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Application of Vulnerability Assessment to a Grazed Rangeland: Toward an Integrated Conceptual Framework

By Valiollah Raufirad, Richard Hunter, Bryan A. Endress, and Setareh Bagheri

On the Ground

- Rangeland vulnerability assessments have the potential to function as conceptual tools for policymakers and rangeland users to ensure the sustainable management of vulnerable rangelands.
- This contribution reviews the different approaches to conceptualizing vulnerability assessments in order to introduce an initial framework for how to construct rangeland vulnerability assessments.
- We present a conceptual framework for designing a rangeland vulnerability assessment that captures a suite of both socioeconomic and biophysical variables.
- This framework also facilitates the incorporation of the local knowledge of rangeland experts and users for further refinement of a rangeland vulnerability assessment applied in a specific locale.

Keywords: vulnerability, sustainability, integrated approaches, biophysical indicators, socioeconomic indicators, Me-Bar and Valdez technique.

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Rangelands account for around 75% of the world's land surface and many are experiencing severe degradation caused by overgrazing.[1–3] This problem is especially acute among rangelands located in arid and semi-arid zones where the effects of climate change and growing human populations are putting rangelands under increasing grazing pressure. Practical advancements in our ability to assess rangeland vulnerability are required to achieve sustainable rangeland management. Vulnerability assessments can reveal the extent to which an ecosystem is susceptible to degradation or a change of state because of perturbations in biophysical or socioeconomic variables. Assessing vulnerability is critical because an ecosystem's vulnerability level will suggest which activities are sustainable in relation to the interactions between the various structures and processes that give rise to the vulnerability.[4–6]

Vulnerability assessments can adopt a socioeconomic or a biophysical approach or an approach that integrates variables from both of those arenas. With the exception of a few studies,[7–10] the effects of both socioeconomic and biophysical variables on rangeland vulnerability have received relatively little attention. As a result, we lack a critical understanding of how rangeland vulnerability assessments can reveal the multifaceted complexities and consequences of land use in these ecosystems. This understanding is necessary to achieve the goals of policymakers, land managers, and rangeland users to achieve sustainable rangeland management.

In the remainder of this paper, we explore what is commonly meant by "vulnerability" and related terms. We then review previous work that underpins our current understanding of vulnerability assessments. Following that, we analyze the approaches and methods of vulnerability assessments to identify those most suitable for incorporation into a rangeland vulnerability assessment. Identification of the socioeconomic and biophysical indicators of vulnerability then allows us to construct a conceptual framework that quantifies rangeland vulnerability. This framework is structured around three essential dimensions of vulnerability (sensitivity, exposure, and adaptive capacity) in relation to three dimensions of sustainability (social, economic, and environmental). We conclude with a prospectus on research into rangeland vulnerability assessment.

Vulnerability and its Dimensions

The concept of vulnerability has appeared in a variety of research contexts to refer to the extent to which a system is likely to be harmed by potential stressors (e.g., biophysical

and/or socioeconomic changes).[11–14] The term vulnerability also addresses the sensitivity and exposure of an ecosystem to external stresses and its ability to adjust, resist, or cope with these stresses.[11,13,15] Exposure refers to the nature and degree to which a rangeland/rangeland user experiences biophysical and socioeconomic stressors. Sensitivity refers to the characteristics of rangelands that make it susceptible to the impacts of biophysical and socioeconomic stresses and their multiscale interactions.[14] Adaptive capacity refers to the capability of an ecosystem to overcome socioeconomic and biophysical stressors (Fig. 1).[15]

Designing a Rangeland Vulnerability Assessment

Vulnerability assessments that model the effects of global-scale biophysical and socioeconomic changes have limited ability to precisely measure exposure in specific ecosystem types at lower scales.[16] Even national-level gains/losses resulting from global changes may not be extrapolated easily or accurately to local areas within the same nation. Moreover, the exposure of particular economic actors, such as rangeland users within a rangeland ecosystem, cannot be described by vulnerability assessment models designed for global scales.[12] The Sustainable Livelihood Framework, developed by the Department for International Development (United Kingdom), describes useful analytical tools for evaluating vulnerability at local levels (Fig. 2).[17]

Although vulnerability is a highly complicated phenomenon that is difficult to measure, scholars have nonetheless been successful in developing methods to conduct vulnerability assessments.[13] One of the most common methods is to quantify vulnerability by running estimated values of predefined indicators through a mathematical formula.[18] Because an indicator method is relatively straightforward to understand and can be readily implemented by different stakeholders, especially in the area of natural ecosystems, this is an appropriate method upon which to base a framework for a rangeland vulnerability assessment. A critical step in creating such a rangeland vulnerability assessment is identifying the salient indicators of vulnerability for a particular ecosystem.

Socioeconomic Rangeland Vulnerability Indicators

Socioeconomic drivers are derived from variables such as level of education, sex, and variety types of capital (human, financial, social, physical, and natural).[13,19] Similar to the sustainable livelihood framework is the framework, developed by the DFID, to classify the five capital groups.[17] This is a "pentagon asset" showing the different types of assets and the importance of their interrelationships (Fig. 3).

Human capital (e.g., education, age, labor) influences the integration of the rangeland users' production system into the market economy and its competition with other means of livestock production.[13,18,20] Social capital (e.g., social status, social unity, beliefs and values, the formal policies of institutions, and the informal practices of social networks) affects access to and use of rangelands, which bears directly on rangeland vulnerability.[5,6] Natural capital (i.e., rangelands and farmlands) has a special impact on developing specific livelihood-coping strategies for drought and other climatic hazards.[21,22] Access to physical capital (e.g., the basic infrastructure and services such as sanitation, electricity,

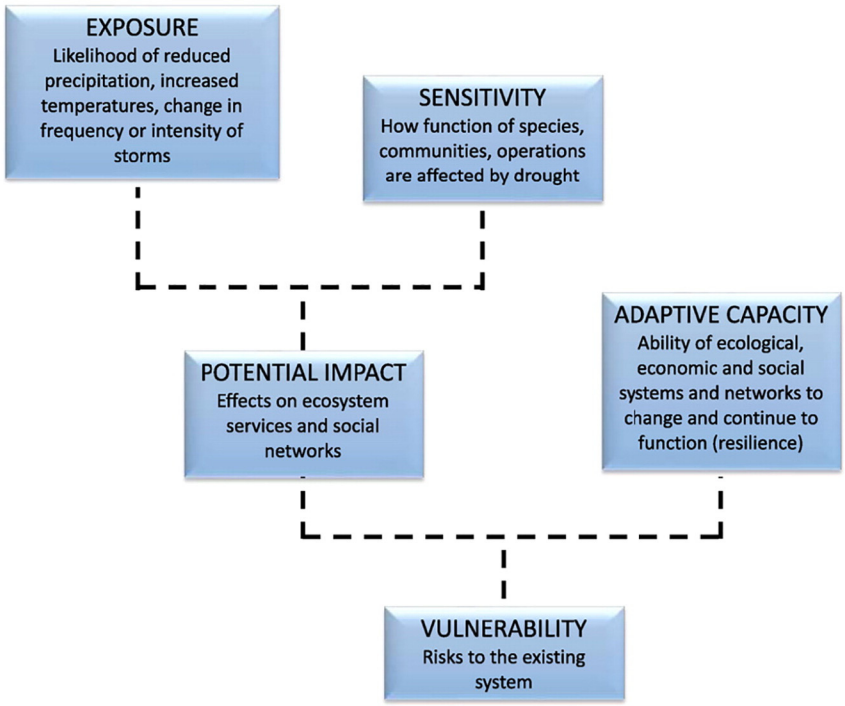

Figure 1. A vulnerability assessment framework for rangeland vulnerability.[15]

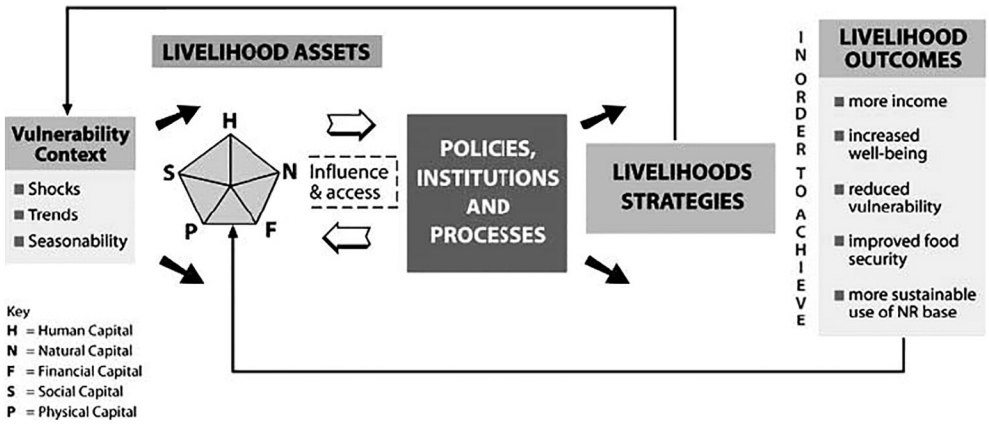

Figure 2. The sustainable livelihood framework.[19]

modern communication devices) enables rangeland users to gain information and track markets. Financial capital (i.e., herd size and composition) plays a vital role in decreasing dependence on the fodder market and protecting rangeland users from price fluctuations.[14] The carrying capacity of most rangelands (in terms of animal units) is usually arrived at through evaluation of vegetation and climatic conditions. However, rangeland users tend to consider the appropriate animal unit in the contexts of the relevant economic conditions and the present availability of forage and labor.[22,23]

Biophysical Rangeland Vulnerability Indicators

Previous research has identified the biophysical indicators that can determine a rangeland's sustainability or vulnerability (Fig. 4).[8–10] Climate change represents a significant biophysical variable increasing rangeland vulnerability through temperature and precipitation fluctuations, as well as its influence on how rangeland users manage their lands in the face of climatic instability.[24] The characteristics of climatic stressors, including the magnitude, duration, and frequency of precipitation or temperature extremes, are important determinants of ecosystem vulnerability through diminishment of forage production and yield, hydrology, and alteration of the vegetative assemblage.[24] Soil-based variables (e.g., texture, depth) affect rangeland vulnerability by influencing directly or indirectly the vegetative assemblage, cover, and yield due to their effects on the soil's resistance to wind and water erosion.[18,25]

Hydrological variables (i.e., depth, quality, quantity) address the percent of surface and underground water, including the length of small, medium, and large streams and rivers and the area of lakes and reservoirs with impaired water quantity and quality.[9,25] The water depth, quality, and quantity indicators are the important measure of water resource sustainability. Water resources in rangelands must be of adequate quality and quantity to support a variety of uses, such as human and livestock consumption, wildlife habitats, agricultural and industrial supply, and recreation.[26]

Vegetative species composition and amount of ground cover help inform rangeland users of the range's carrying capacity. Maintaining a sufficient area of each plant community is necessary to sustain ecosystem processes, as well as the associated animal species dependent upon them. Information on the number (density) and extent (cover percentage) of rangeland plant communities is essential to provide the basic information on vegetation for scientific research and sustainable rangeland management. These data are also critical for a rangeland vulnerability assessment.[8–10]

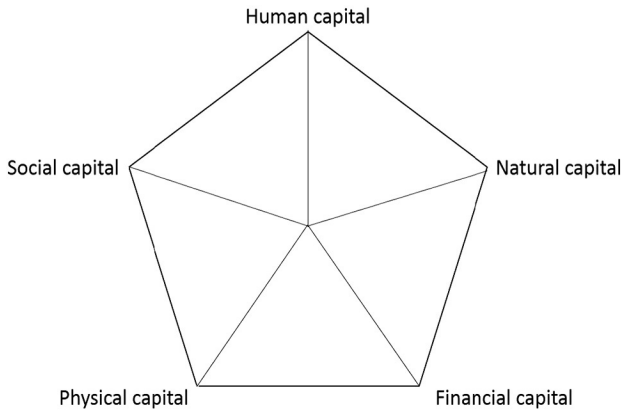

Figure 3. The asset pentagon.[17]

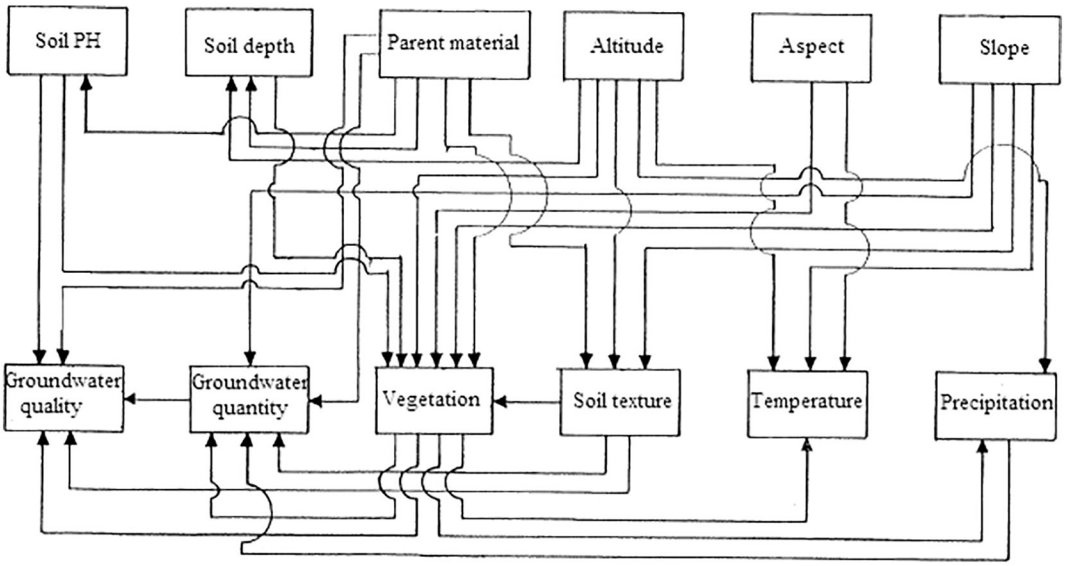

Figure 4. Conceptual framework for biophysical indicators.[8]

A Conceptual Framework for Rangeland Vulnerability Assessment

Figure 5 suggests the complexity for rangeland vulnerability assessment that arises from existing interactions among the drivers that heighten rangeland vulnerability. Similarly, Tahmasebi developed a conceptual framework for vulnerability assessment based on Wisner's designs for assessing the vulnerability of Shahsevan nomads in northwest Iran using an indicator approach that included a suite of socioeconomic indicators.[11,14] In contrast, Jabarian tried to introduce a conceptual framework for vulnerability assessment according to the Food and Agriculture Organization's (FAO) instructions for determining the vulnerability of Caspian Sea ecosystems in northern Iran using biophysical indicators.[11,14,27,28] More recently, Fox et al. and Mitchell have developed frameworks for sustainable rangeland management that incorporated social, economic, and ecological criteria and indicators.[9] In line with their studies, our conceptual framework to assess rangeland vulnerability includes the most important socioeconomic and biophysical indicators. The indicators in this framework cover most of the indicators that were suggested by previous studies to pertain to rangeland vulnerability and are relevant to rangelands in both developed and development countries.[11,13,18]

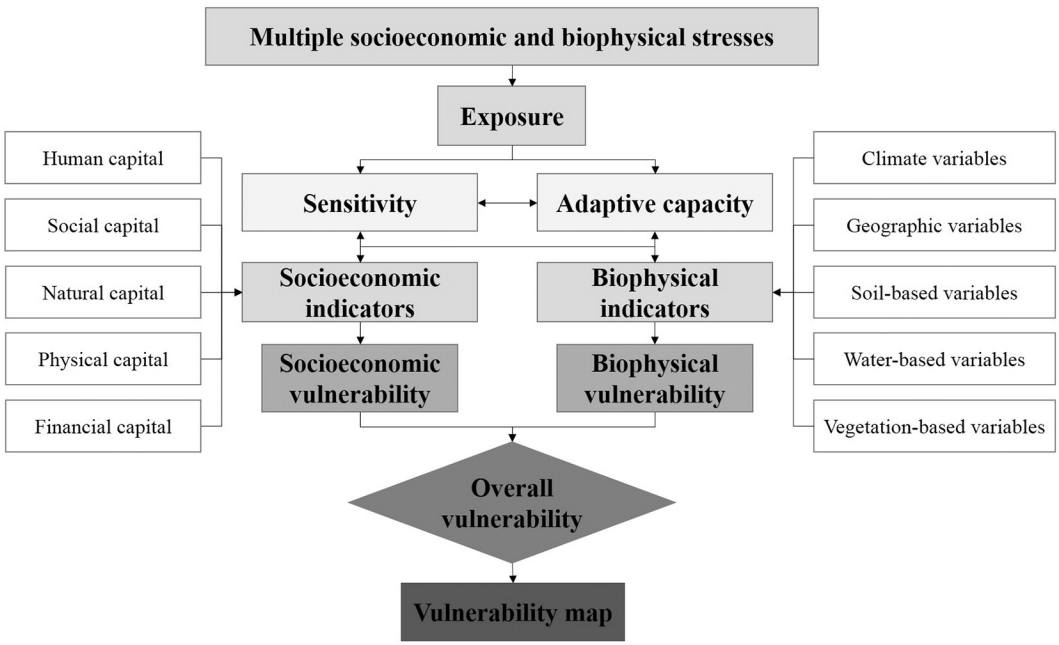

Figure 5. Conceptual framework for rangeland vulnerability assessment.

The first step to assess vulnerability is to calculate the sensitivity of rangeland users to various socioeconomic and biophysical changes (the main three dimensions of sustainability). According to Tahmasebi et al., although calculating the sensitivity of the main five kinds of capital (human, social, natural, physical, financial) is fairly straightforward (e.g., sensitivity of financial capital can be determined using the income obtained from livestock, agriculture, off-farm activities), calculating the natural capital precisely (rangelands and farmlands) can be challenging and is almost impossible in most cases.[14] In this context, they stated that indicators such as the herd twinning rate and the pressure of livestock population on rangelands can be used to measure the sensitivity and adaptive capacity of natural capital. For example, biophysical indicators such as climatic variables affect the quality and quantity of vegetation, soil, and water and thereby influence the socioeconomic status of rangeland users (e.g., income).[5,6]

The second step to assessing vulnerability is to consider the adaptive capacity of rangeland users to different socioeconomic and biophysical stressors. In the early stages of exposure, their adaptive capacity is high because the individual and community try to use their knowledge and capacity to make the necessary adjustments in lifestyle and decrease their vulnerability to future stressors.[28] If the level of exposure continues to increase, then so will vulnerability. Therefore, it is critical that rangeland users and rangeland experts focused on rangelands issues identify and attempt to minimize vulnerabilities early to ensure that rangeland users have the necessary livelihood strategies in place to give them the necessary adaptive capacities.[6] Adaptive capacity is inversely related to sensitivity (Fig. 1).

The third step to assess vulnerability is to identify the most important socioeconomic and biophysical indicators. Among the five types of capital (human, financial, social, physical, and natural), financial and natural capital are the most important because the livestock-based economy of the rangeland users is more frequently affected by external stressors due to the combined impacts of climate change, sociopolitical change, and the rangeland users increasing integration into the market economy.[4]

The fourth step to assess vulnerability is to determine the value and weight of the socioeconomic and biophysical indicators and their importance in shaping biophysical vulnerability, socioeconomic vulnerability, and overall/total vulnerability. To determine biophysical vulnerability, comprehensive methods were introduced by FAO as described earlier (Fig. 4). Because determining the factors influencing socioeconomic vulnerability are time-consuming, using methods that are expedient, understandable, and inexpensive for all rangeland stakeholders should take the highest priority. Among vulnerability assessment techniques, a formula suggested by Me-Bar and Valdez is one of the most appropriate for assessing socioeconomic vulnerability because the technique tries to estimate the values of indicators by rangeland users using a 5-point Likert continuum (from 1 = the most important indicator influencing socioeconomic vulnerability to 5 = the least important indicator influencing socioeconomic vulnerability). The weight of each indicator estimates by rangeland experts using expert scoring. For example, the weights can range from 1 (minimum weight) to 10 (maximum weight).[29]

The last step to assess vulnerability is to produce a map of rangeland vulnerability. This research proposes an integrated use of geographic information systems (GIS) with a conceptual framework of vulnerability to better understand the vulnerable rangelands by identifying 1) the most vulnerable rangelands requiring specific protection measures to enhance sustainable rangeland management and the prevention of biological and socioeconomic risks; and 2) the most effective management interventions to reduce rangeland vulnerability to biological and socioeconomic changes through the selection of suitable indicators that enable discrimination among different levels of sensitivity and pressures to provide evidence of its potential utility for sustainable rangeland management and the mitigation of their vulnerabilities. This cartographic approach to vulnerability not only considers the "of what to what," but also the "where," with a focus on the spatial and temporal dimensions of vulnerability.[30] Vulnerability mapping through integration of biophysical and socioeconomic data in an overall vulnerability reveals areas that are likely to be at greater risk of stresses in the future.[31]

In recent years, the challenge for rangeland managers has been ensuring the long-term sustainability of an area by identifying its biophysical and socioeconomic values against predictable and unpredictable natural and human pressures. As Aretano et al. illustrate, maps produced using GIS techniques represent a practical visual tool for transferring the results of vulnerability assessment to other researchers, policymakers, and the community at a global scale through placing local vulnerabilities within the larger settings that affect processes at multiple scales.[30] Preston et al.'s study of vulnerability mapping concluded that the objectives of the vulnerability assessment are most related to the understanding of the indicators of vulnerability.[31] In particular, Preston et al. emphasized the use of vulnerability mapping to enhance the stakeholder engagement and understanding of the various indicators that influence vulnerability. Combining both biophysical and socioeconomic indicators of vulnerability readily enables the engagement of different stakeholders. The proposed framework captures the biophysical and socioeconomic variables that may influence the vulnerability of rangelands, which allows the mapping of vulnerability and subsequent identification of the most vulnerable rangelands. In this way, the most effective land management interventions can be implemented to address specific biophysical and socioeconomic stressors. The production of these kinds of maps will also aid policymakers and land managers in gauging rangeland sensitivity levels as they work toward sustainable rangeland management.

Conclusions

This conceptual framework for a rangeland vulnerability assessment underscores how vulnerability is a multifaceted

phenomenon. In particular, it describes how vulnerability pertains to rangeland ecosystems through specific socioeconomic and biophysical indicators. The integration of socioeconomic and biophysical indicators is necessary to evaluate the overall vulnerability of rangelands to multiple stresses. The indicators and methodology identified in this study are flexible, are straightforward to implement, and have potentially wide applications. This is especially so because the methodology provides an effective way to assess rangeland vulnerability with minimal investment of time and money. Also, the methodology includes not only expert knowledge but also local knowledge (rangeland users' knowledge) in the rangeland vulnerability assessment. Using experts and rangeland users' knowledge (two main rangeland stakeholders) allows us to perform a detailed analysis of changes in rangeland vulnerability at a scale that is easily interpretable both for nontechnical users (e.g., policymakers and local-level stakeholders) and for technical users (e.g., experts and researchers). As a result, the framework offers a method to involve and actively engage stakeholders in vulnerability assessment. This framework's methodology of construction exemplifies how different disciplinary viewpoints can be successfully represented and compared with inference models. Lastly, this framework for assessing rangeland vulnerability can guide various stakeholders in managing, predicting, and mapping the overall vulnerability of their rangelands.

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Authors are from the Department of Biology and Biochemistry, University of Houston, Houston, Texas, USA (vraufirad@uh.edu; Raufirad); Geography Department, State University of New York College at Cortland, Cortland, NY, USA (Hunter); Department of Animal and Rangeland Sciences, Oregon State University, La Grande, OR, USA (Endress); and Department of Natural Resources, Sari University of Agricultural Sciences and Natural Resources, Sari, Iran (Bagheri).