

Exploring appropriate livelihood alternatives for sustainable rangeland management

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Abstract. Rangeland degradation and vulnerability of livelihoods are two major challenges facing pastoralists, rangeland managers and policy-makers in arid and semi-arid areas. There is a need to make holistic informed decisions in order to protect rangelands and sustain livelihoods. Through a comprehensive literature review on rangeland management policies and livelihood strategies of ‘rangeland users’, it is shown how such policies have affected sustainable rangeland management, how strategies to sustain livelihoods have been incomplete and how there has been a lack of a multi-disciplinary approach in acknowledging them. Accordingly, a set of appropriate livelihood alternatives is introduced and, thenceforth, a framework for their evaluation is developed. Supportive strategies for enhancing resilience are discussed as a research and policy-making gap. In this study, the keys to achieve sustainable livelihoods are acknowledged as ‘livelihoods’ resilience’, where livelihoods need to be supported by access to capital, means of coping with the contexts of vulnerability as well as by enhancing policies, institutions and processes. The paper proposes a set of ‘livestock-based livelihoods’ regarding ‘traditional pastoralism’ as well as ‘their mitigation and adaptation’. Moreover, their transformation to ‘commercial pastoralism’, ‘resource-based livelihoods’, ‘alternative livelihoods’ and ‘migration’ strategies is recognised to be employed by rangeland users as useful alternatives in different regions and under future changing conditions including climate change. These strategies embrace thinking on resilience and are supported by strategies that address social and ecological consequences of climate change consisting of mitigation, adaptation and transformation. It is argued that sustainable livelihoods and sustainable rangeland management will be achieved if they are supported by policies that build and facilitate a set of appropriate livelihood alternatives and keep them in a sustainable state rather than being limited to supporting ‘vulnerable livelihoods’. Finally, future directions for analysing and policy-making in selecting the best alternative to achieve sustainable livelihoods are indicated.

Additional keywords: livelihoods’ resilience, rangeland degradation, rangeland users, supportive strategies, sustainable livelihoods, vulnerability.

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Introduction

Prior to the 1950s, traditional systems of sustainable rangeland management and adaptive livelihood strategies, which had evolved over centuries, were dominant in arid and semi-arid areas (Miller 1999; Ngugi and Nyariki 2005; Dong *et al.* 2007). Due to the low human population, a dynamic equilibrium between human, rangelands and livestock existed. Furthermore, many ‘rangeland users’, especially pastoralists, had developed a wide range of strategies enabling them to deal with the inherent variability of the rangelands and their livelihoods; now, however, new changes and challenges have emerged whose magnitudes are greater than ever before (Klein *et al.* 2011; Martin *et al.* 2014). Socio-economic, cultural, political, ecological and climate changes, accompanied with changes in traditional management systems and development interventions, have

disrupted these well-adapted strategies (Dong *et al.* 2007; Stafford Smith *et al.* 2009; Bedunah and Angerer 2012; Hosseininia *et al.* 2013). In addition, these challenges have contributed to the demise of traditional rangeland systems and have caused rangeland degradation, which has recently been the major challenge of rangeland managers and pastoralists around the world (Azadi *et al.* 2007; Bedunah and Angerer 2012). Consequently, the issue of sustainable rangeland management has become of great interest among policy-makers and researchers who have been searching for ‘new alternatives’ to achieve sustainable rangeland management (Stafford Smith *et al.* 2000; Azadi *et al.* 2007; Dong *et al.* 2009; Bedunah and Angerer 2012; Hosseininia *et al.* 2013).

The general goal of sustainable rangeland management can be considered as the long-term sustainability of rangelands while

ensuring livelihoods of rangeland users in the short-term (Stafford Smith 1996; Snyman 1998; Miller 1999; Stafford Smith *et al.* 2000). Achieving this goal is impossible if rangelands are degraded and livelihoods are vulnerable (Safriel *et al.* 2005; Bedunah and Angerer 2012; Ding *et al.* 2014). These issues originate mainly from increases in the human population that has induced over-exploitation of natural resources, including rangelands, leading to overgrazing as a result of overstocking (Bedunah and Angerer 2012; Holechek 2013; Shang *et al.* 2014). Such concerns have also increased conflicts between different rangeland stakeholders that have decreased the likelihood of the achievement of sustainable rangeland management (Bedunah and Angerer 2012). Accordingly, in order to protect rangelands and improve livelihoods, there has been a focus on the notion of sustainable rangeland management through policies developed by governments and international development agencies (Bedunah and Angerer 2012). Simultaneously, some studies have also focussed on possible ways of reducing degradation and improving livelihoods (Stafford Smith *et al.* 2000; Safriel *et al.* 2005; Azadi *et al.* 2007; Abolhassani *et al.* 2013; Holechek 2013; Tsegaye *et al.* 2013; Ding *et al.* 2014; Shang *et al.* 2014; Dong and Sherman 2015). However, the effects of incomplete policies and the lack of a holistic approach, that includes ecological, human, social, economic and infrastructural elements, still diminishes the quality of rangeland users' livelihoods and limit their 'livelihood alternatives'.

In many cases, lack of this holistic approach has resulted in impractical policies and caused a failure to improve livelihoods and prevent rangeland degradation (Sayre *et al.* 2012; Dong and Sherman 2015). In other words, sustainable rangeland management cannot be achieved if the livelihoods of those who live on the rangelands are neglected. Accordingly, realising sustainable livelihoods is one of the most important goals in approaching sustainable rangeland management. By definition, 'a livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base' (Scoones 1998). To sustain livelihoods, policy-makers and managers need to make holistic decisions, which should be ecologically sound, economically feasible and socially acceptable (Teague *et al.* 2010). Failure to fulfil these goals results in livelihood vulnerability of rangeland users as a main concern.

Although some studies have tried to address this concern, there has been less work on the effects of decisions made and policies applied in the name of sustainable rangeland management and improving rangeland users' livelihoods. It is argued that policy-makers should not only adjust their policies against overexploitation and overgrazing of rangelands but also should make appropriate pro-poor policies and explore how to improve rangeland users' livelihoods. Keeping all these concerns in mind, there are still some major questions relating to the collapse of the traditional systems of rangeland management: (1) what policies and interventions have affected sustainable rangeland management and rangeland users' livelihoods; (2) why the policies that have been implemented resulted in unresolved challenges still remaining; (3) have policies and decisions been towards sustainable rangeland management in general and improving rangeland users' livelihoods in particular; (4) if achieving sustainable livelihoods is a goal, which factors have

been neglected that ended in the failure to achieve this goal; and (5) what livelihood strategies are appropriate to be employed by rangeland users under different conditions and which ones are best in guaranteeing sustainable livelihoods and rangeland management in a given area?

Moreover, such questions direct us to some more fundamental questions. First, if a policy should seek to achieve sustainable livelihoods and rangeland management, which factors and criteria should be considered and how? Second, how should these criteria be prioritised to approach sustainable livelihoods? Finally, how should the decision-making process be modelled to achieve sustainable livelihoods? This paper addresses the first question by reviewing policies, strategies and research on sustainable rangeland management in arid and semi-arid areas. We will argue that sustainable rangeland management has been seen mostly as a one-dimensional (rather than a multi-dimensional) issue, suggesting the need for a more inclusive approach. Next, we use the approach of sustainable livelihoods to discuss various factors including natural, human, social, financial and physical capital, policies, institutions and processes and the vulnerability context of sustainable livelihoods. Finally, we explore 'appropriate livelihood alternatives' for the rangeland users and propose a new framework for evaluation of such alternatives.

Policy deficiencies behind sustainable rangeland management: the need for an inter-disciplinary approach

With the emergence of the sustainable development concept in the 1980s, there has been acknowledgement of the importance of a holistic understanding of complex systems like rangelands. This has led to multi-disciplinary research to understand how rangeland systems operate and how they can be made sustainable.

There is much evidence that recent management and development policies in rangelands have promoted sedentarisation, leading to privatisation, fragmentation and devolution of the rangelands, fencing, the reduction of areas for feed crops, and elimination of grazing. Such policies were implemented in most developing countries regardless of an understanding of grazing ecology and how rangeland systems operate (Dong *et al.* 2007; Behnke 2008; Stafford Smith *et al.* 2009). Hobbs *et al.* (2008) believe that, although the main goal of rangeland fragmentation is to enhance livelihoods and wellbeing, this may come at a cost to ecosystems and human economies. In this regard, Behnke (2008) illustrated hypothetical patterns of rangeland fragmentation and consolidation through developmental trajectories over time. He suggested that degradation mostly occurs in the intermediate fragmented stage (Fig. 1). Further, Stafford Smith *et al.* (2009) argued that, if too much of the key land resources are privatised, fragmented or assigned, previously nomadic cultures on the residual land are disrupted and resource-use strategies become unsustainable. Additionally, Martin *et al.* (2014) noted that disruption of the mobility-adaptive strategies may greatly affect pastoral livelihoods. Development interventions have failed in most cases, and, indeed, their failure would be expected if invalid paradigms underlie them (Ellis and Swift 1988).

In general, failed policy and governance can create structural and social problems that make sustainable rangeland management extremely difficult (Bedunah and Angerer 2012).

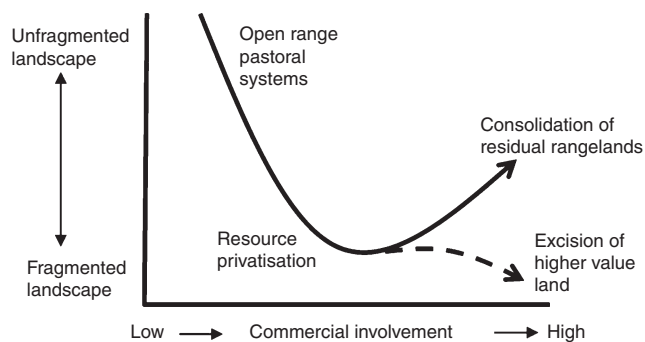


Fig. 1. Hypothetical patterns of rangeland fragmentation and consolidation (Behnke 2008).

Indeed, frequent calls for reversing the negative impacts come from widespread dissatisfaction with failures of the past. In an effort to reverse the negative impacts, Gross *et al.* (2006) proposed making policies on rangelands that closely link their ecological, economic and social aspects, in which the adaptation by participants must be considered. It can be argued that, if the aim is to consolidate the long-term sustainability of rangelands, policy must direct its efforts towards exploring appropriate livelihood strategies *in situ* through recognising traditional pastoralism accompanied with its cultures (i.e. nomadism and mobility) and a combination of other livelihoods.

These can be related to the sustainable rangeland management goals in which ensuring sustainable livelihoods and the long-term productivity of rangelands are crucial. In other words, management for long-term sustainability of rangelands needs to meet the welfare of rangeland users and put their livelihoods at its heart (Snyman 1998). However, focus on delivering 'short-term livelihoods' regardless of 'regional long-term sustainability' may result in continued rangeland degradation. In order to meet local livelihoods, a regional sustainability perspective should be acknowledged. It recognises that the forms of livelihoods are diverse and may have to change for some people (Stafford Smith *et al.* 2000, 2009). This does mean that it is essential to consider the scale at which the objectives of sustainability are relevant.

Moreover, due to the heterogeneity of rangelands, underlying drivers differ from place to place and play out differently in each type of rangelands. Accordingly, different objectives result from different scales and types of rangelands, and bring different key factors which need to be considered in sustainable rangeland management (Stafford Smith *et al.* 2000; Dong and Sherman 2015). Consequently, in order to sustain livelihoods and also protect rangelands, various effects of scale on objectives of social, ecological and economic sustainability must be considered (Stafford Smith 1996; Stafford Smith *et al.* 2000).

In the context of scale, Stafford Smith (1996) classified rangeland variations at four different scales, namely general context, regional, local and human. Accordingly, considering the different contexts of rangelands, Stafford Smith (1996) classified the rangelands in terms of four characteristics, namely low productivity, variable rainfall, mainly natural vegetation and limited scientific attention. Furthermore, Geist and Lambin (2004) identified the six core factors affecting desertification,

namely climate, economic, institutions, national policies, population growth and remote influencing factors. In the millennium ecosystem assessment of dryland systems, Safriel *et al.* (2005) acknowledged four dryland sub-types including sub-humid, semi-arid, arid and hyper-arid. According to this increasing level of aridity or moisture deficit the contribution of rangeland resources from dryland sub-types increases with aridity to 34%, 54%, 87% and 97%, respectively. The semi-arid subtype involves a maximum diversity of biomes covering the largest area among the various sub-types (Safriel *et al.* 2005). More recently, Sietz *et al.* (2011) categorised dryland types into five categories of poverty, water stress, soil degradation, natural agro-constraints and isolation based on the major drivers of vulnerability-creating mechanisms.

All the above discussions provide a holistic perspective on sustainable rangeland management, highlighting the fact that due to the different contexts of rangelands, the main influencing factors should be considered separately for each region. To address these issues, an integrated and transdisciplinary approach is needed, which could provide benefits to the rangeland users through helping livelihoods' improvements and avoiding rangeland degradation. The lack of adoption of an integrated and inter-disciplinary approach is often the main challenge facing sustainable rangeland management.

Looking for an inter-disciplinary approach

Despite the past few decades of policies, programs and approaches in resource management, there still remain unresolved challenges and even intractable problems arising from responses to policies. New structures could not deal with new complex problems, and thus, make it more difficult to achieve sustainable rangeland management. Accordingly, proposed solutions need to recognise the very complex and dynamic nature of these problems (Bedunah and Angerer 2012).

In recent years, some approaches to sustainable rangeland management, such as integrated rangeland management systems (Ngaido 2010), and economically efficient rangeland management (Teague *et al.* 2010), have been proposed. Regarding the former approach, Ngaido (2010) proposed an integrated system for rangeland management addressing three dimensions that include the improvement of natural resources, human, and legal and institutional but ignored the economic and infrastructure dimensions. Teague *et al.* (2010) recognised three dimensions in rangeland sustainability consisting of natural, social and economic capitals among which human and infrastructure capitals were not addressed separately. Also, a standard set of criteria and indicators for sustainable livelihoods (DFID 2001) and sustainable rangeland management (Mitchell 2010) has been introduced to develop frameworks for sustainability assessment and monitoring in rangeland management. As a result, although these approaches have considered socio-economic, ecological and human issues, their deficiency is mainly because they have not paid a particular attention to providing 'appropriate livelihoods' for rangeland users. Nevertheless, they have taken into account the specific context of a particular rangeland, which is a reason for the difference between objectives in pursuing sustainable rangeland management. The above argument reveals that there is a need for an integrative approach which can include all these aspects

to achieve sustainable rangeland management as a multi-faceted concept. Lack of such attention to multiple factors for supporting the development of livelihood alternatives within a framework-based approach and wrong perceptions of sustainable rangeland management in previous research have resulted in impractical policies, which have eventually resulted in a failure in approaching sustainable livelihoods and sustainable rangeland management.

In this paper, as understanding the drivers of livelihoods may enable more appropriate policy support for the development of appropriate livelihood strategies for rangeland users and eventually sustainable rangeland management, we aim to highlight the cornerstones of sustainable livelihoods. In the next section, factors affecting livelihoods in rangeland management are identified.

Livelihood cornerstones in rangeland management

In this section, factors affecting livelihoods in rangeland management are addressed, which are here called ‘livelihood cornerstones’. ‘Livelihood capital’ is defined as the resources through which people meet their basic needs and choose different livelihood strategies. ‘Policies, institutions and processes’ involve factors mediating access to resources and livelihoods, which encompass policies, power, law, authority, governance, organisations, public service delivery, participation, social relations, right regimes, customs and market components. ‘Vulnerability contexts’ refer to susceptibility to seasonal cycles, external shocks and critical trends. Tables 1, 2 and 3 show factors affecting livelihoods with regard to rangeland management issues.

Towards a holistic framework for evaluating appropriate livelihood alternatives

Rangeland degradation and livelihoods’ vulnerability refer to a broad gap between the objectives of sustainability, current

management practices and policies on rangelands. Bridging the gap is a difficult task as there are shortfalls and limitations associated with mono-disciplinary and static approaches, which have made it more difficult to achieve sustainable rangeland management. In socio-ecological systems, such as rangelands, sustainability cannot be seen as a static objective (Rammel *et al.* 2007). In order to overcome such policy deficiencies, a new perspective is needed that places the promotion of livelihoods of rangeland users at the centre of the policy-making agenda. However, such a perspective should be neither limited to grazing nor sustainability, which can take many forms, different paths and alternatives (Walker *et al.* 2004; Stafford Smith *et al.* 2009). Subsequently, a set of ‘appropriate livelihood alternatives’ for livelihoods’ sustainability and a move towards sustainable rangeland management as a dynamic objective should be acknowledged in order to have a better perception and understanding of sustainable rangeland management. Sustainable livelihoods need to be considered as the core of socio-economic systems such as rangelands (Davies *et al.* 2008; LaFlamme 2011; Tsegaye *et al.* 2013) as the survival and security of livelihoods are of central importance to rangeland users (Stafford Smith *et al.* 2000). Stafford Smith *et al.* (2009) emphasised that efforts of users to survive and prosper may result in changes in ecosystem productivity and human wellbeing and asserted that ‘sometimes the problem is not how to increase resilience, but how to increase transformability’, thus, there is a need to ‘facilitate transformation from the kinds of systems they are now to some other kind of system, which may entail changing the ways people make a living, developing new strategies and operating at different scales’. Accordingly, in the next section, in order to introduce ‘appropriate livelihood alternatives’, ‘resilience thinking’ and ‘supportive strategies’ are first recognised, and, thereafter, the alternatives and the necessity of moving towards a holistic framework to evaluate and choose the best alternative are discussed.

Table 1. Livelihood criteria and the relevant sub-criteria for the livelihood capital

Livelihood capital Sub-criteria (first level)	Sub-criteria for the second level
Natural	Water, biodiversity, livestock forage, medicinal value, food value, wildlife, salt and other minerals and firewood
Human	Indigenous knowledge, education, age, gender, skills, health, labour and women’s empowerment
Social	Relationships of trust, membership of groups, user associations, common rules, communal rights, participatory management and collective actions
Financial	Income and access to money, savings, credit insurance, government taxes, pensions and annuities, subsidies, livestock and their products, remittances and pension rights
Physical	Mobility, roads and public transport services, markets, schools, water point supply, sanitation, government buildings and affordable energy

Table 2. Livelihood criteria and the relevant sub-criteria for policies, institutions and processes

Policies, institutions and processes (first level)	Sub-criteria for the second level
Policies	Land reform, nationalisation of rangeland by government, sedentarisation, transition to market economy, privatisation of rangelands, devolution of rangelands, reduction of areas for feed crops, fencing elimination of grazing, free land for grazing, free land for grazing and fragmentation
Institutions	Law and right regimes, custom, authority, social relations and market
Processes	Governance, land tenure, public service delivery, organisational structure and participation

Table 3. Livelihood criteria and the relevant sub-criteria for the vulnerability contexts

Vulnerability contexts (first level)	Sub-criteria for the second level
Seasonality	Climate change, drought, storms, floods, heat stroke and chilling injury
Shocks	Soil erosion, destruction of infrastructure, economic shocks, exchange rate changes, changes in trade terms, diseases, fires, snow and squall
Trends	Land-use change, desertification, heavy grazing, bush and shrub encroachment, the price of grain and forage and devaluation of monetary

Recognition of resilience thinking for developing new livelihood alternatives

Livelihood strategies can be defined as the activities undertaken by households for making their living and are a function of natural, social and economic capital, policies, institutions and processes, and the context of vulnerability. In considering possible future strategies, Walker *et al.* (2004) emphasised that 'strategies for sustainability must take many forms, as there is no 'one-size-fits-all' approach to the future'. To address this and in order to describe various strategies, Armitage (2007) used the concept of 'multiple dynamic equilibria' in which livelihood strategies are characterised by 'low resilience' to 'great resilience'. Moreover, Karl *et al.* (2012) pointed out that 'adapting what we currently know about ecosystems to a future in which rangelands are changing, and in some cases fundamentally different, is a new frontier in rangeland management'. Further, Joyce *et al.* (2013) stated that 'the rangeland profession should draw upon its legacy and professional network to develop multiple strategies (i.e. mitigation, adaptation and transformation) to confront current condition and climatic variability'. Accordingly, we recognise the importance of thinking on resilience for developing livelihood alternatives in which these sustainability-enhancing strategies are acknowledged (Walker *et al.* 2004; Stafford Smith *et al.* 2009; Folke *et al.* 2010; Park *et al.* 2012; Joyce *et al.* 2013). The main underpinning of these alternatives is the belief that innovative strategies are crucial for coping with climate change and addressing their socio-ecological consequences in order to sustain livelihoods (Joyce *et al.* 2013).

In itemising appropriate set of livelihood alternatives, Homewood (2004) noted that possible strategies for pastoralists in Kenya include livestock-based and other resources, tourism, conservation, and migration due to disease, war and drought. Stafford Smith *et al.* (2008), in their study on Australia, indicated a mix of six sources including (1) grazing and tourism; (2) mining; (3) cultural relationships and social capital; (4) welfare; (5) conservation; and (6) the service sector, government and administration. Also, to achieve sustainable development of rangeland-livestock systems in China, Shang *et al.* (2014) recognised 19 strategies, which were divided into four main categories encompassing grassland-forage, livestock, economy and market, and society and culture. However, none of the above authors considered possible options from the perspective of analysing different livelihood strategies.

The above livelihood strategies can be classified into three categories, namely 'livestock-based livelihoods', 'resource-based livelihoods' and 'non-resource-based livelihoods'. Using the livelihood strategies found in the literature, combined with our understanding of the effects of changing conditions on rangelands, and subsequently impacts on livelihoods of rangeland users, can we

make inferences about what livelihood strategies rangeland users can employ under different conditions and/or in different regions?

To this end, we have identified nine main livelihood strategies that address social and ecological consequences of climate change consisting of mitigation, adaptation and transformation. In doing so, we aimed to adapt the systems and also tried to recognise transforming livelihoods for more resilience where risks are likely to be much more severe (Ellis and Swift 1988; Joyce *et al.* 2013). Thus, 'traditional pastoralism' is recognised, and then some changes through mitigation, adaptation and transformation are acknowledged. Although the worst-case scenarios or some other weak alternatives can easily be identified, here we deliberately describe the best-case scenarios/alternatives as 'appropriate livelihood alternatives' that can work in different regions and through which can be provided workable solutions to enhance resilience of livelihoods and guarantee sustainable rangeland management. In the next section we discuss 'adaptive capacity for enhancing resilience' in a frame of 'supportive strategies' and then address appropriate livelihood alternatives for rangeland users.

Supportive strategies: adaptive capacity for enhancing resilience

As underlying drivers differ from place to place, to achieve sustainable livelihoods, it is necessary to consider the diverse contexts of rangelands and climate variability as well as socio-ecological and economic conditions of a given area. Although individuals through self-organisation may cope with these changes and improve or change their livelihoods, most rangeland users need a supportive portfolio, which is called here, 'supportive strategies'.

Historically, rangeland users have been supported by adaptive and resilient strategies, which have been sufficiently robust to cope with a slow-changing operation of their socio-ecological systems (Klein *et al.* 2011). However, they are now experiencing rapid changes in their environment and living conditions as a result of the changing climate and socio-economic conditions, which can affect the sustainability of their livelihoods. Six categories of supportive strategies that can support rangeland users' livelihoods in tackling change have been identified as a useful portfolio of adaptive capacity for enhancing resilience. These strategies are:

- (1) Based on equilibrium and non-equilibrium paradigms and those that address the social and ecological consequences of climate change encompassing mitigation, adaptation and transformation;

- (2) Associated with capacities for self-organisation and strengthening local institutions including collective action, cooperatives, collaborative practices, community-based management, and adaptive co-management;
- (3) Related to the diversification of livelihoods through alternative resources such as forestry, farming, fisheries, tourism, mining;
- (4) Concerned with the development of social services and cultural resources such as social protection, social networks and cultural supportive services;
- (5) Related to the promotion of financial transfers and market services, public transfer payments and incentive-oriented instruments; and
- (6) Linked to legal considerations such as property rights, land tenure and environmental rules and changing the rules as a whole.

Consequently, supportive strategies are those that enhance resilience through building capacity that need to be developed in a certain region whether through rangeland users themselves or governments. Considering the status of a specific region, one or more supportive strategies mentioned can be provided for supporting the rangeland users' livelihoods to build more resilience.

Exploring 'appropriate livelihood alternatives'

Traditional sustainable pastoralism (alternative 1)

'Traditional pastoralism', known as extensive livestock production systems, is one of the most important rangeland-based livelihood strategies in some regions of developing countries although in almost all developed economies other uses (e.g. tourism and mining) far exceed the grazing of livestock. These systems focus primarily on livestock as the main source of income although processing, adding value and marketing livestock products have markedly increased. This livelihood strategy can develop very well in a region where traditional institutions work well, pastoral routes have not been eroded, mobility has not been limited and/or nomadic pastoralism with its culture has been maintained. Herrera *et al.* (2014) reported that in a region where livestock mobility and institutions for communal governance are found, traditional production systems are viable and rangeland degradation is scarce. Stafford Smith *et al.* (2009) stated that, if pastoralism is to be viable, it must utilise key rangeland resources where landscape function is robust, and forage and surface water are available during dry periods. Furthermore, Maru *et al.* (2014) emphasised that, although particular factors must be considered for resilience responses, more attention must be also paid to local knowledge, social capital, and mobility. In general, if all the above conditions are provided and, according to Behnke (2008), population pressures are not strong and rangelands are consolidated, pastoralists may be able to move towards maintaining nomadic cultures, ecosystem functions and traditional livelihood strategies (Stafford Smith *et al.* 2009). Indeed, if there is a region with such conditions, then traditional pastoralism will be sustainable and viable over time in the future.

Although, in case of severe changes like climate change, especially in unstable environments, pastoralists had developed a range of livelihood strategies and resilient systems to cope with the inherent variability in their rangelands and sustain the

livelihoods systems, currently they have to deal with new changes and challenges that is greater than ever before (Klein *et al.* 2011). Many studies have identified that pastoralists are disproportionately vulnerable to risk, drought, hunger and famine in the face of climate variability and their livelihood systems suffer from limitations and barriers, which have been reported by many authors as 'vulnerable livelihoods'. Therefore, even if these production systems survive but continue to be constrained and undermined through neglecting the customary institutions and livestock mobility, rangeland degradation and their livelihoods vulnerability will continue. As Maru *et al.* (2014) pointed out, development policies devised with limited understanding of local conditions or lack of understanding of modern governance institutions, and the ways in which policies are formulated, can also affect the ability of rangeland users to overcome the limitations and vulnerabilities. As a result, rangeland users will face growing erosion of their adaptive capacities, and will become increasingly susceptible to climatic shocks and consequently, their livelihoods will become less resilient and less reliable (Davies *et al.* 2010).

Understanding these strategies and the factors influencing livelihoods enable us to find appropriate livelihood alternatives and determine most appropriate strategies for approaching sustainable rangeland management. Ideally, a sustainable rangeland management system should explicitly recognise different livelihood alternatives to protect and ensure sustainable livelihoods. Traditional livelihood strategies, in some cases, have been improved through adopting some strategies including mitigation. Many of the mitigation ideas are now getting old and outdated and there is a need to introduce some alternatives based on adaptation and transformation through structural changes in which sustainability is recognised as a main goal.

Sustainable pastoralism through mitigation (alternative 2)

Many traditional livestock-based livelihoods, which have incorporated many of the principles of resilience, have enhanced their ability to adapt to and cope with changing conditions of rangelands and have been called 'sustainable pastoralism' (Davies *et al.* 2010; Klein *et al.* 2011; Herrera *et al.* 2014). A set of management measures for mitigation and improvement of these systems has been identified by Joyce *et al.* (2013). They include carbon sequestration and potential to reduce greenhouse gases through better soil management and reducing methane emissions, attained by changing livestock management practices including reduction of livestock numbers, changing the mix of livestock and its distribution (for more discussion see Joyce *et al.* 2013). It is unlikely that application of principles associated with mitigation of pastoral systems can overcome the overwhelming effects of changes and be able to adequately address the problems that these systems are faced with. It is also claimed that due to 'the small and highly variable carbon dioxide fluxes of rangelands and the high transaction costs', mitigation of these systems is likely to become an increasingly poor strategy to deal with future changes and challenges (Joyce *et al.* 2013). As a result, there is a risk with regard to the mitigation strategies developed solely in response to the existing variability. Accordingly, any future strategy for improving rangelands, livelihoods of

rangeland users and coping with future changes need to be developed beyond mitigation.

Sustainable pastoralism through adaptation

As livestock-based livelihoods on their own do not seem to be able to provide a sufficient means of providing sustainable livelihoods for rangeland users and this is very likely to change in the future, adaptation strategies have also been recognised along with mitigation, as the key strategies to improve livelihoods, adapt to climate change and prevent rangeland degradation (Joyce *et al.* 2013). Adaptation strategies specific to livestock production systems include grazing management, alternative livestock breeds or species, pest management, modified production structure, livelihood diversification and geographic relocation (Joyce *et al.* 2013). Moreover, to enhance adaptive capacity for more resilience, some authors have suggested strengthening local institutions, collective action and community-based management (Dong *et al.* 2009; Klein *et al.* 2011; Joyce *et al.* 2013; Herrera *et al.* 2014). Moreover, it is believed that, in countries with 'significant rangeland resources', in order to invest in rangelands to meet future food needs (e.g. through livestock production and ecosystem services), governments need to provide encouragement and supportive policies at macro and micro levels through which adaptive capacity and more self-sufficient of communities can be enhanced (Holechek 2013). Safriel *et al.* (2005) introduced the concept of 'synergies' as the integration of mixed practices or complementary uses where different households or communities combine livestock rearing and other strategies (i.e. livestock herding or farming, afforestation, food trading and other services). Accordingly, the following sections explain various diversification sources and/or synergies, which need to be focussed on for adapting livestock production systems on rangelands accompanied with other resources, with each one having the potential to increase adaptive capacity for enhancing resilience. One or more supportive strategies can help to achieve the best adaptation options.

Adaptation through focusing on rangelands (alternative 3)

It has been emphasised that a strong reliance on rangelands, especially at current grazing pressures of livestock may limit their future sustainable use (Holmes 2002; Azadi *et al.* 2007). Because of unpredictable nature of socio-ecological systems, and that 'carrying capacities of all rangelands are finite', focusing on a single use of resources, such as livestock grazing, may increase livelihood vulnerability (Holechek 2013). Accordingly, rangeland management no longer should be seen as 'livestock-based systems', which involve livestock grazing for keeping, consuming, and selling but also 'livestock-related activities' such as processing, adding value and the marketing of livestock products. It should also include multiple uses of rangelands such as payment for ecosystem services, gathering plant products, tourism, apiculture, pisciculture, mining and carbon sequestration, which provide diverse livelihoods. Thus, this strategy is based on a combination of livestock grazing and development of new strategies dependent on rangelands. It is justified in places where rangeland users are only engaged in

rangeland-based activities and alternative non-rangeland sources of income are not readily available.

Adaptation through focusing on rangelands and other resources (alternative 4)

In some cases, despite providing forage to increase livestock products, rangelands are not be able to provide a safety net for rangeland users where population is high and rangeland resources are limited (Holmes 2002; Safriel *et al.* 2005; Stafford Smith and Cribb 2009; Holechek 2013). As carrying capacity is limited, rangeland users have to benefit from other livelihood resources (Holechek 2013). Therefore, 'multiple uses' of rangelands along with the use of other resources, such as forests, fisheries, tourism, conservation and mining, have to be considered if the goal is to enhance livelihoods' resilience (Stafford Smith and Cribb 2009). Some modifications in livelihood systems (i.e. changes to afforestation or reforestation, agro-pastoralism and silvo-pastoralism), which are applied in response to population growth, environmental changes, and economic and political developments, 'can decrease livestock pressure on rangelands through fodder cultivation and provision of stubble to supplement livestock feed during forage scarcity' (Safriel *et al.* 2005). Moreover, in a recent study, Shang *et al.* (2014) emphasised that supplementary assistance through alternative industries provide new opportunities for rangeland users to supplement their income from other resources such that their reliance on livestock-based production systems can reduce. A mixture of all land-based activities is needed with access to supplementary assistances and more supports that allow them to enhance their resilience.

Looking for sustainable livelihoods through transformation

A rapid change in the climate or socio-economic circumstances of climate change in a specific region or inappropriate management practices can lead to a collapse of production systems and rangeland users is unlikely to be compensated for by mitigation and adaptation strategies. Economic and ecological constraints in such situations may compel a transformative change in livelihood systems and also in alternative ecosystem services (Park *et al.* 2012; Joyce *et al.* 2013); thus, changing livelihoods is unavoidable. Maru *et al.* (2014) argued that longer-term building of desirable forms of responses in resilience needs to be considered for a significant shift or transformation in the governance and rangeland users' livelihoods where transformation is defined as 'capacity to create a fundamentally new system when ecological, economic or social structure makes the existing system untenable' (Walker *et al.* 2004). Thus, in some cases, rangeland users have to transform extensive production systems to new ones, which may be more intensive, or leave livestock rearing and choose other resource-based livelihoods or even leave the rangelands and adopt non-resource-based livelihoods, which may involve migration. Although there is no exact match between the different classifications of rangeland contexts and our classification of the livelihood alternatives, recognition of the diverse contexts is a useful prerequisite to identifying suitable areas for each livelihood alternative. As a result, disappeared or converted rangelands, most degraded and abandoned rangelands, woody

plant encroachment, unsustainable rangelands in terms of limited forage availability and grazing may fall into this category, which requires the creation of new livelihoods for rangeland users (Stafford Smith and Cribb 2009; Joyce *et al.* 2013).

Sustainable pastoralism through transformation (alternative 5)

The growth and viability of extensive production systems are constrained in some countries by inadequately designed and inappropriately chosen policies that are designed to transform rather than enhance these systems (Davies *et al.* 2010). In some countries commercialisation, which is associated with decreased mobility, and the trend towards commercialised meat production, represents a shift into a less productive system reducing pressure on/and the capacity of the rangeland to support rangeland users. Therefore, increased meat production and 'livestock off-take' have been considered as the major policy goals, despite the much greater significance of milk in pastoral economy (Davies *et al.* 2010). Accordingly, as Stafford Smith *et al.* (2009) cited, a shift from the production of milk to meat can change the role of women and thereby can disrupt traditional cultures by transforming the social relations of production. Further, they also argued that changes from a complex mix of livestock, including browsers and grazers, to herds of one commercial species can affect rangeland ecosystems. Consequently, 'commercial pastoralism' presents new risks to pastoral livelihoods and hidden environmental costs (Davies *et al.* 2010). If commercially oriented livestock products are intended to contribute in achieving sustainable livelihoods and sustainable rangeland management, they need to be regulated much more tightly to ensure that environmental damage is accounted for. It has been further argued that, although extensive production is environmentally and socially benign in some places, it will not be capable of meeting the growing demands of an expanding and more affluent world population so that there is no realistic alternative to more intensive production (Steinfeld *et al.* 2010).

In places where commercial pastoralism is considered as the dominant alternative, the value-adding to the range of livestock-based activities including processing activities, dairy products (e.g. milk), and fibre and skins need to be taken into account. Additionally, adding value to livestock through livestock diversity, low stocking rates using highly adapted livestock, provision of market services, dairying and fibre marketing, institutions, cooperatives, and reduced reliance on rangeland forage are important considerations in applying commercial pastoralism (Stafford Smith *et al.* 2009; Davies *et al.* 2010; Steinfeld *et al.* 2010; Holechek 2013). In this regard, Stafford Smith *et al.* (2009) argued that new markets can create new sources for livelihood diversification and enhance resilience. An example from marketing of a cooperative group in Australia has been reported where the organic beef are directly sold as high-value products to Tokyo, Taiwan and New York (Stafford Smith and Cribb 2009). However, it may affect traditional cultures that have not participated in such markets in the past (Stafford Smith *et al.* 2009).

Nevertheless, when there is no opportunity for mitigation and adaptation to achieve appropriate livelihoods, transformation to new systems and intensification can guarantee sustainable

livelihoods, which will be more sustainable if all the above concerns are properly addressed. It means that in order to achieve 'commercial sustainable pastoralism', policy must develop more supports through supportive strategies to maximise assistance for implementation of this strategy.

Transformation to resource-based livelihoods (alternative 6)

Although, over centuries, resource-based livelihoods, such as gathering plant products, especially edible and medicinal plants and firewood, have existed and contributed to livestock-based livelihoods, perceptions about rangeland management as solely a livestock-based livelihood have persisted (Holmes 2002; Stafford Smith *et al.* 2008; Joyce *et al.* 2013). Transformation, as a strategy beyond incremental adaptation, emphasises the development of new ecosystem services including conservation, tourism, hunting leases and mining (Joyce *et al.* 2013). Stafford Smith and Cribb (2009) discussed that, in a region with unsustainable livestock grazing, managers may prefer to focus on other resource-based livelihoods such as conservation or a form of tourism as a main or supportive enterprise. In other cases, gathering edible, industrial and medicinal plant products (e.g. seed, forage, etc.), apiculture, and pisciculture may be promoted for rangeland users who are not willing or are not able to continue livestock-based livelihoods and prefer to remove the livestock from their livelihoods. As a result, this alternative is applicable for those who have less conflict of interests with other rangeland users and have the ability and capacity to adapt to change, as it may provide an alternative for restoring the rangelands and improving their livelihood. It comes from historical sense of independence and self-reliance in the face of variability and uncertainty (Maru *et al.* 2014). As a result, if rangeland users are more supported, especially in terms of legal considerations, they may prefer moving towards an alternative resource-based livelihood.

Transformation to resource-based livelihoods and more support (alternative 7)

As Stafford Smith *et al.* (2009) emphasised, through facilitative transformation, rangeland users can be supported in shifting their livelihoods to resource-based livelihoods. Therefore, in some cases, rangeland users through a participatory processes and/or supplementary assistance and supportive strategies, have restored their land and then utilised it for a resource-based livelihood. Good examples of this strategy are participatory rehabilitation of degraded rangeland, community-based rehabilitation and community-based management, which have been implemented in many countries around the world. In other cases, rangeland users may follow some strategies such as tourism, mining, conservation, apiculture, and pisciculture through utilising other resources like forests and farmlands for their livelihood diversification as well as for more resilience. Supportive strategies are critical for supporting new sources of income and for more resilience.

Non-resource-based livelihoods as a transformation in livelihoods (alternative 8)

These strategies, as alternative livelihoods, are usually utilised by people who are not able to continue resource-related activities.

Some examples include services to support the resident population such as providing goods and services, food, pastoral advice and governance at all scales (Stafford Smith *et al.* 2008; Stafford Smith and Cribb 2009). As long as viable livelihood strategies within a variety of resource-based livelihoods (i.e. rangelands, forests, farm, fisheries, tourism, and mining) cannot be found, rangeland users need to move towards alternative livelihoods, as these resources have a finite capability to provide essential needs of rangeland users (Holechek 2013). These strategies can be chosen by rangeland users themselves as a business opportunity for them. Adopting such livelihood strategies will reduce population pressures on rangeland areas. Consequently, sustainable rangeland management as a balance between rangeland, livestock and human, and their long-term productivity, will be approached and sustainable livelihoods will be met as one of the most important goals in approaching sustainable rangeland management.

Migration as an ultimate change in livelihoods (alternative 9)

Transformative changes, involving migration, are difficult to embark upon unless there is a compelling reason (Joyce *et al.* 2013). In general, rangeland users migrate for one of these three reasons, namely (1) lack of appropriate opportunities for livestock-based livelihoods, (2) lack of capability of development of resource-based livelihoods, and (3) deficiency of alternative livelihoods or opportunities to support their lives and families. Although migration may reduce population pressure on rangeland areas and in some cases lead to improved livelihoods of rangeland users, the reverse is possible if migration is socially disruptive and breaks down local structures including institutions. This means migration in response to drought, war, diseases and better education for children might not improve rangeland users' livelihoods. In some cases, if rangeland users suffer from the same problems causing migration and rangelands' abandonment, mitigation and adaptation strategies cannot change significantly their living conditions and other transformation strategies are not also applicable, thus migrants' remittances may help them to improve their livelihoods.

Migration may be chosen as an appropriate alternative by a group of rangeland users in a given region especially when migrants have left their rangelands and have none or minor conflict of interests with other rangeland users. Therefore, migration of these groups may create a new opportunity for ones who have not yet changed their livelihoods. As a result, migration by itself cannot create sustainable livelihoods for the remaining population rather it can contribute to achieve sustainable rangeland management and sustainable livelihoods for rangeland users through reducing pressures on the rangelands (Shang *et al.* 2014).

Implications for biodiversity

Although some non-livestock-based livelihoods, including resource and non-resource-based livelihoods, and migration, can contribute to achieving sustainable livelihoods in certain regions, the role of livestock, as one of the determinants of biodiversity of the rangelands where grazing is sustainable, should not be overlooked. It has been argued that in non-resilient regions, such

as Australian remote areas where grazing is not economically viable in some instances, there is a greater threat, particularly in the more arid areas, to biodiversity if sustainable livelihoods, achieved through grazing, as a primary type of land use, is phased out (Stafford Smith *et al.* 2000). Furthermore, livelihood strategies should be such that the rangelands are resilient to external shocks and stressors. In other words, they should be able to adapt to short-term shocks (for example, drought) and be resilient to longer-term stresses derived from climate variability as well as social, economic, and ecological changes. Another problem with these ongoing changes is that they can increase the complexity of development programs to make livelihoods sustainable and ultimately they can change socio-economic structures of rural and urban areas, and affect biodiversity.

Implications for rangeland users and policy

Nine appropriate livelihood alternatives have been described above that could be employed by rangeland users for their livelihoods (Fig. 2). Policy-makers, especially in developing countries, face challenges over identifying the appropriate alternatives for investments and desirable ones for the sustainable livelihood of rangeland users and to deliver sustainable rangeland management. Furthermore, the determinants of livelihoods affect the decisions of the rangeland users in selecting a new way of living. In other words, they are crucial for selecting possible strategies which, in turn, affects related policies and investments required for each alternative.

The proposed framework (Fig. 2) can evaluate which livelihood alternatives are suitable for sustainable livelihoods and sustainable rangeland management. The framework also indicates the main determinants of sustainable livelihoods, which include livelihood capital, vulnerability contexts and policies, institutions and processes, which bring together the main drivers affecting livelihood alternatives. Two main questions can be posed: (1) which factors are the main determinants of livelihoods of rangeland users, and (2) which one of the livelihood alternatives and/or which combination of livelihoods approach sustainable rangeland management in a given region, while achieving the sustainable livelihoods of rangeland inhabitants? As sustainable livelihoods approach does not offer a formal research methodology, various evaluation frameworks have to be suggested as important contributors to evaluating sustainable livelihoods. In this study, a new framework has been suggested in order to assess different livelihood strategies among which appropriate alternatives are recognised and can be analysed regarding their criteria at three levels (Fig. 2). Which methodology in a multi-criteria decision-making approach should be used is beyond the scope of this paper.

The main thrust of this paper is that livelihoods of rangeland users in different regions are diverse and policy needs to pay attention to this. All the livelihood strategies described might be possible or/and sustainable and lead to positive outcomes in most countries and in different regions of a country, especially developing countries. If livelihoods are to be enhanced, new policies, institutions and processes are needed, and the vulnerability context requires to be well understood. In general, recognition, that either traditional pastoralism with its culture or sustainability-enhancing strategies need to be supported, can

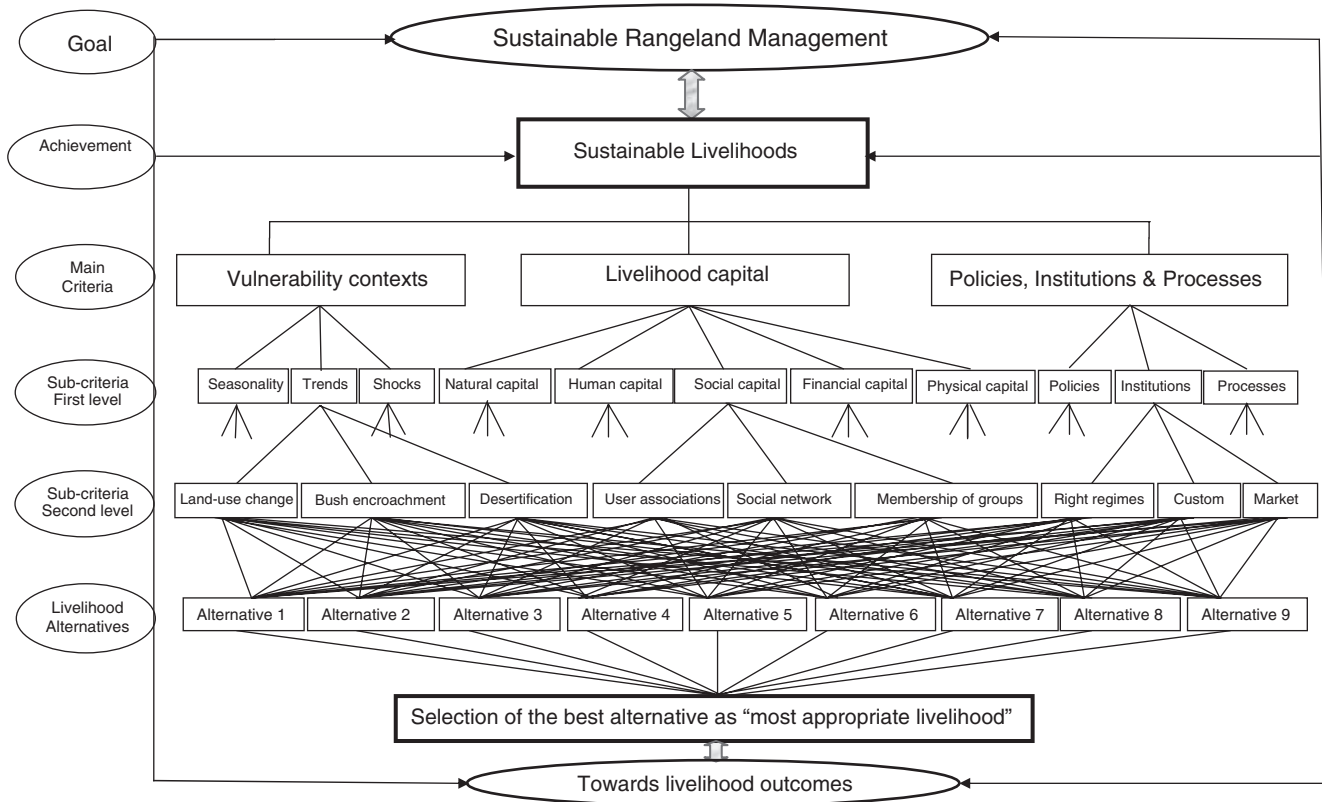


Fig. 2. An ‘appropriate livelihood framework’ for evaluating livelihood alternatives (derived from sustainable livelihoods framework) as a hierarchical (decision) tree for selecting the best livelihood alternative. All sub-criteria in the second level have not been linked with alternatives. Alternatives are (1) Traditional sustainable pastoralism; (2) Sustainable pastoralism through mitigation; (3) Sustainable pastoralism through adaptation by focusing on rangelands; (4) Sustainable pastoralism through adaptation by focusing on all resources; (5) Commercial sustainable pastoralism; (6) Resource-based livelihoods; (7) Resource-based livelihoods and more supports; (8) non-resource-based livelihoods; and (9) Migration.

help policy-makers in preventing the occurrence of undesirable changes including rangeland degradation and livelihood vulnerability as well as promoting desirable changes through developing appropriate livelihood strategies for rangeland users which are steps towards achieving sustainable livelihoods and sustainable range management.

Conclusion

Although sustainable rangeland management has been the subject of many studies, appropriate livelihood alternatives have hardly been addressed in the context of rangeland management. In this paper, rangeland degradation and livelihood vulnerability were seen as the major challenges in approaching sustainable rangeland management. It has been discussed that imperfect and one-dimensional approaches, development interventions and vulnerable livelihood strategies in current planning and policy-making have exacerbated these two problems and have made the achievement of sustainable rangeland management difficult. Moreover, this study has revealed that the effects of incomplete policies, vulnerability contexts on rangelands and neglecting a holistic approach could limit the ‘livelihood alternatives’ of rangeland users and could, therefore, be considered as a threat to sustainable rangeland management. Accordingly, a need for developing a multi-disciplinary approach that includes ecological,

social, economic, human, and infrastructure aspects of sustainable rangeland management has been highlighted.

A new policy-making perspective is needed to overcome the policy deficiencies in order that promotion of livelihoods of rangeland users is at the centre of the policy-making agenda. The need for new approaches in rangeland management policies emerges in line with the evolving concept of sustainable livelihoods. Applying a sustainable livelihoods approach to rangeland management issues can assist policy-makers in designing supportive policies for approaching sustainable rangeland management. Sustainable livelihoods unfold through access to a range of livelihood capital, coping with shocks and stresses, dealing with personal, institutional and policies constraints, and pursuing different livelihood strategies. Nevertheless, in addition to describing the main determinants of sustainable livelihoods, this study has introduced a set of appropriate livelihood alternatives and developed a new framework for their evaluation through which the best strategy for the future of rangeland management can be determined in terms of the state of each area.

Nevertheless, the desired long-term results will not be achieved unless the sustainable livelihood strategies are considered as a part of wider national policy in rangeland management. Moreover, sustainable livelihood strategies depend

on the support of many stakeholders with different perspectives as well as providing many requirements. It should be also noted that the selection of the best livelihood strategies and activities depends on the potential of each area including its location and local people. Due to the heterogeneity of rangelands, there is no one-size-fits-all in different regions and countries. Some regions or localities/people may be ready to apply livestock-based livelihoods whereas others might prefer resource-based livelihoods, and alternative livelihoods or even a wish to migrate to urban areas. Further, it should be noted that, because of the dynamics of social and ecological systems as well as the diversity and variability of rangelands' contexts, it may be different to interpret the result from one region to another region. As local conditions vary, as it is likely that there will be several alternatives which will be appropriate for development in a given region.

Determining which of the livelihood strategies are relevant in a particular situation is the key for sustainable livelihoods. The proposed evaluation framework leads to the selection of the best strategies in a certain region and to design future programs of research-for-planning. The selection of a suitable alternative approach to achieving sustainable livelihoods and sustainable rangeland management is a complex task involving a wide range of decision-making processes that depends on many factors, which undoubtedly can be greatly influenced by the willingness and attitudes of the rangeland users, climate variability, socio-ecological systems and economic-political contexts of each country.

First, rangeland users must decide which kind of livelihood sources (livestock or resource-based and others) would lead to achieving sustainable livelihoods and which strategies can diversify livelihoods and increase their income, and whether they choose alternative strategies or leave the rangelands. Second, they need to analyse which and to what extent influencing factors should be applied to achieve sustainable livelihoods. Finally, they should be aware of the fact that decision-making on such actions mainly depends on access to capital, understanding the vulnerability context and the personal, institutional, and policies constraints. Future research should answer the following questions: (1) how different factors affecting sustainable livelihoods and livelihood strategies should be prioritised and (2) how such a decision-making process should be modelled to achieve sustainable livelihoods and sustainable rangeland management.

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References

Abolhassani, L., Oesten, G., Rajmis, S., and Azadi, H. (2013). Attitudes of rangeland holders towards sustainable range management in Iran: a case study of the Semnan rangelands. *The Rangeland Journal* **35**, 435–443. doi:10.1071/RJ11079

- Armitage, D. (2007). Building resilient livelihoods through adaptive co-management: the role of adaptive capacity. In: 'Adaptive Co-management: Collaboration, Learning and Multi-level Governance'. (Eds D. Armitage, F. Berkes and N. C. Doubleday.) pp. 62–82. (UBC Press: Vancouver, Canada.)
- Azadi, H., Shahvali, M., Van den Berg, J., and Faghiih, N. (2007). Sustainable rangeland management using a multi-fuzzy model: how to deal with heterogeneous experts' knowledge. *Journal of Environmental Management* **83**, 236–249. doi:10.1016/j.jenvman.2006.03.012
- Bedunah, D. J., and Angerer, J. P. (2012). Rangeland degradation, poverty, and conflict: how can rangeland scientists contribute to effective responses and solutions? *Rangeland Ecology and Management* **65**, 606–612. doi:10.2111/REM-D-11-00155.1
- Behnke, R. H. J. (2008). The drivers of fragmentation in arid and semi-arid landscapes. In: 'Fragmentation in Semi-arid and Arid Landscapes: Consequences for Human and Natural Systems'. (Eds K. A. Galvin, R. S. Reid, R. H. J. Behnke and N. T. Hobbs.) pp. 305–340. (Springer: Berlin, Germany.)
- Davies, J., White, J., Wright, A., Maru, Y., and LaFlamme, M. (2008). Applying the sustainable livelihoods approach in Australian desert Aboriginal development. *The Rangeland Journal* **30**, 55–65. doi:10.1071/RJ07038
- Davies, J., Niamir-Fuller, M., Kerven, C., and Bauer, K. (2010). Extensive livestock production in transition: the future of sustainable pastoralism. In: 'Livestock in a Changing Landscape, Vol. 1: Drivers, Consequences, and Responses'. (Eds H. Steinfeld, H. A. Mooney, F. Schneider and L. E. Neville.) pp. 285–310. (Island Press: Washington, DC.)
- DFID (2001). 'Sustainable Livelihoods Guidance Sheets, Numbers 1–8.' (Department for International Development (DFID): London, UK.)
- Ding, W., Ren, W., Li, P., Hou, X., Sun, X., Li, X., Xie, J., and Ding, Y. (2014). Evaluation of the livelihood vulnerability of pastoral households in Northern China to natural disasters and climate change. *The Rangeland Journal* **36**, 535–543.
- Dong, S., Lassoie, J., Shrestha, K. K., Yan, Z., Sharma, E., and Pariya, D. (2009). Institutional development for sustainable rangeland resource and ecosystem management in mountainous areas of northern Nepal. *Journal of Environmental Management* **90**, 994–1003. doi:10.1016/j.jenvman.2008.03.005
- Dong, S. K., and Sherman, R. (2015). Enhancing the resilience of coupled human and natural systems of alpine rangelands on the Qinghai-Tibetan Plateau. *The Rangeland Journal* **37**, i–iii. doi:10.1071/RJ14117
- Dong, S. K., Lassoie, J. P., Yan, Z. L., Sharma, E., Shrestha, K. K., and Pariya, D. (2007). Indigenous rangeland resource management in the mountainous areas of northern Nepal: a case study from the Rasuwa District. *The Rangeland Journal* **29**, 149–160. doi:10.1071/RJ07033
- Ellis, J. E., and Swift, D. M. (1988). Stability of African pastoral ecosystems: alternate paradigms and implications for development. *Journal of Range Management* **41**, 450–459. doi:10.2307/3899515
- Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., and Rockström, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society* **15**, 20.
- Geist, H. J., and Lambin, E. F. (2004). Dynamic causal patterns of desertification. *Bioscience* **54**, 817–829. doi:10.1641/0006-3568(2004)054[0817:DCPOD]2.0.CO;2
- Gross, J. E., McAllister, R. R. J., Abel, N., Stafford Smith, M., and Maru, Y. (2006). Australian rangelands as complex adaptive systems: a conceptual model and preliminary results. *Environmental Modelling & Software* **21**, 1264–1272. doi:10.1016/j.envsoft.2005.04.024
- Herrera, P. M., Davies, J. M., and Baena, P. M. (Eds) (2014). 'The Governance of Rangelands: Collective Action for Sustainable Pastoralism.' (Routledge: London, UK.)
- Hobbs, N. T., Galvin, K. A., Stokes, C. J., Lockett, J. M., Ashd, A. J., Boonea, R. B., Reid, R. S., and Thornton, P. K. (2008). Fragmentation of rangelands: implications for humans, animals, and landscapes. *Global*

- Environmental Change* **18**, 776–785. doi:10.1016/j.gloenvcha.2008.07.011
- Holechek, J. L. (2013). Global trends in population, energy use and climate: implications for policy development, rangeland management and rangeland users. *The Rangeland Journal* **35**, 117–129. doi:10.1071/RJ12077
- Holmes, J. (2002). Diversity and change in Australia's rangelands: a post-productivist transition with a difference? *Transactions of the Institute of British Geographers* **27**, 362–384. doi:10.1111/1475-5661.00059
- Homewood, K. M. (2004). Policy, environment and development in African rangelands. *Environmental Science & Policy* **7**, 125–143. doi:10.1016/j.envsci.2003.12.006
- Hosseini, G., Azadi, H., Zarafshani, K., Samari, D., and Witlox, F. (2013). Sustainable rangeland management: pastoralists' attitudes toward integrated programs in Iran. *Journal of Arid Environments* **92**, 26–33. doi:10.1016/j.jaridenv.2013.01.003
- Joyce, L. A., Briske, D. D., Brown, J. R., Polley, H. W., McCarl, B. A., and Bailey, D. W. (2013). Climate change and North American rangelands: assessment of mitigation and adaptation strategies. *Rangeland Ecology and Management* **66**, 512–528. doi:10.2111/REM-D-12-00142.1
- Karl, J. W., Herrick, J. E., and Browning, D. M. (2012). A strategy for rangeland management based on best available knowledge and information. *Rangeland Ecology and Management* **65**, 638–646. doi:10.2111/REM-D-12-00021.1
- Klein, J. A., Fernández-Giménez, M. E., Wei, H., Changqing, Y., Du Ling, D. D., and Reid, R. S. (2011). A participatory framework for building resilient social-ecological pastoral systems. In: 'Restoring Community Connections to the Land: Building Resilience through Community-based Rangeland Management in China and Mongolia'. (Ed. M. E. Fernández-Giménez.) pp. 3–36. (CABI: Wallingford, UK.)
- LaFlamme, M. (2011). A framework for sustainable rangeland livelihoods. *The Rangeland Journal* **33**, 339–351. doi:10.1071/RJ11023
- Martin, R., Müller, B., Linstädter, A., and Frank, K. (2014). How much climate change can pastoral livelihoods tolerate? Modelling rangeland use and evaluating risk. *Global Environmental Change* **24**, 183–192. doi:10.1016/j.gloenvcha.2013.09.009
- Maru, Y. T., Stafford Smith, M., Sparrow, A., Pinho, P. F., and Dube, O. P. (2014). A linked vulnerability and resilience framework for adaptation pathways in remote disadvantaged communities. *Global Environmental Change* **28**, 337–350. doi:10.1016/j.gloenvcha.2013.12.007
- Miller, D. J. (1999). Nomads of the Tibetan Plateau rangelands in western China. 3. Pastoral development and future. *Rangelands* **21**, 17–20.
- Mitchell, J. E. (Ed.) (2010). 'Criteria and Indicators of Sustainable Rangeland Management.' (University of Wyoming, Cooperative Extension Service: Laramie, WY.)
- Ngaido, T. (2010). 'Integrated Rangeland Management Systems.' (Environment, Production and Technology division, International Food Policy Research Institute: Washington, DC.)
- Ngugi, R. K., and Nyariki, D. M. (2005). Rural livelihoods in the arid and semi-arid environments of Kenya: sustainable alternatives and challenges. *Agriculture and Human Values* **22**, 65–71. doi:10.1007/s10460-004-7231-2
- Park, S. E., Marshall, N. A., Jakku, E., Dowd, A. M., Howden, S. M., Mendham, E., and Fleming, A. (2012). Informing adaptation responses to climate change through theories of transformation. *Global Environmental Change* **22**, 115–126. doi:10.1016/j.gloenvcha.2011.10.003
- Rammel, C., Stagl, S., and Wilfing, H. (2007). Managing complex adaptive systems – a co-evolutionary perspective on natural resource management. *Ecological Economics* **63**, 9–21. doi:10.1016/j.ecolecon.2006.12.014
- Safriel, U., Adeel, Z., Niemeijer, D., Puigdefabregas, J., White, R., Lal, R., Winslow, M., Ziedler, J., Prince, S., Archer, E., and King, C. (2005). Dryland systems. In: 'Millennium Ecosystem Assessment: Ecosystems and Human Well-being: Current State and Trends: Findings of the Condition and Trends Working Group. Vol. 1'. (Eds R. M. Hassan, R. Scholes and N. Ash.) pp. 623–662. (Island Press: Washington, DC.) Available at: www.maweb.org/documents/document.291.aspx.pdf
- Sayre, N. F., de Buys, W., Bestelmeyer, B. T., and Havstad, K. M. (2012). The range problem after a century of rangeland science: new research themes for altered landscapes. *Rangeland Ecology and Management* **65**, 545–552. doi:10.2111/REM-D-11-00113.1
- Scoones, I. (1998). 'Sustainable Rural Livelihoods: a Framework for Analysis. Working Paper 72.' (Institute for Development Studies: Brighton, UK.)
- Shang, Z. H., Gibb, M. J., Leiber, F., Ismail, M., Ding, L. M., Guo, X. S., and Long, R. J. (2014). The sustainable development of grassland-livestock systems on the Tibetan plateau: problems, strategies and prospects. *The Rangeland Journal* **36**, 267–296. doi:10.1071/RJ14008
- Sietz, D., Luedeke, M. K. B., and Walther, C. (2011). Categorisation of typical vulnerability patterns in global drylands. *Global Environmental Change* **21**, 431–440. doi:10.1016/j.gloenvcha.2010.11.005
- Snyman, H. A. (1998). Dynamics and sustainable utilization of rangeland ecosystems in arid and semi-arid climates of Southern Africa. *Journal of Arid Environments* **39**, 645–666. doi:10.1006/jare.1998.0387
- Stafford Smith, M. (1996). Management of rangelands: paradigms at their limits. In: 'The Ecology and Management of Grazing Systems'. (Eds J. Hodgson and A. W. Illius.) pp. 325–357. (CAB International: Wallingford, UK.)
- Stafford Smith, M., Abel, N. O., Walker, B. H., and Chapin, F. S., III (2009). Drylands: coping with uncertainty, thresholds, and changes in state. In: 'Principles of Ecosystem Stewardship: Resilience-based Natural Resource Management in a Changing World'. (Eds F. S. Chapin, III, G. P. Kofinas and C. Folke.) pp. 171–195. (Springer-Verlag: New York.)
- Stafford Smith, M., and Cribb, J. (2009). 'Dry Times. Blueprint for a Red Land.' (CSIRO Publishing: Melbourne.)
- Stafford Smith, M., Moran, M., and Seemann, K. (2008). The 'viability' and resilience of communities and settlements in desert Australia. *The Rangeland Journal* **30**, 123–135. doi:10.1071/RJ07048
- Stafford Smith, M., Morton, S. R., and Ash, A. J. (2000). Towards sustainable pastoralism in Australia's rangelands. *Australasian Journal of Environmental Management* **7**, 190–203. doi:10.1080/14486563.2000.10648501
- Steinfeld, H., Opio, C., Dijkman, J., McLeod, A., and Honhold, N. (2010). Conclusions and lessons learned. In: 'Livestock in a Changing Landscape, Volume 1: Drivers, Consequences, and Responses'. (Eds H. Steinfeld, H. A. Mooney, F. Schneider and L. E. Neville) pp. 373–376. (Island Press: Washington, DC.)
- Teague, W. R., Kreuter, U. P., and Fox, W. E. (2010). Economically efficient rangeland management to sustain ecosystem function and livelihoods. In: 'Range Livestock and Resource Management'. (Ed. V. Squires.) (UNESCO, EOLSS Publishers Co. Ltd: Oxford, UK.)
- Tsegaye, D., Vedeld, P., and Moe, S. R. (2013). Pastoralists and livelihoods: a case study from northern Afar, Ethiopia. *Journal of Arid Environments* **91**, 138–146. doi:10.1016/j.jaridenv.2013.01.002
- Walker, B., Holling, C. S., Carpenter, S. R., and Kinzig, A. (2004). Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society* **9**, 5.