



Managing Rangelands Without Herding? Insights From Africa and Beyond

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In many parts of the world, the utilization of rangelands is based on the targeted movement of herds within and across often vast territories. Crucial for the success of these livestock operations are decisions on how to flexibly allocate animals to the existing vegetation, both in terms of numbers and concentrations, and in space and time. Research from large scale ranching in the prairies of the Americas, and nomadic or transhumant livestock systems in Africa, the Middle East, and Central Asia, suggests that the more precisely specific patches of vegetation at a specific development stage can be targeted, the more beneficial will be the outcome in terms of animal nutrition and productivity. This also holds for the provision of environmental services such as aboveground net primary production, biodiversity preservation, and soil fertility. However, herding requires year-round labor investment, and in rural areas where seasonal migration is an important livelihood strategy, herding may suffer from absence of skilled workforce. Additional obstacles are political neglect and land use competition, insecurity, reduced self-ownership rates of herds, partial social isolation of herders, and hardship of the work. These make herding an increasingly unpopular occupation, especially for the young generation, but there are also factors that drive (young) people to take up or continue this profession. Reduced herding efforts, reflected in the reluctance to utilize remote grazing areas, may lead to overstocking of favorable pastures. This increases the risk of pasture degradation, long-term reduced herd productivity, social conflict, and public criticism of pastoralism as an anachronistic lifestyle and detrimental land stewardship, thereby further fueling the erosion of herding. By reviewing studies from Africa, the Middle East, and southern and eastern Asia, and including some insights from Europe and southern America, we discuss the ecosystem services produced by herding and herd mobility, and reflect on the ecological and social consequences of the loss of herding labor. Highlighting aspects that speak for this occupation at the individual level, we conclude by suggesting interventions that may sustain the herding profession, such as facilitation of labor sharing, labor contracts, improved herder security, and societal payments for ecological and cultural services.

Keywords: arid regions, ecosystem services, labor scarcity, knowledge erosion, marginal land, mobility, pastoralism, social isolation

INTRODUCTION

Rangelands—which account for 40% of the global terrestrial surface (Briske and Woodward, 2016)—support human livelihoods through the grazing of herbivore livestock. Since most of the world's rangelands are located in arid and semi-arid regions, sustainably managing grazing requires a high flexibility of livestock movements, and adjustment of animal numbers and grazing duration to the spatio-temporal variability of forage resources (Bailey et al., 2019). Traditionally, this is predominantly achieved through herding livestock. Even though (virtual) fencing and supplementation strategies can also be applied (Bailey et al., 2019), they require higher monetary input and often have a lower success rate than herding. Herding is, therefore, a key strategy to sustain the multiple globally relevant ecosystem services of rangelands (Briske and Woodward, 2016), and the rationale of livestock mobility, previously viewed as a backwards feature of traditional pastoralism (Niamir-Fuller, 1999), has now been widely embraced by the international development community. Yet, at the same time as this shift in opinion occurs, members of herding families and communities themselves are increasingly seeing no future in herding as a profession. Many contemporary studies report on the decline of herding activities, herd mobility, and an erosion of pastoral livelihoods around the world (Hampshire and Randall, 1999; Niamir-Fuller and Turner, 1999; Fernández-Giménez and Lefebvre, 2006; Homewood, 2006; Hobbs et al., 2008; Galvin, 2009; Sayre et al., 2013; Turner et al., 2014).

In this contribution we elaborate on the supporting, provisioning, regulating, and cultural ecosystem services of herding sizeable flocks of mobile livestock, mostly in agro-/pastoral societies that utilize extensive communal rangelands. Yet, even on commercial ranches livestock may be herded (Bailey et al., 2019) and, where appropriate, we will also refer to this practice. We try to identify reasons for the widely observed loss of interest in livestock herding by addressing the complexity of the herding tasks and the social-ecological conditions under which they are accomplished. Thereby we partly distinguish if the herding person owns the guided flock, is an (unpaid) family member of the flock owner, or a (paid) hired laborer. Irrespective of the herder's age, position, and gender, livestock herding is difficult work that often involves social isolation and limited human nutrition during at least parts of a day (Moritz, 2008; Moritz et al., 2011; Legeard et al., 2014). It also may expose the herder to life-threatening situations such as severe weather, predating animals or banditry. Yet, herding livestock implies not only a range of constraints but also benefits, which are influenced by social and ecological conditions. Understanding these is important to anticipate how herding systems might evolve over time. Such appreciation is needed because irrevocable changes in herding systems may have important ecological, economic, and social consequences.

HERDING TASKS

According to the Oxford English Dictionary (www.oed.com), herding is defined as “Tending sheep or cattle,” but this comprises

of course also other herbivore species kept and managed in herds. Irrespective of the gender and cultural background of the herding person, location, season, and tended animal species, the nutrition of the flock is at the core of the daily herding tasks. This is achieved by guiding the animals across the landscape and providing them with nutritious plants, drinking water and, occasionally, mineral-rich plants or soils, while at the same time preventing field crop and tree damage and mingling of the herd with other flocks. Depending on animal species, regional and cultural settings, and season, further daily tasks include care for newborn animals, their temporal separation from the mothers, milking of lactating females, and locking up the herd in a night corral that protects from predators and thieves. Tasks of milk sale or transformation may be added during times of high milk availability. Work that occurs regularly, but not on a daily basis, includes shifting of night corrals, prophylactic health care measures such as vaccination, treatment against ecto- and endoparasites, and claw trimming. Seasonally relevant are activities related to reproduction management (selection of breeding females and males, temporal inclusion of males in the breeding herd), castration of males not used for breeding, and culling of old or infertile females and males. Once a year shearing or combing of fiber-yielding animals is required, while other tasks are contextual such as marking of new animals in the herd, animal sales and slaughter, hay making, and pen preparation for the winter time (LPV, 2007; Turner, 2009; Legeard et al., 2014; Stépanoff et al., 2017; Soma and Schlecht, 2018; Gantuya et al., 2019).

The multitude of herding tasks, and especially the core activity of guiding and supervising daily grazing, requires the active regular management of animals by a highly skilled person. While being a necessary condition for spatial movements of livestock, herding can result in variable levels of mobility (Turner and Schlecht, 2019): it is both part of sedentary systems where animals are managed around a fixed point, as well as of transhumant and nomadic systems where distance and orientation of flock movements vary according to season. In the latter systems, there is wide variation in the degree to which the locations of the animals' overnight bases change seasonally (Turner and Schlecht, 2019). Furthermore, herding labor invested into grazing management varies widely, depending in particular on the itineraries of livestock on pasture when feeding. In this respect one can distinguish three categories: (i) the “full herding mode” (further termed “herding” and in the center of our debate) whereby a person attends a flock of animals during grazing; (ii) the “herd-release mode” whereby a person guides the flock to a specific location in the morning and then leaves the animals to graze and return to their night resting place on their own or recollects them on pasture later in the day; (iii) the “unattended mode” whereby the flock, throughout its departure from the night resting place until its return to this point, remains on its own (Turner et al., 2005). Herding modes may alternate temporarily according to season, herd composition (age and sexes), and environmental as well as social contexts (Stépanoff et al., 2017).

HERDING PROVIDES MULTIPLE ECOSYSTEM SERVICES

It is not easy to elaborate on the benefits of herding in comparison to fenced or unattended grazing of an area by herbivore livestock, because several of the ecosystem services are, at a first glance, provided by any grazing system, no matter the mode of attending the animals and restricting them to the piece of land to be grazed. However, for each of the points specified below, we will elaborate the advantages of the herding duty, which we define as the judicious decision on when and how long to move a given herd to a specific pasture—on a daily, weekly or seasonal basis (Anderson et al., 2014; Lécivain et al., 2014). Exploiting vast (semi-/arid) rangelands with spatio-temporally highly variable abiotic and biotic environmental conditions, by mobile flocks of herbivorous animals, has been widely reported to be ecologically adapted and economically sound (Butt, 2010; Behnke et al., 2011; Brottem et al., 2014; Turner et al., 2016a). At the level of the individual animal and the herd, skillful herders move the animals across the landscape to best meet their nutritional requirements, which vary across seasons and individuals as well as during a day (Van Soest, 1994). Skillful herding aims at offering the animals the most nutritious forage possible (Turner and Hiernaux, 2008; Butt, 2010; Lécivain et al., 2014), and a higher amount of biomass than under unattended grazing (Turner et al., 2005) or random walks (Schlecht et al., 2006). Accordingly, well-nourished animals will show good performance with respect to growth, reproduction, lactation, and health (Krätli et al., 2013). This benefits their (employed) herders and owners, as well as the customers of live animals and the consumers of meat and milk. Herding can, therefore, improve the provisioning services of any of the pastoral systems defined by FAO (2001). By-products that are not easily altered in their quantity and quality by the herding mode are hides/skins and horns. For fiber provided by sheep, goats, camels, camelids or yaks, it is especially the cleanliness of the material that may improve with herding. While adequate animal nutrition stabilizes fiber yield, it cannot substantially enhance this genetically determined trait once the supply of sulfur-containing (essential) amino acids or their precursors is granted (Van Soest, 1994).

Herding the animals during nighttime instead of daytime provides additional grazing opportunity during hot parts of the year, which often coincide with periods of feed scarcity and poor feed quality (Turner and Schlecht, 2019). Since animals may increase their resting periods during the noon hours, usually the hottest part of the day, feed intake and animals' condition improve through night grazing (Turner and Hiernaux, 2008). Even though unattended animals may also night-graze on their own, the time they are actively feeding during the night is shorter and often restricted to the neighborhood of their corral as compared to herded night grazing (Ayantunde et al., 2000a,b). Within a fenced paddock, night grazing of unattended animals may be safe, whereas predators and physical obstacles may threaten the well-being of animals grazing in open areas (Scotton and Crestani, 2019). Furthermore, in areas where animal theft is common, herded animals are better protected. Yet, where armed robbery and terrorism prevail, herders practicing night grazing

may even face higher risk of being attacked than during the day when the pastures are more populated (Ayantunde et al., 2000b).

As far as the provision of livestock dung is concerned, and its use as fertilizer, composting substrate, building material or fuel, herding can enhance its use-efficiency by concentrating excreta on specific fields through night-corralling. In the Sahelian and Sudano-Sahelian zone, but also in mountainous regions of Europe, this was traditionally promoted through manuring contracts (Heasley and Delehanty, 1996; LPV, 2007). Manure can also be accumulated in night corrals from where it can be collected and utilized for different purposes. Quantity and quality of excreta deposited on corralled fields, and in (night) resting areas, are primarily determined by those herding skills that govern quality of forage encountered and quantitative feed intake (Schlecht et al., 2004; Ayantunde et al., 2018). Manure quality, especially its concentration of undigested—fibrous—plant material and of phenolic compounds such as tannins, determines the rate and extent of decomposition by soil microbiota (Somda and Powell, 1998; Ingold et al., 2018), thus affecting supporting ecosystem services. The choice of the herds' resting place, and time spent there, determine the amount of excreta deposited but do not alter manure quality. Targeting excreta on specific fields or accumulation spots is not easily accomplished with unattended animals that are grazing fenced paddocks. Commercial ranches in Kenya often use makeshift enclosures to corral livestock at night with the objective of targeted dung concentration to generate areas of highly nutritious vegetation. Mixed livestock-wildlife operations may employ this system to create areas of attraction for herbivore wildlife for purposes of touristic game viewing (Porensky and Veblen, 2015).

In adjusting animal numbers and grazing duration (stocking densities), as well as re-/visits to vegetation composition, phenological stage, biomass yield, and soil conditions of a pasture, herding also provides a series of supporting as well as regulating services. Firstly, it can maintain or enhance aboveground net primary production and with it root growth of herbaceous species (Kurtz et al., 2016). Well-fed and thus well-performing animals emit less carbon dioxide equivalents per unit of milk or meat produced than less well-fed animals. Therefore, herding can contribute to decreasing the carbon footprint of pastoral systems by lowering carbon emissions per unit of produce and by increasing pasture-based carbon sequestration (Kurtz et al., 2016; Vigan et al., 2017; Stanley et al., 2018). On the other hand, also removal of herbaceous biomass and keeping landscapes open is a service provided by herders and their flocks. In Europe, for example, various culturally very old and unique landscapes, with specific structure and biodiversity such as the Lüneburg Heath or the Swabian Jura, depend on transhumant herding systems (Härdtle et al., 2002). In the Mediterranean regions of France and Greece, keeping understory vegetation short by herded flocks of small ruminants is an important service to prevent or at least decrease the risk of summer bush fires (Legéard et al., 2014; Rodríguez-Ortega et al., 2014).

Trampling, especially by small ruminants, may compact sandy soils and thus decrease erosion risk, as demonstrated by the traditional dike sheep farming along the coastal zone of the

North Sea in The Netherlands and Germany (van Bodegom and Price, 2015). If herds are specifically guided to silty loams immediately before the onset of the rainy season in tropical regions, trampling can also loosen soil crusts, and by this enable plant re-colonialization of spots sealed with micro-crusts (Hiernaux et al., 2009). Yet, loosening soil crusts in the dry season, when recolonization will not immediately follow, may lead to wind and eventually also water erosion of the loosened topsoil (Belnap, 1995). Thus, soil fertility management through grazing animals must identify the exact timing of hoof action with respect to soil and climatic conditions (Savadogo et al., 2007). Furthermore, skillful herding can make use of the animals' function as vectors that redistribute nutrients and organic matter within and across landscapes (Schlecht et al., 2004, Turner and Hiernaux, 2015).

By using locally adapted herbivores, traditional herding often contributes much more than paddock-based grazing operations to maintaining the genepool of critically endangered livestock breeds with their unique adaptive traits to hot or cold climates, poor feed quality, mountainous terrain, and specific disease challenge (LPV, 2007; Köhler-Rollefson et al., 2009; Kaufmann et al., 2016). Whereas, Fulani in West Africa, Maasai in East Africa, and herders in Madagascar, Oman, and eastern and southern Asia conduct their herds on foot with a variety of whistles and herding stick signals, herders in Central Asia, the Americas, and Oceania often move their flocks from horseback. In Europe, Oceania, and North America, use of herding dogs is common (Faye, 2008). These companion animals often also belong to specific breeds with unique traits and globally shrinking purebred populations.

Last, but by no means least, herders and their herds provide cultural services, from the simple picturesque motif for tourists, coffee table books, travel guides and other media, to the preservation of century-old traditions with internationally (United Nations) recognized heritage value such as the Hunting Eagle Festival of Kazakh herders, and the “*naadal*” festivals of Mongolians. Other examples are the annual crossing of thousands of cattle into the Inner Delta of the Niger River at Diafarabé in Mali, regionally important events such as the start of the “*Cure Salée*” season for cattle herds in In-Gall, Niger, the various “*Schäferlauf*” festivals in the German county of Baden-Württemberg, and the many regional gatherings for the “*Almabtrieb*” (French: “*Désalpes*”) of transhumant cattle and small ruminant herds in the European Alps. Further cultural services are the above-mentioned conservation of a diversity of regional livestock breeds, and the preservation of specific grazing-shaped landscapes that, beyond their ecological habitat functions, also have high recreational value at regional as well as international level (LPV, 2007; Metera et al., 2010; Provenza and Meuret, 2014).

HERDING NEEDS KNOWLEDGE, SKILLS, AND NETWORKS

The essence of herding is deciding about when to move an animal herd, of a given size and composition, to a specific pasture,

how long to stay there, when to move further, and where to (Roe et al., 1998; Schareika, 2001; Krätli et al., 2013; Anderson et al., 2014; Savini et al., 2014). Thereby, the herder must have a good knowledge of the (different) animals' physiological status and respective nutritional requirements, their feed preferences, and feeding behavior (Turner and Schlecht, 2019). S/he should also know the botanical composition of the pasture, its biomass yield and nutritional value, the spatio-temporal distribution and availability of different (types of) pastures, and the plants' phenological status at the moment of grazing (Meuret et al., 1994; Bailey, 2005; Provenza et al., 2007). The latter aspects also require knowledge on pasture quality over time (historical knowledge/tradition) and in dry vs. moist years (Angassa and Beyene, 2003). Further necessary knowledge pertains to the presence or absence of medicinal and poisonous plants, location and qualities of soils with higher content of (essential) minerals, water availability and quality, soil borne and vector borne diseases such as anthrax and trypanosomiasis or Rift Valley fever, and of predators and poisonous animals such as snakes or scorpions (Angassa and Beyene, 2003; Feldt et al., 2020). With view to future re-usage of the grazing area, knowledge is also decisive on the growth behavior of both desired and unwanted range plants following a grazing event. Therefore, apart from deciding on the where and when to allocate a herd of animals to an area of pasture, a skilled herder also decides on whether to allow the herd to spread out or to concentrate on particular patches of vegetation, depending on the effects desired (Meuret and Provenza, 2015) in the animal (e.g., intake of more soluble carbohydrates when grazing plant tops vs. intake of more protein when grazing plants further down), and in the vegetation (e.g., increasing defoliation and trampling effects to suppress undesired range plants vs. stimulating tillering by light through moderate grazing). In the case of using companion animals for moving (horses, camels, dromedaries), guiding or guarding (dogs) the flocks, herding also requires knowledge, practice and experience in working with these individuals (Savalois et al., 2013). Another important task of herders is keeping animals out of cultivated zones to avoid crop damage and conflicts with crop farmers (Turner et al., 2016b; Feldt et al., 2020; Houessou et al., 2020). This can only be assured by full-day attendance of the flock (Turner and Hiernaux, 2008).

With mobile phones functioning in many remote regions where herders operate, the tasks of identifying the best available grazing grounds at any given moment and the possibilities to avoid conflicts, ranger patrols, and livestock raids have recently been simplified (Turner et al., 2014; Butt, 2015; Waters-Bayer and Bayer, 2016; Djohy et al., 2017). However, the typical herding tasks remain, namely to move the animals to often remote grazing grounds, to stay there for a period of a few days to several months, and to care for the herd in a setting of poor infrastructure and limited human support (Moritz, 2008; Moritz et al., 2011; Legard et al., 2014). Shifting to unattended grazing in such situations reduces herd mobility and increases grazing pressure on areas close to campsites or settlements (Turner et al., 2005; Altmann et al., 2018); furthermore, it may increase livestock loss through predation or theft (Meriggi and Lovari, 1996; Sangay and Vernes, 2008). Yet, herding strategies may well vary for different

livestock species: in some valleys of Gilgit-Baltistan (northern Pakistan), where the herd-release mode prevails for yaks, these are oriented toward a particular pasture and then left to graze on their own, and for the rest of the day the herder accompanies small ruminants. Here, the herding of small ruminants has increased the proportion of heavily stocked areas near campsites and settlements since they are guided to pasture only after the large ruminants have been released and are brought back early to the corral. This restricts grazing time and spatial range of small ruminants (Hameed et al., submitted), whereas yaks have ample time to distribute across the pastures (Khan et al., 2013).

Although herd movements and herding patterns are primarily shaped by environmental and climatic conditions, cultural and social factors, as well as institutions, often also play an important role (UNDP, 2003; Kreuzmann, 2004; LPV, 2007; Turner et al., 2014). For wider-scaled mobility patterns facilitated by herding, it is important to recognize that the locations of seasonal overnight bases are strongly affected by herders' social networks. This reflects the vulnerability of herders on the move who are managers of significant wealth "in the bush" that attracts not only wildlife predators but also thieves (Feltdt and Schlecht, 2016). Having a sedentary "host" who can potentially support the bypassing herder and herd is an important consideration in choosing movement destinations. In the West African Sahel, transhumant herders often choose locations with access to markets, that are relatively secure, and where agricultural land-use pressure is sufficiently low to avoid problems of crop damage (Turner et al., 2014). While the biophysical conditions (i.e., forage, water, absence of diseases) are key, social and institutional factors are influencing broader patterns of herd mobility. For (transhumant) herders with no or only little experience in long distance movements, the knowledge exchange with experienced herders or settled agro-pastoralists is particularly important to gain spatial knowledge, build social contacts and learn how to adjust herd composition and movements to the areas visited (Bassett and Turner, 2007; Houessou et al., 2020).

For the individual or group responsible for the herd, the quantity and quality of available herding labor matters. Full herding requires following a herd for most of the day, depending on the quality of feed and the nutritional status of the livestock (Turner and Schlecht, 2019). Moreover, as outlined above, herding involves a range of activities beyond steering animals across a heterogeneously foddered landscape. Herders often perform veterinary care, scout new pasture areas, search for lost animals, transfer animals to other management herds and markets, and milk and water animals (Figure 1). In many dryland areas, watering animals involves the onerous task of drawing water from deep wells or digging temporary wells in dry wadi or depression areas. Moreover, the length of a grazing day increases as quality forage becomes more sparse. Herding is then more difficult and may require additional labor to navigate herds through areas of higher cultivation pressure or difficult terrain where livestock can get lost. Furthermore, herds on the move, distant from a home base, often require a minimum of two herders, so that when livestock are lost or stolen one herder can search while the other one stays with the herd (Turner and Hiernaux, 2008).



FIGURE 1 | Herders' duties requiring collaborative work: **(A)** fetching water for cattle (Niger); **(B)** shearing sheep (Mongolia); and **(C)** marketing animals (Niger).

Next to the number of available herders, the quality of their labor also matters. Herding is a profession that requires stamina, perseverance, knowledge, and the capacity to endure partial social isolation (Moritz et al., 2011). Within traditional pastoral communities, the variation in these qualities across herders is

well-known (Turner, 1999; Stépanoff et al., 2017). Some of these qualities are tied to experience and ultimately age. Older herders with less stamina and strength will often be more inclined to rely on herd-release forms of grazing management, whereas youth charged with herding may display less endurance and knowledge. On the other hand, tasks may also be split between family or community members (Schlecht et al., 2009). While elders with much experience give the general direction on which areas to graze and which water points to use, younger family members will actually do the more arduous tending to the animals on pasture. In this context children are often assigned the tasks of tending to small ruminants or calves near the overnight enclosure (Turner, 2009; Aufderheide et al., 2013). Depending on the animals' physiological status, Rendille pastoralists of northern Kenya split their camels into a highly mobile "fora"-herd tended by young men of the warrior age and a less mobile "moro"-herd (Kaufmann, 1998; Aloo et al., 2008) kept closer to the homestead. While the latter flock returns to the homestead every night and supplies the household with milk, the former is often absent for long periods of time without returning to the settlement.

In different agro-/pastoral systems, the group that is responsible for assigning livestock herders varies. While the family (variously defined) is most often the herd managing unit, herds may also be managed jointly by multiple families or village communities on a permanent or seasonal basis. Joint herding can take different forms including the sharing of herding tasks by several persons, the hiring of herding labor for livestock owned by communities, the entrustment of livestock to others, and the joint movement of individual family herds together (Davies and Hatfield, 2007; LPV, 2007; Turner and Hiernaux, 2008; Li and Huntsinger, 2011; Butt, 2015). Group management may allow to access broader social networks that can be solicited during long-distance movements. Moreover, groups benefit from a broader knowledge base and greater access to herding labor. Still, the major constraint to joint management and labor sharing is that different members may have different ideas about which decisions to take when. This reflects the highly variable biophysical and social conditions under which herding operates and may even be found among brothers for family herds. Thus, labor sharing and joint herding may occur in an *ad hoc* manner or on a more temporary basis: transhumance herds move together and share labor *en route*, or herds are combined or split during the year depending on labor demands (Turner and Hiernaux, 2008).

Labor sharing often occurs during periods of particularly high labor demand. Beyond appropriate time allocation to different tasks that are directly connected to the daily herding duty, herders need support by family, peers or kin groups for laborious tasks such as disease (prevention) treatments, marking and milking the animals, hay making, and shearing (Figure 1). The time herders spend with their animals, and preference for individual or group herding, thus also depends on the location of the pasture and the season, as well as on tasks at seasonal campsites, on hay-making plots or at the main settlement where crop farming may take place (Sangay and Vernes, 2008; Nkedianye et al., 2011; Soma and Schlecht, 2018). As shown by the example of the Mongolian Altai, shearing of sheep, felting

of wool, and vaccination of livestock are jointly organized by several families on the summer pastures. Often, it is the male household head and the older generation who are joining forces, whereas women and younger family members move to urban centers for education and employment (Fernández-Giménez et al., 2017) and only briefly visit the alpine meadows during summer vacations.

HERDING IS UNDER THREAT

High variability of precipitation has always determined forage availability in semi-/arid lands primarily exploited by herded flocks, but the effects of the recently accelerating phenomena of climate change increase the spatio-temporal variability of precipitation (Al-Kalbani et al., 2015; Lv et al., 2018). Climate change induced variation in precipitation make the adjustment of animal numbers to forage and water resources more difficult (Godde et al., 2019). In the Karakoram Mountains of Central Asia, increasingly hotter summer temperatures have been reported to lead to massive melting of glaciers (Anwar and Iqbal, 2018). Meltwater streams can wash away pathways and bridges, temporarily obstructing access to high altitude summer pastures. This was witnessed, for example, in Shimshal, Gilgit-Baltistan, in July 2017 (Hameed et al., submitted). Whereas increasing environmental variability requires higher flexibility of herd movements (Niamir-Fuller and Turner, 1999; Kreuzmann, 2011), the latter are increasingly hampered by mining activities, land development projects, and cropland encroachment onto tracking routes and pastures (LPV, 2007; Hobbs et al., 2008; Dureau and Bonnefond, 2014; Turner et al., 2014, 2016b; Haller et al., 2016). Cropland encroachment is partly triggered by population growth, but the opening up of new markets through improved infrastructure is another driver for herders' dwindling space for maneuver. It promotes the expansion of cash crop cultivation (Hobbs et al., 2008; Sayre et al., 2013; Turner et al., 2014, 2016a), and renders livestock herding more difficult at the local level. In West Africa, increasing local cropping pressures foster herd movements from the home territory during the cropping season. As cropping pressures continue to grow, households may reduce their livestock holdings and rely increasingly on stall-fed modes of management (Turner et al., 2014). In most semi-/arid regions of the world, cropping densities are highly heterogeneous and adequate pastures are only available if livestock can be moved at subnational to district scales. The ability to move despite locally high levels of competing land uses, such as agriculture, can only be maintained through government protection of key pastoral resources, such as movement corridors and water points, that allow herders to reach these pasture areas (Turner et al., 2016b). The historic neglect of pastoralists' rights to such key resources that are necessary for mobility has contributed to the erosion of both, the net benefits of herder-facilitated mobility and, as a consequence, the engagement in herding *per se* (LPV, 2007).

Another growing threat to herding is the expansion of banditry and terrorism in numerous remote arid areas of sub-Saharan Africa—from Mali across Burkina Faso, Niger and

northern Nigeria into Chad, in the Horn of Africa and in arid parts of Kenya. Also affected are the more humid but sparsely settled northern zones of Ivory Coast, Cameroon, the Central African Republic (Alemu, 2018; Abdullahi, 2019; Feldt et al., 2020), and southern Madagascar (Feldt and Schlecht, 2016). Given the wealth on the hoof they are managing in highly insecure areas, herders are at serious risk of attack. Threats of animal theft and to personal life increasingly reduce herders' safe operational space in such areas, and may even lead to abandonment of agro-/pastoral use. In consequence, land use pressure may increase in secure areas that are already more densely populated and present little opportunity for flexible herd mobility (Feldt et al., 2020).

A further reason for the erosion of herding services is the reduced labor availability for grazing management of livestock in open rangeland conditions. Shortage of herding labor may not simply be a result of household demography (e.g., a household's dependency ratio) but may result also from necessary labor diversion to other purposes (e.g., agriculture, trade). Whereas Samburu herder-owners of cattle and small ruminants in Marsabit County, Kenya, were found to start milking at 5:30 to 6:00 a.m., then taking their animals to pasture and returning to the overnight enclosure at 4:00 p.m., well-paid hired herders on a Kenyan ranch started their duties at 5:30 a.m. and returned to the enclosure at 6:00 p.m. (Aufderheide et al., 2013).

Households' decisions to invest scarce labor resources into herding are also shaped by the perceived benefits of this investment. Hereby it is important to recognize that the size of benefits from herding investments depends on the size of the herd and the degree to which the herd manager owns livestock within this herd. As herd size declines, benefits from labor investments into herding will also decline unless labor-sharing arrangements are put in place (Little, 1985; Turner, 1999). In many parts of the world, the family or individual in charge of herding may own very few animals in the managed herd, with herding services being compensated through wage or entrustment contacts (Little, 1985; Turner, 1999; LPV, 2007; Legeard et al., 2014). Due to either lower incentives for contracted herders or constraints placed on them by livestock owners, herds with low self-ownership rates have been reported to receive lower quality herding and exhibit more constricted patterns of grazing (Little, 1985; Turner, 1999; Turner and Hiernaux, 2008). However, there are also examples of high quality herding labor invested by wage-earning herders (Moritz et al., 2011; Baumont, 2014).

Loss of herding labor, whether permanent or temporary, leads to the transfer of herding tasks to elderly persons, (younger) males and females (Turner and Hiernaux, 2008), or hired local (West Africa) or foreign (Oman) laborers (De Bel-Air, 2015), as depicted in **Figure 2**; this is frequently accompanied by a decline in livestock mobility (Turner et al., 2005). If grazing the animals is assigned to less experienced persons, they often do not allocate sufficient time to herding duties and lack the aforementioned knowledge and skills (Turner and Hiernaux, 2008; Derville and Bonnemaire, 2010; Jasra et al., 2016): In Gilgit-Baltistan, young and inexperienced herders were accused of guiding the flocks rather arbitrarily and being unable to bring back all animals to the night resting place at the end of the day (Hameed

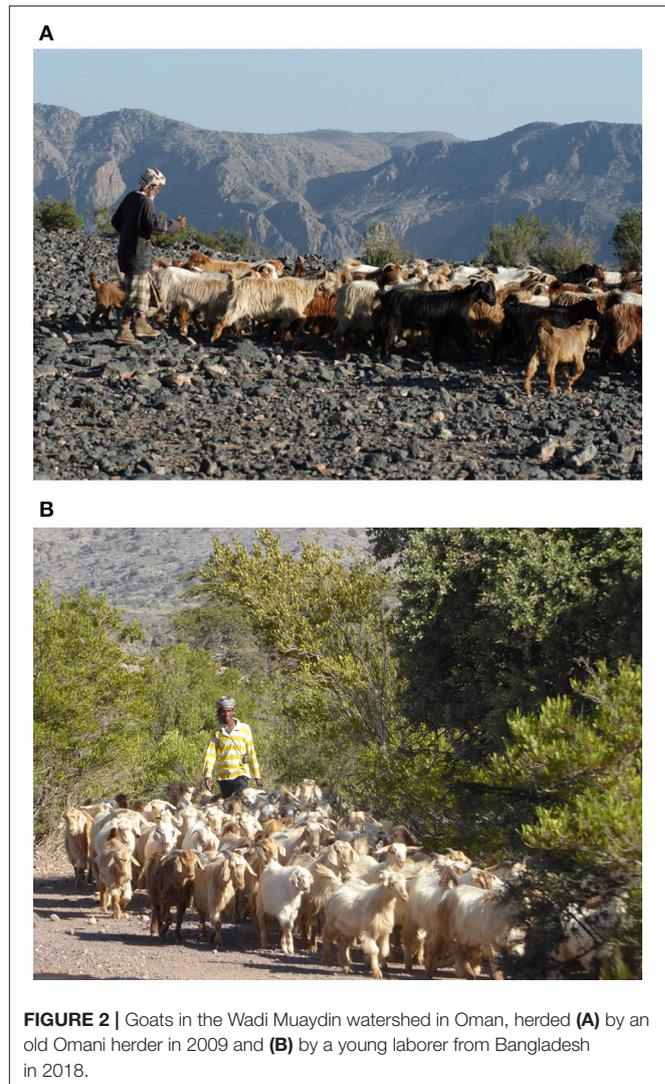


FIGURE 2 | Goats in the Wadi Muaydin watershed in Oman, herded **(A)** by an old Omani herder in 2009 and **(B)** by a young laborer from Bangladesh in 2018.

et al., submitted). Declining availability of herding labor can also reduce the prevalence of longer-distance herd movements and shift grazing management toward less labor-intensive options such as the herd-release mode (Turner and Hiernaux, 2008) or fenced grazing (LPV, 2007; Legeard et al., 2014).

APPEAL OF HERDING FOR YOUTH

The erosion of the herding profession is not only shaped by reduced investments into herding by livestock owners and managers, but also by a loss of the attractiveness of herding as an occupation. Often, long hours have to be spent in remote areas with few amenities and poor communication infrastructure (Baumont, 2014; Legeard et al., 2014; Djohy et al., 2017), on a profession that the broader society depicts as primitive (Fernández-Giménez and Estaque, 2012; Feldt and Provost, 2018). Coupled with the continuous vigilance required and risks to be endured in areas of increasing farmer-herder

conflicts and armed insurgencies, this decreases the profession's appeal to young men who constitute the vast majority of herders.

Herding families can include some of the wealthiest and of the poorest members of rural communities. Some herding families are sufficiently rich in livestock to offer adequate subsistence for the family and provide their young men with the resources needed to marry and establish herds of their own. For those owning few livestock, the herding profession is poorly remunerated (Moritz et al., 2011). In West Africa, for example, young men or boys simply herd for their fathers or older brothers and may receive little beyond the right to milk the livestock entrusted to them by their owners (Turner, 2009). Those who work for a wage earn very little and often take on the risk of paying for crop damage caused by livestock not owned by them but under their care (Bassett, 1994). Labor contracts are often not transparent with herders having little recourse against owners who refuse to pay herding fees. Distrust between owners and herders prevent reforms of the labor contract so that herders are not paid in animals as a living wage (Turner and Hiernaux, 2008). Understandably, there is a sense of hopelessness among herding youth who often see little economic future in an occupation that they are born into. However, in the context of modernization and intensification of the pastoral livestock sector (Schareika et al., 2020), it may even be advantageous if members of the younger generation choose other professions—as long as there are still qualified individuals available for the herding tasks (Yeboah and Jayne, 2018).

Resource-poor rural regions of the world, where pastoralism predominates, are major source areas for intra- and international labor migration of young men (ILO, 2018). Labor emigration of youth offers both challenges (Wu et al., 2014) and benefits (McKay and Deshingkar, 2014) to rural families. Due to the year-round demands for herding labor in areas such as the Sudano-Sahelian zone of West Africa, labor emigration rates among herders have historically been lower than among farming youth, whose families primarily need their labor during the cropping season (Turner and Hiernaux, 2008). Increasing migration by (young) herders often leads to schism within the family given the hardship such departure imposes on the remaining family members (Hampshire and Randall, 1999; Turner and Hiernaux, 2008; Feldt and Schlecht, 2016), and can result in herders never returning to their occupation.

Multiple and amplified challenges to herding, and the growing ambivalence about herding as a profession among rural youth, have led to a significant decline of livestock herding in many parts of the world (LPV, 2007; Kreutzmann, 2011; Fernández-Giménez and Estaque, 2012; Fernández-Giménez et al., 2017; Schareika et al., 2020). The basic conditions that have allowed herding to function effectively have faded in many regions that formerly were characterized by mobile pastoralism: unrestricted movements across vast territories, personal security, sufficient livestock ownership among herding families, remunerative markets for livestock and products, economic viability of herding contracts, working relations among herders, herd patriarchs, and owners, and social coherence within kin groups (LPV, 2007; Hobbs et al., 2008; Turner and Hiernaux, 2008;

Fernández-Giménez and Estaque, 2012; Sayre et al., 2013). In some regions, the ongoing social-ecological transformations have undermined the viability of the herding profession. In other regions, herding continues despite severe challenges, due in large part to the ecological and productive benefits it provides. The “herding socialization” of children often shapes their personalities, and the everyday inclusion into herding tasks from a young age fosters the development of a pastoral personality. Many young(er) herders are aware of family or clan traditions and perceive the herd as the family's economic and social wealth (Schareika et al., 2020). They are proud of their knowledge and skills which manifest themselves in well-fed animals that are constantly compared to the herds of peers. Across different regions, strong individual commitment to the herding lifestyle can, therefore, still be found, as it provides purpose, contentment, pride, and social integration (LPV, 2007; Moritz et al., 2011; Legeard et al., 2014; Turner et al., 2014). Beyond restricted economic alternatives that may keep herders within their occupation (Adriansen, 2008; Turner, 2009), gradually acquiring their own animals may still be an option for young herders to become economically independent (Moritz et al., 2011; Gonin and Gautier, 2015). Also, in the “western” world, young women and men from urban contexts may decide to take up the herding profession because they find satisfaction in a meaningful, ecologically compatible, and valuable activity that requires and fosters a very particular relationship to the animals and the landscape and provides personal pleasure (Baumont, 2014; Legeard et al., 2014).

HERDING MERITS SUPPORT

Wherever the herding profession disappears, its multiple benefits also vanish. The above discussion of the advantages of herded grazing shows that its erosion may entail, among other things, overgrazing (Altmann et al., 2018), biodiversity loss, soil fertility decline, and in some parts of the world even increased risk of bush fires (Mancilla-Leytón et al., 2013). The judicious utilization of animal impact on vegetation and landscape in order to influence their development as a whole is one of the objectives of the more recently discussed grazing strategies (Holistic Planned Grazing—Savory and Butterfield, 1999; Targeted Grazing—Frost et al., 2012; Multi-Paddock Grazing—Teague et al., 2013; Circuit Grazing—Gregorini et al., 2017). One major tool to achieve animal impact on vegetation is concentrating large numbers of animals on defined and spatially limited areas of vegetation for a time-span long enough to achieve the desired impact by defoliation (feeding), trampling, and deposition of feces and urine. This concentration can be achieved by either narrowing the allotted pasture space for a given number of animals or by increasing the number of animals on a given space for the period of time until the desired effect is reached. The former can be achieved by dividing the available area into many small paddocks so as to achieve the stocking density needed to produce the desired effect, and then rotate to the next paddock. This is possible where enough capital is available for fencing, and where water and mineral resources can be provided easily in every

paddock. In many extensive grazing systems, however, fencing is not feasible at all and water and mineral resources are distributed unevenly (Legeard et al., 2014). Yet, even in most fenced systems, paddock sizes are so large that the existing herds are far too small to achieve the desired impact. In such circumstances, pooling herds into larger grazing mobs and herding these in a “strip-grazing” mode through existing paddocks is an option to employ livestock for shaping the environment. Strip grazing is commonly used in North American grazing systems to create firebreaks (Taylor, 2006), virtually eradicating all plant matter from the grazed strip. Pooling several smaller herds into a tightly bunched larger grazing mob herded jointly by several herdsmen has also been employed in Laikipia, Kenya, to remove standing dead biomass and induce fresh regrowth, to deposit dung and stimulate vegetation regrowth on bare patches, and to increase livestock performance (Odadi et al., 2019). In Corrientes, Argentina, (unattended) high intensity grazing was experimentally employed by Kurtz et al. (2016) and showed different effects depending on its timing throughout the year. In all cases, there was additional vegetation growth in autumn and the proportion of green biomass in the overall biomass increased over the following 12 months, but most prominently when high intensity grazing was performed in winter. Pooling animals on an organic Namibian livestock farm into three large (unattended) flocks and rotating them sequentially through all ranch paddocks following a grazing plan devised according to Holistic Planned Grazing principles permitted stocking rates of 45 kg livestock biomass per hectare (range 17–48). These stocking rates were well above those of neighboring farms and still permitted taking additional animals in for grazing during drought (Isele, 2014). At the same site, an on-farm experiment comparing the customary grazing regime with the increased stocking density indicated higher forage biomass production under higher stocking (Ludwig et al., 2019). However, stocking rates and densities tested were far off the high impact grazing approach of Kurtz et al. (2016) in northern Argentina. While scientists are on one hand rather critical to recommend larger scale adoption of such herding and grazing practices, they acknowledge the reported benefits and seek ways to integrate this into their range management concepts (Briske et al., 2011; Teague et al., 2013). Given the above, skillful herding may become a new livelihood option for the youth even if livestock production may be pushed onto ever more marginal rangelands in order to free space for cropping of plant-based human food. On the other hand, reluctance to utilize remote pasture areas, loss of herding labor and herding skills, and the resulting reduction of herding efforts may lead to persistently high animal numbers in socio-culturally and economically more attractive areas than those classically used for grazing (Altmann et al., 2018). In Gilgit-Baltistan, for example, two thirds of interviewed herders classified today’s conditions of alpine spring and summer pastures as poor and mentioned high animal numbers and short daily and seasonal walking distances as major reasons for the perceived degradation (Hameed et al., submitted). Much of the persistently heavy stocking was traced back to the unavailability of skilled herding labor, but also to time constraints and modern herders’ aspiration for leisure. Next to (the risk of) pasture degradation, such trends reduce overall

herd productivity and stimulate public criticism of pastoralism, all further fueling the erosion of (traditional) herd mobility and herding.

The difficulty of developing strategies to support the herding profession stems from the fact that its decline, as described above, is caused by a combination of different, location-specific factors. Therefore, there is no single solution, such as the formation of pastoral associations, that may effectively address the problem across regions (Fernández-Giménez and Estaque, 2012; Ulambayar et al., 2017). There are, however, a number of interventions, which, depending on local contexts, may be effective in reducing pressure on the herding profession and increase its attractiveness. Despite stereotypes of unruly movements and pastoral resistance to law and order, herding and large-scale herd mobility need a certain degree of effective governance and order to function properly (Haller et al., 2016). In agro-/pastoral areas experiencing rapidly expanding agricultural pressure, government support and on-the-ground protection of key pastoral resources is needed to enable mobility. If herd mobility is inhibited by insecurity or land use pressure, the productive benefits of herding decline relative to more labor-extensive forms of livestock rearing. Therefore, governments around the world are well-advised to pass legislations that aim at protecting pastoral resources such as movement corridors, water points, and encampment locations (Brottem, 2014; Hubert et al., 2014; Kitchell et al., 2014). Indeed, in its policy framework for pastoralism, the African Union (2013) has highlighted the need for pro-pastoral interventions, and several African countries developed policies to facilitate mobility at national and regional level (Bonnet and Héroult, 2011; Dongmo et al., 2012; AFD, 2014). What is less widespread is a consistent framework fostering local communities to develop land use agreements that accommodate herder-facilitated livestock movements to key pastoral resources at least on a seasonal basis (Kitchell et al., 2014).

Another promising approach to stimulate herding consists in the support of local mechanisms for labor sharing. These should not only include the recognition of customary forms of joint livestock management, but also increase the use and security of livestock entrustment and herding wage contracts. Livestock owners must feel secure when allowing their animals to be managed in distant pastures by someone else. In many places, more persistent and tractable ownership markings on animals will help the building of trust between herders and livestock owners. Information sharing about the locations of herds, as facilitated by mobile phone use, would help as well.

Overall, herding as a profession needs to be better remunerated with respect to alternative livelihood pursuits (LPV, 2007; Fernández-Giménez and Estaque, 2012; Legeard et al., 2014). Herding may not be abandoned because livestock rearing *per se* is not profitable, but because only a very low fraction of the profit is allocated to herding services (Aufderheide et al., 2013). Some herders reportedly state that they must steal from the owners’ livestock in order to support their families given their low wages. Livestock owners, on the other hand, recognize that effective wages are low, but also emphasize that they are

unwilling to compensate herders more fairly because they are stealing their livestock (Turner, 2009). Such situations require the development of institutions that secure ownership claims to livestock and develop adequate wage levels for employed herders (Aufderheide et al., 2013).

In many parts of the world, the current declines in herding as a profession are neither due to forced sedentarization and livelihood change, nor has there been a significant expansion of feedlots or ranching systems by governmental initiatives. Instead, traditionally mobile pastoralists themselves shift to such modes of livestock rearing because they currently perceive higher benefits in a world governed by “capital logic” (Schareika et al., 2020). To halt this trend, the multiple ecosystem services provided by skillful herding of domestic herbivores must be recognized and rewarded by society, not only by attributing an “intangible cultural heritage” label to herding, but by allocating tangible (financial) benefits. Furthermore, the recognition and appreciation of this profession as an ecologically important high-quality activity may also need to be assisted by professional training programs (Fernández-Giménez and Estaque, 2012; Jallet et al., 2014).

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CONCLUSIONS

Being based on in-depth knowledge and judicious utilization of ecological processes rather than on external inputs, the laborious task of skillful herding greatly contributes to the sustainable utilization of pastures, particularly in the world's marginal, semi-/arid and mountainous regions. Recognizing and rewarding its multiple ecosystem services, developing mechanisms and tools that make herding less strenuous and politically, socially and financially more secure and attractive, might at last slow down the erosion of this millennia old profession and livelihood strategy and at the same time promote sustainable rangeland and landscape management.

AUTHOR CONTRIBUTIONS

ES: conceptualization and initial writing. MT: contribution on mobility, labor, and policies. CH: contribution on grazing impacts on vegetation. AB: contribution on animal-soil-plant interactions and photographs. ES, MT, CH, and AB: final shape of manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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