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Review of Pastoralists' Resilience and Adaptation to Climate Change: Can Technology Help Pastoralists Mitigate The Risks?

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Abstract

In the changing environments globally, it is essential to look deeply into the effects of climate change on rangelands, pastoralists and livestock grazing, and into how the pastoralists cope with the climatic changes and challenges. There is a scientific rationale behind the pastoralists' adaptation strategies for coping with the climate variability. The present review-based paper explores how the rangelands and nomadic pastoralism are critical for grassland biomes and ecosystems. It is scientifically es tablished that the pastoralist lifestyles are not only most sustainable in present times but also most resilient, given the challenges of climatic variability. As the changing climates globally pose threats to grassland ecosystems and associated natural resources, pastoralists and their livestock are affected greatly by erratic weathers and changing availability of palatable biomass. Available literature proves that the pastoralist people hold much of the knowledge about how to adapt in hostile and varying climates. For example, the pastoralists adopt strategies such as rotational use of pasturelands, division of livestock, diversification of livestock, predicting rainfall and seasonal changes, and so on. In addition to understanding the resilience and adaptation strategies of pastoralists, present paper addresses how the technology might help nomadic pastoralists build their resilience on the face of climate change. This paper finally discusses the need to test various technologies in biological, ecological and anthropological contexts of the rangelands and pastoralism so that dying lifestyles and cultures of the marginalized nomadic people can survive in hostile climate change regime.

Keywords: Pastoralism, climate change, adaptation, resilience, rangelands, technology, livestock

1. Introduction

Researchers are now largely in agreement that pastoralism is uniquely well adapted to dryland environments. As an economic and social system, it operates effectively in conditions of low and highly variable rainfall while managing the intricate relationship between man and the natural environment (UNOCHA, 2007). Economists have recorded that the pastoralism in sub-Saharan Africa and Asian countries like Mongolia, Kyrgyzstan and Tibet is supporting national economies considerably through livestock production, thereby proving to be a viable lifestyle. However, in relation to climate change and changing rangeland ecosystems, the life and livelihoods of nomadic pastoralists and their livestock are increasingly affected. Pastoralists have demonstrated that they are only the one who can best adapt to the ramifications of climate change by means of over a dozen of localized coping strategies. The scientific communities and the world in general should know the scientific bases of such resilience and adaptation. Despite the known resilience of pastoralists, at times they are not found fully capable of coping and adapting to rapidly changing environments. With the degradation of pasture, the grazing time is reduced, which affects the livelihoods of nomads. Scientific evidences show that climatic shocks together with a decline in mobility will threaten pastoralists' survival considerably. The ability to make a living from animals is being affected by increasing drought, extreme cold, storms and reduced availability of vegetation for livestock herding. In such daunting situations, the potential technologies can help nomadic pastoralists build their extended resilience for adapting, mitigating or surviving the climate changes. Most important is the task of assessing the potential technologies that can be used by nomadic pastoralists to build their resilience for adapting, mitigating or surviving the climate change. In this assessment, the ecological imperatives and pastoralists' logic needs to be critical angles. There is huge investment in developing and studying the market-oriented science and technologies, leaving scanty space for dying lifestyles and cultures of the marginalized part of humanity. Therefore, it is of utmost necessary to invest in new breed of technologies required by the pastoralists to mitigate climate change risks.

This review-based discussion paper is aimed at galvanizing debates for reducing the risks and vulnerabilities of mobile pastoralists and for enhancing their resilience and coping capacities. Scientific and technological constituencies and institutions need to intervene on these aspects and help the most vulnerable and marginalized social groups mitigate the risks of changing environments. Obviously, the understanding and opinions may act as inputs for making or reforming policies guiding future of pastoral people and rangeland resources. The examples highlighted in this paper have been discussed mostly in African and Asian contexts.

2. Rangelands and Pastoralism: Why do the pastoralists matter?

It is believed that about half (6,700 mha) of the Earth's land surface is covered by the scant vegetation associated with natural rangelands . More of the land surface of the earth is used for grazing than for any other purposes (Reid, Galvin and Kruska, 2008). The land where most herding peoples and livestock make a living are characterized as open grazing lands, including savannahs, grassland, prairies, steppe and shrub lands (Neely, Bunning and Wilkes, 2009). These grazing lands cover 61.2 million km^2 or 45% of the earth's surface (excluding Antarctica), 1.5 times more of the globe than forests, 2.8 times more than cropland, and 17 times more than urban settlement (Næss, 2013). Explicitly, the grazing land covers 77% of Australia, 61% of Africa, 49% of Asia and 18% of Europe (Reid, Galvin and Kruska, 2008). Likewise, the dry and pastoral lands occupy over 70% of the Horn of Africa . This ranges from 95% of the total land area in Somalia and Djibouti, to more than 80% in Kenya (Government of Kenya, 2004), 60% in Uganda (WISP, 2007), and between 30-60% in Tanzania . Similarly, India's rangelands are estimated to be about 121 mha, about 18 mha of which lie in Hindu Kush region (Seth, 1997).

Grasslands–the basis for livestock production – cover about 70% of the global agricultural area (Næss, 2013). For instance, extensive pastoral production occurs in 25% of the global land area from the dry lands of Africa and the Arabian Peninsula, to the highlands of Asia and Latin America and the Arctic parts of Fennoscandinavia and Russia (Næss, 2013). The livestock is the fastest growing agricultural sector, and in some countries it accounts for 80% of GDP (Neely, Bunning and Wilkes, 2009). It is aptly estimated that more than one billion people depend on livestock, and 70% of the 880 million rural poor living on less than USD 1 per day are at least partially dependent on livestock (Neely, Bunning and Wilkes, 2009). In subSaharan Africa alone it is estimated that more than 50 million people live as nomadic pastoralists. Nomadic and transhumant pastoralists may number 100-200 million people globally .

If we see the distribution of pastoral communities, the pastoralists are found in many parts of the world, including Africa, Central Asia, the Arctic and southern & eastern Europe. The main livestock species kept by pastoralists are cattle, donkeys, goats and sheep, although they also keep, e.g., alpaca and llamas in the Andes, camels and horses in east-central Asia, the dromedary in Africa and West Asia, reindeer in northern Eurasia, and yak on the Tibetan Plateau (Reid, Galvin and Kruska, 2008). Distribution of pastoralist people depends on the geo-climatic conditions of different biomes in the world, and resulting adaptation of their animals to localized conditions. Essentially, the distribution of hoofed animals is subject to ecological constraints. For example, reindeer can only successfully be herded in the tundra, camels in the desert, and yaks only in high altitude regions. However, the adaptability of sheep, goats, and, to some extent, horses and cattle, are far greater, and for this reason the geographical distribution of sheep and goats is much wider (Khazanov, 1994). The sheep and goats are able to pasture in the same ecological zones, and they often graze together.

Scientific research demonstrates that pastoralists and pastoralism make significant contributions to local, national and regional economies. Researches of Simel (2009) and Hesse (2009) into African pas¬toralism show that pastoralism is considerably more productive per hectare than commercial ranching or sedentary livestock keeping in similar environmental conditions, and that the high productivity of livestock in pastoral systems not only supports millions of pastoralists but also contributes significantly to other sectors of national and regional economies. Economists have estimated that pastoralists produce 10% of the world's meat, supporting some 200 million pastoral households who raise nearly 1 billion head of camel, cattle and smaller livestock (Nori, Taylor and Sensi, 2008). Noticeably, compared to settled farmers in Africa, pastoralists produce 50-70% of all the milk, beef and mutton produced in the continent (Næss, 2013). Likewise, in Iran, while comprising only 1.5% of the total population, pastoralists keep 25% of the national herd (Næss, 2013).

Dyson-Hudson and Dyson-Hudson (1980) conceptualize nomadic pastoralism as the coexistence of dependence on livestock with spatial mobility. Chatty and Sternberg (2015) narrate that the nomadic or mobile pastoralism has long been a sustainable livelihood in a diverse range of countries because of herders' ability to move and manage risk in marginal landscapes where domesticated animals efficiently convert limited ecological productivity into sustenance. Pastoralists exert control over their animals based on their preferences for livestock's products they make a living of either directly, or indirectly, through the usage of products from domesticated animals (Spooner, 1973). In fact, the agroecological principle of enhancing crop-animal interactions is usually discussed at the farm level. But when zooming out to the territorial level the interaction between livestock and vegetation (be it cultivated or naturally occurring) is a principle that pastoral communities embody (Farming Matters, 2016). Extensive livestock grazing is an excellent example of managing biodiversity and soil

fertility. For example, through the transport of seeds and insects by livestock, the migration of pastoralists and their flocks supports habitat connectivity and biodiversity (Farming Matters, 2016).

Referring the above foundation, the pastoralism should be treated most often as an adaptation to semi-arid open country in which farming cannot be easily sustained without importing irrigation water from far distances. Pastoralism is usually the optimal subsistence pattern in these areas because it allows considerable independence from any particular local environment. When there is a drought, pastoralists disperse their herds or move them to new areas. Farmers rarely have these options. They suffer crop failure and starvation in the same situation. A pastoral subsistence pattern reduces the risk when there is an irregular climatic pattern . Other scholars believe that the pastoralism is a complex and sophisticated adaptation to environments marked by extreme variability in temperature and precipitation. Thus, the key to pastoralism is mobility, which permits temporary exploitation of resources that are not sufficient to sustain a human and herbivore population for an entire year . A host of features of nomadic life reflect the demands and costs of mobility and of dependence on herds of animals to convert the energy stored in grasses to the milk and meat that feed the human population. Such societies commonly develop a conscious and explicit nomadic ethos, which values mobility and the ability to cope with problems by moving away from threats or toward resources and which disparages permanent settlement, cultivation of the earth, and accumulation of objects .

3. Inherently Resilient Lifestyles of Pastoralists

The pastoral communities across the world have developed their own ways of adapting to the highly variable geophysical, climatic and biotic conditions of rangeland areas over thousands of years (Shaoliang and Sharma, 2009). Mobile livestock grazing, for example, is a traditional mechanism developed by herders to cope with changes in the availability of water and grass at different places and times induced by climate variability. It is well documented that pastoral practices have always adapted to new and threatening challenges and found an outlet to cope with mounting constraints (Kreutzmann, 2013). Subsequenty, the Intercooperation (2006) found that aridity is not a limiting factor in livestock rearing and that communities in more arid regions are more dependent on livestock production. Basically, this reflects the embedded resilience the pastoralists have in their lifestyles. The production systems of pastoralists also seem quite resilient to adverse conditions. But, Næss (2004) notices that the production system of pastoralists can be highly variable and unpredictable and nomadic pastoralist in Tibet have, in response, adopted a number of flexible livestock production strategies and other subsistence strategies that minimize risks. Apparently, Tibetan nomads have dealt with blizzards and cold weather for thousands of years (Goldstein and Beall, 1990; Miller, 1998; Miller, 2000).

McCabe (1997) writes that pastoral management strategies are best understood as rigged towards risk aversion rather than strategies that emphasize maximization. Galaty and Johnson (1990) have put it in the words: “The essential pastoral strategy is probably neither maximization nor optimization, but risk aversion, which is an attempt to decrease uncertainty by anticipation. Domestic security is increased through creating alliances across ecological zones, distributing livestock among friends, securing rights in dry season pastures, increasing herds in anticipation of future losses. Short term tactics include punctuated movements to take advantage of new grass, depriving humans of milk to feed calves, or keeping animals within the home to increase security.” White (1997) explains that pastoralists have evolved strategies that aim instead to absorb risk through adaptive management. Therefore, pastoral strategies are not viewed so much as directed towards maximizing animal numbers, but rather directed primarily towards securing a predictable food supply in a highly unpredictable environment (Næss, 2004). Roe, Huntsinger and Labnow (1998) argue: “[…] that the central concern of pastoralist is to manage a predictably unpredictable environment better, so as to establish a reliable flow of life-sustaining goods and services from rangeland ecosystems that are in fact an endogenous part of their production system.” Furthermore, labour sharing between pastoral families during periods of stress is a form of social safety-net that can carry vulnerable families through drought and flood events (Kirkbride and Grahn, 2008). Plainly speaking, the pastoralists are believed to be the experts at maximizing the use of rangelands, a capability demonstrated by numerous research studies (UNOCHA, 20007). For example, studies by Cossins and Upton (1987) showed that the Ethiopian Borana pastoral system had higher returns of both energy and protein per hectare than industrialized ranching systems in Australia (Scoones, 1995). Ranches in Australia produced just 16% of the energy, whereas Borana system produced 30% of the protein per hectare. Other research shows similar results for collective use of pasture in countries such as Zimbabwe, Kenya and Botswana. According to Homewood (2009), the pastoralists are only able to utilise marginal lands and they take only temporary advantage of richer areas with high rainfall, high nutrient forage or both.

4. Climate Change and its Effect on Pastoralism

Global climate change caused by the accumulation of greenhouse gases in the atmosphere is an accepted reality. Hulme et al. (2001) analyzed future rainfall changes for three African regions–the Sahel, east Africa and southeast Africa–to illustrate the extent of differences for these regions and to place future modeled changes in the context of past observed changes. Although model results vary, there is a general consensus for increased rainfall in east Africa, drying in southeast Africa, and a poorly specified outcome for the Sahel.

The scientists are also predicting an increase in variability and extreme events as a result of warming (UNOCHA, 20007). Under the most rapid global warming scenario, increasing areas of Africa will experience considerable changes in summer or winter rainfall. Large areas of equatorial Africa will experience increases in December-February rainfall of 50–100% over parts of eastern Africa, with decreases in June-August rain over parts of the Horn of Africa (Desanker and Magadza, 2001). While pastoralist mobility may give some resilience to climate change, the climatic shocks together with a decline in mobility will threaten pastoralists' survival considerably.

Undoubtedly, the grassland ecosystems and the livestock they support are highly vulnerable to climate change impacts (ADB, 2013). In such ecosystems, the main documented climate change impacts are (i) decreasing pasture biomass; (ii) intensifying pasture degradation and desertification; (iii) increases in harmful insects, locusts, and rodents; and (iv) loss of biodiversity and rare species. Moreover, the decrease in food abundance and extreme cold temperatures lead to lower productivity and higher mortality rates of livestock. The direct impacts of climate change on the Himalayan rangelands, for instance, are observed in the form of evaporation and runoff, changes in vegetation composition and diversity, changes in above-ground productivity, changes in decomposition rates, changes in carbon sequestration effects, increased risk of fire disasters, drying-up of wetlands/peatlands, drowning of pastures close to glacier lakes, and changes in wildlife habitats (Shaoliang and Sharma, 2009). As a matter of fact, the natural vegetations of pastoral rangelands are very sensitive to rainfall variation, and thus the nomads are almost the first community that realizes the impact of drought as forage deficits (Tahmasebi, 2012). So, the climate change is affecting pasture quality and water resources and disrupts the rural landscape (Chatty and Sternberg, 2015). As a consequence, the ability to make a living from animals is being affected by increasing drought, extreme cold, storms and reduced availability of vegetation for livestock herding (Chatty and Sternberg, 2015).

The impact of climate change on vulnerability of pastoral nomads is increasingly being acknowledged by many scholars (Galvin, 2009; Birch and Grahn, 2007; Tahmasebi, 2012). Kirkbride and Grahn (2008) lament that the pastoralists, who inhabit the drylands or high altitudes, are among those who live with the effects of climate change. Scientists generally argue that pastoralists have been managing climate variability for millennia. However, the unprecedented rate and scale of human-induced climate change is beginning to pose more problems. For example in Oman, a 0.6 °C annual temperature increase and 21% decrease in precipitation from 1990 to 2008 have intensified water scarcity and increased evapo-transpiration in the pastoral interior of the country, resulting in catastrophic storm episodes and reduced ecological productivity (Chatty and Sternberg, 2015). Similarly, Mongolia has experienced a 2 °C warming trend since 1940, recurrent drought, changes in precipitation and in seasonality, and reduced water sources (Chatty and Sternberg, 2015). The 2010 zud (extremely harsh winters) resulted in the death of approximately 8.5 million livestock or 20% of the 2009 national herd in Mongolia. As many as 770,000 herders were affected of which 43,500 were left without a single animal and 164,000 lost more than half of their livestock (National Statistics Office of Mongolia, 2010 cited in Vernooy, 2011). Nomadic livelihoods, which fully depend on the weather, are becoming increasingly vulnerable as a result (Vernooy, 2011).

Climate change impacts reported by herders of Mongolia (ADB, 2013) include (i) increased frequency of freezing winters and droughts; (ii) decreased precipitation; (iii) earlier melting of snow cover; (iv) drying up of lakes, rivers, and springs; (v) decrease in the number of pasture plant species; and (vi) decreased biodiversity. Likewise, Saami reindeer husbandry in Norway is characterized by environmental unpredictability and occasionally harsh winters can have dramatic negative effects on reindeer population densities (Næss and Bårdsen, 2010). Some areas of Tibet Autonomous Region lost 70% of their total livestock population in 1998, which was estimated over 3 million heads of livestock (Næss, 2004). In Tibet, Aru nomads' animals are greatly affected by random, unpredictable and uncontrollable ecological factors, especially blizzards, but also the cumulative effects of snow and poisonous grass (Næss, 2004). Wang et al. (2014) have discovered that warmer climate is favourable for winter rangeland pests, which are poisonous if ingested by livestock. Their survey shows that herders in Luoma Town of Tibet are the most exposed to rangeland pests, as 24 households were affected and 7 heads of yak died in year 2011. Also in the winters of 1997 to 1998, tens of thousands of herders in Nagqu County suffered heavy livestock losses because of severe snowstorms (Wang et al., 2014). Dry regions face further acute effects of erratic rainfall and water/food scarcity. The uncontrollable ecological factors change from year to year, and cause decrease in herds so as the pastoralists function in a non-stable manner (Goldstein et al., 1990; Miller, 1998). As Hurst et al. (2012) observed the Boran pastoralists of Ethiopia, as a result of changing climate, travel significantly greater distances to reach pasture and water. Traveling greater distances also places extreme caloric demands on cattle and exposes them to disease. Livestock walk farther for food and water, and may expend more energy than they consume. They may also travel from areas that are disease-free to areas where disease is endemic (Hurst et al., 2012). There are social impacts too associated with the changing environments. In this context, the Indigenous Peoples of Africa Coordinating Committee (IPACC) explains that rural African women often bear the brunt of climate change impacts, including lack of food, water and energy sources increased instances of illness and the resultant stress on the family. This often results in domestic violence and the lack of resources to deal with daily needs (Marais, 2011).

With the degradation of pasture, the grazing time is reduced, which affects the livelihoods of nomads. For instance, there happens a severe fodder shortage in winter and spring in Wasai of Dalag County, Tibet (Jianzhong, Yingying and Yili, 2011). The impact of rangeland degradation further aggravates by synergistic effect of impeding climatic change in vulnerable and fragile ecosystems (Maiti et al., 2014). So, the effects of degradation and climate change needs to be seen synergistically.

5. Herders' Adaptation to Climate Change

Shifts in weather patterns, seasonality of precipitation and recharge of sub-surface water sources are vital to the viability of herding (Chatty and Sternberg, 2015). According to Chatty and Sternberg (2015), the ability to obtain adequate fodder to fatten animals in harsh hot or cold landscapes is the endemic challenge. Nevertheless, the pastoralist people hold much of the knowledge about how to adapt, such as where to find water during droughts (Marais, 2011). Marais (2011) also documented that nomadic pastoralists of Africa traditionally cope with drought through a variety of practices, such as: (1) Rotational use of pasturelands, which allows pasture to recover after intense grazing; this recovery period is becoming harder to secure as more farmers move onto traditional lands; (2) Division of livestock: only the strongest animals are taken on longer migrations; (3) Raising different types of livestock (such as cattle and goats), which have different grazing habits and reduce herders' risk of losing all their animals to one disease; (4) Traditional knowledge of rainfall and seasonal changes.

Certain cases of adaptation are highlighted here. The harsh winter provides the greatest challenge to pastoralists of Mongolia. Catastrophic storms, coming in midwinter or at the spring lambing season, wipe out entire herds or severely reduce their numbers. So, as part of adaptation strategies, the herders move to special winter campsites, and they reduce the size of the herd by slaughtering, in late fall, of animals that are thought unlikely to survive the winter . Recent research on resilience in the Mongolian pastoral social-ecological system has found that "storage" (animal fat and/or weight gain, hay, fodder, and grazing reserves) was a crucial adaptation strategy (ADB, 2013). Flexibility in the social organization of herders, movement patterns, and livestock management practices (such as controlling livestock reproduction rates and timing, or selling livestock before the winter to reduce feed amounts and costs) were also identified as strategies employed by herders with lower livestock mortality rates (Altanbagana and Chuluun, 2010). Wang et al. (2014) conducted studies in Nagqu County, a remote area of the northern Tibetan Plateau of China, and observed that local herders have developed various adaptation strategies, such as planting forage grass, buying fodder from the market, renting pastures, joining formal or informal cooperatives, and diversifying their livelihoods.

Further, Maiti et al. (2014) have recoded 10 different types of coping mechanisms adopted by Brokpa pastoralists in western Arunachal Pradesh of India. Such mechanisms are: (1) proliferation of yak-cattle hybridization; (2) migration to higher altitudes; (3) duration of migration being expanded by 2-3 months; (4) change in timing of migration; (5) herd diversification; (6) change in pasture utilization practice; (7) rejuvenation of degraded high altitude pastures; (8) feed supplementation; (9) adopting livestock healthcare practices; and (10) searching of alternative sources of income. V&A Program (2009) has also recorded in India that the livestock keeping is more tolerant to heat stresses and dry spells than other agricultural livelihood activities. Similarly, Tahmasebi (2012) investigated that Shahsevan pastoralists of Iran adjust their herd size or grazing period to the variation of rangeland vegetation based on prevailing and rapidly changing climate conditions. The Shahsevan are able to delay their arrival to the mountain pastures and allow the vegetation to mature enough by utilizing the intermediate pastures for days or even weeks (Tahmasebi, 2012).

Sometimes the pastoralists change their lifestyle too in a bid to cope with the climate change. Marais (2011) quoted Aboubakar Alabachir, a camel herder from Niger, speaking of his experiences and how recent droughts have impacted traditional practices: "Droughts have caused our community to shift from year-round pastoralism to agro-pastoralism, in which we rely on herding for only part of the year and practice subsistence farming during the rest. This has increased food security and has been a positive adaptive strategy. Our community has also changed the herds to more drought-resilient types of camels." In continuation of such observations, Hurst et al. (2012) have documented the weather prediction strategies of Boran pastoralists of Ethiopia. They found that traditional system of weather prediction includes a variety of techniques: reading livestock intestines; locating and identifying specific species of plants that are in leaf or flower; and interpreting astrological signs. Luseno et al. (2003) also described probabilistic forecasts, use of indigenous climate forecasting methods. By Boran pastoralists of Ethiopia, the regions are designated as wet season grazing areas and dry season grazing areas. The dry season grazing areas tend to be areas of relatively lower elevation where water accumulates, thereby allowing pasture growth even in the absence of significant rainfall (Hurst et al., 2012). In times of drought, kallos are used to mitigate, to an extent, the distances that weaker animals have to travel for pasture. ILRI (2000) has documented that the distance trekked by livestock for water sources is almost tripled during drought occurrence. Key resource areas that are set aside during the rainy season are also used up during the drought.

Interestingly, the pastoralists assess the importance of forage plants on the basis of their availability during scarce seasons and not according to their land cover or watershed management potentials (Drees et al., 2010 cited in Kerven et al., 2011). A study in the Wakhan mountain region of northern

Afghanistan noted that agro-pastoralists may anticipate feed shortages by increasing the quantity of feed stored or destocking, especially when fodder production competes with food production for families' subsistence (Kreutzmann, 2003). Notably, as a response to the degradation of pastures, the nomads have employed other strategies, such as renting pasture, providing supplementary feed, and diversifying their livelihoods (Jianzhong, Yingying and Yili, 2011). Eventually, local strategies adopted by nomads can provide valuable insights into ecological restoration and livelihood improvement in the region and suggest changes to means promoted by local government (Jianzhong, Yingying and Yili, 2011).

6. Adaptation through Livestock Management

According to White (1997), "pastoralists attempt to maintain a herd whose size and age/sex structure will enable them to withstand the vicissitudes of risky conditions." Keeping multiple species can have some advantages: herds tend to be more stable, and permit a wider use of pasture. Multi-specialization can, therefore, be viewed as a risk reducing strategy. For example, yaks can survive longer than sheep and goats when the grassland is covered by snow. Furthermore, a blizzard kills yak in the course of one night than it kills sheep and goats (Næss, 2004). On the contrary, Lybbert et al. (2004) have observed that when herd size falls below a certain threshold in pastoralists systems, the transhumant livelihoods cannot be maintained.

Examples of such adaptation are plenty. Goldstein and Beall (1990) recorded that the composition of herds from the western parts of Tibet to the eastern parts changes depending on the quality and quantity of vegetation. For the Bhotiyas of Kumaon (India), environmental uncertainties have changed the distribution of economic production. The extreme conditions of the high altitude and the meagre available resource base has forced these pastoral people to evolve strategies for the optimal management of their resources (Ives and Messerli, 1989; Farooquee, 1998). According to Farooquee (1998), to better manage their huge herds, the sheep and goats were divided into three categories – those used for procreation, for wool production, and as pack animals – in terms of care and attention given to the animals. The first category of these animals received the utmost care; they were generally kept indoors during rain and snow. They were also fed the most nutritive grasses and most aromatic plants in the pastures. These animals were not confined to one place in the pasture for a long time. Consequently, the second and third category got less care and attention. They produced and maintained the breeds of livestock which yielded more income and were more economical to maintain (Farooquee, 1998).

In the same way, East African pastoralists manage their herds in dry spells through changing herd diversity and herd size, and herd splitting and maintaining of female-dominated herds (WISP, 2007; ILRI, 2000). Hurst et al. (2012) have reported changes in animal husbandry practices the Boran pastoralists maintain during the droughts: (1) herd mobility is maintained to ensure that herds can find pasturelands not decimated by drought; (2) certain traditional communal grazing areas are not utilized for a season to provide extra nourishment for sick, young, and lactating animals in times of scarcity; (3) sick animals are isolated from healthy animals to prevent the spread of disease; and (4) animal injuries and diseases are treated using local knowledge. Thus, the practice of supplementation of livestock grazing with other feeds is common during droughts (Kirkbride and Grahn, 2008).

7. Diversification and Mobility as Adaptation Strategies

Strategies for countering unpredictability and variability within a pastoral production system can be grouped into four basic categories, namely (a) diversification, (b) mobility, (c) physical storage and (d) exchange. Diversification is where the underlying principle is that by broadening the base of subsistence system, either by using a wider range of plant and animal species or by exploiting broader and more varied areas (i.e. niches), reduces the risk of catastrophic shortages (Næss, 2004). Also, species diversification reduces the danger of losing an entire herd from one disease (White, 1997). Næss (2013) highlights that mobility is used to manage resource variability, for example, during droughts where pastoralists have moved from affected areas to unaffected (or less affected) areas.

Due to the warmer temperatures and increasing precipitation in Qinghai-Tibetan Plateau, the mobility of herders has increased as part of pastoral risk management strategies (Næss, 2012). Likewise, as the landscape in southern Ethiopia has become drier, the presence of drought-tolerant livestock has increased. Currently, proportions of different types of cattle in Boran herds are being reduced compared to goats and camels, which are more drought-tolerant and disease resistant (Hurst et al., 2012). Thus, livestock diversification has become one of the most universally adopted coping mechanisms in Borana territories. Nearly all Boran pastoralists have multispecies herds that include goats, with increasing numbers of herds adding camels (Hurst et al., 2012).

8. Technology Usage by Pastoralists for Risk Mitigation

Using the technologies to reduce the impacts of climate change has been reported sporadically. Not many studies exist on this aspect. Waters-Bayer and Bayer (2016) have reported that pastoralists now use mobile phones to obtain information about conditions for moving herds: weather, pasture and water availability, disease, conflict along trekking routes. They are reported to stay in touch with family members and herders in their base and mobile camps, and can make herd management and marketing decisions from a distance. Mobile phones are supposed to help pastoralists grasp new market opportunities, e.g. in camel meat and milk (Debsu et al., 2016). In Kenya, a study recorded that 93% of Maasai

herders rely on cell phones for some aspects of pastoral work (Butt, 2015). In Mongolia, about 90% of the herders use cell phones and almost as many have small solar panels to recharge the phones and provide electricity for light, radio and TV. The Mongolian Government supports the spread of such solar power units throughout the rangelands (Hay, 2015). Safaricom-promoted M-Pesa is believed to have facilitated money flows for the vast majority of pastoralists in Kenya who do not have bank accounts (Reinke and Speradini, 2012). In developed countries, the pastoralists use motor vehicles for transporting their animals, feed, meat, etc. (Waters-Bayer and Bayer, 2016). In Chad, for example, groups of pastoralists use mobile phone to communicate information of birth, death and health status of the people and the herds (Jean-Richard et al., 2014). Kenya herders are reported using geo-localized app and making the satellite-based forage maps more precise (Steele, 2015). Herders of Europe are reported developing their own GIS-based monitoring system so that they can adjust herd movements to avoid dangers and take advantage of better pastures along migration routes (Maynard et al., 2008). It is reported that Mongolian and Kenyan pastoralists are assessing vegetative cover using satellite data to apply for insurance of livestock (Little and McPeak, 2014; Chelangʻa et al., 2015). Digital identification of animals, as applied in Botswana and Uruguay (Mooketsi, 2013; Davies, 2014), have largely failed due to complex computerized technology and its inadequate availability; however, the application of digital technology was attempted there too.

Technologies no doubt have influence in 21st century on the pastoralists as well. But the promoters of technologies and development agencies want more to exploit resources and economic benefits than to help the herders in mitigating the risks of climate change. For example, the application of hi-tech in extractive industries and irrigated farming in parts of the rangelands is depleting non-renewable resources and ousting pastoralists from strategic grazing areas, thus threatening the entire pastoral system. Often, the external investors can profit from extractive industries or irrigated farming for only a short period, until the resources are depleted or the high production cost or environmental damage ends the venture (Waters-Bayer and Bayer, 2016). But in that short time, they can destroy the resource use system that pastoralists have used in the larger area for generations (Waters-Bayer and Bayer, 2016). The scholars further argue that potentials of hi-tech must be seen through the lens of pastoralists. The hi-tech world tends to hubris: as if technology can solve all problems. This mindset does not fit pastoral logic (Waters-Bayer and Bayer, 2016). The pastoralists have recognized some hi-tech innovations that can support them in deciding about herd movements, managing animal health and marketing pastoral products. So far only the cell phone usage has proved to be useful and easier for pastoralists in many corners of the world. Rests of the technologies need institutional inputs and complex training before making use of it.

9. Need of Using Technology for Mitigating the Climate Change Risks

Despite the pastoralists' adaptation to the dryland conditions and their ability to make economic contri¬butions in spite of very harsh conditions they oper¬ate under, the pastoralists' resilience to climatic shocks is decreasing and their vulnerability is increasing. Unfortunately, simply changing traditional migration patterns as a means of coping with climate change will not mitigate all of the climate change-related risks. Migration over extremely large distances exacerbates the negative energy balance of the cattle in the region, an imbalance that can be compounded by exposure of naïve populations to novel disease. In the short-term more cattle will survive, but in the long-term more cattle will perish (Hurst et al., 2012). This is due to poor mitigation and adaptation strategies put in place during extreme droughts, which are aimed at saving human lives but which have no focus on livestock as the main asset for the survival of pasto¬ralists. The vulnerability of pastoralists is being exac¬erbated by their marginalization from policy proc¬esses, brought about by their lack of knowledge and capacity to engage in such processes and by power imbalances (Simel, 2009). In such grim situations, can the technology help pastoralists improve their adaptability, resilience and mitigation abilities?

Marais (2011) articulates that there is a huge need to understand how local communities organize themselves and use the knowledge they have built over generations for coping with the impacts of climate change. She quoted Indigenous Peoples of Africa Coordinating Committee (IPACC) speaking in a panel of United Nations Framework Convention on Climate Change (UNFCCC) that the need for better understanding of the scientific information on weather and climate to help them make better management choices as the system changes in unprecedented ways (Marais, 2011). World Meteorological Organization's Global Framework for Climate Services stresses that it's not enough to provide climate information; it needs to be accurate, easy to understand and accessible. There must also be ways for pastoralists to give feedback on the usefulness of information and whether it has improved their livelihoods (Marais, 2011). Næss (2012) suggests, "to increase our understanding of climate change-related effects on pastoral adaptations, satellite-based measures directly linked to both vegetation characteristics and climatic variables should be utilized in future studies rather than, for example, overall changes in precipitation and temperature". Marais (2011) further stressed on building the links between traditional knowledge and adaptation and strengthen the two-way information exchange between pastoralists and the meteorological sector. She argued that much of this information is already documented in the form of climate diaries where community members record their observations, existing weather records and local oral histories of traditional knowledge. Such recorded information may be shared on

websites and portals. However, making this information easily accessible to pastoralists and supporting dialogue for meaningful feedback from both groups is an ongoing challenge (Marais, 2011). Simultaneously, the leaders of Boran pastoralists in Ethiopia informed that the younger generations of Boran are more adept in interpreting external information and that government and NGOs have been attempting to implement more and better warning systems. They expressed that the information on these warning systems is valuable, but sometimes difficult to understand (Hurst et al., 2012).

Hurst et al. (2012) studied how the Boran pastoralists in Ethiopia used, and could potentially use the information and communication technologies (ICTs). Some of Boran pastoralists use the cell phone for gathering information on markets, locating pasture and water for cattle, knowing conditions of pastures and water sources, communicating with satellite camps, locating lost cattle, and communicating with traders (Hurst et al., 2012). Internet and weather forecasting information are not comfortably used by elder generation of these pastoralists. Hurst et al. (2012) further noted that the weather, pasture, and water reports by radio or distribution of satellite imagery local officers may be an avenue for disseminating information. As access to the internet increases via USB wireless modems, the use of ICTs can be helpful in accessing up-to-date information on demand. Shaoliang and Sharma (2009) point out that the pastoralists need to be helped understand what is happening so that they can identify possible solutions and make adaptive efforts.

10. Conclusion

There are technologies being pushed to tap the production systems of pastoralists as well as to increasingly enclosing the rangeland resources; yet, the extractive push of technologies lacks an ecological and anthropological rationale with appropriate scientific grounds. Documentation of existing usage of technologies (e.g. cell phones) by nomadic pastoralists in various ways for assessing, adapting, mitigating or surviving the climate change would assist in understanding the technological interface with the pastoralist communities and the ecological edge of the applications.

11. Recommendations

Various technologies that may have potential in context of nomadic pastoralists could be: (1) Mobile Phones and Apps; (2) Early Warning & Weather Forecasting Systems; (3) Radio; (4) Geospatial Information Technology (GIT) such as participatory mapping & GIS (institutional use), participatory 3 dimensional modeling (institutional use), GPS technology (individual or institutional use), Google Earth mapping (institutional use), cyber tracker (individual or institutional use); (5) Internet-Based Platforms (institutional use) like rangeland observatory and pastoralists' networking platforms; and (6) Technologies for Veterinary Care. Additionally, there is pertinent need to understand and correlate the ecological edges of climate change impacts where technology might help understand/measure. Following critical aspects should be considered as the ecological edges: (i) Changes in density, species composition and abundance of palatable plants in rangelands; (ii) Occurrence and distributions of succulent and medicinal plant species; (iii) Changes in habitats, landscapes, soil, productivity, etc. of rangelands; (iv) Changes in weather, precipitation, and ice melting; (v) Extent of water availability and distribution of water holes; (vi) Connectedness of groundwater aquifer with water bodies; (vii) Zonation of rangeland territories based on occurrence of pathogens and parasites; (viii) Changing nature of glaciers and ice melting phenomenon; and (ix) Changing movement patterns of wildlife causing damage to livestock. With selective and appropriate technological interventions, the scientific community needs to act to help the nomadic pastoralists in fragile rangeland ecosystems while addressing the critical requirements of suggested ecological edges.

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