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Review

Tanzanian rangelands in a changing climate: Impacts, adaptations and mitigation

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ABSTRACT

Livestock are central to the livelihoods of Tanzanians who rely on them for income via sales of milk, meat, skins and draught power. Owning livestock is amongst the ways in which many Tanzanians could diversify their risks, increase assets and improve their resilience to changes in climate. Though local coping strategies can deal with shocks in the short-term, they are hardly able to cope with more frequent and severe climate events. Observably, temperature, rainfall and atmospheric CO_2 concentration interact with grazing and land cover change to influence rangeland quality and composition. Increased temperature increases drought stress and tissue lignifications in plants and, consequently, affects their digestibility and decomposition rate. Increased temperature and lower rainfall also increases vegetation flammability resulting in a shift in species composition due to increased fire frequency. Literature indicates that, Tanzania rangelands receiving between 400 and 1000 mm of rain per year (e.g. Kongwa, Monduli, Kiteto, Simanjiro, Ngorongoro, Babati, Hanang, Mbulu and Karatu) have greatest impact on climate change on surface drainage. A 10% drop in rainfall of 1000 mm per year in a rangeland results in a decline in surface drainage of only 17%, while in areas of 500 mm per year will result in a 50% decline. Interventions such as controlled animal stocking rates, sustainable yield and use of good pasture will lessen the negative impacts of climate change on rangelands. Opportunities for reducing greenhouse gas emissions on rangelands include maintaining or increasing carbon sequestration through better soil management and reducing methane production by altering animal management practices on rangelands. There is a need to focus on enabling herd mobility through securing better access to water resources, land use planning, and improve early warning systems and supporting a diversification of livelihoods.

Keywords: Kongwa ranch, livestock, rainfall patterns, Maasai, surface drainage.

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INTRODUCTION

Importance of rangelands in Africa, East Africa and Tanzania

Africa's rangelands, covering 43% or nearly 13 million km^2 of the continent's land surface, are comprised mostly of the woodlands or shrubs and grasslands (Thornton et al., 2006). Although a significant amount of livestock production also occurs within the agricultural lands, the land use is more pronounced in the rangelands. More importantly, the composition and productivity of rangelands are influenced primarily by rainfall, fire and grazing and are associated with changes in temperature and the concentration of atmospheric CO_2 over longer time (Fischlin et al., 2007). Literature also narrates that a wide range of land use systems governed by complex land tenure arrangements affect Africa's rangelands.

In East Africa, thousands of pastoralists herd their livestock in the semi-arid to arid areas. Climate analyses suggest that there have been highly differential impacts of climate change (Thornton et al., 2002). For instance, parts of East Africa have become drier, with considerable reduction in the length of the growing season. Meanwhile, other areas such as southern Kenya and northern Tanzania are becoming wetter, with increases in the

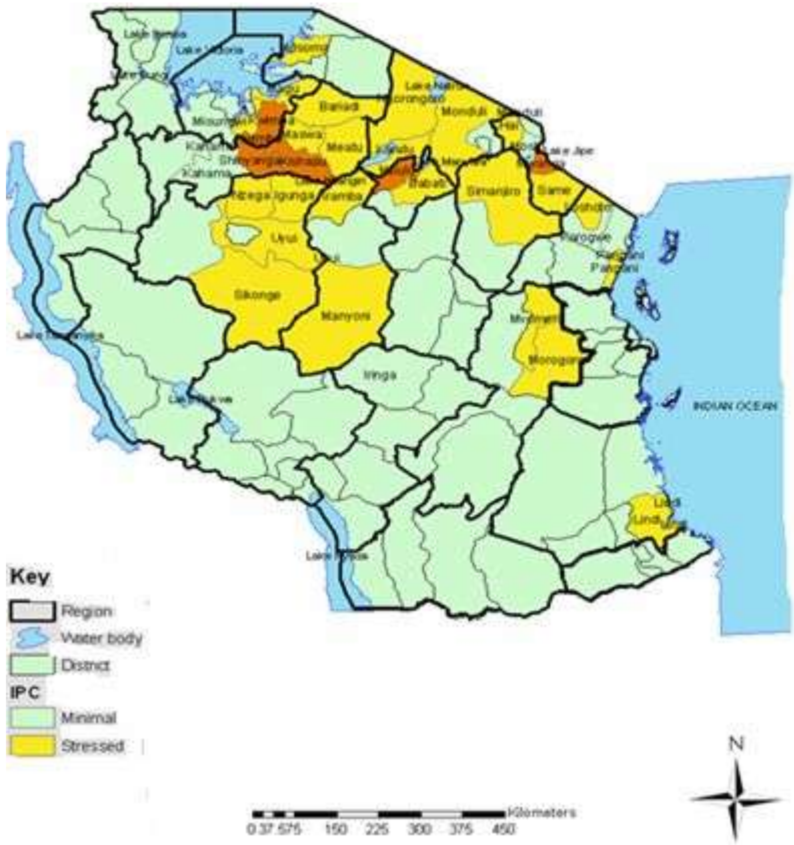

Figure 1. The areas affected by climate change associated with pastoralism in Tanzania. Source: Economic Survey 2012.

length of the growing season. This variability has made fundamental changes to ecosystem structure and function which in turn affect human land-use and livelihoods. This situation potentially makes these populations more vulnerable to climate change. It shows that East African rangelands are generally heterogeneous, due to spatial gradients of climate, soils, landscape and disturbance as narrated by Coughenour and Ellis (1993). Furthermore, literature have documented that rainfall is erratically distributed in arid than in mesic systems, highlighting that adequate rainfall from year to year cannot be assumed for a given location (Ellis, 1994).

Tanzania is endowed with a livestock resource and ranks first in the SADC and East African Communities (EAC) and third in Africa in terms of cattle population. The estimated livestock population amounts to 19.5 million cattle, 13.8 million goats, 3.7 million sheep and 45 million indigenous chickens (Economic Survey, 2011; Tanzania National Census of agriculture, 2012). Meanwhile, rangeland resource is estimated at 61 million hectares of which about 44 million hectares are for grazing and 17 million hectares are fallow and forestland. This resource is currently supporting about 17 million tropical livestock units (TLU). Evidently, distribution and ownership of livestock is highly skewed with about 70% of the herd being concentrated in eight administrative regions including, Shinyanga, Mwanza, Singida, Mara, Tabora, Arusha, Manyara and Dodoma. These areas are stressed by accrued number of livestock, including the areas in which the pastoralists tend to shift and occupy as shown in Figure 1. The dominant pastoral tribes include the Maasai, Gogo, Taturu, Barabaig, Sukuma, Iraqw and Kaguru.

The livestock enterprise generates over one-quarter of agricultural GDP. Approximately 98% of the livestock industry belongs to traditional (small) owners, with some ranches constituting the remaining 2%. The ranches include Kongwa (37,682 ha), Kalambo (64,560 ha), Kitengule (41,700), Mzeri (41, 296 ha), West Kilimanjaro (36,350 ha), Mkata (74,295 ha), Misenyi (40,857 ha), Dakawa (53,600 ha), Manyara (17,951 ha), Uvinza (56,175 ha), Kikulula complex (76,940 ha), Usangu (43,725 ha) and Ruvu (56,170 ha) under the National Ranching Company (NARCO).

Livestock are central to the livelihoods of Tanzanians who rely on them for income from sales of milk, meat and skins, draught power and manure, amongst other uses. In that case, owning livestock is amongst the ways in which many Tanzanians are able to diversify their risks,

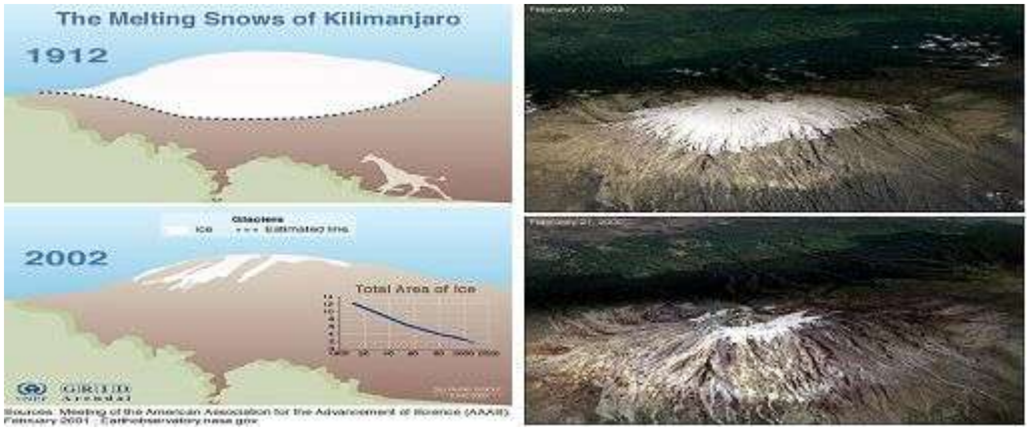

Figure 2. The melting of glacier in Mount Kilimanjaro. Left: 1912-2002, Right: 1993-2000.

increase their assets and improve their resilience to sudden changes in climate, diseases outbreaks and unfavourable market fluctuations. Furthermore, evidence from Vice-President's Office (2007) reveals that the severe droughts hit most parts of the country in 2009, leading to severe food shortages, massive loss of livestock, water scarcity and acute shortage of power signify the vulnerability of the country to impacts of climate change.

This paper therefore analysed various literature on the impacts and management measures against climate change. The paper analyses the implications of these impacts to the health and sustainability of rangelands, a lesson to inform policy in Tanzania.

Overall climate change indicators in Tanzania

Overview

Tanzania being the largest, most populous, and poorest country in East Africa is likely to feel the impacts of climate change more than the rest. Diverse climatic conditions, corresponding to the country's varied topology has masked considerable variation at the sub-national level. As for other countries, Tanzania will continue to suffer from effects of climate change in terms of changes in temperature, rainfall patterns, the frequency and intensity of extreme weather events (and conditions) including sea-level rise.

Temperature rise

According to a study commissioned by the Government of Tanzania, global warming is expected to raise mean annual temperatures by 3 to 5°C, and average daily temperatures by 2 to 4°C by 2075 (Vice-President's Office, 2003). Meanwhile, a report by the Organisation for Economic Cooperation and Development (OECD) is somewhat more conservative, predicting an average annual increase of 2.2°C by 2100 (Agrawala et al., 2003). Both studies agree, however, that the rise in temperature will be greater during cooler months (June to August) than warmer ones (December to February). The research also points out that increases will be most marked in central and western regions, where temperatures may rise by up to 4°C and less striking in north-eastern areas, where there may be a warming of up to 2.1°C. Arguably, the most iconic indication of climate change is the glacial retreat that has been observed on Mount Kilimanjaro. Figure 2 illustrates the decline in the volume of ice at the mountain's summit between 1912/1992 and 1993/2002. It projects that if current trends persist, the glacier may disappear entirely by 2025. That means there will be considerable implications for the local ecosystem, which provides critical water services and supports the livelihoods of over a million local inhabitants and livestock in the western semi arid plains of Kilimanjaro.

Rainfall patterns

Rainfall predictions are less certain. Indeed, major discrepancies remain between climate models. However, the most commonly used projection for Tanzania foresees annual rainfall increasing by 10% overall. According to the models, the timing of rains will continue to become less predictable and their intensity, more unpredictable. Furthermore, it is envisaged that seasonal variations will continue to be more prominent, with a 6% decline in rainfall between June and August (traditionally the dry season), and a 16.7% increase between December and February (the main rainy season). Additionally, significant regional variations have been observed. Areas with a 'bimodal' rainfall pattern (north-east, north-west and northern Tanzania) have been receiving 5 to 45% more rain during both seasons. Areas with a 'unimodal' rainfall pattern (central, western, southern, south-western and eastern Tanzania) on the

Figure 3. Photo in the left shows dead animals due to drought in 2009 in Northern Tanzania and in the right is flooding areas in Kilosa District in 2010.

Figure 4. Calamitous effect of drought on Maasai cattle in Northern Tanzania.

other hand, have been experiencing reduced precipitation of between 10 and 15% (TMA).

Extreme weather events and conditions

Information by the Working Group on Climate Change and Development (WGCCD) (2005) reveals that extreme events are likely to pose the greatest climate change threats in Tanzania as demonstrated in Figure 3. They have happened in the form of drought (e.g. in 2009 especially in northern Tanzania) and flooding e.g. Kilosa in 2010 and Dar es Salaam as expressed by Mwananchi Newspaper (2012) in 2011.

This situation makes Maasai to shift to various places in search of pastures e.g. Morogoro, Tanga, and Lindi. However, the sequel of drought circulates destroying a number of cattle as presented in Figure 4.

Moreover, sudden events such as the *El Nino* episode of 1997-98, highlighted the country's vulnerability to climatic hazards. For example, the event led to drought, flooding and triggered national food insecurity, with severe food shortages that raised food prices, increased power rationing and imbued extensive livestock and cash crop losses (United States National Drought Mitigation Centre, 2012). Recently, flooding has damaged human settlements, infrastructure, property and livestock in Dar es Salaam and was associated with the spread of diarrhoea (The Guardians, 2012).

Sea-level rise

Global warming causes ice caps to melt in Polar Regions of the world. It is predicted that sea-level rise of 8 to 96 cm will occur by 2100 within an area of 800 km coastline that comprises a coastal population of 16% (IPCC, 2007). This implies that the sea-level rise signifies a considerable impact on Tanzanias' coastal communities, livestock and the ecosystems they depend on. Regions with the hardest hit include Dar es Salaam, Tanga, the Coastal region, Mtwara and Lindi. Other impacts include land loss, coastal erosion, damage to coastal structures and properties, loss of coastal and marine ecosystems (e.g. mangroves, fish, coral), saline intrusion in fresh water bodies (e.g. in the Rufiji delta) and Inundation of low-lying coastal areas (e.g. the Maziwe island in Pangani, Tanga) (Personal Commun. on effects of climate change on marine life, 2012).

IMPLICATIONS OF CLIMATE CHANGE TO TANZANIA RANGELAND RESOURCES

Change in forage quality and rangeland composition

Observably, temperature, rainfall and atmospheric CO_2 concentration interact with grazing and land cover change to influence rangeland quality and composition. Increased temperature increases drought stress and tissue lignifications in plants and, consequently, affects their digestibility and decomposition rate. Further still, increased temperature and low rainfall increases vegetation flammability and fire frequencies rendering changes in species composition. Conversely, fire hazards have been common in Kongwa ranch and most grazing areas in Kiteto and Kilindi Districts in recent years. The amount and timing of rainfall has also influenced rangeland species composition in these sites. This situation has led to spread of bushy vegetation. Further, an extended drought has resulted into increased mortalities of perennial plants and the tendency of switching to an annual-dominated flora such as *Bracharia* spp and *Cynodon* spp (Hein, 2006).

Bush encroachment in Kongwa Ranch for example, occurs as a result of the invasion of shrubs and trees mainly *Acacia* and *Albizia* species into previously grassy rangelands. In view of this, Lao (2011) pinpoints that encroachment has been a common phenomenon in Kongwa Ranch which leads to an increase in biomass but deteriorate rangeland productivity. Increase in the concentration of atmospheric CO_2 could enhance the process of bush encroachment in two important ways. Firstly, less transpiration could result in more plant available-water, particularly at depth, where deeper-rooted *Acacia* and other shrubs have their roots. Greater access to water could further increase the length of their growing season and increase their competitive dominance to the exclusion of shorter growth forms such as grasses and perennial herbs. Another mechanism for the increase in bush encroachment suggests that an increase in CO_2 results in faster growth rates of saplings. This enables them to escape more quickly the height at which fire usually kills young trees. During fire practicals with students and village dwellers in Kongwa these characteristics were clearly seen where most young trees were killed by uncontrolled fire.

Change in water resources

Three main hydrological regions (dry, intermediate, wet), based on their perennial drainage densities (total perennial stream length per unit area), exists. Various research findings showed that it is in the intermediate region receiving between 400 to 1000 mm of rain per year that the impact of climate change on surface drainage will be greatest as highlighted by Mary and Majule (2009) and FAO (2007). Kongwa ranch for example receives about 250 to 600 mm of rainfall per year. Other pastoral districts such as Monduli, Kiteto, Simanjiro and Ngorongoro receive below 800 mm and districts such as Babati, Hanang, Mbulu and Karatu receives between 800 to 1000 mm of rainfall. The impact is felt non-linearly and drier areas within this range experiences significantly greater loss in surface drainage with a decrease in rainfall than wetter areas. For example, a 10% drop in rainfall in a region of 1000 mm per year will result in a decline in surface drainage of only 17% while in areas of 500 mm per year will result in a 50% decline. Such a dramatic response in surface drainage to decreasing rainfall could have devastating consequences for this intermediate hydrological zone of which most of Tanzanian rangelands situate (ranches and grazing plains). Evidently, the decrease in surface drainage coupled with an increase in water demand by livestock and people which emanates from increased temperatures challenges traditional coping strategies and increases tensions around already scarce water resources. Experience have shown that communities in Babati, Kongwa and Handeni (rangeland areas) are experiencing decline in ground water level due to drying of water in wells, springs and rivers that used to give water throughout the year. The drying has affected both people and livestock including wild animals as illustrated in Figure 5. In Rufiji delta where some pastoral communities from Ihefu wetland (Mbalari) are currently residing, water in wells are becoming salty which is not favourable to both people and livestock.

Change in land use systems and rangeland-based livelihoods

The general reduction in productivity is happening in most rangelands in Tanzania and other parts of Africa which has caused a shift in traditional activities including livestock keeping (Easterling et al., 2007). Decrease in

Figure 5. Photo showing death of cattle due to lack of water and food in Northern Tanzania.

the length of the growth period and rainfall variability in marginal crop production areas has rendered cultivation too risky and therefore has resulted into a switch of production systems. In the in-depth studies for REDD strategy, some villagers said, they lost about 40 head of cattle due to drought which devastated much of the Arusha Region, especially districts inhabited by the nomadic pastoralist communities such as Longido, Ngogorongoro, Monduli and Simanjiro. This is because droughts forced many youths from the Maasai community to rush to towns for petty jobs such as serving as watchmen or working in beauty salons.

The villagers also reported a switch to alternative breeds and species e.g. from cattle to sheep, goats or chickens, which were better adapted to more marginal conditions. A reduction in income and livelihood security for people who derive their lives and livelihoods primarily from rangelands has been observed in Tanzania (Easterling et al., 2007). It was for example reported (The Guardian Newspaper, 2011) that some Maasai pastoral communities in Arusha have started to keep chicken, perform beekeeping and fish farming, livelihood activities that they have never done before. One of the respondents in the in-depth studies in Babati was quoted saying “We haven’t forgotten what happened in 2009, as thousands of livestock died in this area because of prolonged drought and many Maasai remained without anything. Some pastoralists have committed suicide because of massive death of cattle.” Drought went hand-in-hand with the drying up of water sources in the area, posing a threat to animal life. The 2009 drought was the very devastating among Maasai communities’ historical record, as a similar one occurred in 1914, when large numbers of livestock, wild animals and people died in the area (The Guardian Newspaper, 2011).

Human adaptation measures

Adaptation refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences. Since the rise in mean temperature was detected, pastoral societies in Tanzania has begun to adapt to the change. According to a respondent in the in-depth of adjustment to climate change in the study of 2010, supplementary feeding of livestock is one of the adaptation measures to cope with climate change impacts. Business people for example, earned extra money for transporting maize husks and sunflower cakes (feed supplements) from Morogoro and Mbeya to Arusha, Singida and Mwanza. Adaptation may be more problematic in some pastoral systems where production is very sensitive to climatic change and the rate of adoption of new technology is slow.

Intervention such as controlled animal stocking rates is the most promising management activity to lessen the negative impact of climate change on rangelands. However, the trend of livestock are still increasing year to year as presents in Figure 6, thereby triggering challenges to the interventions.

Other interventions include proper rangeland management, including sustainable yield and use of good pasture areas while marginal or poor condition areas are allowed to rest, has become increasingly necessary under climatic conditions. Improvement and intensification of management in some Tanzanian

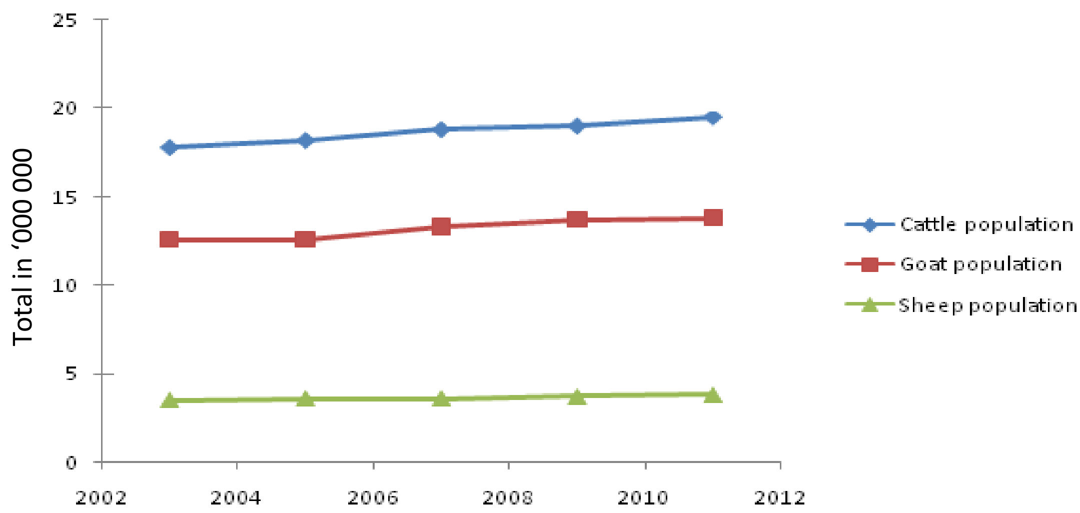

Figure 6. Trends of three species of livestock in Tanzania. Sources: Agricultural economic survey 2023.

ranches have the additional benefit of reducing average methane emissions per head of livestock because of improved feed quality. In Kongwa ranch, for example, management option in the plan includes changing species composition through planting leguminous plants. Currently, legume-based grassland systems are thought to become more important in the future because legumes improve the nutritive value of forage. The use of leguminous species is important as a means of producing more-sustainable forage systems (Riveros, 1993). The species generally show larger yield responses to elevated CO_2 than do grasses at warm temperatures and also show enhanced nitrogen-fixation rates as demonstrated by some scholars (Campbell et al., 1995) and other authors (Newton et al., 1994) or researchers (Crush et al., 1993). In some grass-dominated rangelands like Serengeti National Park, improved pastures may help to adapt livestock grazing strategies. In these systems, there are significant interventions including selection of forage type, selective animal breeding, pasture renewal, irrigation, and other practices. Although these interventions provide opportunities for grazers to adapt systems, they are however not commonly practised in Tanzanian rangelands.

Mitigation measures

Overview

Opportunities for reducing greenhouse gas (GHG) emissions on rangelands include maintaining or increasing carbon sequestration through better soil management (Ojima et al., 1994), reducing methane production (Cicerone and Oremland, 1988). This aspect is attained by altering animal management practices (Howden et al., 1994). Furthermore, it could be achieved by using sustainable agriculture practices on rangelands capable of sustaining agriculture (Mosier et al., 1991). Productivity and carbon cycling in rangeland ecosystems are directly related to the amounts and seasonal distribution of precipitation and are only secondarily controlled by other climate variables (Sampson et al., 1993). In fact, Walker (1993) advocates that rangeland productivity may vary as much as fivefold because of timing and amounts of precipitation.

Reduction of animal numbers

For long time, most pastoral communities in Tanzania have been reluctant to reduce number of their livestock until the drought hit of 2009. Reduction of animal numbers increases carbon storage through better plant cover (Ash et al., 1995) and decrease methane emissions. With sufficient rainfall, this practice has a positive ecosystem effect. However, reduction in livestock numbers requires alternative sources of food for Tanzanians, and thus may lead to changes in national food policy.

Changing the mix of animals

Changing the mix of animals on a given rangeland in the country can increase carbon storage and decrease methane emissions, but the benefit derived depends on the kind of rangeland and the proposed mix of animals together with small proportions of chickens. Up scaling the chicken enterprise in a mix with goats and cattle as shown in Figure 7 could improve sustainability of the livestock industry in the country. However, since

Figure 7. Shows goats (browsers), chickens (scavvengers) and cattle (grazers at the botom).

Tanzania has mainly cattle and small stock of sheep and goats, the mix is not ecologically efficient; rather, it may reflect an economic risk aversion in bad times, where cattle may die and goats survive. In contrast, Tanzania has a mix of cattle and wildlife ruminants in her rangelands which are both ecologically and economically efficient.

Changing animal distribution

Changing animal distribution through salt placement, development of water sources, or fencing can increase carbon sequestration through small increases in plant cover overall and improved status of the root system (due to less intense grazing) (Campbell and Smith, 1993). None of the changes in animal distribution, however, is expected to affect methane production. Animal-management practices will be specific to local and regional production systems; for example, fencing and/or placement of salt may not be useful in herding systems and may potentially interfere with wildlife migration. Costs and practices will vary widely by region.

Mixed vegetation

In almost all Tanzanian rangelands, woody species and grasses coexist. In this way, management practices to enhance both woody and herbaceous productivity increase carbon storage and reduce methane emissions per unit product from domestic and wild ruminants (Bond and Midgley, 2000). This is due to improved quality of the diet. There are numerous potentialities for improvement of the livestock industry such as enrichment planting or agro forestry, rangeland rehabilitation in the degraded regiment and fodder production and conservation for supplementing key animals such as lactating cows (Caceres, 1993).

Watershed improvement

Practices involving the development of dams with large-scale water-storage capacity may improve long-term carbon storage and reduce animal methane production per unit product as articulated by Tanzania Metrological Agency (2005) by improving the quality of the diet through improved animal-management options and improved food-production systems. However, such projects are expensive and can result in social and cultural dislocation and may result in increases in both human and animal population density.

CONCLUSIONS AND RECOMMENDATIONS

Evidence from research on climate change is now overwhelmingly convincing that climate change is real and that the poorest and most vulnerable people will be the worst affected. Tanzania`s rangelands are dominated by extensive livestock production systems and securing these assets particularly for poorer households in the face of climate change is a major challenge. To overcome the challenge, focus on enabling herd mobility through securing better access to water resources and increasing access to more land, particularly when it is marginal for crop production is needed. It is important to improve our early warning systems, enabling pastoral groups to better engage with policy debates, building stronger conflict management institutions and supporting a diversification of livelihoods, perhaps through tourism and conservation. We should also remember that the impact of climate change is not the only factor that will affect livestock production on Tanzanian rangelands. High population growth, rapid rates of urbanization and the high mortality of Tanzanians from HIV/AIDS are only a few of many other factors which will influence Tanzania's agricultural environments, including her rangelands.

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