Rangelands Livestock Production Systems

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Rangelands as referred to herein can be defined as uncultivated lands that provide multiple ecosystem services for society, sustain habitat for grazing and browsing animals, and support the livelihoods of pastoralists and ranchers [1][2]. Under this definition rangelands comprise up to 70% of the world's land area and include natural grasslands, deserts, temperate forests, and tropical forests [1]. Greenhouse gases (GHGs) released into the lower atmosphere mainly by the burning of fossil fuels and other anthropogenic activities have caused the earth's temperature to rise by 1 °C since the 1860s [3][4]. If GHG emissions continue to rise, an increase in global temperature up to 3 to 5 °C is projected by the end of this century [4]. Extreme weather events are already increasing in frequency and severity in the US and globally [3][4][5]. Global concern is growing over the possibility that eventual irreversible, catastrophic climate change will result in massive loss of human livelihoods and mortality through adverse impacts on food production systems over both croplands and rangelands [3][4][6][7][8][9][10][11][12].

livestock and ranching production systems | Adaptive management | heat waves and drought risks

1. Abstract

Climate change is increasingly putting pressure on the sustainability of rangeland-based livestock production systems. Mismanagement of rangelands can significantly exacerbate the climate change process. Under droughts, heat waves, and other extreme weather events, management of risks (climate, biological, financial, political) will be more important to enhance the sustainability of ranching than the capability to expand livestock products output to meet the rising demand for meat due to population growth. Traditional ranching could become financially unsound across large areas if climate change is not adequately addressed. Replacing traditional domestic livestock with highly adapted livestock may be the best strategy on many arid rangelands. Rangeland policy, management, and research will need to be heavily and innovatively focused on addressing climate change related challenges.

2. Introduction

Although climate change is now widely recognized as the biggest global threat to the future of humanity, it is an extremely difficult problem to solve. While there is global agreement on the immediate need to significantly reduce GHG emissions, climate change is a "tragedy of the commons" issue (see [13]) at the highest level in which no single country benefits from its own actions to limit GHG emissions as long as other countries are unrestricted in their emissions through enforced international agreements. This is also applicable to the need to address the sustainability of rangeland production systems collectively due to their large spatial extent. Local scale applications of mitigation and sustainability strategies may have limited effects as climate change impacts such as increased drought frequency and heat waves are mostly driven by global scale environmental changes linked to high GHG emitting developed countries. Social equity between affluent, developed, and poor, undeveloped countries is a critical and complicated consideration in formulating fair global scale climate mitigation and adaptation solutions. Contentious parts of any international agreement will involve how quickly large, highly developed countries (major GHG emitters) such as the US are required to reduce their GHG emissions and how much flexibility smaller, developing countries (minor GHG emitters) will have for emissions increases needed to improve living standards. In most cases, people in poor, undeveloped countries depend on rangelands and/or mixed (i.e., farm and ranch) livestock production systems as a major source of food supply.

Rangelands can and do play a significant role in climate change processes through a combination of factors that involve grazing ruminant GHG emissions, grazing ruminant management, shifts in landscape vegetation, sites for economic developments (subdivisions), sites for energy developments, and sites for carbon sequestration. Understanding how these factors (i.e., grazing ruminants, vegetation change, land use change) impact climate and rangelands is key in developing sound rangeland and ranch management strategies to mitigate and adapt to climate change. The main objective of this paper is to provide a current review of the linkages between rangelands, ranching, and climate change. While the analysis is generally focused on US rangelands, it also provides a relevant global perspective and suggests potential strategies for sustainable rangeland livestock production systems elsewhere.

3. Data, Model, Applications and Influences

3.1. Rangelands, Energy, and Climate Change

The area of world rangeland ecosystems (Figure 1) is being impacted by several opposing anthropogenic and natural processes that can result in (a) an increase in rangeland areas such as conversions of tropical forests into grazing lands, glaciated areas into rangeland, and cropland to rangeland due to climate change, soil degradation, and/or depletion of irrigation water supply from aquifers and drying of rivers [14]; or conversely (b) a decrease in rangeland areas such as conversion of arable rangelands into croplands, and rangelands into urban landscapes (e.g., [12]). For example, recent findings suggest that the depletion of large aquifers used for irrigation, such as the Ogallala in the Southern Great Plains of the US, is already causing shifts from cropland to rangeland [15]. Despite these findings, it is evident that there is a lack of information on the quantitative changes in rangeland spatial extent and quality (i.e., productivity) and their accuracy for different countries worldwide. This knowledge gap limits the ability to sustainably manage these ecosystems. Because rangelands are often viewed as unproductive marginal lands, public investment in research and development of rangeland-based systems is frequently low. This phenomenon is unlikely to change unless policy makers and society at large are made aware of the role that rangeland ecosystem services have in supporting human wellbeing [16]. Still, overall it appears that rangeland areas will experience a net increase in most parts of the world due to climate change impacts that involve desertification and retrenchment of snow and ice [14][15].

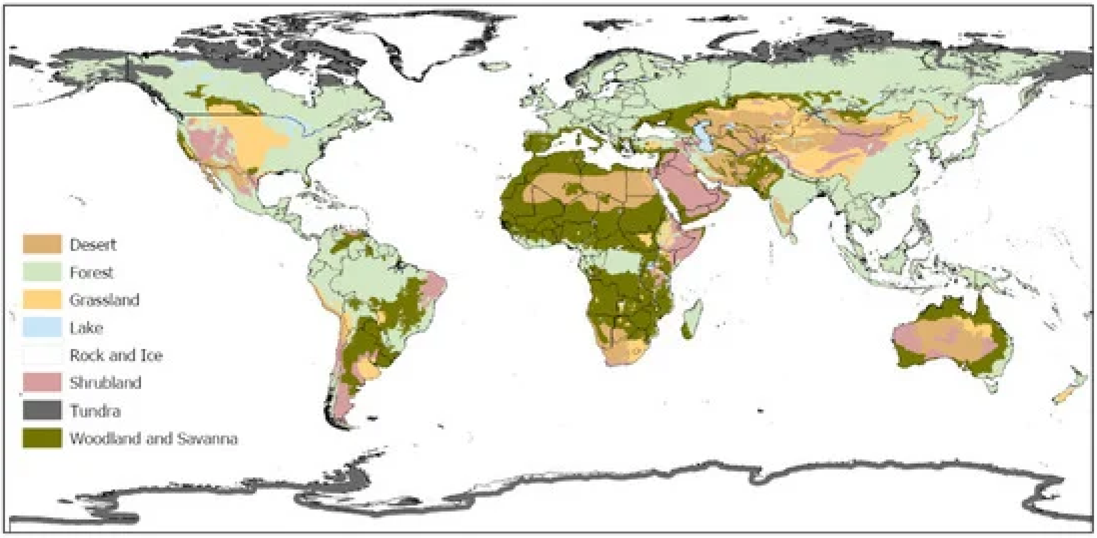

Figure 1. Distribution of global rangelands based on terrestrial ecoregions of the world (source: University of Idaho and World Wildlife Fund [17]).

Conversion of rangelands to other land uses is frequently linked to human activities associated with energy and industrial development. Rangelands are often used for extraction of fossil fuels and renewable energy development. Since 2000, the impacts of energy development on western US rangelands have greatly increased due to rapid expansion of unconventional crude oil extraction and development of wind and solar power [18][19][20][21].

One study estimated that the losses of rangeland and forest landscapes from crude oil and natural gas development across central North America had increased 10 fold during the 2000–2012 period [20]. Estimates of rangeland losses to renewable energy development are lacking, but they will be substantial if wind and solar power become the primary replacements for fossil fuels [21][22]. Major adverse environmental impacts from energy developments on rangeland ecosystems include air and water contamination, loss of wildlife habitat, loss of livestock grazing capacity, increased earthquakes, and loss of esthetic values [19][21]. Conversely, energy developments are providing landowners with a significant source of income from crude oil and natural gas leases and provision of sites for wind and solar power developments [21]. How energy developments are impacting rangeland area and ecosystem services regionally and globally is an important knowledge gap that needs to be addressed in the future.

Moreover, conversion of rangelands into economic/industrial developments such as buildings, roads, power lines, and pipelines can negatively impact their provision of ecosystem services and cause them to become significant contributors of fossil fuel GHG emissions Reducing the loss of farmland, forest, and rangeland landscapes from urban sprawl through more compact development can potentially reduce US fossil fuel use by 20% or more and thus significantly lower GHG emissions [23]. The US is slowly trending towards higher energy conservation (e.g., mass transit, multi-level apartments, inner city revitalization, toll roads) but still remains near the top of the list in terms of per capita energy use [23][24].

Some mitigation strategies have been introduced to slow conversion of rangelands into urban/industrial landscapes. Generally, these strategies are related to the adoption of land use regulatory policies and taxes (i.e., a top-down approach) as described in [21]. They include imposing taxes on fossil fuels, toll roads, restrictions on motorized vehicle use, and regulating land subdivision. These regulations can incentivize people to live in compact, high-density communities where various transportation needs can be met by walking or mass transit as opposed to long commutes by car. Through the application of these approaches, not only are fossil fuel emissions reduced, but other benefits include lowering fossil fuel depletion rates, reducing urban sprawl, minimizing habitat fragmentation, and reducing congestion and air pollution in cities. If aggressively applied, these approaches can potentially reduce global fossil fuel use (especially crude oil) by 20 to 30% within 10 to 15 years [21][23]. Energy conservation practices are widely applied in Europe, which has about one-half the per capita fossil fuel use of the US [21][24].

Financial incentives have also been advocated to protect rangelands from development and sustain or enhance their ecosystem services [25]. Commonly, landowners receive payments from non-government organizations for conservation easements, which are legal agreements to sustain ecosystem services and not develop specified lands [25]. Restoration practices can be a part of this approach. Land ownership in the western US is often an interspersed mosaic of private and public ownership [26]. Collaborative participation projects to minimize development and enhance ecosystem services over large rangeland areas of diverse ownership have evolved and increased since the early 1970s [26][27]. Examples of effective participatory conservation plans involving large, diverse western US rangeland areas were provided by [25][26]. Internationally, incentive programs similar to those used in the US have been effective in conserving African wildlife over large landscapes [28]. Taxes on fossil fuels were a commonly recommended means of funding financial incentives for tropical rain forest protection.

4. Conclusions

Over the coming decades, rangeland livestock producers will benefit from a major increase in demand and prices for meat and other livestock products. The biggest challenge confronting ranchers and rangeland livestock producers will likely be climate change, which is expected to have region-specific impacts [29][30].

The use of conservative stocking rates across the board will likely continue to be an important tool to adapt to the increased variability in precipitation patterns and droughts. In all cases, this conceptual analysis suggested that strategies and management practices that improve the efficiency of ranching enterprises will play critically important roles. The importance of rangelands in terms of ecosystem services as well as food and fiber production will become increasingly significant over the next few decades as the forces of resource depletion and climate change intensify. Rangeland policy, management, and research will need to be heavily focused on the climate change problem. We recommend that research and extension funding involving ranch monitoring programs be strengthened at both federal and state levels. At the international level, multilateral organizations such as the UN must play an increasingly visible role in strengthening awareness among world leaders regarding the need to invest in rangelands and the peoples that depend on them. The biggest knowledge gaps at present involve the degree and rate of change that has recently occurred in climatic, land area, and forage conditions for different types of rangelands in the US and globally. Another major knowledge gap involves the proper assessment of how climate change is impacting the viability and profitability of rangeland livestock production operations in different rangeland regions and ecosystems. There is also a current lack of understanding on how climate change trends will influence livestock disease outbreaks. SI strategies (Figure 2) will likely alter the carbon and water footprints of rangeland-based beef production, but these relationships are still poorly understood.

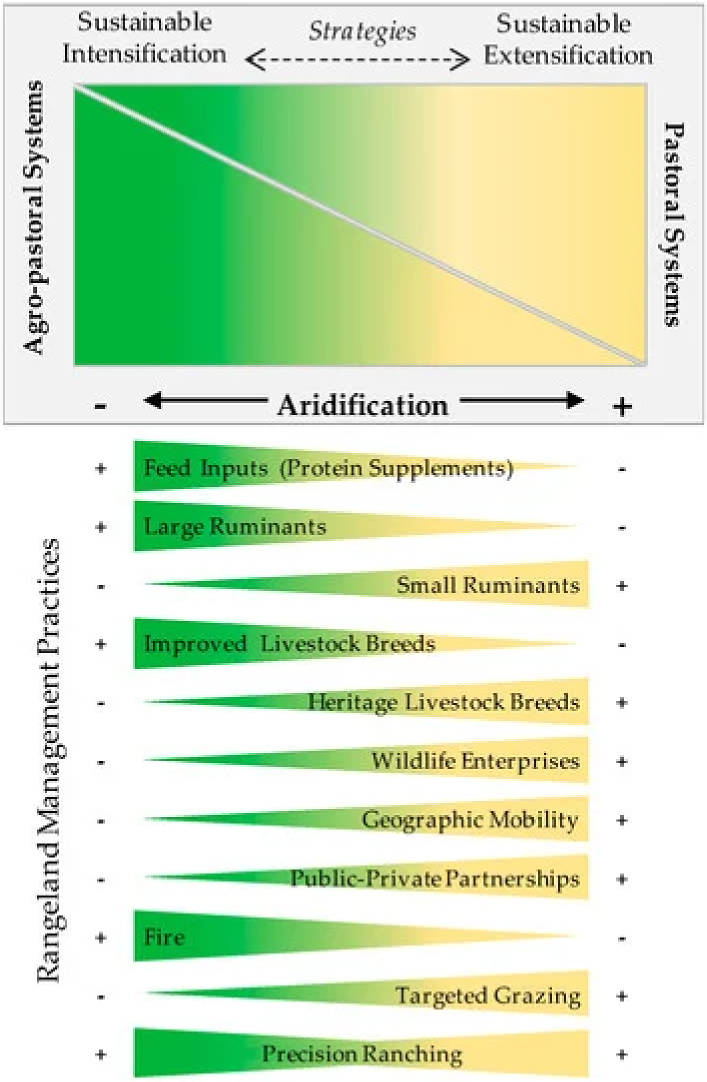

Figure 2. Conceptual diagram of adaptation strategies and rangeland management practices for ranching systems in the western US relative to predicted regional impacts of climate change. In regions predicted to become more arid, ranching systems are likely to evolve towards purely pastoral-like low-input systems and are predicted to remain viable using sustainable extensification strategies and tactics. At the opposite extreme of the continuum, in regions with little to no aridification, ranching systems are likely to evolve towards becoming agro-pastoral systems and are predicted to remain profitable using sustainable intensification strategies and practices.

Climate stability, water purification, air purification, nutrient cycling, and biodiversity are among the critical ecosystem services needed by human societies but often taken for granted by them. The global human population, now at almost 8 billion compared to one billion during most of human history, is jeopardizing the very foundation of ecosystem services on which it depends [7][8][14]. Based on the UN's projections, the world human population will likely exceed 10 billion by 2050 [31]. We strongly agree with [8] that endless exponential growth in human population and natural resource consumption is not compatible with human civilization sustainability.

Because rangelands account for 50 to 70% of the world's land area and generally support natural or near natural vegetation, they play a critical role in providing the ecosystem services essential for human existence [1][14][25]. Rangelands will undoubtedly become more important for ecosystem services, as well as food and fiber production, as the world moves towards 2050. This will occur as problems of global warming, scarcity of fresh water, species extinction, and contamination of air and water intensify in response to more people in the world desiring higher material and food consumption. Rangelands, when properly managed, can sustainably provide people with food, fiber, and ecosystem services [1][8]. Conversely, human societies must recognize that rangelands have a finite capability to provide these essential components of human life. At global, national, regional, and local levels, the authors consider the conservation and enhancement of rangeland landscapes a critical part of climate change mitigation and adaptation. Therefore, the authors advocate government policies and regulations that more heavily emphasize rangeland research and management as part of the solution to the climate change problem.

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