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The role of pastoralism in regulating ecosystem services

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Summary

Pastoralism is rarely viewed as a major future form of land use, because of well-documented cases of rangeland degradation, attributed to irrational overstocking by pastoralists, and the subsequent losses of ecosystem services. However, pastoralists were actually encouraged to settle and adopt such strategies, copied from rangelands with higher and more reliable rainfall. This curtailed mobility resulted in a shift from opportunistic and extensive land use to more intensive and settled forms of use. The purpose of this review is to examine the link between pastoralism and the provision of ecosystem services by rangelands, focusing on biodiversity conservation and carbon sequestration.

Pastoralists employ several techniques to manage rangeland resources, including mobility, herding, corralling, grazing reserves and the use of fire. With these strategies, pastoralists have contributed to the enhancement of rangeland biodiversity and the long-term conservation of important wildlife habitats. Pastoralists also possess detailed knowledge of rangeland plants and their uses, which could be valuable in the assessment, conservation and utilisation of rangeland biodiversity. Similarly, traditional pastoral rangeland management practices, such as the use of seasonal grassland reserves and livestock mobility, influence vegetation composition, coverage and abundance in rangelands and offer tools for biomass and soil carbon restoration, contributing to the mitigation of climate change.

However, various internal and external factors have curtailed traditional management practices and livestock mobility, breaking the co-evolved balance of vegetation, wildlife and land use, thus exposing rangeland to continued livestock pressure, which often leads to degradation. Rather than abandoning pastoralism, the revitalisation of traditional practices and indigenous knowledge is vital to secure sustainable livelihoods for millions of pastoralists and to maintain rangeland biodiversity and ecosystem services.

Keywords

Biodiversity – Carbon – Carbon sequestration – Climate change mitigation – Ecosystem services – Habitat conservation – Indigenous knowledge – Pastoralism – Rangeland biodiversity – Rangelands – Traditional practices.

Introduction

Across the globe, rangelands occupy almost half of the Earth's surface (1). This review focuses on 'extensive' rangelands which are ill-suited to intensive agriculture, due to high evapo-transpiration which exceeds rainfall, and so are predominantly used for extensive livestock production (2). More than 200 million pastoral households depend on these extensive rangelands (3) and keep 35% of the world's sheep, 23% of its goats, and 16% of its cattle and water buffalo (4). Rangelands also provide humanity with a wide array of ecosystem services (5, 6). Ecosystem services are 'all the benefits people get from their environment' and can be categorised into four types: provisioning, regulating, supporting and cultural (6). Ecosystem services

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accrued from rangelands include all four of these types, i.e. provisioning services, such as food, fibre and genetic resources; regulating services, such as water and air quality; supporting services, such as primary production, water and nutrient cycling; and cultural services, such as recreation and religious sites (7, 8).

Rangeland degradation in arid and semi-arid areas and the subsequent loss of economic returns and other ecosystem services are well documented in the literature (6, 9, 10). Irrational overstocking by pastoralists is assumed to be the main culprit of perceived rangeland degradation (11, 12), and overgrazing is thought to be inevitable in pastoral systems (13). In an effort to curb perceived rangeland degradation, pastoralists were encouraged to settle and adopt strategies copied from rangelands with higher and more reliable rainfall (14). External interventions, such as irrigation and other water and ranching schemes, encouraged pastoralists to become less mobile (15). This curtailed the two basic elements of sustainable rangeland management: short but intensive grazing and browsing by large herds, and opportunistic exploitation of fodder by moving livestock to areas that had received sufficient rainfall (16). Coupled with a rising population, the weakening of customary institutions and the loss of key dry-season grazing areas to alternative land uses, such settlement contributed to the impoverishment of pastoralists and worsening of rangeland degradation (8, 17).

The intensification of land use through crop farming or ranching (18) shifts grazing patterns further away from traditional use, leading to both more and less intense grazing. Both of these changes in grazing have been associated with adverse impacts on vital ecosystem services (19). The purpose of this paper is to examine the link between pastoralism and rangelands' provision of ecosystem services, focusing on biodiversity conservation and carbon sequestration.

Pastoralists and rangeland biodiversity

Rangelands are strongholds of biodiversity, harbouring a variety of plants, animals and microbes of ecological, economic and socio-cultural importance (20). Rangelands cover a variety of terrestrial biomes which are extremely heterogeneous. Major driving forces for the biological diversification of rangelands are relative aridity, seasonal patterns of rainfall, fires and herbivore pressure. A combination of these factors, coupled with topography and geology, determines selection pressures, resulting in the development of a variety of adaptive strategies (21). For example, on the African savanna, humans and their livestock have left long-term legacies by creating and maintaining landscape heterogeneity (22).

The overall biodiversity of rangelands is declining due to various factors, including land-use changes and intensification, dryland fragmentation, the introduction of invasive species and mismanagement (23, 24, 25). Up to 20% of rangelands are undergoing some form of severe degradation (6), resulting in the loss of biodiversity and ecosystem services associated with it (26) (Fig. 1). Apart from the ecological aspects, the loss of biodiversity has significant implications for the food security of millions of people who depend on rangelands for their livelihood (24). That is why rangeland management strategies that promote biodiversity conservation are urgently needed (27).

Pastoralists employ several techniques to manage rangeland resources, including mobility, herding, corralling, grazing reserves and fire (28, 29). The livestock mobility inherent to pastoralism is crucial for rangeland maintenance, improvement and regeneration (30). Pastoral communities conduct seasonal migrations with their herds, between wet- and dry-season grazing areas, to secure a constant supply of fodder, water and salt licks. Mobility also minimises the risk of livestock disease and raiding (31). Livestock routes have been found to support greater biodiversity as a consequence of their direct and indirect effects on plants, as well as on other above- and below-ground consumers, predators and nutrient cycles (8, 32). On a smaller spatial scale, pastoralists also employ herding to control patterns of herbivory along migration routes (28). Such grazing management enriches species diversity, maintains vegetation cover, reduces soil loss (33) and improves connectivity between adjacent ecotones (34). Effective grazing management can also stimulate the growth of new pasture, improve mulching, reduce invasive weeds and improve mineral and water cycling (5).

Pastoralists have also influenced savanna ecology through their creation and abandonment of livestock bomas (thorn-fence corrals that pastoralists traditionally use to protect their livestock at night) (35, 36). Bomas develop into long-term, nutrient-rich, ecosystem hotspots with distinctive plant communities (37, 38). Old bomas maintain a higher biomass and proportion of palatable species than unfenced sites (37, 39). Their distribution also influences the distribution and movement of large wild herbivores (39). For example, in central Kenya, wildlife species browsed nine times more frequently among old bomas than at other sites (38). Pastoralists also set aside part of their rangelands as physically or socially fenced grazing reserves (28, 29), although this is not common among all pastoral groups. Grazing reserves are commonly used as dry-season reserves to feed mainly calves and sick animals. Compared to open communal grazing areas, grazing reserves exhibit a greater composition of palatable grass species (40, 41).

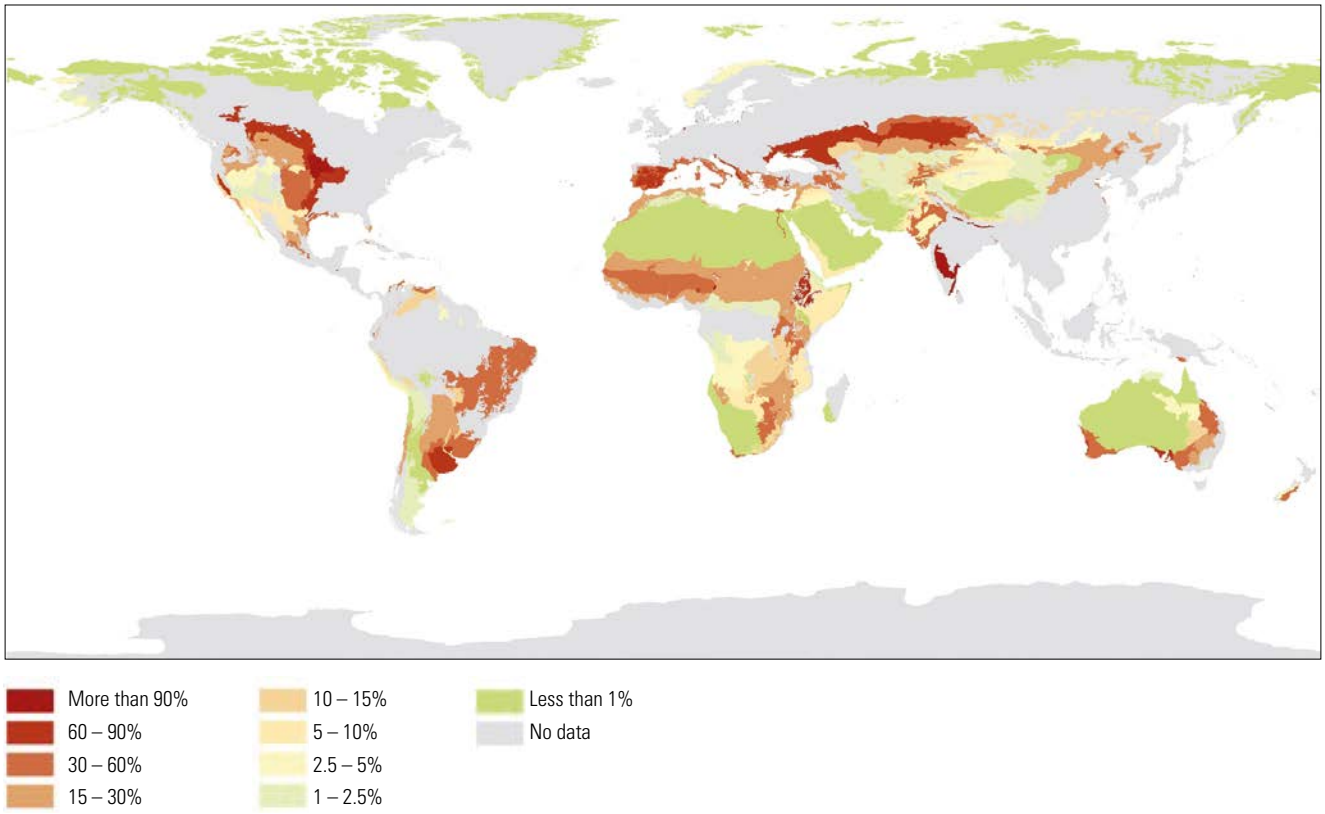

Fig. 1
Global pattern of habitat loss showing values above average for most pastoralist areas
Source: Delia Mändli, Physical Geography and Environmental Change, University of Basel

Another tool used by pastoralists to maintain the quality of fodder in rangelands is fire. Controlled burning suppresses the encroachment of woody species and promotes the growth of palatable grasses, creating a favourable environment for livestock but also for wildlife species (30, 36). In turn, a ban on the use of fire in southern Ethiopia has contributed to a significant increase in bush cover, from 40% in the 1990s (42) to 52% in 2002 (43), forcing Borana pastoralists to increasingly rely on camel pastoralism rather than the cattle husbandry on which they have traditionally depended for centuries (44). The use of fire by pastoralists also maintains a patchwork of habitats, such as open areas important for several endangered bird species, which are only found in savanna grass and shrublands (45).

Carbon sequestration

Rangelands are an important repository of carbon, both in the soil and vegetation, and play an indispensable role in mitigating the rising concentration of carbon dioxide (CO_2) (46, 47, 48, 49). Rangelands store 241 petagrams (Pg), about 30% of the world's terrestrial carbon (50, 51), and sequester between 200–500 kg of carbon per hectare per year (8). Although tropical forests store large amounts of carbon above ground – 212 gigatonnes (Gt) – tropical savannas have greater potential to store carbon below ground than any other ecosystem (52). About 90% of carbon sequestered by rangelands is stored in the form of soil organic carbon, with an estimated carbon sequestration potential of 0.01–0.30 Gt per year (53). Rangelands account for about one-quarter of potential carbon sequestration in world soils (54, 55).

One of the negative repercussions of rangeland degradation is the release of carbon sequestered in the rangeland to the atmosphere. Lal (47) estimated a total historic loss of 20–30 Pg of carbon due to desertification. As much as 100 million tonnes of CO_2 equivalent per year is released to the atmosphere annually, due to overgrazing (56). This net emission might increase in the future when carbon burial in colluvial sinks, associated with soil erosion and the dynamic replacement of soil carbon at eroding sites, declines.

The classification of sinks is based on the global assessment of soil degradation (57) and current soil erosion and soil-erosion-induced lateral carbon fluxes (58) (Fig. 2). Light degradation and erosion < 2 tonnes per hectare per annum

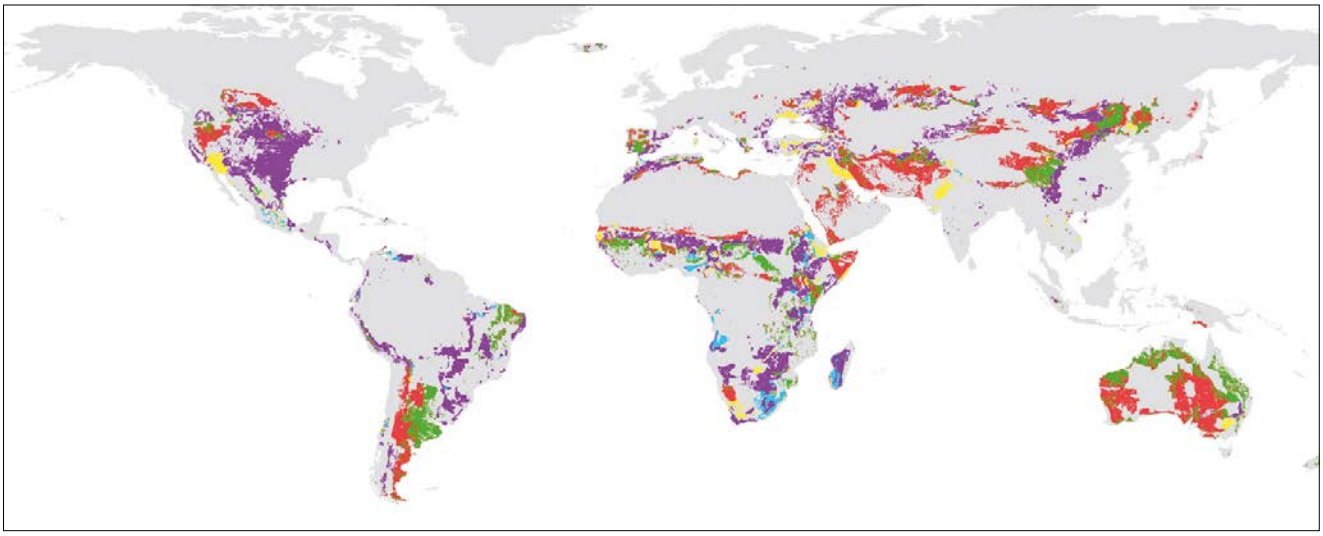

Fig 2
Carbon sinks induced by soil erosion, indicating closing terrestrial sinks in areas used for pastoralism
Source: Delia Mändli, Physical Geography and Environmental Unit, University of Basel

(t ha a^{-1}) generate no carbon sink because of the lack of a significant lateral flux. In contrast, light and moderate degradation with erosion of up to 10 t ha a^{-1} generate a high lateral carbon flux. This soil-to-sink flux leads to a reduction of net carbon emissions (59) and is maintained by the dynamic replacement of carbon from litter conversion (60). It is not sustained when there is degradation of soil and vegetation. Strong degradation and erosion > 10 t ha a^{-1} are likely to have already reached this stage, i.e. contributed to a former carbon sink that has already ceased to absorb carbon due to the destruction of soil and vegetation. There is considerable uncertainty in such estimates of soil carbon fluxes from rangeland degradation and the contribution of pastoralism to degradation (2, 61). However, there is consensus among researchers on the challenges posed by rangeland degradation and the need for rangeland rehabilitation to restore its carbon sequestration potential (2).

Rangeland rehabilitation could make a significant contribution to offsetting part of the increase in global CO_2, with the additional benefit of improving the productivity of the rangeland itself (47, 48). By adopting various rangeland rehabilitation measures, the total potential for carbon sequestration in drylands can be increased by 0.9 to 1.9 Pg carbon a^{-1} for a maximum of 50 years (62).

The traditional rangeland management practices of pastoralists can be used to mitigate climate change and rising atmospheric carbon dioxide concentrations (63). Pastoral rangeland management practices such as the use of fire and livestock mobility influence vegetation composition, coverage and abundance in rangelands and thus dictate their carbon sequestration potential (63). Moreover, rangeland-based adaptation strategies – such as seasonal grassland reserves (40) – are likely to benefit vegetation and soil carbon sequestration. A study conducted in southern parts of Ethiopia has reported a higher total carbon stock ($p < 0.01$) in enclosed rangeland areas (300.4 t carbon $ha^{[-1]}$) than in rangelands under different management regimes (63). A related study conducted in China also reported significantly increased carbon and nitrogen in areas protected from grazing (64). The pastoralist use of rangelands can maintain carbon stocks stored below ground that could be lost if these rangelands are converted into farmland.

Conclusion

Pastoralists are often blamed for rangeland degradation and so traditional pastoralism is not seen as a major land use for the future. However, an increasing amount of research contradicts this view (61, 65). Rangeland management practices inherent to pastoralism have shaped rangeland environments for millennia (29) and contributed to the enhancement of rangeland biodiversity, as well as the maintenance and conservation of important wildlife habitats (33, 66, 67, 68, 69). Moreover, pastoralists possess detailed knowledge of rangeland plants (19, 70, 71), which could be used for the assessment, conservation and utilisation

of rangeland biodiversity (29, 72). Similarly, traditional pastoralism tends to preserve more carbon and offers tools for biomass and soil carbon restoration, contributing to the mitigation of climate change. But various internal and external factors (such as unfavourable government policies, the loss of key grazing areas to competing land uses, an increasing population and climate change) have curtailed traditional management practices and livestock mobility, breaking the co-evolved balance of vegetation, wildlife and land use, and therefore exposing rangeland to continued livestock pressure, often leading to degradation. Rather than abandoning pastoralism, the revitalisation of traditional practices and indigenous knowledge is vital to secure sustainable livelihoods for millions of pastoralists, to maintain rangeland biodiversity and to preserve ecosystem services.

Le rôle du pastoralisme dans la réglementation des services écosystémiques

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Résumé

Parmi les modalités d'utilisation des terres, le pastoralisme n'est guère considéré comme présentant un fort potentiel d'avenir, en raison d'exemples bien documentés de prairies dégradées suite à leur surexploitation irrationnelle par les pasteurs, entraînant une baisse des services écosystémiques qui leur étaient associés. Il faut toutefois rappeler que ces mêmes pasteurs avaient d'abord été encouragés à se sédentariser et à adopter ce type de stratégies, directement inspirées des pratiques d'élevage appliquées dans les prairies bénéficiant de précipitations plus importantes et plus fiables. Le déclin de la mobilité s'est traduit par le passage d'une utilisation opportuniste et extensive des terres à des formes d'exploitation plus intensives et sédentarisées. Les auteurs se sont attachés à faire apparaître les liens entre le pastoralisme et les services écosystémiques rendus par les prairies, en premier lieu la protection de la biodiversité et la séquestration de carbone.

Les pasteurs recourent à diverses techniques pour gérer les ressources des prairies, dont la transhumance, la conduite des troupeaux, l'érection de clôtures, la rotation des pâtures et l'usage du feu. En déployant ces stratégies, les pasteurs ont contribué à améliorer la biodiversité des prairies et à assurer la conservation durable d'habitats importants pour la faune sauvage. Les pasteurs possèdent également une connaissance détaillée des espèces végétales poussant dans les prairies et de leur utilisation, qui s'avère précieuse pour évaluer, conserver et utiliser la biodiversité des prairies. De même, les pratiques pastorales traditionnelles de gestion des prairies telles que la rotation saisonnière des parcelles et les déplacements des troupeaux influent sur la répartition, la couverture et l'abondance de la végétation des prairies et constituent des outils permettant de réparer la biomasse et de séquestrer le carbone des sols, contribuant ainsi à atténuer le réchauffement climatique.

Néanmoins, plusieurs facteurs internes et externes ont limité les pratiques de gestion traditionnelles et la mobilité des troupeaux, brisant l'équilibre d'une coévolution parallèle de la végétation, la faune sauvage et l'exploitation des terres, et exposant de ce fait les prairies à une pression permanente, souvent suivie de leur dégradation. Plutôt que de renoncer au pastoralisme, il est désormais crucial de revitaliser les pratiques traditionnelles et les savoirs autochtones afin de sécuriser les moyens de subsistance de millions de pasteurs et de préserver la biodiversité des prairies et les services écosystémiques.

Mots-clés
Atténuation du changement climatique – Biodiversité – Biodiversité des prairies – Carbone – Connaissances autochtones – Pastoralisme – Prairies – Pratiques traditionnelles – Protection des habitats – Séquestration du carbone – Services écosystémiques.

La función del pastoreo en la regulación de los servicios ecosistémicos

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Resumen
Al pensar en las principales modalidades de usos del suelo de cara al futuro, rara vez se tiene en cuenta el pastoreo. Ello se debe a la existencia de casos probados de degradación de los pastos, atribuida a un acopio excesivo e irracional por parte de los pastores, y a la consiguiente pérdida de servicios ecosistémicos. La realidad, sin embargo, es que las comunidades de pastores fueron alentadas a asentarse y adoptar tales procederes, importados de zonas de pastizales con niveles más elevados y constantes de pluviosidad. La consiguiente limitación de la movilidad llevó a pasar de un uso oportunista y extensivo de las tierras a modalidades de explotación más intensivas y sedentarias. Los autores examinan aquí el vínculo entre el pastoreo y los servicios ecosistémicos ligados a los pastizales, centrándose sobre todo en la conservación de la diversidad biológica y el secuestro de carbono.
Las sociedades de pastores emplean varias técnicas para gestionar los recursos que suponen las tierras de pasto, en particular la movilidad, el uso de rebaños, corrales y reservas de pastizales y el recurso al fuego. Con estas estrategias los pastores han contribuido a mejorar la diversidad biológica de los pastizales y a conservar duraderamente importantes hábitats de la fauna salvaje. Estas sociedades atesoran asimismo un detallado conocimiento de las plantas que forman los pastizales y de sus usos, lo que puede revestir gran utilidad para evaluar, preservar y utilizar la biodiversidad de los pastizales. Análogamente, las prácticas tradicionales de gestión de pastos que aplican los pastores (como el uso de reservas estacionales de tierras de pasto o la movilidad del ganado) influyen en la composición vegetal, la cobertura y la abundancia de los pastizales y brindan así herramientas para restaurar la biomasa y el carbono del suelo, ayudando con ello a mitigar el cambio climático.
Sin embargo, hay una serie de factores internos y externos que han coartado las prácticas de gestión tradicionales y la movilidad del ganado, alterando el equilibrio entre vegetación, fauna salvaje y usos del suelo que se había alcanzado por coevolución y sometiendo así a los pastizales a una presión ganadera continua, que a menudo acaba por degradarlos. Más que de abandonar el pastoreo, se trata pues de revitalizar las prácticas tradicionales y el saber indígena como expediente crucial para procurar medios de sustento duraderos a los millones de personas que viven del pastoreo y a la vez mantener la diversidad biológica y los servicios ecosistémicos de los pastizales.

Palabras clave
Carbono – Conservación de los hábitats – Diversidad biológica – Diversidad biológica de los pastizales – Mitigación del cambio climático – Pastizal – Pastoreo – Prácticas tradicionales – Saber indígena – Secuestro de carbono – Servicios ecosistémicos.

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