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Rangeland health integration for improved One Health outcomes: Status and prospects

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Executive summary

The inter-linked nature of production constraints in pastoral rangelands in East Africa suggests that pastoralist livelihoods can be improved and multiple One Health objectives achieved through integrated action to improve the health of pastoralists, their livestock, land and resource base. Actions that integrate both rangeland and livestock health may be more effective and efficient than isolated single-discipline actions. The ultimate goal of this integration is to implement linked land-livestock management actions based on how livestock movements, grazing patterns, and efforts to restore rangeland condition and productivity, can be changed in ways that also reduce the likelihood of disease transmission, reduce parasite loads, or otherwise benefit the health of livestock and people. All components of rangeland management in pastoral systems can be better integrated into One Health frameworks, including grazing management and the planning of non-rangeland land uses at the large 'local' scales of pastoralist management, and rangeland restoration at the small scales of severely degraded patches. Grazing management links to livestock health through improving or maintaining rangeland productivity and available pasture area, which in combination with planning of non-rangeland land uses prevents constriction of pastures that concentrate livestock and exacerbate risks of disease transmission and parasite exposure. Restoration at small scales may also reduce threats to livestock health, such as risks of tsetse flies and trypanosomiasis, and ticks and tick-related health problems, which may be reduced by reversing degradation from shrub encroachment into rangelands. Building information systems that practically influence the decisions of pastoralists and local rangeland institutions on where to graze animals, where not to, and when, is technically feasible with the sufficient and appropriate engagement of pastoralist producers. Effective integration of land health with veterinary care and other options to preserve or improve livestock health can enhance One Health outcomes in pastoral rangelands.

Introduction

In the rangelands of East Africa, pastoralist livelihoods are frequently and severely affected by drought, competition for resources (Reid et al. 2014), and livestock diseases including zoonoses (Onono et al. 2013). These long-standing constraints to pastoralist grazing and livestock management often interact with one another, with livestock disease outbreaks accompanying droughts (Wilcox et al. 2019, Filho et al. 2020). In more recent decades newer problems have arisen, especially more frequent droughts due to climate change, rangeland degradation, and the fragmentation, individualization and conversion of rangelands to other land uses (Hobbs et al. 2008, Nkedianye et al. 2011). Using these drivers to contextualize One Health in rangelands is useful for research and design of integrated management actions able to achieve multiple One Health objectives. Degradation by another name is poor rangeland health, as quantitatively defined by deviation of indicators for ecosystem functioning from baseline expectations (Herrick et al. 2019). Drought and declining amounts and consistency of rainfall are major degradation drivers (Wilcox et al. 2017). Livestock densities and movements are greatly affected by these drivers, thereby affecting the incidences and spread of diseases and parasites that threaten livestock health. Climate change and rangeland degradation are altering the ranges and prevalence of disease vectors, leading to emerging infectious diseases (EIDs) (Bett et al. 2017, Wilcox et al. 2019, Egeru et al. 2020) invading areas where previously absent.

One Health approaches generally refer to greater effectiveness and efficiency from transdisciplinary integration of medical, veterinary and environmental health improvement (Zinsstag et al. 2011). The inherently inter-linked nature of problems in East African pastoralism may suggest that solutions addressing multiple aspects of One Health would be more effective than isolated efforts focused on rangeland health, livestock health or human health independently. For example, rangeland health supports animal health and production, and human health and livelihoods, through relatively clear and direct connections. That is, healthier and more productive rangelands produce more and healthier livestock and livestock products, which pastoralists depend on for food, nutritional security, health and income. Linked solutions addressing all three One Health components simultaneously would be more effective and efficient than isolated actions, such as possible approaches to improving livestock health through grazing management and restoration in rangelands. In other words, how can livestock movements, grazing patterns and efforts to restore rangeland conditions and productivity be transformed in ways that also reduce the likelihood of disease transmission, reduce parasite loads or otherwise benefit the health of livestock and people?

The concept of integrated land, livestock and human health actions holds strong promise in pastoral rangelands. However, what these solutions would be, and how they would be implemented by pastoralist individuals and institutions remains unclear. For example, one of the simplest truly integrative land-livestock management changes possible would be resting of a certain portion of a rangeland for restoration (Ash et al. 2011, Robinson et al. 2020, Sircely et al. *in press*). Resting this area would also contribute to control or threat reduction of livestock diseases and/or parasites (e.g. by blocking high-risk herd contacts at a decisive moment in time). To target and implement resting where and when 'win-win' land and livestock health benefits will both result, information gaps and planning constraints need to be overcome, even for this 'minimum standard' for One Health integration of rangeland health. An example of a stronger challenge is whether 'bunched' grazing of large herds in small areas, for brief with rapid movements among pasture areas (Butterfield et al. 2006) creates One Health synergies, or results in trade-offs for pastoralists. Rangeland health may benefit (Odadi et al. 2017), but livestock health may not. If sufficient veterinary controls are in

place, bunching may produce synergistic benefits to both land and livestock health—but if diseases and parasites are left unchecked, a trade-off between livestock health and land health may result (either way, depending on fine-scale herd contacts). Given massive seasonal and spatial variation in rainfall and the complex dynamics of disease spread, answering this question would require substantial information that is currently unavailable. Long-term experiments of five or more years (Briske et al. 2008) would be an ideal research approach, but this method is costly and would need to be conducted in multiple locations able to represent the variation among different rangeland ecosystems and production systems. The most feasible approach would be to use action research to follow 'natural experiments' (e.g., Western et al. 2009) in rangelands where pastoralists have already started implementing bunched grazing. Truly integrative land-livestock management strategies would strike a parallel with known approaches for achieving joint environmental, livestock and human health gains from water point management in pastoral areas. Existing approaches include fencing water points and using solar water pumps and troughs (Mamburi 2014) to control contamination of water points and water-borne illnesses, while also conserving water use (and reducing greenhouse gas emissions of nitrous oxide). For land health to take its place in One Health, this type of decisive, fully integrative action faces a number of information gaps and planning challenges in pastoral rangelands.

One of the loftier goals of One Health in pastoral rangelands is to provide systems for monitoring the health of people, animals and ecosystems simultaneously. The aim is to enable timely responses as problems emerge, with management actions integrated for maximum synergy among multiple objectives. Some of the first information systems for pastoral areas in East Africa were early warning systems (EWS) for predicting forage scarcity, which have long been available (Angerer et al. 2001, Matere et al. 2020). However, the use of EWS by pastoralists remains low. More recently, mobile applications able to track pasture and water conditions in real-time have led to creation of several prototypes (Alulu et al. 2020, Fascendini et al. 2020, Machado et al. 2020). All these platforms are multi-purpose, collecting and disseminating additional information on markets (Alulu et al. 2020) and disease outbreaks (Fascendini et al. 2020; Machado et al. 2020).

Coordinated action on management of land and livestock health in pastoral areas will require estimating over large scales (100s to 1,000s of km2) the relative magnitudes of pasture and water conditions, prevalence of livestock health threats, and livestock densities and movements. Collecting this monitoring data on a large scale, and analysing and disseminating this information to the ground, remain significant challenges in spite of major technological advances. The published literature does not present clear operational means for tracking spatial patterns of disease transmission from movement of livestock in pastoral systems in Africa, or pastoralist systems in general. Recently, though, spatial patterns of herd contacts have been used to indicate risk of disease transmission (Ekwem et al. 2021). Rangelands are known to be complex adaptive systems (Reid et al. 2014), with many residents and livestock owners, and covering vast areas; the area of pastoralist 'rangeland units' in East Africa is in the order of 100s to 1,000s of km2 (Robinson et al. 2021). Certainly, the complexity, vastness and large number of herds in pastoral rangelands are to be reckoned with, motivating the use of efficient, lower-cost approaches, often employing relatively simple technologies.

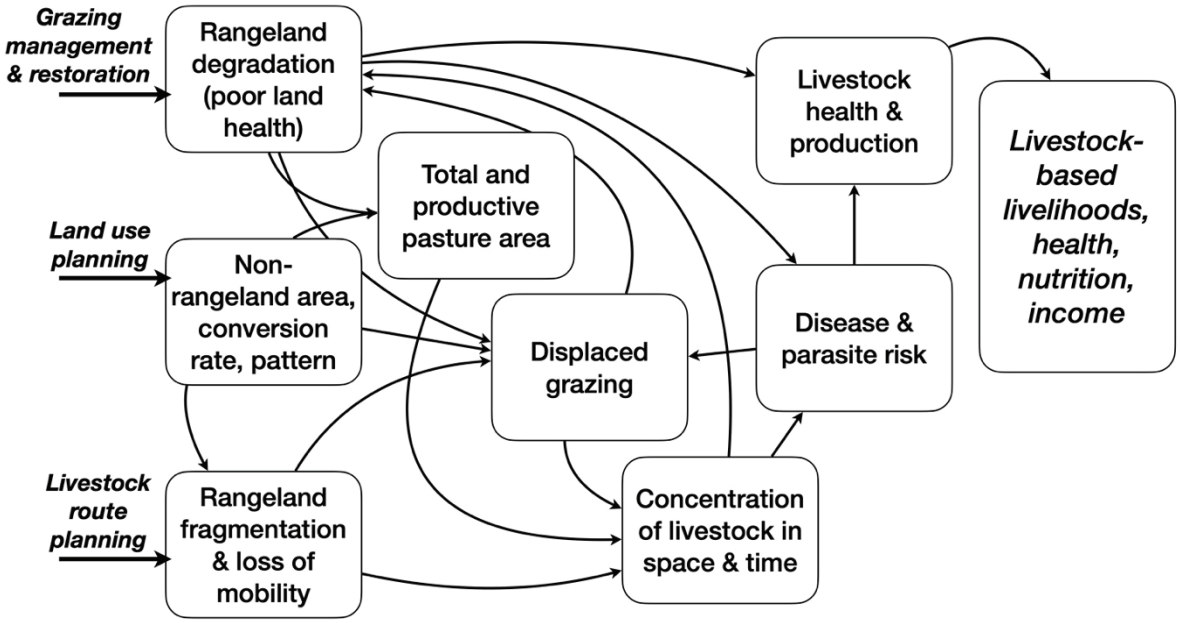
Linked rangeland and livestock health problems in pastoral rangelands

To place One Health integration in a real-world context, the example of Arda Olla, a rangeland unit in southern Ethiopia, illustrates common problems and possible solutions that are relevant in pastoral rangelands in East Africa. The information on Arda Olla presented here was collected during a rangeland management planning exercise conducted in March of 2021 (Sircely and Eba, *in press*). The local rangeland institution in Arda Olla has a hybrid leadership composed of *Garre* clan elders and local government (*kebele*) officers; it also has a similarly hybrid clan-based/government (*kebele*) governance approach. The boundaries are government-defined *kebele* boundaries, while the management practice of seasonal grazing is largely traditional; both traditional and government leaders make key management decisions together. Rules and by-laws of the institution have traditional roots, though repeat, flagrant violators may be referred to the *kebele* government. Arda Olla does not have government recognition of user rights, as Somali region has not yet enacted a process for government certification of user rights to communal lands. While Arda Olla cannot represent all pastoral rangelands, most of the rangeland management and One Health problems and solutions encountered in Arda Olla are common in pastoral areas of East Africa, thus serve as an instructive case study.

Common causes of degradation in the rangelands of East Africa include increasingly recurrent droughts, contraction and fragmentation of grazing areas, and heavy and/or disorganized grazing (Reid et al. 2014). Degradation reduces the area of productive pasture available, in addition to reducing overall rangeland productivity, and the health and production of livestock (Figure 1). The situation is similar in Arda Olla; the management planning team noted that drought, heavy grazing and tree cutting (especially in the smaller highland forest area) were the main causes of degradation. Rangeland contraction and fragmentation are caused indirectly by increasing cropping areas, settlements, private exclosures, and other non-rangeland land uses—as non-rangeland areas continue to expand, the contraction of total pasture area intensifies, and livestock movement can be blocked (Hobbs et al. 2008). In Arda Olla, these non-rangeland land uses are mostly cropping areas, but at some point, private exclosures will be a key cause as their areas increase.

Multiple livestock health problems are directly linked to poor rangeland health in Arda Olla: forbs that are toxic for livestock, tsetse flies (*Glossina* spp.) and trypanosomiasis (though historically absent), ticks that cause mastitis and spread tick-borne diseases, soil-transmitted helminths such as roundworm (*Ascaris lumbricoides*), hookworms (*Ancylostoma duodenale* and *Necator americanus*), tapeworms (*Taenia* spp.) and whipworm (*Trichuris trichiura*). Each of these have been linked to one of the main forms of degradation in Arda Olla – shrub encroachment into formerly grassy savannas. Expanding shrub cover appears to provide a better habitat for the tsetse fly, a vector for trypanosomiasis (Egeru et al. 2020), ticks (Negasa et al. 2014), plus likely soil-transmitted helminths (Brooker et al. 2006).

Figure 1. Rangeland health links to One Health outcomes in pastoral rangelands.



*At far left are management actions to improve One Health through rangeland health.

Other threats to livestock health in Arda Olla are indirectly linked to rangeland health, in association with the concentration of livestock into smaller areas of the rangeland, including *peste des petit ruminants* (PPR), foot-and-mouth disease (FMD), contagious caprine pleuropneumonia (CCPP), lumpy skin disease and internal parasites. This concentration of livestock is caused in part by rangeland degradation reducing productivity and productive pasturage area, expansion of cropping areas which results in reduction of total pasture area, and fragmentation of rangelands and blocking of livestock movements mostly by cropping areas, private exclosures and settlements. Pastoralists in Arda Olla report the use of several approaches to protect the health of their livestock through grazing patterns and livestock movements: avoiding grazing around toxic forbs; shifting locations where animals are kept at night to avoid parasites; and separating herds to avoid high livestock densities where the risk of disease is high. Areas with tsetse are also avoided (Hamandawana et al. 2007, Egeru et al. 2020). All these strategies were drawn from the local or traditional knowledge and experience of pastoralists, demonstrating the importance of embracing this knowledge when developing management approaches.

As non-rangeland areas expand and the size of pastures decline, land use constraints interact negatively with rangeland degradation to displace grazing to other areas, potentially degrading pastures elsewhere in the rangeland (i.e. anywhere forage can be found). Meanwhile, cropping areas, private exclosures, settlements and even gullies fragment the rangeland, thus blocking livestock movements, which results in further concentration of livestock. Because of these interacting forces, pastoralists' livestock frequently cause rangeland degradation and face greater threats of disease, as they become concentrated into smaller and smaller areas.

Large congregations of livestock in small pasture areas can be ecologically beneficial (Butterfield et al. 2006, Hempson et al. 2015)—but only for limited periods of time. This approach is variably referred to as bunched grazing, mob grazing, flash grazing or holistic grazing. However, when livestock heavily and repeatedly graze the same areas for long periods of time, repetitive consumption of individual grasses eventually results in death, especially during periods of drought (Anderies et al. 2002). Since deep-rooted, productive perennial grasses are preferred by livestock and can re-grow after grazing (often into the dry season, especially in areas retaining soil moisture) these valuable species are often lost. As perennial grasses decline, and heavy, consistent grazing continues, the result is more severe degradation such as soil erosion, and encroachment of shrubs and non-palatable or toxic herbaceous plants that replace grasses (Milchunas and Lauenroth 1993, Barger et al. 2011) with vegetation of little value. Rather than reducing erosion, in

most drylands the inter-spaces between shrubs channel surface runoff at higher speeds, accelerating erosion and gully formation (Barger et al. 2011, Ravi et al. 2019). Since shrub encroachment is a common form of rangeland degradation (Kimiti et al. 2017), including in Arda Olla, and shrubs can increase habitat for disease vectors and parasites (Brooker et al. 2006, Negasa et al. 2014, Egeru et al. 2020), the transition to shrubby conditions may pose multiple threats to livestock health.

The concentration of livestock into smaller portions of a rangeland poses risks to livestock health due to a higher probability of herd contact (VanderWaal et al. 2017) that may transmit diseases, which will likely also move through social networks (Omondi et al. 2021), and from a higher likelihood of parasite exposure (Brooker et al. 2006). Pastoralists are sometimes aware of these risks and take action to mitigate them, as described above and documented elsewhere (e.g., Alhaji et al. 2018). Avoidance of disease-prone areas (Hamandawana et al. 2007, Egeru et al. 2020) further reduces the effective pasture area. Furthermore, under-grazing of these areas accelerates shrub encroachment, thus exacerbating threats from tsetse, ticks and worms. As livestock are concentrated into progressively smaller portions of the rangeland, the risk of disease and parasites increases, and heavy, unrelenting grazing causes progressive degradation. Ultimately, livestock become concentrated into the few pastures that maintain reasonable pasture quality, can be feasibly accessed, and where diseases and parasites pose a relatively lower risk. At present, the extent of the rangeland unit in Arda Olla that fits this description at any given point in time is less than 50% of the total area—increasing this proportion would significantly improve rangeland condition and productivity, livestock health and production, and thereby the livelihoods of the pastoralists.

Through these convoluted pathways, the use and management of land, livestock densities and movements, plus diseases and parasites can have significant and negative effects on livestock health and production, on rangeland health and productivity, and on the health, and well-being of people (Figure 1). By identifying and seizing on One Health synergies, and minimizing trade-offs facing livelihood objectives, feasible and significant improvement in One Health is possible. It will most likely be achieved through integrated action inclusive of rangeland and livestock health.

Linked rangeland and livestock health solutions in pastoral rangelands

Rangeland management planning is an important element of One Health in pastoral rangelands, setting the foundation for more specific actions such as control of livestock disease. Briefly, management plans provide for large-scale grazing management, planning of non-rangeland land uses, and small-scale restoration based on the larger plan. The rangeland management plan for a pastoral rangeland unit sets the large-scale structure for improving livestock-based livelihoods, upon which One Health approaches inclusive of rangeland health can be built. In response to ongoing rangeland degradation, the management objectives of Arda Olla were: (1) to restore areas heavily degraded by encroachment of shrubs and toxic plants, plus major soil erosion including gully formation; and (2) to increase production and quality of forage and browse across the entire rangeland unit.

On a larger scale, rangeland management in pastoral systems is accomplished through a combination of improved grazing management and planning of non-rangeland land uses. To address the management objective of enhancing forage and browse quantity and quality across all of Arda Olla, planning of grazing and non-rangeland land uses was conducted. The overall grazing plan did not change dramatically, and some of the greatest gains in Arda Olla would come from an enhanced sense of local ownership over rangeland management. This perception can be cultivated by the promise of greater livelihood benefits from rangelands, if everyone follows the rules (Ostrom 1990). As in most pastoral systems, Arda Olla employs traditional seasonal grazing (Oba 2012) where pastures that are naturally more productive are reserved for the dry season, while less productive pastures are grazed during the wet season. Access to water in different pasture areas also greatly influences these grazing patterns.

Seasonal pastoralist grazing contrasts with rotational grazing, which is generally not feasible in pastoral drylands (Campbell et al. 2006). This is because prescription of stocking rates is limited by erratic rainfall (Ellis and Swift 1988, Behnke and Scoones 1992), plus the large transaction costs involved in coordinating tight grazing patterns. Even where transaction costs are low on private ranches, quantitative evidence reveals that rotational grazing does not maintain better rangeland condition or livestock production when compared to continuous grazing (Briske et al. 2011). An intermediate approach to grazing management can be termed ‘planned grazing’, in which a pastoral rangeland is divided by a local rangeland institution into a handful (e.g. 4–7) of large grazing blocks (Odadi et al. 2017). The aim is to build a loose rotational system upon the existing framework of traditional seasonal grazing. These ‘loose’ rotations using large ‘blocks’ of land might benefit livestock health by enabling minimum separation of herds to limit disease transmission. Regardless of the guiding approach, the main objective of grazing management in pastoral areas is not so much to plan grazing, as to ensure that all pastures within a rangeland receive some amount of periodic rest. This resting is most critical in dry season grazing areas and other key resource areas, the main foundation for traditional pastoralist seasonal grazing in East Africa.

Planning of non-rangeland land uses limits the contraction of pastures on account of the expansion of cropping areas, private exclosures and settlements. Private exclosures were seen by the planning team as currently benefitting rangelands by increasing the feed supply and reducing the grazing burden on the larger rangeland, as opposed to a problem due to pasture contraction (Nyberg et al. 2019). However, as their area increases, private exclosures will

join cropping areas in reducing the available total pasture area. Actions to mitigate undergrazing of areas infested with tsetse and other livestock health risks would contribute further to maintaining adequate pasture area.

Grazing management and planning cannot reverse degradation in the most severely degraded portions of a rangeland; the problem can only be addressed through restoration. A restoration plan was created for Arda Olla to address the management objective of healing bare ground and re-establishing a productive mix of grasses and woody browse in heavily degraded zones. The most feasible first step was manual removal of encroaching toxic plants and shrubs from heavily degraded areas. Other restoration options proposed by the planning team included digging trenches for soil and water conservation, reseeding and planting of fodder shrubs and trees in areas protected from grazing, and gully rehabilitation. The only restoration options previously applied in Arda Olla were soil and water conservation structures. This implies that residents would benefit from building their knowledge on how to successfully apply rangeland restoration techniques.

Each of these restoration options would potentially help restore rangeland condition and productivity. However, their costs and benefits vary greatly, and largely depend on the details of their implementation, including sufficient post-restoration resting from grazing. Removal of encroaching shrubs and toxic forbs was selected by the planning team for ongoing action research restoration trials (Sircely et al. *in press*) managed by the Arda Olla rangeland institution with technical support as needed. Removal of encroaching, non-palatable and toxic plants will release grasses from competition and improve grass cover and productivity, reduce soil erosion and increase the effective area of pasture available to the species that are most sensitive to these toxic forbs, that is, goats and sheep. Arda Olla currently plans to restore approximately 40 hectares per year in this manner. At this rate, however, even under-estimating that 5% of the rangeland needs treatment currently, it would take over 15 years to apply this approach throughout the rangeland unit. Many of these areas would also need to be re-treated after a few years. The efficiency of active restoration methods can be improved, but clearly, larger-scale strategies are required to target and reinforce active restoration.

The likelihood that removal of shrubs and toxic forbs will be successful and sustainable is increased by targeting this restoration option to specific portions of the rangeland called for in the restoration plan. The trial is specifically designed to restore heavily degraded areas on red soils (nitisols) in valuable dry season grazing areas that pastoralists rely on when forage is scarce, milk production is low and the risk of livestock mortality is higher (Oba 2012). Another reason for targeting based on the management plan is that grazing will need to be controlled for three months after restoration, meaning that locations must fall where this is feasible. Restoration needs to be in areas that will not be cropped soon, another link to the larger rangeland management plan. Restoration techniques are best targeted mostly through local knowledge, with technical support and oversight, to areas where they are likely to be most beneficial. For example, in Arda Olla, removal of shrubs and toxic forbs will be located, according to the planning team, in areas with high density of problematic vegetation, with high potential to regenerate productive forage and browse (i.e., not persistently or stably degraded), and on areas of red soils outside of the hilly highland portion of the rangeland. Although active restoration is generally costly, there are some low-cost techniques such as resting for the briefest effective period feasible (Ash et al. 2011; Robinson et al. 2020; Sircely et al. *in press*).

Restoration provides stronger effects per unit area, but on small, degraded patches of a rangeland. Grazing management provides weaker effects per unit area, but on the large scale of the entire rangeland. Restored patches will not transform the larger rangeland unit until after many years of application. In addition, active restoration requires significant resources often beyond the means or will of pastoralists or their local institutions. Grazing management is constrained by collective action to decide and adhere to plans, and the transaction costs involved in this work. These costs increase greatly as the size of paddocks or 'blocks' are reduced, with each division of the rangeland grazed for a shorter period of time. All rangeland management options in pastoral areas in East Africa can be constrained by drought, conflict and local 'ownership' over rangeland management (Opiyo et al. 2012, Odadi et al. 2017). Arguably, in most pastoral rangelands, both improved grazing management and active restoration are required ingredients for increasing productivity and the area of productive pasture available (Figure 1), especially in more degraded rangelands.

As pasture access and productivity increase, and livestock herds are released from pressures leading to their concentration, both degradation and risk of diseases and parasites to livestock should be jointly mitigated. Planning of non-rangeland land uses such as crops, private exclosures and settlements is essential for the prevention of unsustainable contraction of total pasture area. This, together with protection of livestock routes help maintain local mobility of livestock to preserve overall pasture access and to prevent degradation. Each of these actions—implementing grazing plans, land use plans, and restoration plans—contributes to mitigating concentration of livestock and risk of diseases and other threats to livestock health, in addition to their main intended effects of improving rangeland health and productivity (Figure 1).

For these reasons, rangeland management for One Health revolves around an effective rangeland management plan with local credibility. Once the rangeland management plan is at work, even if implementation is imperfect, more sophisticated One Health integration becomes more feasible. Identifying practical actions that can provide tangible One Health synergies for land and livestock health, however, remains a challenge. Even a simple prediction such as what part of a rangeland can be rested, where disease control and rangeland restoration will both result from resting, requires a fair amount of information on livestock densities and movements, disease prevalence and risk. This knowledge will need to be delivered in a timely manner for the action of pastoral individuals and their local rangeland institutions.

Integrative One Health and information in pastoral rangelands

To make practical and decisive linkages between livestock health and land health, more work remains. Producing large-scale outcomes such as improvement in whole-rangeland forage availability, allowing for movements and distribution of livestock that reduce the risk of health threats associated with high concentrations of herds, requires information to understand and respond to the linked nature of land and livestock health. The nascent state of existing information systems able to identify, design, target, and implement integrative One Health actions inclusive of rangeland health can be developed much further.

Tracking livestock movements and densities to inform land-livestock management practice in real-time can apply a variety of techniques. Using GPS collars to track pastoral herds commonly gives coarse or noisy information (Mosomtai et al. 2018) of often uncertain representativeness and interpretation, although risk factors for disease transmission can be identified (Ekwem et al. 2021). In one study, individual cattle in 49 herds in Laikipia, Kenya were collared with GPS, to track movements, herd contacts and to model transmission of a hypothetical disease (similar to FMD) at the scale of a private ranch (VanderWaal et al. 2017). High replication of GPS collars is feasible for research at smaller scales, but suggests that sufficient replication may not be pragmatic at or beyond the scales of local management, or may be costly. Alternatively, using GPS to track movements of livestock-owning households is highly feasible (Moritz et al. 2013, Tyrrell et al. 2017), though it does not track all the herds of each livestock owner. Information on herd movement is often accessible through easier, faster and more affordable methods, as livestock movements and routes are generally common knowledge to pastoralists. Simple approaches such as interviews (Omondi et al. 2021) and participatory mapping (Irwin et al. 2015) can provide the main structure of most livestock movements at local level, in-migrations from near and far, and concentrations of livestock, indicating joint risk of disease, parasites, and rangeland degradation. However, since participatory methods will coarsely estimate the probability of herd contacts, methods to capture fine-scale herd contacts would be needed. With strategic, lower-cost approaches to collection and dissemination, the technology is available for pasture and water access, livestock density and movements, and possible disease outbreaks and high-risk areas to be delivered to pastoralist producers and local producer institutions in near real-time.

Veterinary and medical systems on the ground and emergency response could register magnified impacts if livestock density and movement are modified by pastoralists themselves, for both personal and communal benefit, to alter disease dynamics and to restore rangelands. The complexity, physical area and number of interlocked challenges in pastoral rangelands motivates the use of lower-cost methods such as syndromic surveillance (Bodha et al. 2017, Oyas et al. 2018), linked ground monitoring and remote sensing approaches (Fascendini et al. 2020), and citizen science (Chepkwony et al. 2018), likely based on relatively simple technology with large spatial coverage. Concerns over data quality, including accuracy of crowd-sourced versus monitoring data collected by trained individuals (including the general public) and in terms of bias toward settlement areas and bias of responders, and the availability of mobile infrastructure in exceedingly rural pastoral rangelands, should shape technology selection (Chepkwony et al. 2018).

The technology exists to build an integrated approach able to provide simultaneous, near real-time information flows (e.g. weekly), on livestock density and movements, possible disease outbreaks and high-risk areas, and pasture and water access, up to the local level of administrative units and rangeland units, for dissemination back down to rangeland unit sub-divisions or finer scales. Provided that pastoralists drive the selection and presentation of information, models of information flows can be calibrated on stated preferences of pastoralists, and parameterized on preferences revealed from actual use. One Health information systems should have the overall goal of providing pastoralist-prioritized information to inform grazing, movement, disease control, and watering over the large scales of local pastoralist management and movement of livestock (100s–1,000s of km^2). One clear lesson that has emerged from initiatives to source and provide information in pastoral areas is that multiple concerns of pastoralists should be included, such as risk of conflict and wildlife-human conflict (Chepkwony et al. 2018), since such critical information is valuable to pastoralists, and may more effectively motivate use of the information provided as well as contributions to open platforms.

Since rangelands are so complex and large, and each is uniquely different, creating effective information systems cannot follow a single, rigid blueprint. Building from a perspective of flexibility produces methods that can be applied in a wide variety of local contexts (e.g., rangeland area, climate, productivity, reliance on livestock versus crops, security, market access). Collapsing the great complexity of pastoralist rangeland management and institutional systems across East Africa is a major simplification, yet general principles for the design of information systems is needed. These systems should be able to issue specific, accurate alerts at local level on potential risks and dangers related to a variety of potential shocks, hazards, and opportunities. By communicating this information upwards to local rangeland institutions, local government, civil society, researchers, and data providers, stronger approaches can be built.

Even a minimum-data approach to integrated One Health information services through collection, collation, and most importantly dissemination to inform management decisions, could be valuable. These management decisions primarily include where to send and graze animals (and where to avoid), and where to water them, based on where disease risk is relatively low and adherence to local plans providing for rangeland restoration. These decisions should be built to accommodate traditional pastoralist means of protecting livestock health to be most effective, meaning they will need to be somewhat different everywhere. This specificity of local context is effectively approached through active and earnest engagement with pastoralists and their local rangeland management institutions. The key link in this process of local engagement are the local rangeland management institutions on account of their responsibility and their formal or informal authority to make rangeland management decisions such as on movements and densities according to institutional norms and rules. Generally, most of these local institutions have elements that can be strengthened, and technology appropriately applied can help improve communication and coordination, reducing the large transaction costs of managing communal livestock and rangelands. This assistance to local rangeland institutions will be more effective and efficient through combined information systems that comprise livestock densities and movements according to grazing management plans, water availability, livestock disease and health threats, and other key hazards such as risk of conflict and wildlife-human conflicts.

Conclusion

By connecting livestock grazing, restoration and control of threats to livestock and human health, truly integrative One Health approaches that mainstream rangeland health will provide the tools for more effective management strategies. Results from the management planning workshop in Arda Olla underscored the importance of considering the resource base, its management, and how management can change to not only restore productivity but also control diseases, parasites and other livestock health problems. Clearly, land use and management, livestock densities and movements, and diseases and parasites frequently and negatively affect livestock health and production, thereby diminishing the health, well-being, and livelihoods of pastoralists.

Any integrative One Health action to effectively improve the health of both land and livestock will be most effective when they are fitted into the plans of local rangeland institutions. Here the role of management planning comes to the forefront, as efforts to control the spatial risk patterns of threats to livestock health will be most effectively targeted to specific locations within a rangeland, based on grazing patterns given by the rangeland management plan. Local institutional oversight on the expansion of non-rangeland land uses and active restoration of heavily degraded locations provide additional levers to improve One Health outcomes at the scales of rangeland and livestock management.

The One Health concept of using inter-linked solutions to address inter-linked problems is relevant and promising in pastoral rangelands in East Africa. However, further development is required before actions can be effectively implemented. Returning to the earlier example of the simplest possible truly integrative land-livestock management action brings the challenge into a clearer light—predicting and implementing resting of a certain portion of a rangeland to serve dual purposes of rangeland restoration and control of diseases and parasites. Again, this is a minimum expectation for One Health integration. However, such an approach would require information on spatial and temporal patterns of grazing and livestock health threats, and would need to be tailored for implementation by local rangeland institutions. Even this simplified action would require significant data collection over time on both rangeland condition and livestock health. Thorough collaboration with pastoralist producers and their local institutions for implementation would also be required.

Information systems are needed to identify, design, target, and implement truly integrative One Health actions inclusive of rangeland management and livestock management in space and time. Since land-livestock health interactions will differ somewhat for each rangeland area, information used to predict and design land-livestock management synergies will be best generated from multiple replicate rangeland systems representative of major gradients in social factors such as market access and cropland conversion, and fundamental ecological factors such as climate and rangeland productivity. In contrast to discipline-specific monitoring and dissemination, systems geared to integrate information on pasture and water availability, livestock densities and movements, threats to livestock health, and other key hazards facing pastoralists in a particular area, may be taken up more readily.

Feasible and significant improvement in One Health is possible to the extent that One Health synergies can be identified and seized upon to inform and adjust land and livestock management practice. Achievement of multiple One Health objectives will likely be most efficiently achieved through integrated action inclusive of rangeland and livestock health, that will translate into better pastoral livelihoods, health, nutrition, and income.

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