International Journal of Agricultural Science Research Vol. 4(7), pp. 132-139, July 2015
Available online at http://academeresearchjournals.org/journal/ijasr
ISSN 2327-3321 ©2015 Academe Research Journals

Review

Review on dynamics of the environment and promises of the indigenous cattle genetic resources toward coping up with environmental changes: The case of Ethiopian cattle breeds

Tesfaye Amene Dadi

Department of Animal Science, College of Agriculture and Natural Resources, Mizan-Tepi University, P.O. Box 260, Mizan-Tepi, Ethiopia. E-mail: tesfuam@gmail.com.

Accepted 9 June, 2015

Review work was done to assess the impact of climate change on the livestock production sector and the unique traits found in indigenous breeds to mitigate the climate changes. Currently, the world is facing a number of challenges, of which climate change is a priority area. The effect of climate change on biodiversity in general and domestic animals in particular is articulated in different scale. Ethiopia as a poor country has little to do to curb the situation in terms of a variety of technologies. Climate change could be particularly damaging to countries which are dependent on rain fed agriculture and under heavy pressure from food insecurity and often famine caused by natural disasters. Livestock production in Ethiopia is already under pressure from climate change due to change in water quality and quantity, animal feeds resources, heat stress, and disease and vectors. However, as a country rich in biodiversity there are a number of options where the country could mitigate the problems faced in livestock production sector. To the truth of world dynamicity, livestock production and indigenous genetic resources utilization systems should have to be in line with this frequent and unpredictable changes. Indigenous cattle breeds are a valuable source of genetic material because of their adaptation to harsh climatic conditions, ability to better utilize the limited and poor quality feed resources and their tolerance to a range of disease found in different corners of the country. In economic terms, these indicative data suggest that such adapted breeds if managed properly, supported with appropriate research direction and comprehensive review of research done on indigenous cattle breeds, can provide insurance against possible change in production system. Therefore, in the context of climate change, strategies for livestock research and innovation, and indigenous cattle production in Ethiopia should be geared towards exploitation of cattle genetic resources and the utilization of such adapted indigenous breeds to cope up with climate change.

Key words: Dynamics of the environment, environmental changes, indigenous cattle genetic resources.

INTRODUCTION

The effect of climate change on biodiversity in general and domestic animals in particular is articulated in different scales by Gitay et al. (2002), CBD (2009) and FAO (2009). Some other papers provide a general overview of the expected impact of climate change on livestock production (Adams et al., 1998; Smit and Skinner, 2002) and changes in production systems and species composition (Seo and Mendelsohn, 2007, 2008). Analyses of its effects on livestock (McCarthy et al., 2001; Seo and Mendelsohn, 2008) showed that climate can affect livestock directly through imposing on animal growth, products and reproduction and indirectly (Adams et al., 1999, McCarthy et al., 2001) influencing the quantity and quality of feedstuffs such as pasture, forage, grain and the severity and distribution of livestock diseases and parasites (Seo and Mendelsohn, 2006). Climate change will have a notable impact on Ethiopia's temperature and precipitation. As estimated by Cline

(2007), average annual temperatures nationwide could rise from 3.1°C by 2060 to 5.1°C by 2090. In addition, precipitation is projected to decrease from an annual average of 2.04 mm/day (1961-1990) to 1.97 mm/day (2070-2099), for a cumulative decline in rainfall of 25.5 mm/year. The combination of generally increasing temperatures and shifting rainfall amounts and patterns will clearly have impacts on crop and livestock agriculture of the country. As a result, feed shortage and water resources scarcity will be critical constraints on livestock production in the Ethiopian context. The situation is expected to be more pounced in areas where exotic genotypes are being utilized as these animals are not adapted to high temperature, water and feed shortage.

The use of adapted animal genetic diversity as one strategic option for climate change adaptation and mitigation is proposed as genetic mechanisms used to influence fitness and adaptation. The most important issue is the ability to exploit livestock adaptation differences for climate change. A wealth of literature is available on adaptation differences between Zebu and Taurine cattle (Frisch, 1972; King, 1983; Burns et al., 1997; Prayaga et al., 2006). Bos Indicus is generally more heat resistant than Bos Taurus (Burns et al., 1997), with Zebu cattle maintaining lower rectal temperatures, lower respiration rates and lower water requirements than Taurine breeds (King, 1983). Under such circumstances, the use of exotic breeds to confined production environments depends on the availability and prices of feed and water. The question is how long can the production environment of high-output breeds be maintained in view of expected increases in feed, labour and water prices? On the other hand, many local breeds, particularly those from Africa, are already adapted to high temperatures and harsh conditions (Rege, 1999; FAO, 2006).

In this regard given its geographical location, diversified ecology, its huge population size and cattle types which have evolved over time, Ethiopia is considered a centre of diversity for animal genetic resources (Beyene and Bruke, 1992; Hanotte et al., 2002; Ayalew et al., 2003). However, these indigenous breeds are complained for being 'low' producers. In the absence of comprehensive research, review and other written material on characterization, proper selection, and conservation, it is unfair to complain over these genotypes. As part of such efforts, this paper focused on this limitation to fill that gap. Therefore, this review paper was designed with the following objectives:

- To review the impact of climate change on the livestock production sector.
- To review the genetic diversity found in indigenous breeds to mitigate the climate changes.

CLIMATE CHANGE

In the developing world, livestock production is rapidly changing in response to a variety of environments. Globally, human population is expected to increase from around 6.5 billion today to 9.2 billion by 2050. Thus, more than 1 billion of this increment will occur in Africa. Rapid urbanization is expected to continue in developing countries and the global demand for livestock products will continue to increase significantly in the coming decades (Delgado et al., 1999). The potential impact of these drivers change on livestock systems and the resource-poor people who depend on them for their livelihoods is considerable. These impacts will be influenced by both supply-side shifts in natural resource use as well as market-led demand changes.

Changes in frequency and severity of extreme climate events have significant consequences on food production and food security (IPCC, 2007). In the future, the investigators stated that about 1.3 billion poor people, at least 90% of them, would be located in Asia and sub Saharan Africa, and climate change will have major impacts on more than 600 million livestock dependent people (Thornton et al., 2002). Climate change could be particularly damaging to countries which are dependent on rain fed agriculture and are under heavy pressure from food insecurity and often famine caused by natural disasters (Deressa, 2006).

CLIMATE CHANGE IN ETHIOPIA

Both instrumental and proxy records have shown that there is significant variations in the spatial and temporal patterns of climate in Ethiopia. According to NMA (2006), the country experienced 10 wet years and 11 dry years over 55 years analyzed, demonstrating the strong inter-annual variability. Between 1951 and 2006, annual minimum temperature in Ethiopia increased by about 0.37°C every decade. The climate change profile for Ethiopia also shows that the mean annual temperature increased by 1.3°C between 1960 and 2006, at an average rate of 0.28°C per decade (McSweeney et al., 2008).

The temperature increase has been most rapid from July to September (0.32°C per decade). It is reported that the average number of hot days per year has increased by 73 days (an additional 20% of days) and the number of hot nights has increased by 137 days (an additional 37.5% of nights) between 1960 and 2006. IPCC's mid-range emission scenario showed that from 1961 to 1990, the average mean annual temperature across Ethiopia will increase by between 0.9 and 1.1°C by the year 2030 and between 1.7 and 2.1°C by the year 2050. The temperature across the country could rise by between 0.5 and 3.6°C by 2080, whereas precipitation is expected to show some increase (NMA, 2006). Unlike the temperature trends, it is very difficult to detect long-term rainfall trends in Ethiopia, due to the high inter-annual and inter-decadal variability. According to NMA (2006), between 1951 and 2006, no statistically significant trend in mean annual rainfall was observed in any season. As compared to the 1961 to 1990 analysis, annual precipitation showed a change of between 0.6 and 4.9% and 1.1 and 18.2% for 2030 and 2050, respectively (NMA, 2006). The percentage change in seasonal rainfall is expected to be up to about 12% over most parts of the country (ICPAC, 2007).

NMSA (2001) has also stressed that mean temperature and precipitation in Ethiopia have been changing over time. Over the past 60 years, some of the years have been characterized by dry rainfall conditions resulting in drought and famine, whereas the others are characterized by wet conditions. Droughts in Ethiopia can shrink household farm production by up to 90% of a normal year output (World Bank, 2003). All these have effects on animal genetic resources directly on heat stress (Thornton et al., 2009), emergence, spread, and distribution of livestock diseases (Baylis and Githeko, 2006), feed and water availability (Thornton and Gerber, 2010) and genetic mechanisms which influence fitness and adaptation (Hoffmann, 2010).

COMMON AREAS OF ECO-SYSTEMS AFFECTED BY CLIMATE CHANGE HAVING DIRECT RELATION WITH LIVESTOCK PRODUCTION

Water scarcity

Water scarcity has become globally significant over the last 40 years and accelerating conditions for 1-2 billion people (MEA, 2005). Population growth, economic development and climate change impacts the global water availability in the future. If today's food production and environmental trends continue into the future, they will lead to crises in many parts of the world (Masike, 2007). The response of increased temperature on water demand by livestock is well-known. For Bos Indicus, water intake increases from about 3 kg/kg DM intake at 10°C ambient temperature to 5 kg at 30°C, and to about 10 kg at 35°C (NRC, 1981). For Bos Taurus, intake at the same three temperatures is about 3, 8 and 14 kg/kg DM intake. Some of this water intake comes from forage, and forage water content itself will depend on climate-related factors; forage water content may vary from close to 0-80%, depending on species and weather conditions (Masike, 2007).

Effects of climate change on animal feeds resources

One of the most important effects of climate change on livestock production is changing the animal feed resources. Indirect effects on feed resources can have a significant impact on livestock productivity, carrying capacity of rangelands, buffering ability of ecosystems and their sustainability, prices of stovers and grains, trade in feeds, changes in feeding options, greenhouse gas emissions and grazing management.

Changes on the primary productivity of crops, forages and rangelands are probably the most visible effect of climate change on feed resources for animals. Thus, it also causes changes in species composition in rangelands and some managed grasslands that are an important determinant of livestock productivity. As temperature and CO_2 levels change due to climate change, the optimal growth ranges for different species also change; species alter their competition dynamics and mixed the composition of grasslands (Deressa, 2006).

Minson (1990) showed that increased temperature, increased lignifications of plant tissues and reduced digestibility and degradation of plant species are directly related to climate changes on quality of plant materials. This leads to reduced nutrient availability for animals and reduced livestock production, which may have impacts on food security and reduced the production of milk and meat for smallholders (Sirohi and Michaelowa, 2007).

Climate changes on heat stress

Easterling and Apps (2005) stated that lack of appropriate physiological models that are related to climate and animal physiology limited the confidence that can be placed in predictions of impacts. It is clear, however, that warming will alter the heat exchange between animal and environment in feed intake, mortality, growth, reproduction, maintenance and productions (SCA, 1990). Sirohi and Michaelowa (2007) cited from Hahn (1999) stated that the thermal comfort zone for temperate-region adult cattle ranged from 5-15°C. Whereas McDowell (1972) noted that significant change in feed intake and numerous physiological processes do not occur in the range of 5-25°C. However, the thermal comfort zone is influenced by a range of factors and is much higher in tropical breeds because of both better adaptation to heat and lower food intake of most domestic cattle. Clearly, hot and humid conditions can cause heat stress in livestock, which will induce behavioral and metabolic changes, including reduced feed intake and thus a decline in productivity. Rotter and van de Geijn (1999) suggested that impacts of heat stress may be relatively minor for the more intensive livestock production systems where some control can be exercised over the exposure of animals to climate. Similarly, the impacts of increased frequencies of extreme heat stress on existing livestock breeds are neither known nor are there critical thresholds in the relationship between heat stress and physiological impacts (Sere et al., 2008).

Climate changes on livestock diseases and vectors

Altered patterns of diseases in animals are a significant and permanent threat as a result of climate change. This may include: (1) the emergence of new diseases and (2) a change in the prevalence of existing diseases, particularly those spread by biting insects. A wider geographic distribution of known vectors and/or the recruitment of new strains to the vector pool could result in infections spreading to more and potentially new species of hosts (McManus, 2009). Changes in climate will influence arthropod vectors, their life cycles and life histories, resulting in changes in both vector and pathogen distribution and changes in the ability of arthropods to transmit pathogens (Tabachnick, 2010). Therefore animals will be exposed to different parasites and/or diseases, as indicated by the predicted change in the distribution of, for example, the Tsetse fly in Africa (Tabachnick, 2010), putting an even greater pressure on production and the survival of livestock breeds.

The OIE Scientific Commission has concluded that climate changes are likely to be an important factor in determining the spread of some diseases, especially those that are vector-borne. The two most mentioned emerging and re-emerging cattle diseases in a recent OIE survey are Catarrhal fever (Bluetongue) and Rift Valley fever (OIE, 2008). Bluetongue is an infectious, non-contagious disease of wild and domestic ruminants, and has considerable economic impact partly due to direct losses from death and reduced production in affected livestock but, more importantly, because of the restrictions on international trade in animals and animal germplasm between Blue-tongue virus infected and non-infected areas (Calistri et al., 2004; Wilson et al., 2009). The global distribution of Bluetongue virus infection changed drastically in recent years (Wilson and Mellor, 2008) and climate change may be partly responsible for this profound change in the global distribution of the Bluetongue virus (Wilson and Mellor, 2008; Mellor and Wittmann, 2002). Studies have demonstrated that the vectors of the disease are affected by temperature (Garry, 2000; Wittmann, 2002) and have indicated a possible role of humidity (Wittmann, 2002) and precipitation (Wilson and Mellor, 2008).

The complexity of climate change is associated with so many factors like vectors (McDermott et al., 2001). Tsetse are very sensitive to environmental change, either due to climate or direct human impacts on habitat but the impacts vary in major species groups. Forest and riverine species are much more sensitive to climatic factors than savannah species, while riverine species are much more adaptable to increasing human population densities than the other groups. Sleeping sickness, particularly the gambiense type, will continue, as now, to be a major problem, if concerted control efforts are not implemented. The impacts of changes in ecosystems on infectious diseases depend on change in ecosystems, the type of land-use, disease specific transmission dynamics, and risky and susceptibility of the populations (Patz et al., 2005). According to Baylis and Githeko (2006), climate change may affect infectious diseases on their pathogens and higher temperatures may increase the rate of development of pathogens or parasites (Harvell et al., 2002).

Other pathogens are sensitive to high temperature and their survival may decrease with climate warming. Similarly, those pathogens and parasites that are sensitive to moist or dry conditions may be affected by changes to precipitation, soil moisture and the frequency of floods. Changes to winds could affect the spread of certain pathogens and vectors (Wittmann and Baylis, 2000).

World Health Organization (1996) stated that climate change is indirectly affecting the abundance and distribution of the competitors, predators and parasites of vectors themselves, thus influencing patterns of disease. It may also be that changes in ecosystems, driven by climate change and affect land-use, could give rise to new mixtures of species, thereby exposing hosts to novel pathogens and vectors and causing the emergence of new diseases. As Baylis and Githeko (2006) noted, climate change-driven alterations to livestock husbandry in Africa, if they occur, could have many indirect and unpredictable impacts on infectious animal disease in the continent. It has been observed that combinations of drought followed by high rainfall have led to wide-spread outbreaks of diseases such as Rift Valley Fever and bluetongue in East Africa and African horse sickness in the Republic of South Africa.

PROMISE OF INDIGENOUS CATTLE BREED TOWARD MITIGATING CLIMATE CHANGES

Ethiopia is considered a center of diversity for animal genetic resources in general and to cattle in particular. Indigenous cattle breeds in Ethiopia are a valuable source of genetic material because of their adaptation to harsh climatic conditions, their ability to better utilize the limited and poor quality feed resources and their tolerance to a range of diseases found in these regions. Despite the significant contribution of cattle to the country, little attention is given to identify, characterize and conserve the diversity of the various classes of livestock (Zewdu, 2010).

According to Kerstin and John (2004), the Borana cattle in northern Kenya and southern Ethiopia have unique traits that make them suitable for the harsh environment in the lowlands and have ever been part of the pastoralists' identity. Almost all the traditional and cultural rites of the pastoralists in these areas revolve around the Borana cattle, which are also the main source of their income. According to them, another important reason for conservation of the local breeds is the multiple use of their various traits in uncertain situations, for instance, in the case of climate change, catastrophes, loss of resistance due to changing environment, protection failures (Tsetse controlling) etc. Equally important is the fact that the preserved breeds might possess qualities that are not yet known but which could be of some use in the future.

Disease tolerant

Trypanosomiasis transmitted by tsetse flies is one of the most important animal health problems in Africa -

occurring mainly in West and Central Africa, and in parts of East Africa. Other types of trypanosomiasis are significant problems both in Africa and in other regions. Parasite resistance associated with control based on trypanocidal drugs, and sustainability problems involved in the implementation of tsetse control programmes, have increased interest in the use of integrated control methods including the utilization of disease tolerant breeds of livestock (FAO, 2005).

Trypanosomosis is one of the major impediments to livestock development and agricultural production in Ethiopia contributing negatively to the overall development in general and to food self-reliance efforts of the nation in particular. While tsetse-borne trypanosomosis is excluding some 180,000 - 200,000 km^2 of agriculturally suitable land in the west and southwest of the country, 14 million head of cattle, an equivalent number of small ruminants, nearly 7 million equines and 1.8 million camels are at the risk of contracting trypanosomosis at any time (Langridge, 1976; MoARD, 2004).

A comparative study on the response of the four (Horro, Sheko, Abigar and Gurage) breeds to the natural challenge of trypanosomosis in the Ghibe valley revealed that Sheko breed has manifested very high overall average packed cell volume (PCV) values, the lowest mean trypanosome prevalence rate and the least number of trypanocidal treatments and lower mortality rate as compared to the other studied breeds (Lemecha et al., 2006). Reproductive performance of the four breeds was also studied in areas with tsetse belt. The results showed that the Sheko breed had more calves than other breeds, slightly higher birth weights, and the highest calving rate of 51%. The Abigar breed exhibited the worst reproductive performance with only 1 calf in the study time, less aggressive sexual behavior, and the lowest calving rate of 3% due to high tsetse challenge (Lemecha et al., 2006). The good reproductive performance under trypanosomosis challenge is also considered to be the strong indicator of trypanotolerance of indigenous breed. Therefore, the presence of huge amount of diversified types of indigenous cattle can favor Ethiopia to cope up with unexpected environmental changes now and in the future too.

Environmental adaptation

As a result of global warming, livestock types/strains that are better adapted to higher ambient temperatures, lower nutritional value of the grass in some cases, and expansion of diseases, especially ticks and tick borne diseases in Africa (Scholtz, 2010), must be promoted and improved in the developing countries. With such challenges, matching genotypes with production environments will become more crucial, requiring the utilization of diverse genetic resources with the appropriate mix of genetic potential for growth, milk production, resistance to diseases and prolificacy (Blackburn and Mezzadra, 2006).

Adaptability of an animal can be defined as the ability to survive and reproduce within a defined environment (Prayaga and Henshall, 2005) or the degree to which an organism, population or species can remain/become adapted to a wide range of environments by physiological or genetic means (Barker et al., 2009). An improved understanding of the adaptation of livestock to their production environments is important, but adaptation is complex and thus difficult to measure (Scholtz, 2010). Several proxy-indicators for adaptation are available and these include reproductive traits such as fertility, survival, birth rate and perinatal mortality; production traits such as growth rate, milk production, low mortality and longevity; and health traits such as faecal egg counts and number of external parasites (Bonsma, 1980, 1983; McManus et al., 2011; Scholtz et al., 1991).

Adaptation can also relate to either resistance or tolerance. Resistance means that animals do not get affected by unfavorable conditions, or they quickly get accustomed to them. Tolerance means that the animals stay affected but continue to live, with or without some degree of discomfort (McManus et al., 2008; Raberg, 2007). McManus et al. (2011) discuss the consequences of decisions made in animal breeding and the effect thereof on genetic variability, adaptability and conservation. The conclusion is that a production system approach should be taken when deciding on which breed should be used and decisions taken should be in the context of cost-benefit and practical applications. This will allow a more pragmatic look at the use of technology and the evaluation of different production systems.

A study that estimated the heritabilities of traits related to heat stress found high heritabilities of 0.75 ± 0.08, 0.36 ± 0.09 and 0.63 ± 0.08 for black spots, hair length and hair diameter respectively (McManus et al., 2008). Different genetic groups reacted differently on exposure to solar radiation and drastic temperature changes by changing their behavior and productivity, although they also suffered from changes in various physiological parameters (Roberto et al., 2007). Some studies comparing tolerance within and between breeds in different corners of the world showed that in general the breed has an effect on the tolerance to heat, but that groups of animals within a breed also showed varying tolerance to heat (McManus and Miranda, 1997; McManus, 2009; Quesada et al., 2001).

It is important to note that there are large differences between breeding cattle for the subtropics/tropics and temperate areas, the main difference being in trait definition. Cattle in subtropical and tropical environments are subjected to numerous stress factors (Prayaga et al., 2006), among which are: 1) parasites (tick and tick borne diseases, internal parasites, flies), 2) seasonally poor nutrition, 3) high temperatures or high daily temperature variation, 4) humidity (both high and low), and 5) temperament which is exaggerated by extensive production systems.

Even though there is no much comprehensive research done on Ethiopian cattle breeds, indigenous cattle are well adapted to tropical conditions and have high degree of heat tolerance, which are partly resistant to many of the diseases prevailing in Ethiopia and have the ability to survive long periods of feed and water shortage. These attributes have been acquired through natural selection over hundreds of generations. They are all essential for successful animal production. Indigenous stocks represent a genetic resource which should not only be conserved for future use, but should also be fully exploited for short-term benefits (Rege and Lipner, 1992).

CONCLUSION

The combination of increasing temperature and shifting rainfall amounts and patterns from climate change will clearly have impacts on livestock agriculture. With such challenges from the environmental changes, matching genotypes with production environments will become more crucial. The use of adapted animal genetic diversity as one strategic option for climate change adaptation and mitigation is proposed as genetic mechanisms influence fitness and adaptation. The most important issue is the ability to exploit livestock adaptation differences for climate change. Ethiopia considered as a centre of diversity for animal genetic resources could do more provided that its genetic resources is exploited properly. This of course demands proper characterization and setting up of appropriate breeding program, since no much comprehensive research has been done yet on this sector. Indicative performance data from different study provided evidences on the potential of these well adapted but underfed and mismanaged genotypes. Proper integration of such valuable genetic resource into strategies of adaptation and mitigation of climate change should be taken as one potential option. The most important issue is the ability to exploit the adaptation differences that the cattle do have for climate change.

REFERENCES

Adams RM, Hurd BH, Lenhart S, Leary N (1998). Effects of global climate change on agriculture: an interpretative review. Climate Research 11, 19–30.

Agyemang K, Dwinger RH, Little DA, Rowlands GJ (1997). Village N'Dama cattle production in West Africa: six years of research in the Gambia. Nairobi. International Livestock Research Institute and Banjul, International Trypanotolerance Centre.

Ayalew W, King JM, Bruns E, Rischkowsky B (2003). Economic evaluation of smallholder subsistence livestock production: lessons from an Ethiopian goat development program. Ecol. Econ. Vol. 45, 473-485.

Barker JSF (2009). Defining fitness in natural and domesticated population. In adaptation and fitness in animal populations. In: van der Werf JHJ, Graser HU, Frankham R. and Gondoro C, Eds, Evolutionary and Breeding Perspectives on Genetic Resource Management, Springer, Amsterdam.

Baylis M, Githeko AK. (2006). The effects of climate change on infectious diseases of animals. Report forthe Foresight Project on Detection of Infectious Diseases, Department of Trade and Industry, UK Government. 35

Bertipaglia ECA, Silva RG, Cardoso V, Maia ASC (2007). Estimativas de parâmetros genéticos e fenotípicos de características do pelame e de desempenho reprodutivo de vacas holandesas em clima tropical. *Revista Brasileira de Zootecnia*, 36, 350-359. doi:10.1590/S1516-35982007000200011

Beyene Kebede, Bruk Yemane (1992). Animal genetic resource and breed characterization works in Ethiopia. In: Rege JEO and Lipner ME (eds). African animal genetic resources: Their characterization, conservation, and utilization. Proc. of the research planning Workshop held at ILCA, Addis Ababa, Ethiopia, 19-21.

Blackburn H, Mezzadra C (2006). Policies for the management of animal genetic resources. *Proceedings of the 8th World Congress on Genetics Applied to Livestock Production*. Belo Horizonte. www.wcgalp8.org.br/wcgalp8/articles.

Bonsma JC (1980) Livestock production: A global approach. Tafelberg Publishers, Cape Town.

Bonsma JC (1983) Man must measure: Livestock production. Agi Books, Cody.

Burns BM, Reid DJ, Taylor JF (1997). An evaluation of growth and adaptive traits of different cattle genotypes in a subtropical environment. Australian Journal of Experimental Agriculture 37, 399–405.

Calistri P (2004). Bluetongue in Italy: Part I. *Veterinaria Italaliana*, 40, 243-251. http://www.ncbi.nlm.nih.gov/pubmed/20419672.

Convention on Biological Diversity (CBD) (2009). Connecting biodiversity and climate change mitigation and adaptation. Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change, Montreal, Technical Series No. 41, pp. 126.

Cline WR (2007). Global Warming and Agriculture: Impact Estimates by Country. Washington, DC:http://www.cgdev.org/content/publications/detail/14090

Delgado C, Rosegrant M, Steinfeld H, Ehui S, Courbois C (1999). Livestock to 2020: the next food revolution. Food, Agriculture and the Environment Discussion Paper 28. IFPRI/FAO/ILRI, Washington, DC, USA.

Easterling W, Apps M. 2005. Assessing the consequences of climate change for food and forest resources: a view from the IPCC. Climatic Change 70, 165–189. Ehrenfeld, D., (2005). The environmental limits to globalization. Conservation Biology. 19(2): 318–326.

FAO (2005). Trypanotolerant livestock in the context of trypanosomiasis intervention strategies. by K Agyemang. PAAT Technical and Scientific Series No. 7. Rome.

FAO (2006). Breed Diversity in Dryland Ecosystems. Information Document 9, Fourth Session of the Intergovernmental Technical Working Group on Animal Genetic Resources for Food and Agriculture. FAO, Rome. Available at: http://www.fao.org/Ag/againfo/programmes/en/genetics/documents/ITWG.

FAO (2009). Threats to Animal Genetic Resources – Their Relevance, Importance and Opportunities to Decrease Their Impact. CGRFA Background Study Paper 50, pp. 55. Available at: ftp://ftp.fao.org/docrep/fao.

Frisch JE (1972). Comparative drought resistance of bos indicus and bos taurus cattle in Central Queensland. Relative weights and weight changes of maiden heifers. Aust. J. Exp. Agric. Anim. Husbandry 12, 231–233.

Gerry AC, Mullens BA (2000). Seasonal abundance and survivorship of *Culicoides sonorensis* (Diptera: Ceratopogonidae) at a southern California dairy, with reference to potential bluetongue virus transmission and persistence. J. Med. Entomol., 37, 675-688. doi:10.1603/0022-2585-37.5.675.

Gitay H, Sua´rez A, Watson RT and Dokken DJ (2002). IPCC Technical Paper V. Climate Change and Biodiversity. IPCC Technical Paper V. IPCC, Geneva, Switzerland, pp. 85.

Hanotte O, Bradley DG, Ochieng JW, Verjee Y, Hill EW and Rege JEO (2002). African pastoralism: Genetic imprints of origins and migration. Science, Vol. 296 :336-339.

Herrero M, Hanotte O, Notenbaert A, Thornton PK (2008). Potential of modelling animal genetic resources data in relation to other existing data sets. In: Pilling, D., Rischkowsky, B. and Scherf, B., Eds., Report on the FAO/WAAP Workshop on Production Environment Descriptors for Animal Genetic Resources Report, Caprarola, 6-8 May 2008. www.fao.org/docrep/meeting/022/mb386e.pdf

IPCC (Intergovernmental Panel on Climate Change) (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Summary for policy makers. http: // www. ipcc.cg/ SPM13apr07.pdf.

King JM (1983). Livestock Water Needs in Pastoral Africa in Relation to Climate and Forage. ILCA Research Report No. 7, Addis Ababa.

Masike S. 2007. The impacts of climate change on cattle water demand and supply in Khurutshe, Botswana. PhD thesis, University of Waikato, New Zealand.

McCarthy J, Canziani OF, Leary NA, Dokken DJ, White C (2001). Climate Change 2001: impacts, adaptation and vulnerability. Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, UK.

McDermott JJ, Christianson PM, Kruska RL, Reid RS, Robinson TP, Coleman PG, Jones PG, Thornton PK (2001). Effects of climate, human population and socio-economic changes on tsetse-transmitted trypanosomiasis to 2050. In R. Seed, S. Black (ends). World Class Parasites – Vol. 1. The African Trypanosomes, Kluwer, Boston.

McDowell RE (1972). Improvement of Livestock Production in Warm Climates. Freeman, San Francisco, California. 711.

McManus C, Miranda RM (1997). Comparação das raças de ovinos santa inês e bergamácia no distrito federal. *Revista Brasileira de Zootecnia*, 26, 627-636.

McManus C (2009). Heat tolerance in Brazilian sheep: Physiological and blood parameters. Tropical Ani- mal Health and Production, 41, 95-101. doi:10.1007/s11250-008-9162-1.

McManus C, Cobuci J, Braccini Neto J, Paiva SR (2011). Decision making in animal breeding programs and their consequences for animal production. *Revista Brassileira de Reprodução* Animal, 35, 69-76. http://www.cbra.org.br/pages/publicacoes/rbra/v35n2/RB 358%20McManus%20pag69-76.pdf.

McManus C (2011). The challenge of sheep farming in the tropics: Aspects related to heat tolerance. Brazilian J. Anim. Sci., 40, 107-120. www.sbz.org.br/revista/artigos/66266.pdf.

Mellor PS, Wittmann EJ (2002). Bluetongue virus in the Mediterranean basin 1998-2001. Vet. J., 164, 20-37. doi:10.1053/tvjl.2002.0713.

MEA (2005). Ecosystems and Human Well-Being: Our Human Planet. Summary for Decision Makers.TheMillennium Ecosystem Assessment, online athttp://www.millenniumassessment.org.

Minson DJ (1990). Forage in Ruminant Nutrition. Academic Press, San Diego.

NRC. 1981. Effect of Environment on Nutrient Requirements of Domestic Animals. Subcommittee on Environmental Stress, National Research Council. National Academy Press, Washington DC.

OIE (2008). Report of the Meeting of the OIE Scientific Commission for Animal Diseases. http://www.oie.int/downld/SC/2008/A_SCAD_feb2008.pdf.

Prayaga KC, Henshall JM (2005). Adaptability in tropical beef cattle: Genetic parameters of growth, adaptive and temperament traits in a crossbred population. Aust. J. Exp. Agric., 45, 971- 983. doi:10.1071/EA05045.

Prayaga KC, Barendse W, Burrow HM (2006). Genetics of Tropical Adaptation.

8th World Congress on Genetics Applied to Livestock Production, August 13–18, Belo Horizonte, Brazil.

Prayaga KC, Barendse W, Burrow HM (2006). Genetics of tropical adaptation. Proceedings of the 8th World Congress on Genettics Applied to Livestock Production. Belo Horizonte. www.wcgalp8.org.br/wcgalp8/articles.

Purse BV, Brown HE, Harrup L, Mertens PP, Rogers DJ (2008). Invasion of bluetongue and other or- bivirus infections into Europe: The role of biological and climatic processes. *Revue Scientifique et Technique*, 27, 427-442. http://www.oie.int/doc/ged/D5503.PDF.

Quesada M, McManus C, Couto FA, Araújo D (2001). Tolerância ao calor de duas raças de ovinos deslanados no Distrito Federal. *Revista Brasileira de Zootec- nia*, 30, 1021-1026.

Raberg l, Sim D, Read AF (2007). Disentangling genetic variation for resistance and tolerance to infectious diseases in animals. Science, 318, 812-814. http://lac-repo-live7.is.ed.ac.uk/bitstream/1842/2140/1/Ra berg%20text%20figs%20SOM.pdf

Rege JEO, Tawah CL (1999). The state of African cattle genetic resources II: geographical distribution, characteristics and use of present-day breeds and strains. Anim. Genet. Resour. Inform. 26:1-25.

Roberto JVB, Souza BB, Silva ALN, Justiano SV, Freitas MMS (2010). Parâmetros hematológicos de caprinos de corte submetidos a diferentes níveis de suplementação no Semi-Árido Paraibano. *Revista Caatinga*, 23, 127-132.

Rotter R, van de Geijn SC. 1999. Climate change and its effects on plant growth, crop yield and livestock. Climatic Change. 43: 651–681.

SCA (Standing Committee on Agriculture) 1990. Feeding Standards for Australian Livestock: Ruminants. CSIRO Publications, East Melbourne, Australia.

Scholtz MM, Spickett AM, Lombard PE, Enslin CB (1991). The effect of tick infestation on the productivity of cows of three breeds of cattle. Onderstepoort J. Vet. Res., 58, 71-74. www.ncbi.nlm.nih.gov/pubmed/1881659.

Scholtz MM (2010). Environmental-genotype responses in livestock to global warming: A Southern African perspective. South Afr. J. Anim. Sci., 40, 408-413.

Seo SN, Mendelsohn R (2006). Climate change adaptation in Africa: A microeconomic analysis of livestock choice. CEEPA Discussion Paper No. 19, Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Seo SN, Mendelsohn R (2007). An analysis of livestock choice: adapting to climate change in Latin American farms. World Bank Policy Research Working Paper 4164, pp.18.

Seo SN, Mendelsohn R (2008). Measuring impacts and adaptations to climate change: a structural Ricardian model of African livestock management. Agric. Econ., 38, 151–65.

Sere C, van der Zijpp A, Persley G, Rege E (2008). Dynamics of livestock production systems, drivers of change and prospects for animal genetic resources. Animal Genetic Resources Information. 42: 3–27.

Sirohi S, Michaelowa A (2007). Sufferer and cause: Indian livestock and climate change. Climatic Change. 85: 285–298.

Smit B, Skinner MW (2002). Adaptation options in agriculture to climate change: a typology. Mitigation and Adaptation Strategies for Global Change 7, 85–114.

Summers BA (2009). Climate change and animal dis- ease. Veterinary Pathology, 46, 1185-1186. doi:10.1354/vp.09-VP-0139-S-COM.

Tabachnick WJ (2010). Challenges in predicting climate and environmental effects on vector-borne disease episystems in a changing world. J. Exp. Biol., 213, 946-954. doi:10.1242/jeb.037564.

Thornton PK, Jones PG, Alagarswamy A, Andresen K (2009). The temporal dynamics of crop yield responses to climate change in East Africa. Global Environmental Change (to be submitted). Impacts on and Adaptation of Agro-ecological Systems in Africa, are found on CEEPA e-Library at its website link (www.ceepa.co.za/discussionp2006.html) and can also be accessed directly through the project link.

Thornton PK, Gerber P (2010). Climate change and the growth of the livestock sector in developing countries. Mitigation Adapt. Strateg. Glob. Change 15, 169–184.

Wilson A, Mellor P (2008). Bluetongue in Europe: Vectors, epidemiology and climate change. *Parasitology Research*, 103, 69-77. doi:10.1007/s00436-008-1053-x

Wilson WC, Mecham JO, Schmidtmann E, Jimenez sanchez C, Herrero M, Lager I (2009). Current status of bluetongue virus in the Americas. http://ddr.nal.usda.gov/dspace/bitstream/10113/23231/1/I ND44152599.pdf.

Wuletaw Z (2004). Indigenous cattle genetic resources, their husbandry practices and breeding objectives in North-western Ethiopia. M Sc. Thesis. Alemaya University of Agriculture, DireDawa, Ethiopia.

Wittmann EJ, Mellor PS, Baylis M (2000). Effect of temperature on the transmission of orbiviruses by the biting midge, *Culicoides sonorensis*. Med. Vet. Entomol., 16, 147-156. doi:10.1046/j.1365-2915.2002.00357.x.

Wittmann EJ, Mellor PS, Baylis M (2002). Effect of temperature on the transmission of orbiviruses by the biting midge, *Culicoides sonorensis*. Med. Vet. Entomol., 16, 147-156. doi:10.1046/j.1365-2915.2002.00357.x.

Zewdu WG (2010). Genetic and phenotypic characterization and design of a breeding strategy for an indigenous cattle breed in North Western Ethiopia; A contribution for sustainable genetic resources utilization. Submitted Commission for Development Studies at the oead-gmbh Boku University of Natural Resources and Applied Life Sciences, Vienna, Austria.