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Climate change and pastoralism: impacts, consequences and adaptation

M. Herrero [1]*, J. Addison [1, 2], C. Bedelian [3], E. Carabine [4], P. Havlík [5], B. Henderson [1], J. van de Steeg [6] & P.K. Thornton [1, 7]

(1) Commonwealth Scientific and Industrial Research Organisation, Agriculture, 306 Carmody Road, St. Lucia, 4067 Qld, Australia
(2) Land and Water, ATSIP Building, 1 James Cook Drive, James Cook University, Townsville, 4810 Qld, Australia
(3) Department of Anthropology, University College London, 14 Taviton Street, London WC1H 0BW, United Kingdom
(4) Climate and Environment Programme, Overseas Development Institute, 203 Blackfriars Road, London SE1 8NJ, United Kingdom
(5) Ecosystems Services and Management Programme, International Institute for Applied Systems Analysis, Laxenburg 2361, Austria
(6) HAS University of Applied Sciences, Onderwijsboulevard 221, 5223 DE 's-Hertogenbosch, the Netherlands
(7) CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS), International Livestock Research Institute, PO Box 30709, Nairobi 00100, Kenya
*Corresponding author: Mario.Herrero@csiro.au

Summary

The authors discuss the main climate change impacts on pastoralist societies, including those on rangelands, livestock and other natural resources, and their extended repercussions on food security, incomes and vulnerability. The impacts of climate change on the rangelands of the globe and on the vulnerability of the people who inhabit them will be severe and diverse, and will require multiple, simultaneous responses. In higher latitudes, the removal of temperature constraints might increase pasture production and livestock productivity, but in tropical arid lands, the impacts are highly location specific, but mostly negative. The authors outline several adaptation options, ranging from implementing new technical practices and diversifying income sources to finding institutional support and introducing new market mechanisms, all of which are pivotal for enhancing the capacity of pastoralists to adapt to climate variability and change. Due to the dynamism of all the changes affecting pastoral societies, strategies that lock pastoral societies into specified development pathways could be maladaptive. Flexible and evolving combinations of practices and policies are the key to successful pastoral adaptation.

Keywords

Adaptation – Climate change – Food security – Institution – Livestock – Pastoralism – Resilience – Vulnerability.

Introduction

Pastoralists and agro-pastoralists are one of the most climate-change-vulnerable groups on the planet (1). It is necessary to increase their resilience to protect their livelihoods in the short term. Increased climate variability could decrease herd sizes as a result of increased mortality and poorer reproductive performance of the animals. This decrease in animal numbers would affect food security and would compromise the sole dependence of pastoralists on livestock and their products, as well as the additional benefits they confer. Under increased climate variability, the need for diversification of income, a strategy often (and increasingly) employed in pastoral areas, becomes ever more important. Climate change and, increasingly, climate variability will have substantial impacts on environmental security as well, as the conflicts over livestock assets often observed in these regions are likely to escalate in the future as a result of changes in environmental conditions. Short-term adaptation can be achieved by:

– implementing schemes to protect pastoralists' assets, such as easy-to-implement early warning systems and index-based insurance schemes (instead of compensating for actual livestock losses, these systems pay compensation on the basis of easily measurable environmental 'indices' that affect livestock production, e.g. if vegetation levels fall below a certain threshold, policy-holders receive a payment)

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– creating incentives to incorporate pastoralists into the market economy to generate cash income

– developing safety nets so that disenfranchised people can access food and public services in times of hardship, which will involve developing food storage systems, improving water accessibility and developing institutional networks to support pastoralists.

Investing in adapting pastoralist and agro-pastoral systems to future climate change is essential. This requires an appreciation of the fact that we need to start taking action now in order to have the right systems in place by the time the impacts of climate change are felt. This has implications for the strategic allocation of resources and the development of institutions and technology that will help effect these changes. There is a need to increase investments in infrastructure, particularly roads, as they ensure the connectedness of pastoralist communities and foster their integration into markets and into the wider economy. At the same time, livestock product market chains and food systems will need to be developed along with appropriate support systems, so that all consumers have equitable access to safe, cheap food locally. Technology will play a significant role in adapting pastoral and agro-pastoral systems to climate change, by, for example, helping to improve methods for harvesting water and sourcing feed, facilitating the substitution of species (i.e. from cows to camels) and enabling the production of different breeds to cope with different environments or disease burdens. New alternatives to diversify incomes may be essential in some agro-pastoralist systems. Below, the authors review these issues and offer examples of adaptation successes. They conclude with a brief description of the research that is needed to advance and integrate the short- and long-term climate adaptation agenda into a coherent social development agenda in pastoral regions.

Climate change and pastoral systems

Impacts of climate change on pastoral systems

The impacts of projected climate change on livestock systems have been covered in recent reviews (1, 2). The impacts on grazing systems include changes in herbage growth (brought about by changes in atmospheric CO_2 concentrations and rainfall and temperature regimes) and changes in the composition of pastures and in herbage quality. In higher latitudes, future increases in precipitation may not compensate for the declines in forage quality that accompany projected temperature increases, and cattle will experience greater nutritional stress in the future (3). Increases in CO_2 concentrations and precipitation will tend to increase rangeland net primary production, though this increase in production will be modified, positively or negatively, by increased temperatures (4, 5, 6). At least to the 2050s, increases in CO_2 will benefit C_3 pasture species, although warmer temperatures and drier conditions will tend to favour C_4 pasture species (7). The proportion of browse in rangelands may increase in combination with more competition if dry spells are more frequent (1). In a future East Africa with a warmer, wetter climate, for example, C_4 grass productivity may decrease, while tropical broadleaf growth may increase. In such regions, decreasing grass cover would likely result in more competition for forage amongst grazing species (8). Changes in net primary productivity in African and Australian rangelands are likely to be largely negative (9). Projections into the future generally indicate widespread negative impacts on forage quality (2). The results of global integrated assessments addressing the effects of climate change on land use, economics and changes in the productivity of the livestock, agriculture and forestry sectors suggest a variety of different impacts. They range from modest but beneficial impacts on rangeland systems, especially under CO_2 fertilisation effects and in colder regions (5, 10), to detrimental impacts that reduce pastoralism's contribution to household income and oblige pastoralists to transition to other types of more diversified production systems to maintain livestock productivity (6). Differences arise from a host of uncertainties, so there is uncertainty as to the type and magnitude of likely impacts in many situations.

Over shorter time horizons, climate risk in pastoral landscapes will be affected by increases in the variability of rainfall (which is often already highly variable), both temporally and spatially (1, 2, 11). Climate risk will also increase through the increased frequency of extreme events, such as drought, flooding, and extreme highs and lows in temperature. The semi-arid and arid rangelands are likely to see increasing rainfall variability, with associated impacts on rangeland productivity. This may have significant negative effects on herd dynamics, stocking density and the productivity of pastoral production systems. In arid and semi-arid Kenya, for example, the loss of animals and subsequent losses in milk and meat production to 2030 as a result of increased drought frequency could amount to more than US $630 million (12). Changing frequencies of extreme weather events such as flooding will affect certain diseases too: for example, outbreaks of Rift Valley fever in East Africa are associated with increased rainfall and flooding due to El Niño–Southern Oscillation events.

How might climate change affect the vulnerability of pastoralists?

Although there is uncertainty surrounding the exact nature of the impacts that climate change will have on livestock

production and productivity, we can be sure that they will have a knock-on effect on incomes and food security in rangelands across the globe. In lower latitudes, in particular, livestock are a critically important risk management asset for hundreds of millions of people, and the impacts of increasing climate variability on downside risk and on the stability of livestock production and human well-being from year to year may be substantial. Some information exists as to how and where the vulnerability of livestock keepers in the rangelands may change in the coming decades; for example, areas that are food insecure and vulnerable to the impacts of future climate change have been identified across the tropics and subtropics (13), and areas of high exposure to climate change were identified using downscaled climate data from the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (14). Some of this analysis, rerun with newer climate data from the IPCC's Fifth Assessment Report (2), is presented below.

Figure 1 shows estimates of rainfall variability (the coefficient of variation [CV] of annual rainfall) in the different rangelands of the globe (15). The average CV for the rangelands globally is about 30%, compared with an average for rainfed croplands of about 23%. Figure 2a shows how several climate change thresholds are expected to change by 2050 (predicted using a high-emissions scenario [the IPCC Representative Concentration Pathway 8.5] and data from an ensemble of 17 climate models [CMIP5]) (16, 17, 18). Several threshold flips are mapped; the first two will have negative effects on production and productivity in those areas of the rangelands that are so affected, while the third may have positive effects via the extension of growing

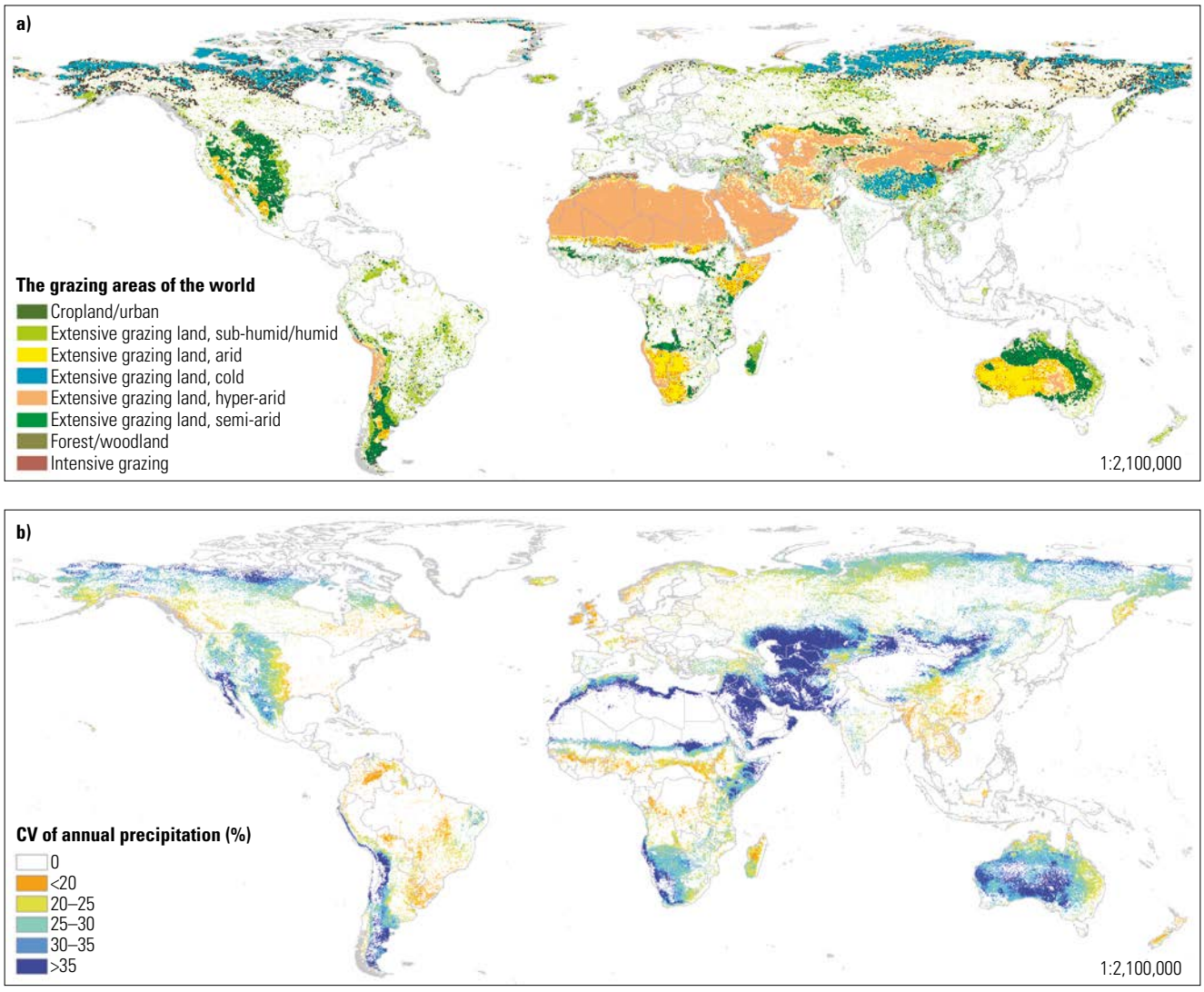
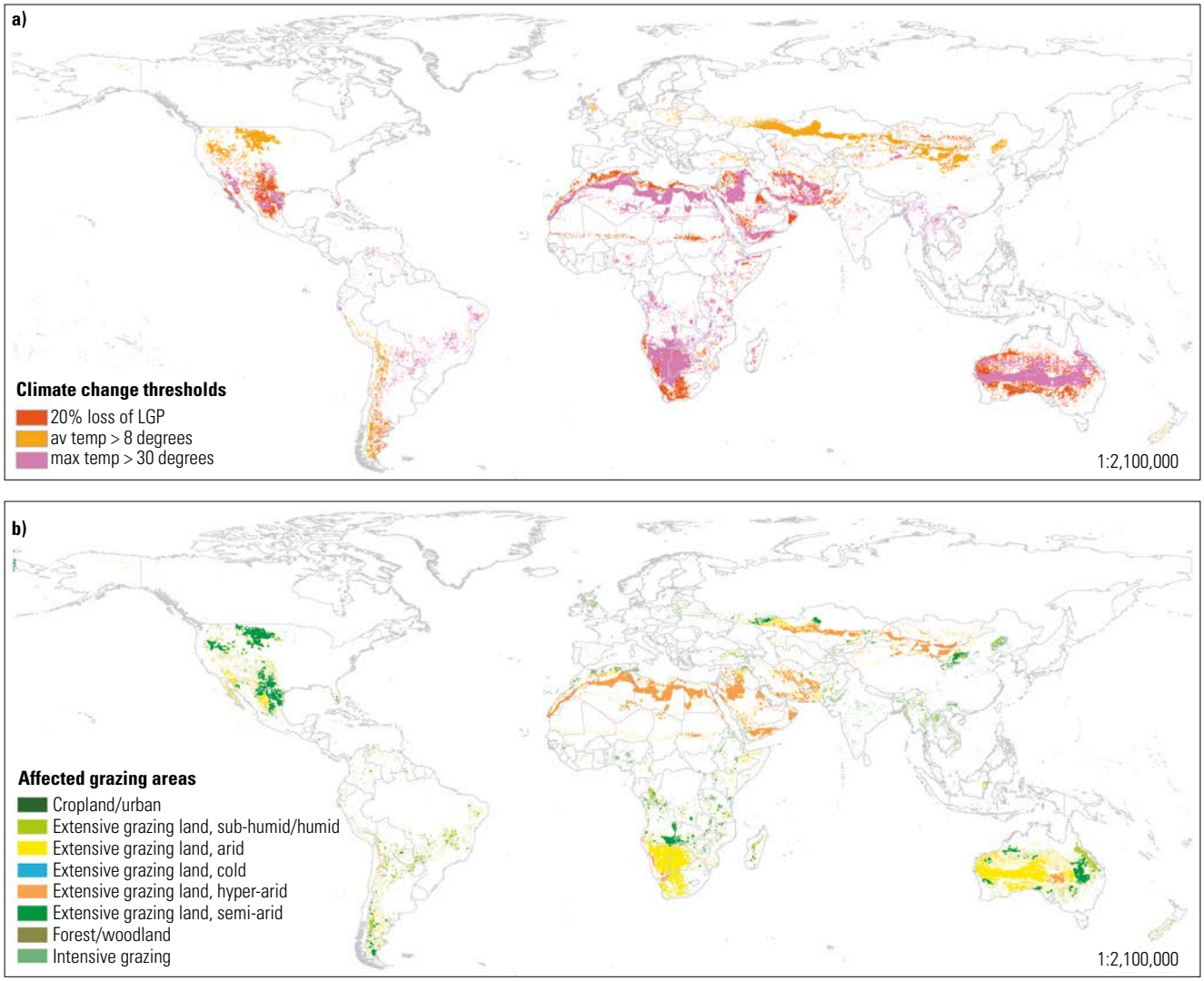


Fig. 1
Estimates of rainfall variability in the world's rangelands
a) The grazing areas of the world (15)
b) The coefficient of variation (CV) of annual rainfall in the grazing areas



LGP: length of growing period

Fig. 2
Projected changes to climate change thresholds in different types of land area by 2050
a) Three climate change thresholds mapped on the rangelands
b) Grazing areas affected by three climate change thresholds
Projections to 2050 using a high-emissions scenario (RCP8.5) developed by the Intergovernmental Panel on Climate Change and data from an ensemble of 17 climate models taken from the fifth phase of the Coupled Model Intercomparison Project (CMIP5) of the World Climate Research Programme (16, 17, 18)

seasons and/or an increase in the land areas suitable for rangeland vegetation:

– areas of the rangelands that are projected to undergo a reduction in the length of growing period (LGP) of more than 20% between 2000 and 2050

– areas with an average maximum temperature (both annual and during the primary growing season) that flips from below 35°C to greater than 35°C by 2050

– areas in which the average annual temperature flips from below 8°C in the 2000s to above 8°C by the 2050s.

LGP is the average number of growing days per year, and the authors use it here as a proxy for the number of grazing days. In the lower latitudes, reductions in LGP as a result of changing rainfall patterns and increasing temperatures indicate increasing water limitations in the future. Substantial reductions in LGP are projected across rangeland systems, particularly in Africa and Australia. It is also projected that the average maximum temperature flip to above 35°C will be widespread across Africa and Australia, and in pockets of Central and South America and Asia. This is a critical threshold for rangeland vegetation and heat tolerance in some livestock species. The average temperature flip to above 8°C will affect western parts of the United States,

parts of Central Asia, and the Andean rangeland systems running from north to south down South America. It is possible, therefore, that between now and the middle of the century the growing period in these rangelands could expand and that they could become increasingly suitable for some kinds of rangeland vegetation.

Exposure to climate change impacts will increase across large parts of the rangelands (Fig. 2b); some of these effects may be positive (removal of temperature constraints), but many will be negative. The vulnerability of pastoralists to the effects of climate change will be highly differentiated across geography, income levels, and governance arrangements, amongst other things (19). In sub-Saharan Africa, for example, pastoralists are already facing substantial challenges: poverty rates are high throughout the region, and food security is poor, except possibly in the rangelands of southern Africa (20). Few studies have explicitly investigated the impacts of climate change on global rangelands and poverty, nutrition and health. One study shows that increased climate variability may increase severe child stunting by 62% in South Asia and 55% in East and southern Africa by 2050 (21), although many other variables may affect undernutrition too (22). Another study of the possible effects of increases in rainfall variability on the prevalence of underweight children (a proxy for food security) suggests substantial increases in the prevalence of underweight children in the future, and many of these children will be in the rangelands (23).

Adaptation in pastoral systems

Adaptation to climate change is a process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities (24). Historically, pastoralists have had relatively high adaptive capacity in inhabiting arid and semi-arid areas (25, 26). Climate variability more strongly stimulates adaptation than changes in climate (23, 27). The high levels of climatic variability that characterise the global rangelands suggest that pastoralists should be well able to adapt to a changing climate, but the current envelope of adaptive practices may not be sufficient. In some contexts, transformational adaptation may be needed (25, 28, 29). Several analyses of pastoralist sensitivity to climatic shocks have indicated entry points by which pastoralist livelihoods can be better supported in response to a changing climate (16, 30, 31, 32, 33), some of which are outlined in Table I. Nevertheless, many pastoralists see climate change as just one of many important factors affecting their livelihoods; others include human and livestock population growth, globalisation, conflict, competition for land, changes in land tenure and land use, intensification of production, voluntary and government-facilitated sedentarisation of nomadic pastoralists, and institutional changes (34, 35). To be effective, strategies to adapt to climate change should take into account the full range of risks pastoralists face, and be integrated with development and mitigation approaches (24).

Many adaptation options are available to pastoralists (Table II), with different strengths and weaknesses. Below, the authors discuss these in relation to possible trade-offs amongst different objectives, their reversibility, whether they avoid being maladaptive (so do not increase vulnerability to climate change), and whether they avoid reducing the efficacy of greenhouse gas mitigation efforts by further contributing to carbon emissions (36, 37, 38, 39).

Knowledge systems

The role of indigenous knowledge in responding to climate variability and change is well recognised (40, 41). Pastoralists' knowledge underpins longstanding traditional practices for using resources and managing climate variability. These practices are part of their strong social organisation and customary institutions, and include strategies such as mobility, flexibility, adaptability and reciprocity, all of which enable pastoralists to effectively manage risk associated with their variable environments.

While traditional pastoral systems have inherent adaptive capacity, pastoralists' ability to cope with drought and climatic shocks is challenged by continued environmental, political and socio-economic marginalisation. Constraints to adaptation include insecurity, lack of credit and public services, a lack of human capital, limited technical knowledge, inadequate infrastructure, and limited access to markets (42). Cultural factors are also particular barriers to adaptation in pastoralist systems (43, 44). Many pastoralist groups have strong cultural attachments to their landscape and way of life, such that they may not take up alternative livelihood activities easily (45). Historical changes in climate have caused significant shifts in culture and economy (46), suggesting that localised knowledge systems exist only within a defined climate envelope. In some contexts, strong place identity can lead to lower adaptive capacity (47, 48). Nevertheless, multiple knowledge systems need to be included in vulnerability assessments and adaptation planning processes.

Formal education to facilitate income diversification, secure jobs and access information is an essential long-term adaptation strategy. A household head with higher levels of education and/or a transferable skill-set is a significant determinant of adaptation to climate change (49), often via livelihood diversification (50), although alternative livelihood options are not always available (51). Education systems for pastoralists are currently being developed that do not constrain pastoral mobility (52), with precedents

Table I
Typology of impacts of climate change on rangelands and the nature of the adaptation response required
Source: Ash *et al.* (25)

Change variable	Nature of impact	Type of impact (Gradual or threshold[a])	Examples of strategies to manage the impact and limits to adaptation
Increasing CO_2	Increased plant productivity, altered species composition, decreased forage quality	Largely gradual change, but there are likely to be some threshold changes in species composition (woody–grassy balance, weeds, sufficient fuel loads for fire)	Enhanced fire and weed management strategies may help manage vegetation change for some time, but it is likely that unavoidable transitions will occur. The effects of declining forage quality could be managed through nutritional supplements and grazing management strategies
2°C temperature increase (increasingly unavoidable)	Longer growing seasons in cold climates, some reduction in plant growth in dry climates, some heat stress in animals, contraction of grazing zones around water sources, species shifts in C_3/C_4 mid-latitudes	Gradual change	Animal breeding for heat tolerance, altered herd and grazing management, additional shade, altered fire regimes, more efficient use of water resources, enhanced opportunities for increasing productivity in temperate climates
4°C temperature increase (likelihood increasing)	Likely to be beyond the coping range of animals (and possibly humans) in some environments, significantly reduced plant production in hot climates	Thresholds likely to be crossed where production systems in hot climates fail	Limit to adaptation reached in some hot environments; change to seasonal use of resources
Decreasing rainfall (mid-latitudes)	Increased exposure to drought, water resources less reliable, especially where year-round stream flows become seasonal	Gradual change in many environments, but thresholds might be crossed where water resources reach critical levels, particularly systems that are dependent on seasonally available key resources	Improved use of seasonal climate forecasts and increased effort on improving their skill, increased use of water storage, recalculation of safe stocking rates, increased mobility or availability of other forage resources, cropping land becomes marginal with conversion to pasture
Increasing rainfall (high latitudes, tropics)	Increased water availability for other uses, potentially more flooding in some areas	Gradual change	Opportunities for diversified agricultural use, pressure to convert pastoral land to agriculture where soil quality permits
Increase in extremes/ variability	Direct impacts (which may be catastrophic, e.g. *dzuds*[b] in Mongolia) on vegetation and herd viability, on the vectors, and on the extent and severity of livestock diseases	Likely to be threshold changes	Support from policy to help deal with extreme events (e.g. drought relief, flexibility in land tenure arrangements); limits to adaptation will be tested by extreme events recurring frequently

a) a sudden, large-scale and, often, irreversible change that occurs when a critical threshold is exceeded
b) *dZud*: extreme winter weather: snow and ice prevent access to water

such as Australia's School of the Air programme to draw upon and new initiatives such as the National Commission for Nomadic Education in Kenya (NACONEK) (53).

Diversification and structural adjustment

Pastoralists may respond to shocks and stresses in various ways: diversifying livelihood options, supplementing pastoral incomes with farm or off-farm income, and leaving pastoralism altogether (54) (see Table I). Diversifying herd composition can help to cope with drought and increasingly restricted mobility, for example via increasing the proportion of small stock compared with cattle (55), as the former have lower feed requirements and shorter gestation times (56). The switch to small stock may be increasingly important in Kenya (57), though in Mongolia's Gobi Desert it may prove maladaptive, as the transition to a market-based economy and high cashmere prices have driven an increase in goat numbers which may negatively affect their relative advantage (51, 58).

Diversification of pastoral livelihoods is widely observed, and options include cultivation, wage or salaried labour, trade, and business (49, 50, 59, 60). The most prevalent alternative livelihood options in the rangelands of sub-Saharan Africa are diversification into crop-based agriculture and intensification of livestock production,

Table II

Examples of climate-related adaptation strategies

Reversibility relates to the ability of the strategy to be modified or stopped if found to be unsuitable to a changing climate. The risk of maladaptation relates to the strength of potential negative effects (economic costs, opportunity costs) that may occur if that potential adaptation option does not match a future climate envelope

Adaptation strategy	Description	Reversibility	Risk of maladaptation
Mobility	Mobility allows the opportunistic and effective use of patchy and heterogeneous resources, and helps minimise the effects of droughts (71) and extreme winters (74)	High	Low
Diversification of livestock composition	A diversified livestock composition allows livestock keepers to utilise available forage in different seasons, as well as produce a variety of livestock products. Drought encourages a shift from grazers (cattle and sheep) to browsers (goats and camels) which are more resistant to drought	Moderate	Low
	Livestock breeding to maintain drought tolerance	Moderate to low	Low
Supplementation of fodder	Preparation and purchase of hay and other feeds during drought, to increase livestock productivity and resilience during vulnerable periods. Fodder banks help feed calves, sick animals, and milking cows during dry months	High	Low to moderate
Restocking/destocking	Build up herd size in recovery periods to prevent total loss of herd during drought. During drought, culling of weak livestock for food and cash needs	Moderate to high	Moderate
Development of water sources	Ground water	Low	Moderate to high
	Rain water harvesting	Low	Low to moderate
Sharing, loaning and gifting of livestock	Part of pastoralists' traditional social networks, but intensifies during and after drought. Also sharing of labour between families to act as a social safety-net	High	Low
Saving/credit schemes	The conversion of livestock resources into financial resources through uptake of saving schemes which can smooth livelihood volatility. Credit schemes may help with investment that can increase productivity or livelihood diversification	High	Low
Early warning systems/ access to climate change information	Use of intricate systems of local knowledge to predict weather or forecast a climatic event. This allows pastoralists to better plan for and manage drought (for example, agro-pastoralists in Kenya use indigenous indicators of rainfall variability to interpret meteorological forecasts)	High	Low
Cultivation	Opportunistic cultivation in areas with high agro-ecological potential	Moderate	Low to moderate
Intensification	Substitution of land for non-renewable inputs such as inorganic phosphate and ground water	Low	Moderate to high
Off-farm income	Alternative sources of income, e.g. through casual labour, petty trade, manual labour, migration to towns and cities	Moderate	Low
New market opportunities	Responding to new market demand and opportunities (for example, pastoralists in the Horn of Africa are responding to the growing demand for camel milk in urban areas and to new international camel milk markets)	Moderate	Low
Education	An increase in education amongst pastoralist communities, resulting in increasing opportunities for new employment and diversification, and participation in national political processes	Low to moderate	Low
PES/EbA	Involvement in market-based schemes for water, carbon, tourism, etc. as an income diversification strategy	Moderate	Low to moderate
Cash transfers and remittances	Cash transfers from social protection programmes; remittances from pastoralists who migrate out of pastoral areas for wage labour in towns and cities. These help support the pastoral family to buy food, livestock, and for other needs	Moderate to high	Low to moderate
Structural readjustment	Pastoralists permanently leave pastoralism, and resource flow between the urban and pastoral social-ecological system is significantly reduced	Low	Moderate

EbA: ecosystem-based adaptation
PES: payments for ecosystem services

including an increased proportion of smaller stock (35, 61, 62). Diversification helps supplement livestock-based incomes and reduce risk.

Some pastoralists may exit pastoralism and agriculture altogether. In western China, where there have been changes in property rights, grazing bans, resettlement programmes and government policies to promote intensification, this type of structural adjustment is already occurring (63). However, an increased reliance on fossil fuels and water to facilitate the intensification promoted by the government potentially exposes pastoralists to price shocks instead of production shocks and may be maladaptive in a context of declining precipitation and groundwater recharge. In contrast, in rural Mongolia, opportunities for off-farm income are limited and although there is net movement to urban areas, many return because of limited employment opportunities (58). In this situation, high mobility pastoralism has been maintained; the urban–rural boundary is fluid and resources (labour, meat, education services) can be shared, spreading the risk of climatic shocks and stresses (64). In other situations, permanent structural adjustment may need to be a part of the adaptation toolkit.

Institutional processes

In many cases, pastoralists have been marginalised from national economies and political systems. There are potentially large adaptation gains to be made from institutional strengthening in terms of policies and planning, economic options, and the regulatory and legal context. Leveraging 'soft' institutional and financial processes may be effective for adapting under high levels of uncertainty, given that they are relatively inexpensive and easy to reverse (37). In comparison, 'hard' infrastructure options may be expensive, contribute to carbon emissions and be difficult to reverse (65). Policies that reduce the high transaction costs of remittances and improve banking services so that livestock wealth can be quickly and cheaply converted into interest-raising cash (and vice versa) can encourage responsiveness, flexibility and innovation, as can insurance schemes and policies that allow pastoralists to freely access healthcare outside their district (Table I).

As rangelands become increasingly fragmented (34, 66, 67) and traditional coping and buffering mechanisms are eroded (35), there is often a need for increasingly intensive inputs to deal with stresses such as drought. Many respond to changes in land tenure by attempting to expand the size of the managed resource through land reform or consolidation of fragmented units within the system and developing new and existing social networks to negotiate access to key resources at certain times (62, 63). However, perverse outcomes that may erode adaptive capacity can accompany these changes. In China, the introduction of property rights exclusive to the level of the household has exacerbated the effects of climatic shocks on pastoral livelihoods by facilitating the monetarisation of a system that previously relied more upon reciprocal altruism between pastoralists (67). Government policies and programmes that facilitate fluidity in social, human and resource capital through time and space, like those described earlier, may minimise maladaptive adaptation to climate change while delivering improvements in pastoral livelihoods.

In many parts of the world, regional, national and sub-national governance bodies have made progress towards developing policy, planning and building institutions for adaptation (24). But climate policy frameworks remain fragmented between and within levels and sectors, and can act as a barrier to adaptation when context-specific cultural and traditional factors are ignored (24, 68, 69). In West and East Africa, regional bodies have been moving towards resilience-building policy and planning frameworks such as the Intergovernmental Authority on Development (IGAD) Drought Disaster Resilience and Sustainability Initiative (IDDRSI) and the Permanent Interstate Committee for Drought Control in the Sahel (CILSS). Convergence around such initiatives should increase coordination of investment and activities in the drylands.

At country level, National Adaptation Plans need to be integrated into economic and development planning and linked to sub-national action, particularly in developing countries. As pastoralist areas are often marginalised from centres of power, their needs are not adequately addressed in national planning processes. This is changing slowly, with decentralisation of climate adaptation funds in Senegal and Mali and devolution of planning powers to lower levels of governance in Kenya (70), for example. Kenya's Ending Drought Emergencies (EDE) framework aims to integrate multi-sectoral planning around the drivers of vulnerability in drylands, which include conflict, climate change and demographic change (71).

Cross-level or cross-sector tensions become more obvious in the context of high pastoral mobility, which is highly adapted to climate variability, unpredictability and dispersed resources (72, 73, 74, 75). Community-based Natural Resource Management (CBNRM) programmes, which have sought to encourage the establishment of local institutions for mutual assistance during periods of climatic shock, can increase knowledge exchange, information access, linking capital and proactive behaviour (76), but may struggle to garner national-level government support. There is a clear role for civil society here in facilitating knowledge exchange and advocating for adaptation action across scales.

Reducing vulnerability: financial options

Social protection will continue to play an important role in supporting poor and vulnerable pastoralist households

under a changing climate. Traditionally, this has involved food relief in times of stress, but recent social protection programming aims to be adaptive, incorporating climate risk (77, 78) and moving towards cash transfer.

Both public- and private-sector investment have a role to play in developing and implementing adaptation options. However, the private sector may not provide the needed adaptation options due to the costs, incentives and resources required (24). In pastoralist systems, transaction costs for the private sector are high and are caused by low human capital and limited market support services. Governments can support enterprises by creating incentives and structuring markets appropriately (79, 80). Several social and economic variables can facilitate livestock markets, including regulatory conditions and supporting services (infrastructure, processing facilities, extension services, etc.). Having the requisite services and the right regulatory framework is important for improving the climate for investment (Fig. 3).

Social networks, community funds and disaster relief can provide assistance in response to extreme events while reducing poverty levels. More formal financial services targeted at the relatively unstructured livestock sector can help pastoralists take adaptive actions and can reduce the impact of losses. For example, access to microcredit facilities can drive household- and community-level adaptation. Insurance services, including transportation insurance and index-based livestock insurance (which has been piloted in Mongolia [81] and Kenya [82]), can reduce the risk of loans. While such schemes are likely to be important tools in climate change adaptation, their benefits may not be immediate (51). Governments and international organisations can play a role by scaling up and promoting existing initiatives and improving their commercial viability.

Markets

Commercial fodder production, fattening and finishing operations and water supply enterprises (which combat fodder shortages during drought by facilitating the production of animal food) can offer opportunities for managing climate risk and adding value to livestock production by upgrading or diversifying the livestock value chain. In addition, the private sector is supporting the management of climate risk by investing in veterinary pharmaceuticals that tackle animal disease, thus enabling pastoralists to protect their livestock assets. New animal and crop varieties, traditional knowledge, and improved water management technology also provide opportunities for reducing climate risk and increasing income (83). Many

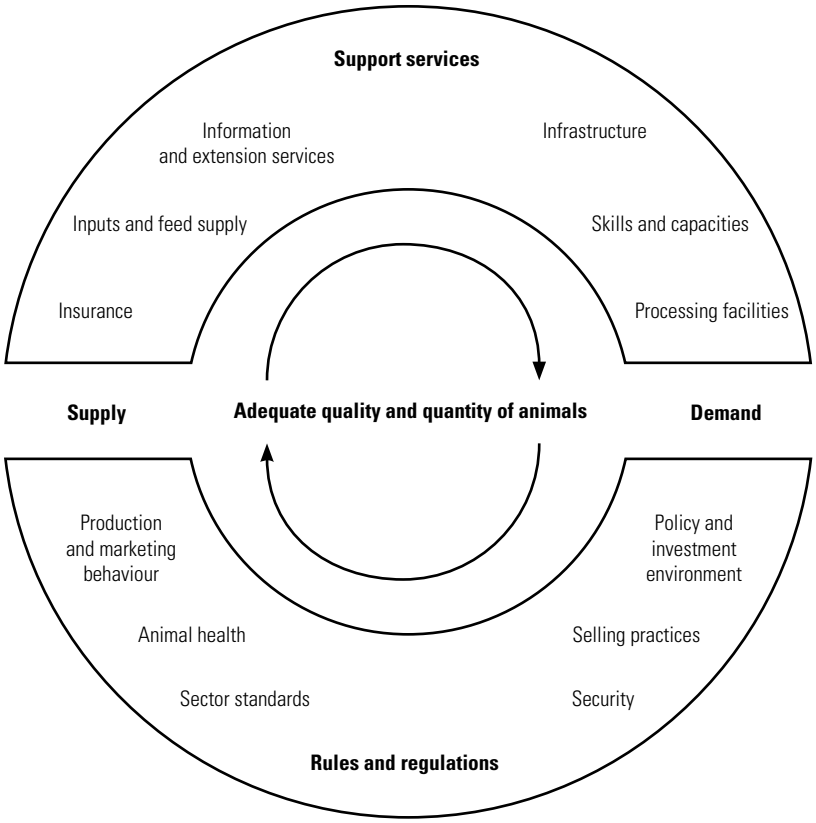


Fig. 3
Social and economic variables facilitating livestock markets in the world's rangelands

pastoralists are willing to pay for improved services, if the benefits are clear (81). On the other hand, the private sector can have difficulty selling their products and services to pastoralists due to the relative lack of exposure of these communities – for instance, most pastoralists are not familiar with insurance products.

Climate extremes and disease shocks can lead to high price volatility and high transaction costs, preventing participation in markets (84). Structural inefficiencies in livestock markets include long distances to market, inconvenient timing and location of sales, high transport costs, high taxation, and insecurity (79). Price distortions exist due to physical and informational factors, with improvements in these having the potential to increase market integration (85). The trade in live animals and meat from Kenya to Ethiopia increased 2.3 times between 2005 and 2013, the equivalent of beef exports from the United States (86), but this export trade is highly unstable in the face of shocks, indicative of substantial structural inefficiencies.

Payments for ecosystem services (PES) and ecosystem-based adaptation (EbA) offer a potential livelihood diversification and climate change adaptation option. Examples of EbA implementation include rehabilitating watersheds, promoting agroforestry and conservation agriculture, and creating new markets for income generation and livelihood diversification, e.g. quarrying and tourism (87). Although attractive in that they conserve the environment and contribute to poverty reduction, PES schemes can increase pressures on scarce land and water, risk poor people's access and rights to land, weaken cultural values, and have high transaction costs. Participation in PES schemes can create trade-offs for climate-resilient livelihoods and create problems of equity and justice, with gender inequalities increasing where property rights favour men, which is common in pastoral systems (88, 89, 90).

Infrastructure and technology

Aside from adaptation measures that directly target vulnerability, other adaptation measures more directly target climate change. Structural and physical options for adaptation are currently receiving a significant proportion of adaptation finance but need to be considered carefully in light of an uncertain climate envelope. It is important to examine the options in order to avoid possible maladaptation and ensure that vulnerable societies do not become locked into an unsuitable development pathway that will be difficult to get out of (39, 91, 92). Roads may increase access to markets for pastoralists and potentially reduce poverty, but a suitable regulatory environment and complementary hard infrastructure will also be needed to maximise benefits for the poorest (93); for example, in Kenyan pastoral systems there is a need for loading ramps, holding facilities and water sources (72). However, infrastructural development may have unexpected negative impacts too; for example, large-scale projects such as the Lamu Port South Sudan and Ethiopia Transport project (www.lapsset.go.ke), which aims to build an oil pipeline and new road and rail facilities to connect cities across East Africa, will open up large areas of pastoral land in northern Kenya to further development, which may exacerbate conflict over land tenure and resource use in the region (94).

There is a need for better market information systems that leverage available telecommunications to reduce issues of information asymmetry where other channels (such as word of mouth) might fail. Rangeland producers who sell at local markets can be paid less than half as much as producers trading at terminal markets due to lack of price information (95), with reverse price differentials in input costs during climatic shocks (58). By reducing information asymmetry, mobile telephone ownership can increase prices received at local livestock markets (96). Although the social mediation of access to grazing resources may have its own challenges (97, 98), the expansion of such technology offers opportunities for pastoralism in the future. Similarly, the dissemination of climate information and early warning systems (EWS) can be improved via information and communications technology. Where risks are complex and take longer to develop, such as with droughts, EWS can help prevent large losses of life (99). Better understanding is needed of the social processes that mediate the uptake of these systems and the constraints to acting upon the information they provide. There is also a need to develop EWS that consider multiple hazards and to invest in climate observation networks and strengthen the capacity of scientific institutions (65).

Conclusions

The impacts of climate change on the rangelands of the globe and on the vulnerability of the people who inhabit them are likely to be severe and diverse in nature, at least until the middle of the current century, regardless of the trajectory that emissions take over the coming decades. Global annual average surface temperature is already 1°C above the pre-industrial average, as represented by the 1850–1900 reference period (100). Pastoralists in the past have proved remarkably adept at adapting to a highly variable climate, but the last time the global temperature was this high was more than 100,000 years ago; pastoralists' experiences in recent millennia may prove totally inadequate for adapting to the current rate of change.

The rangelands are undergoing considerable changes. In some places, increasing population densities are rapidly modifying the accessibility to land, water and feed that makes pastoralism a viable livelihood strategy for millions

of livestock keepers around the globe. Rising incomes throughout the developing world are affecting consumption patterns and modifying expectations, with lasting impacts on traditional socio-cultural value systems and kinship networks. Globalisation and the massively expanding role of information and communications technologies are having an increasing influence on formerly remote and isolated communities. Social capital that was once geographically bounded is now spreading across larger areas because of changing flows of people, resources and information, all of which can provide alternative sources of income. Depending on context, some of the measures outlined above will lead to incremental climate change adaptation (in some places this adaptation will take the form of increased market orientation and a move towards more intensified farming) and an increased ability of pastoralists to manage climate-related risks. Other shifts, including social innovations and changes in behaviour, institutions, and cultural norms, may be more transformative. Indeed, for some of the rangelands that will undergo considerable increases in exposure to climate change in the future, there may be no alternative to an exit from agriculture, coupled with education and development of alternative livelihoods for those affected.

Pastoral systems face serious complications in the coming decades, and in several regions their performance in terms of human development outcomes such as poverty, education and health is already relatively poor (20). Options do exist for improving these, through combinations of policies and through alternative institutional arrangements and new technologies. The options are likely to vary with context and over time as the future climate change envelope becomes less uncertain. Understanding what is possible, what is not, and where, will be critical for effectively improving rangelands and the livelihoods of pastoralists.

Le changement climatique et le pastoralisme : effets, conséquences et adaptation

M. Herrero, J. Addison, C. Bedelian, E. Carabine, P. Havlík, B. Henderson, J. van de Steeg & P.K. Thornton

Résumé

Les auteurs examinent les principaux effets du changement climatique sur les sociétés pastorales, en particulier ceux qui affectent les prairies, le bétail et d'autres ressources naturelles ainsi que les répercussions durables sur la sécurité alimentaire, sur les revenus et sur la vulnérabilité des populations. Le changement climatique va profondément et diversement affecter les prairies de la planète et le degré de vulnérabilité des personnes qui y vivent, ce qui imposera de déployer des réponses multiples et simultanées. Si dans les latitudes plus élevées, la suppression de certaines contraintes liées aux températures permet d'augmenter la production d'herbage et d'accroître la productivité du bétail, dans les terres arides tropicales les effets du climat, très spécifiques selon les endroits, sont majoritairement négatifs. Les diverses solutions adaptatives mises en avant par les auteurs, depuis la mise en œuvre de nouvelles techniques et la diversification des sources de revenus jusqu'à la recherche de soutiens institutionnels et la création de nouveaux mécanismes de marché, sont toutes déterminantes pour améliorer la capacité des pasteurs à s'adapter à la variabilité et au changement climatiques. En raison du caractère dynamique des changements affectant les sociétés pastorales, les stratégies consistant à confiner ces sociétés dans des tracés spécifiques de développement risquent de s'avérer contreproductives en termes d'adaptation. Un assortiment souple et évolutif de pratiques et de politiques est la clé d'une adaptation pastorale réussie.

Mots-clés

Adaptation – Bétail – Changement climatique – Institution – Pastoralisme – Résilience – Sécurité alimentaire – Vulnérabilité.

Cambio climático y pastoreo: efectos directos, repercusiones y adaptación

M. Herrero, J. Addison, C. Bedelian, E. Carabine, P. Havlík, B. Henderson, J. van de Steeg & P.K. Thornton

Resumen

Los autores examinan los principales efectos del cambio climático sobre las sociedades pastorales, en particular los que afectan a las tierras de pasto, el ganado y otros recursos naturales, así como sus repercusiones más indirectas sobre la seguridad alimentaria, los ingresos y la vulnerabilidad. El cambio climático traerá consigo diversos efectos de gravedad que influirán en los pastizales del planeta y la vulnerabilidad de quienes viven de ellos, efectos que exigirán múltiples respuestas simultáneas. En altas latitudes, la desaparición de las limitaciones ligadas a la temperatura podría deparar una mayor producción de los pastizales y con ello una mayor productividad del ganado, pero en las tierras áridas tropicales los efectos dependerán en gran medida de las condiciones de cada localidad y serán mayormente negativos. Los autores destacan varias posibilidades de adaptación, desde la aplicación de nuevos procedimientos técnicos y la diversificación de las fuentes de ingresos hasta la obtención de apoyo institucional, pasando por la instauración de nuevos mecanismos de mercado, todas ellas soluciones cruciales para dotar a las sociedades de pastores de mayor capacidad de adaptación a la variabilidad y la evolución del clima. Teniendo en cuenta el dinamismo de cuantos cambios afectan a las sociedades pastorales, toda estrategia que las encorsete en una u otra vía específica de desarrollo podría resultar inadaptada. La clave para una adaptación fructífera de esas sociedades estriba en combinaciones de prácticas y políticas que sean flexibles y evolucionen en el tiempo.

Palabras clave

Adaptación – Cambio climático – Ganado – Institución – Pastoreo – Resiliencia – Seguridad alimentaria – Vulnerabilidad.

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