12); Sustainability (3); Revista Mexicana de Ciencias Pecuarias (0); Review of Agricultural Economics (2); Preventive Veterinary Medicine (25); Outlook on Agriculture (9); Oryx (5); Natural Hazards (2); Land Use Policy (28); Land Economics (2); Journal of Arid Environments (18); Human Ecology (15); Historia Mexicana (0); Global Environmental Change-Human and Policy Dimensions (69); Geoforum (154); Frontiers in Ecology and the Environment (94); Environmental Monitoring and Assessment (13); Bulletin of the American Meteorological Society (114); Biological Conservation (20); American Journal of Agricultural Economics (44); Agroecology and Sustainable Food Systems (9); Wildlife Science: Connecting Research with Management (0); Wildlife Research (10); Weed Science (7); Water Resources Management (0); Water Alternatives-An Interdisciplinary Journal on Water Politics and Development (4); Urban Ecosystems (7); Sociological Inquiry (1); Social Science Journal (11)
1	Scientific Reports (1); Risk Analysis (61); Revista Ra Ximhai (2); Revista Cientifica-Facultad de Ciencias Veterinarias (0); Restoration Ecology (7); Rangeland Journal (5); Range Management and Agroforestry (0); Quarterly Journal of Speech (51); Invasive Plant Science and Management (8); Interciencia (5); Human-Wildlife Interactions (0); Historical Methods (6); Historia Agraria (6); Hispanic American Historical Review (8); Growth and Change (39); Frontiers in Agricultural Sustainability: Studying the Protein Supply Chain to Improve Dietary Quality (6); Forest Policy and Economics (3); Food Policy (10); Ethnohistory (5); Environmental Science & Policy (17); Environmental History (1); Environmental Conservation (1); Environment and History (2); Environment and Behavior (16); Ecosystem Services (24); Ecosphere (19); Ecological Modelling (15); Ecological Applications (5); Disability and Health Journal (2); Cuadernos de Desarrollo Rural (1); Computers and Electronics in Agriculture (19); Climate Research (23); Canadian Geographer-Geographe Canadien (2); California History (0); Botanical Sciences (1); Ariel-A Review of International English Literature (0); Applied Soil Ecology (129); Antipode (4); Annals of the Association of American Geographers (9); Animal Welfare (22); American Journal of Industrial Medicine (0); American Economic Review (22); American Behavioral Scientist (11); Ambio (1); Agrociencia (3); Agriculture Ecosystems & Environment (28); Agriculture and Human Values (2); Agricultura

Sociedad y Desarrollo (0); Adolescence (8); Public Health Nursing (4); Political Geography (13); Plant Ecology (2); Natural Resources Journal (2); Natural Resources Forum (28); Natural Resource Modeling (6); Mitigation and Adaptation Strategies for Global Change (3); Mathematical Social Sciences (28); Latin American Perspectives (1); Landscape Research (8); Journal of Sociolinguistics (4); Journal of Political Ecology (3); Journal of Occupational and Environmental Hygiene (5); Journal of Fish and Wildlife Management (1); Journal of Environmental Planning and Management (1); Journal of Agribusiness in Developing and Emerging Economies (0); Journal of the American Veterinary Medical Association (1); Journal of Agricultural & Environmental Ethics (5); Journal of Agriculture Food Systems and Community Development (0); Journal of Agromedicine (5); Journal of Animal Science (3); Journal of Applied Ecology (8); Journal of Applied Meteorology (22)

APPENDIX D

SEMI-STRUCTURED INTERVIEW SCRIPT

Identity

- First, what is your name and the name of your ranch/farm/operation?
- Do you yourself identify as a rancher, farmer, business/agribusiness operator, etc.?
- **I am interested in the experiences of a range of producers from farmers to ranchers to agribusiness operators, and more specifically, I am interested to understand the unique roles of each of these operators. I noticed that you identified your operation as a [select title]. What does it mean to be [select title] operation versus a [select title]?**
- **What does it mean to be a [selected title], and how is a [select title] different from a [select title]?**
- **How many years have you been a [selected title], and where your parents [select title]? Note: If prompted by the participant, a lengthier discussion of family history may develop. If not, this discussion will be continued below with questions regarding succession.**

Land Use

- Can you describe your operation to me? Note: Depending upon what the individual mentions, may follow-up with some more specific questions regarding scale?
- (If not mentioned above) What type of operation do you run, and what livestock are involved in the operation? Note: Depending upon the response of the individual, I will follow-up with questions regarding breeds, breed selection, and potentially, scale?
- In addition to livestock production, are you involved in other enterprises (e.g., hay production, tourism, construction, etc.)?

Livelihoods

- Have you experience a major event such as drought? If yes, can you walk me through the experience?

If yes and after the initial overview, we will address the below matrix:

Event	Did you have a drought plan in-place? If yes, was it useful?	Effect of the event	Your Response	Community Response	Who was Affected within the household? How?	Who was Affected within the community? How?	What were some sources of support? Note: If only income-based support is mentioned, I will inquire more broadly regarding

							support (e.g., family, church, academic institution)?

Note: If an event(s) is identified, this will prompt discussion on the role of community and individuals in livelihood coping strategies.

- How has this experience changed you and your operation?
- Is there anything important about the drought event that I forgot to ask about?

Change

- What are the main things that have been changing in this community over the past five years or so? Has the economic base changed (e.g., from agriculture to oil & gas or to tourism)?
- Are the kinds of people who live in the community change and if so how? Is the population size changing? If yes, why are people migrating in and out of the community? Why have you remained in the community?
- (If not discussed in the Individual/identity section above) How did you become a [select title]?
- Do you have a person or institution to continue the operation of your ranch or farm once you retire? If so, who, and how did you establish the relationship with this individual?
- People have told me that ranching, farming, or more generally, a rural lifestyle can be in our DNA, passed down and maintained? How do you think ranching/farming/rural lifestyles could be maintained in the US? What do you see as the future of ranching/farming/rural lifestyles in the US?

Well-being and Gender

- **In your experience, have you observed or experienced negative changes to ranching/farming in the last five years? Last 10 years? Have these changes impacted your life in the last five years? Last 10 years?**
- **In your experience, have you observed or experienced positive changes to ranching/farming in the last five years? Last 10 years? Have these changes impacted your life in the last five years? Last 10 years?**
- **More specifically, what have been the main challenges for you and your operation over the past five years (e.g., labor shortage, marketing, production, etc.)? Last 10 years?**
- **Has your access to natural resources changed over the past 10 years (e.g., access to land, water, etc.)?**
- **Have you seen changes in the roles of men and women over the past five, 10 years, and across the last few generations? If yes, can you describe some of these changes? How have you seen the lives of women improved, and how have women become more disadvantaged? How have the lives of men improved, and how have men become more disadvantaged?**
- **Have you observed that certain individuals or groups of people are excluded from the benefits of the ranching/farming lifestyle? If so which group or groups of people? Have you observed that certain individuals or groups of people have recently been welcomed into the ranching/farming lifestyle? If so, which group or groups of people?**

- **Are there organizations or institutions have held you back from gaining a better living? Are there people in the community who are particularly disadvantaged by the way these organizations or institutions work? If so, which group or groups of people? Inversely, are there organizations or institutions have helped you to gain a better living? If yes, how have they supported you?**
- **What changes would you like to make to your lifestyle or operation? What has held you back from making these changes? What are some opportunities that may help you achieve your desired goals?**

Wrap-up

- Is there any question or questions that you would like to ask me?
- Is there anything that I missed or should have asked?

APPENDIX E

Below, we presented the confusion matrix of the model classifier (Table A-1). We also calculated accuracies as compared to the NLCD (A-1) for the model overall and for each study site in each NLCD year (i.e., the 20-mile buffers around the study communities). The accuracies demonstrate relative consistency across the available NLCD years (Table A.2).

Table E.1. Confusion matrix of the model classifier.

	Water	Developed	Barren	Forest	Shrubland	Herbaceous	Cultivated	Water	Total	User's Accuracy (%)
Water	431									
Developed	127	10245	22	487	1081	5485	5549	325	2332	43.9
Barren	65	87	1404	14	227	235	93	12	2137	65.7
Forest	41	232	1	77	4239	211	73	514	7598	93.0
Shrubland	86	548	385	9	52513	7963	549	156	6733	78.0
Herbaceous	192	3234	886	917	26931	279259	24750	150	3376	82.7
Cultivated	88	2932	39	24	303	20318	92054	270	1184	77.7
Water	247	537	6	950	1731	1173	1963	723	1384	52.3
Total	515	18069	2796	768	87108	314720	12523	140	6439	
Producers Accuracy (%)	83.6	56.7	50.2	92.0	60.3	88.7	73.5	51.5	89	

$$\text{Classification Accuracy} = \frac{\text{total number of correction classifications}}{\text{total number of classifications}} \quad (\text{E.1})$$

Table E.2. Statistical evaluations of accuracy of classification outputs for the two study site sites (i.e., the 20-mile buffers around the study communities) compared to the National Land Cover Database (NLCD) classifications.

Year	Weld Site	Larimer Site
2001	0.889	0.745

2004	0.900	0.742
2006	0.877	0.723
2008	0.871	0.748
2011	0.913	0.78
2013	0.886	0.742
2016	0.904	0.75
Overall	0.894	0.747

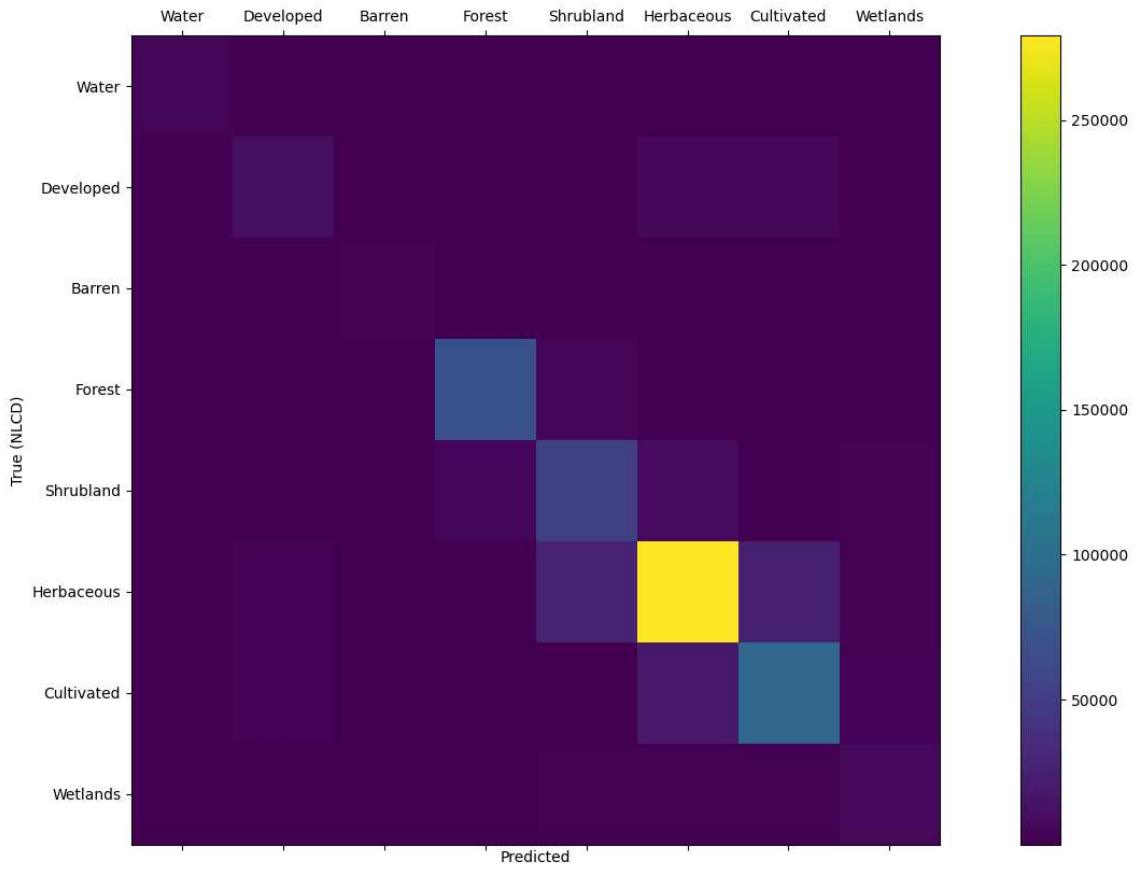


Figure E.1. Confusion matrix of the model classifier.

APPENDIX F

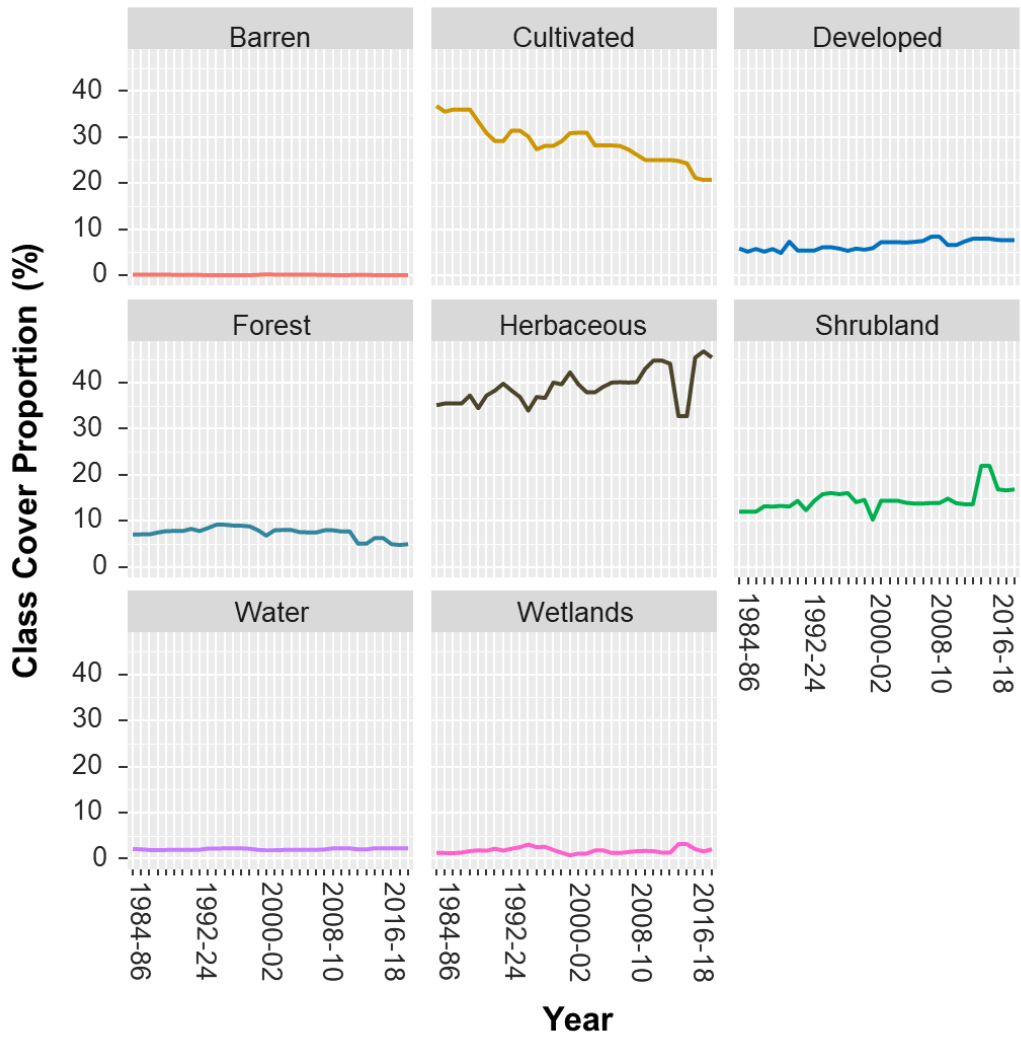


Figure F.1. Faceted class cover proportion (%) for barren, cultivated, developed, forest, herbaceous, shrubland, water, and wetlands in the northeastern Larimer County, Colorado study site.

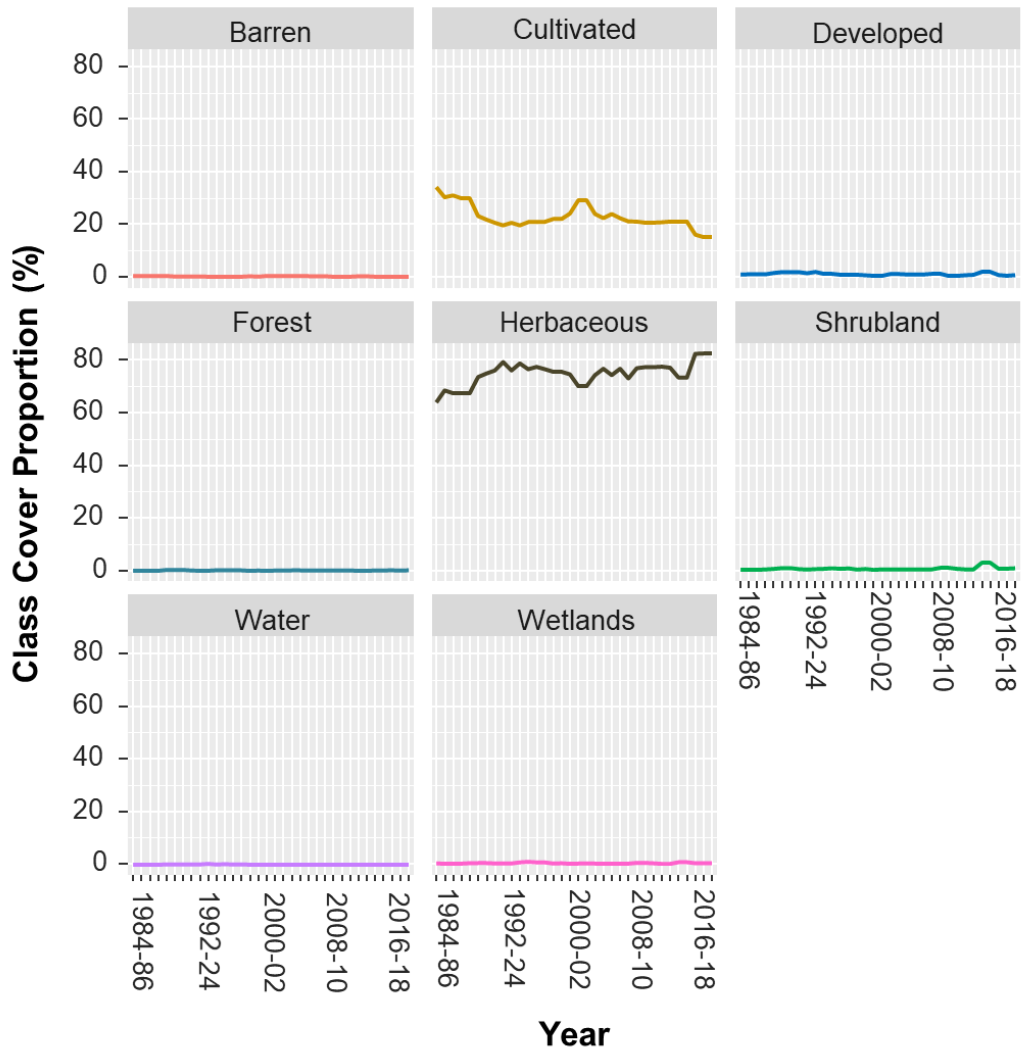


Figure F.2. Faceted class cover proportion (%) for barren, cultivated, developed, forest, herbaceous, shrubland, water, and wetlands in northcentral Weld County, Colorado study site.