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Goat production as a mitigation strategy to climate change vulnerability in semi-arid tropics

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ABSTRACT

Due to climatic variability in semi arid tropics, livestock production faces many challenges that threaten its viability. This is a review that looks at the potential of goat production as one of the many mitigating strategies in confronting climate change in semi arid tropics. The discussion focuses on specific goat ethological, morphological and physiological characteristics that have environmental adaptation implications. Physiological, behavioral and morphological responses let goats effectively thrive in unfavorable climate change induced environmental conditions. These responses are important in matching goats to specific environmental conditions and ensuring a sustainable level of production. Severe feed shortages resulting from changes in rainfall pattern, and water scarcity are some of the major climate change induced environmental stressors, which have caused livestock capacity decline. Their negative influence on livestock production calls for use of adapted livestock species to cope with unavoidable climate change effects. Goats have shown to be a remarkable animal species that possess distinctive qualities enabling it to excel efficiently in harsh tropical environments. As climate change takes a centre stage in defining livestock productivity in semi arid tropics, there is greater need to stress what type of livestock species to keep. Therefore, the selection of adapted livestock species will be critical in sustaining productivity under this increasingly challenging environment. Identification of livestock species adaptable to semi arid tropics, is recommended for achieving sustainable levels of production. This is on the understanding that selection of adapted livestock species counteracts the negative effects of climate change in such a way that productivity can be maintained and improved. While other species tend to be highly vulnerable, goats have evolved a unique and fascinating array of physiological, morphological and reproductive characteristics, which have contributed to their survival and proliferation in unique unfavorable tropical environmental niches. This points to the fact that promotion of goat production may be a viable mitigation strategy in the context of climate change. It is thus suggested that as climatic variability worsens, goats will assume a critical role in livestock production due to their adaptive features, such as feeding behavior, disease and heat tolerance. These behavioral, morphological and physiological characteristics enable goats to effectively cope with the stressful nature of the vast semi arid tropics. The discussion concludes with the understanding that promotion of goats becomes a key component of semi arid tropics livestock production systems. Due to goats' numerical strength and greater adaptability to varying harsh tropical environmental conditions, they offer a compelling solution to livestock production capacity utilization to minimize destabilizing factors associated with the uncertainties of climate change.

1. Introduction

Climatic change is expected to increase the likelihood of livestock capacity decline in semi arid tropics. This discussion looks at the potential of goat production as one of the many mitigation options in confronting climatic variability in semi arid tropics. It focuses on specific behavioral, morphological and physiological characteristics that have ecological adaptation implications for survival and productivity in unfavorable tropical environmental conditions. It is postulated that livestock production vulnerability to climate change can be ameliorated by promoting adapted livestock species which possesses the widest margin of adaptation. This is on the understanding that climate change induced factors perpetuate environmental stressors on livestock production resulting in reduced productivity.

Between 75 and 80% of goats in developing countries are found in the tropics, where type of vegetation is mainly tall grass savanna, grassland and tropical dry forest (Heady, 1983). FAO (1980) states that the developing countries at tropics have 94% of the world's goat population. This is on the background that the role of goats in maintaining sustainable food security have been widely demonstrated in unfavorable semi arid tropical conditions (Peters, 1987). The ability to survive, reproduce and produce of goats in harsh environmental conditions has been attributed to adaptation, as they deliver multiple products and services, and make valuable contribution especially to the poor in the rural areas (Assan 2013).

Goats can withstand heat stress and can endure prolonged water deprivation, making them more adaptable to adverse climatic and geographical conditions, where cattle and sheep can not survive (Azizi, 2012). Campbell (1998) describes the contrasting and variable environments in which goats can survive, showing that goats are very adaptive to variation in environmental conditions. Among the most dynamic climatic conditions where goat thrive are found in the arid and semi-arid regions of the tropical belts, where extended periods of dryness (6±8 months) are punctuated by erratic rainfall and brief eruption of forage production (Devendra, 1990). The most profound characteristics of the semi arid tropics are water scarcity and fluctuating precipitation; unpredictable weather and rainfall. Rainfall is even more irregular, and water availability more limited, which makes livestock production extremely difficult (FAO, 1989). Considerable water stress and dwindling feed resources, result from insufficient and unreliable rainfall is expected to increase the likelihood of livestock capacity decline (Ngigi, 2009). Houghton et al. (2001) concluded that direct effects from air temperature, humidity, wind speed and other climate factors, influence animal performance, growth, milk production, wool production and reproduction. Despite these unfavorable phenomenon in the semi arid tropics, goats have shown themselves to be an extremely adaptable livestock species, by being found at any altitude and different agro-ecological regions (Devendra, 1999). Elsewhere, it has been consistently shown under different tropical environmental conditions that goats indigenous to harsh environments perform better than other domesticated ruminants (King, 1983; Shkolnik and Silanikove, 1981) because they are anatomically ideal for grazing and browsing. Many other behavioral characteristics can be logically assumed to provide the basis for much of what makes goats different from other herbivores and survive in unfavorable semi arid tropics. Goats' thriving in harsh tropical environments represents a climax in the domestic ruminants capacity to adjust to such areas (Thanh, 2006), where water sources are scarcely distributed and feed sources limited in quantity and quality. The ecological, physiological and feeding adaptive behavior of goats in unfavorable tropics makes them an appropriate candidate to sustain livestock production in the context of climate change.

2. Goats structural characteristics, adaptation and climate change

Goats are homeotherms, therefore excess heat must be eliminated for the animals to be in a thermal balance state (Adedeji, 2012). In some goat breeds enlarged appendages are meant to increase surface area, as a result promoting heat loss. However, the capacity to eliminate heat from the body to reach a thermal balance may vary in different species. Examination of thermoregulatory behavior in different goat breeds inhabiting a highly seasonal dry semi arid areas showed that goats travel shorter distances and rest more during the hottest and drier hours of the day. They extend their tongues to lower body temperatures via evaporative cooling. This makes goats more efficient in thermoregulatory especially in the dry season which is characterized by high ambient temperatures, low relative humidity and the near absence of rainfall. Variation within morphological traits provide ecological adaptation to climatic variability. Goats have special ecological adaptation for browsing such as a split upper lip, narrower muzzle, long legs for climbing and different tolerance to plant chemicals (Mc Gregor, 2000). The narrow muzzle place goats at an advantage when only very short pasture is available. Heat is a major constraint on animal productivity in the tropical belt and arid areas (Silanikove, 1992). Silanikove (2000) opined that the amount of heat absorbed by an object from direct (solar) radiated heat depends not only on the temperature of the object, but on its color and texture with dark surfaces radiating and or absorbing more heat than light colored surfaces at the same temperature. Solar radiation in the tropics considerably increases thermal load on the animal grazing during the day. The amount of radiant heat absorbed by the animals coat is partly determined by coat color, length and condition of its hair (Acharya et al., 1995). Goat colors and hair structures in goats have an important role to play in the adaptability to different ecological zones (Banerji, 1984). Pelt color have a significance in thermoregulation (Hetem, 2010). Coloration is thought to be an important factor in the reduction of heat absorption. Bilaterally wattled white and swiss marked goats had the lowest rectal temperature and heat stress index. Indicating that these lighter colored goats were more tolerant to the prevailing environmental conditions.

Increased respiratory rate is an immediate response of goats to environmental stress (Hales and Brown, 1974). The lighter coat pigmentation absorbs less solar radiation coupled with heat regulation ability. The lowest physiological parameters observed in favor of lighter pigmentation could be as a result of less absorption of solar radiation and possession of heat regulation mechanism. The highest respiratory rate observed in black goats could have resulted from attempts to dissipate body heat by panting in order to increase body cooling by respiratory evaporation since the major evaporative heat loss mechanism is panting in ruminant. Goats are well adapted to extreme temperatures, with their fleece/coats providing an insulative layer which protects them from cold and heat. Insulation in the form of hair or body fat protects tissues beneath. The propensity towards multicoat colors is an adaptation to withstand pronounced seasonal fluctuation in the intensity and duration of light, heat and cold in the semi arid tropics (Katongole et al., 1996). The thermal comfort zone for goats is wide, ranging from 0-30 0C (32-85 0F). This is due to their lighter colored coat which reflect more light relative to darker coat which will absorb more light. This result is reduced body temperatures and more water conservation. Multicolored medium sized goat breeds are appropriate selection criteria in the tropical environment. Crossbred goats tolerated changes in environmental conditions due to their prominent white coat color and skin pigmentation (Otoikhian et al., 2009). Fleece structure showed a remarkable association with environmental conditions. In the semi-arid to humid zones, short coats of coarse fiber enable goats to withstand high rates of radiation or humidity. Goats inhabiting the arid zones have long-haired, coarse-fiber fleeces to protect against heat during the day and cold at night. In the mountainous areas of central Asia, goats have a top coat of long coarse fibers and a seasonal undercoat of short, fine fibers to protect against extreme cold. Angora or mohair goats have long, white and wavy fleeces and live in mid-altitude (Turkey) and dry, high-altitude areas (Lesotho). This therefore suggest that coat color goats could be used as an indirect and affordable selection criteria in the tropical environment. Coat color had a significant influence on heat tolerance traits which include rectal temperature, pulse rate, respiratory rate and heat stress index (Adedeji, 2012). Hemmer (1990) concluded that domesticated animals can be aided by the use of certain goat colors or patterns, which are related to behavior through common metabolic pathways of pigments and catecholamine neurotransmitters. It is reasonable to suggest that coat color in goats can be used for selection as an indirect and affordable selection criteria in the tropical environment.

Another important adaptation of goats to ecological conditions is their variable body size. Goats inhabiting hot, humid environments have small bodies (dwarfs), while those living in dry environments or in areas with a wide diurnal temperature range usually have larger bodies (Horst, 1984). The combined effect of appropriate body size and feeding behavior enables goats to withstand environmental stress. This is one of the reasons for the relatively high disease tolerance attributed to goats under unfavorable environmental conditions. Apart from thriving in arid desert areas, goats are found under a much wider range of climatic conditions. They are known to succeed in tropical rain forests, being the domesticated animal with the largest ecological distribution (Epstein, 1965). Goats are able to produce under varying and frequently unfavorable environmental conditions. They have managed to adjust to different environments in which they are reared because of their feeding behavior, body size and variegated coat color. Ecological conditions, feed resources and the interaction with cropping subsystems determine the goat management system. Recovery capacity of goats from drought is very remarkable due to their efficient reproductive behavior and variable body size (Horst, 1984).

3. Goats feeding behavior and climate change

One of the impacts of climate change on animal production is availability of forage in terms of quantity and quality (Rotter and Van de Geijn, 1999). Under arid tropical environments, where feed resources are restricted in quantity and quality, differences among ruminants in energy requirements and digestive efficiency are very important criteria for the selection of the most appropriate type of animal to be grown in particular circumstances (Devendra, 1990). This is reflected in the efficiency of the use of gross energy for production. Goats survive in varying environmental conditions and the different nutritional regimes under which they were evolved and subsequently maintained (Aziz, 2010). There are three aspects of dietary behavior of goats which makes them adapt to varying environmental conditions and these are selectivity, degree of browsing/grazing and flexibility. These are most adaptive features enabling goats to survive, reproduce and produce in marginal semi arid tropics. Goats are intermediate and fixed feeders that can graze and browse, and can use grasses as well as shrubs (Hofmann, 1989). This preference has been linked to underlying morphological digestive capacity. As browsers goats, have simple digestive system with profuse saliva production to efficiently process their feed (Holechek, 1984). They are more flexible in their feeding behavior changing their preference quite quickly. The selective, flexible and browsing nature of goats enables them to consume very nutritious food from many plants regarded as weeds (Mc Gregory, 2000). This makes them more selective feeders than either sheep or cattle. Lechner-Doll et al., (1995) observed that adapted goats can select high quality feed during the dry season while sheep showed less selectivity to high quality feed. They can choose from a wider range of plants including browse from trees and shrubs. Goats have evolved with a greater ability to browse and to digest lower quality herbage than other ruminants. Research has shown that goats are generally superior to sheep in digesting feeds with digestibility between 50 and 60% and that goats have an advantage in digesting the fiber component of the diet. While these findings show goats utilize feeds of low digestibility better than sheep it certainly does not mean that the production of goats increases as the quality of grazing or roughage decreases (Mc Gregory, 2000). Goats are extremely useful and effective in combating undesirable bush encroachment (Maloiy et al., 1979).

Feeding behavior of goats in response to plant toxins has also been studied. The ability to avert to particular feeds due to the presence of toxic level of tannins in black brush caused a transient decrease in ingestion of current season twigs by goats (Provenza, 1992; 1997). Goats can successfully graze on pastures which means they can be kept from extensive grazing to close confinement and housing. The ability for goat to graze and browse a wide range of unpalatable forage species is a necessary adaptive characteristic in livestock breeding in future. This is on the understanding of the uncertainties of climate change on forage species. Goats are browsers predominantly feeding on bush and shrubs. Browse and grass are ingested in the ratio of 82 and 16%, respectively (Viljoen, 1980). This makes goats utilize virtually any pasture and also excel under intensive conditions such as cultivated pastures. Their grazing habits or behavior make goat less susceptible to parasite infestation which occurs in the grass cover.

The rumen plays an important role in the evolved adaptations by serving as a huge fermentation vat and water reservoir. The water stored in the rumen is utilized during dehydration, and the rumen serves as a container, which accommodates the ingested water upon rehydration. The rumen, the salivary glands and the kidney coordinately function in the regulation of water intake and water distribution following acute dehydration and rapid rehydration. The feeding behavior is modified in frequency in goats, which resort to more frequent and shorter meals in order to reduce heat associated with rumen fermentation (Lechner-Doll et al., 1995). Goats in the tropics, when possible, eat a diet composed of tree-leaves and shrubs (browse), which ensure a reliable and steady supply of food all year around, albeit, from a low to medium quality food. Some of the physiological features of ruminants defined as intermediate feeders like large salivary gland, the large absorptive area of their rumen epithelium, and the capacity to change rapidly the volume of the foregut in response to environmental changes are most likely responsible for the goat' superior digestion capacity. Behavioral adaptation play a major role in goat production. Migration and use of shade during feeding have been used to an advantage by goats.

4. Goats functional adaptation and climate change

Goat living in harsh environments represents a climax in the capacity of domestic ruminants to adjust to such areas. This ability is multi-factorial, low body mass, and low metabolic requirements of goats can be regarded as an important assets. This minimize their maintenance and water requirements, in areas where water sources are scarcely distributed and food sources are limited by their quantity and quality. This ability to reduce metabolism allows goats to survive even after prolonged periods of severe limited food availability. Other physiological mechanisms such as sweating or panting to lose heat or adapt to severe water economy assist in survival in unfavorable conditions. The urine is highly concentrated in kidneys to avoid the need to drink water under severe water economy. These physiological mechanisms make goats able to thrive in extreme temperatures and limited water (Cain et al., 2005). There is a positive interaction between the better recycling rate of urea and a better digestion of such food in desert goats. In their review of osmoregulation in large herbivores Maloiy et al (1979) classed these animals into three main physiological ecotypes, the goat falling into the category of arid zone animals with low rates of energy and water turnover, and with medium to high urine concentration ability. The rumen plays an important role in the evolved adaptations by serving as a huge fermentation vat and water reservoir. The water stored in the rumen is utilized during dehydration, and the rumen serves as a container, which accommodates the ingested water upon

rehydration. Some of the adaptive physiological features for goats are large salivary gland, the large absorptive area of their rumen epithelium, and the capacity to change rapidly the volume of the foregut in response to environmental changes. These are most likely responsible for the goat's superior digestion capacity. Goats in the tropics, when possible, eat a diet composed of tree-leaves and shrubs (browse), which ensure a reliable and steady supply of food all year around, albeit, from a low to medium quality food. A skillful grazing behavior and efficient digestive system enable goats to attain maximal food intake and food utilization in given condition.

In semi arid areas with low erratic rainfall and the scarcity of surface water limits the use of pastures and determine the availability of livestock drinking water. Physiological adaptation of goats was observed where the ratio of water intake to urine voided, goats voided volumes of urine proportional to the volume of water drunk which would result in less moisture loss by the water deprivation. Giger Reverdin and Gihad (1991) reported that the water requirement for maintenance of goats in temperate climates is 107 ml/kg BW0.75 and indicated that water requirement under different ambient temperatures based on previous work ranged between 3.15 kg/kg DM at 230 C to 4.71 kg/kg DM at 350 C. Ahmed and El Kheir (2001) reported that desert goats raised under traditional systems may be watered only once every 3-6 days, when water is scarce. Their study was based on Bedouin and

Barmer goats as examples of adapted goats that can live on a once every four days watering regime. Goats have shown to tolerate water deprivation in general arid conditions. Elsewhere various reports on responses of ruminants to water deprivation in harsh environments have been published by Aganga et al., (1988) in West Africa, Schoen (1968) in East Africa and Sibanda et al., (1997) in Southern Africa. Devendra (1971) observed increased digestibility as length of water deprivation increased and there was no clear effect of water deprivation on feed intake. Langhans et al., (1991) observed that feed intake is less affected by water deprivation in adapted pygmy goats as compared to non adapted breeds. Fecal moisture content decreased with increased water deprivation, suggesting that goats were able to adjust their water output to their water intake. Goat tolerance to water deprivation may be due to their ability to limit urine and fecal water excretion (Adogla-bessa and Aganga, 2000). Goats drunk less water in winter, consume more feed, convert feed more efficiently and gain more weight in winter than in summer. Drinking behavior is affected by water restriction whereby water deprived goats tend to drink large volumes of water in one bout upon watering, and this ability is more pronounced in goats than sheep (Giger-Reverdin and Gihad, 1991). However, there is a tendency of goats experiencing higher level of dehydration in summer than in winter, probably due to water loss by thermoregulatory mechanisms and direct evaporation. The adaptability to water stress and the changes it induces under different physiological status include decreasing in feed intake and body mass loss. Saliva production is one of the major important mechanism for water deprivation. The rumen may play an important role is a reservoir of water source in the event of water stress. Length of gestation, kidding rate, post partum interval and inter kidding period were not affected by water stress in goats (Mittal, 1989).

The general homeostatic response to thermal stress in mammals include raised respiration rates (Yousef, 1985), panting, drooling, reduced heart rates, positive sweating (Blazquez et al., 1994), decreased feed intake as well as reduced milk production (Albright and Alliston, 1972; Liu, 1989). Black goats seem to reduce energy expenditure in winter but experience higher solar heat load in hot conditions. Therefore lighter coats in goats may be selected for future as condition get progressively hotter and drier with climate change. The numerical strength of goats in the tropical and sub tropical areas of the world indicate that they are more heat tolerant then other animals (Mittal, 1989). Heat stressed water deprived goats maintained their milk production for 48 hours despite a decrease in body weight of about 20% (Maltz and Shkolnik,1984). Feeding behavior is affected by high temperatures, nocturnal feeding has been documented in goats in order to avoid high temperatures during the day. Barhanu et al., (1994) showed that physiological observation in goats did not show signs of stress and the mean values of parameters observed were within the limits of tolerance to heat stress. The challenges of climate change will call for an animal with an efficient physiological response to heat stress and these attributes augur well with the uncertainties associate with climate change variability. The use of adaptive genotypes such as goats may sustain production in this regard by balancing the ability to produce and reproduce in stressful environment. As the adverse impacts become more frequent and severe, knowledge on how to deal with climatic variability with the objective of maintaining production by using adaptive species is paramount. This can only be achieved by utilizing adapted livestock species such as goats, because of their efficient reproductive system and a small body which allow an easy adjustment of flock size to match the available resources. Facilitating the integration of goats into flexible small scale production systems is possible due to their small size.

5. Goat improvement without compromising adaptability

Goat improvement can not be overemphasized, however the retention of adaptability traits will be crucial taking into account the challenges of climate change. In the context of climate change, any future goat improvement research, it is imperative to target productive traits but at the same time retaining the adaptive traits for sustainable livestock production. Goat improvement should be pursued in tandem with subjecting animals to simulated effects of climate change such as water deprivation, heat and nutritional stress. This will assist in substantiating the physiological and behavioral responses of goats to various environmental stressors associated with climate change. An improved understanding of the adaptation of goats to changing environmental conditions is thus important, however the measurements of adaptation may be complex and difficult (Scholtz et al., 2013). Goat breeding should consider adaptability has one of the single most important component of animal breeding in the unforeseen consequences of climate change. Goats adaptive capacity need conservable attention to reduce vulnerability to climate change. It is suffice to mention that the previous research imposed on the semi arid tropics disregarded adaptability as an important component of goat improvement , and did not take cognizance of the unforeseeable negative impact on livestock production. The output from any goat improvement program should aim at producing animals which tolerate unfavorable environmental conditions to ameliorate the negative effects of climate change. Animal genetic resources which cope with the harsh tropical environmental conditions need to be given greater attention in livestock production. The extent of goats to thrive in a situation where feed resources are dwindling and water being scarce will be the basis of genetic improvement research. Adaptation may take the form of morphological, physiological and ecological characteristics. The complexity of breeding for these traits may emanate from the fact that their proposed effects are not mutually exclusive because they occur together in an additive or synergistic fashion. Disregarding adaptability traits as major components of animal improvement will have a serious hindrance in accruing maximum benefits from livestock production ventures in semi arid tropics. Goat selection may consider adaptation characteristics which fits the perceived livestock production ventures to mitigate the effects of climate change.

A recent focus on non market valuation methodologies in valuing animal genetic resources need to be considered in the event of climatic variability. Drucker et al., (2001) and Roosen et al., (2005) have highlighted the potential role of non market valuation methodologies in valuing animal genetic resources. This emanate from the understanding that many of the benefits derived from the existence of well adapted indigenous animals species are not transacted in any market. Recent application show such methodologies reveal useful estimates of value that are placed on the market, non market and potential breed attributes. It means in future goat breeding should focus on other attributes considered secondary, such as adaptability, disease resistance, water and heat stress aversion by animals. Molecular genetics and simulation studies are likely to have a considerable impact on identification of adaptability traits. DNA tests for traits that are difficult to measure currently such as disease resistance and adaptability will be particularly useful. Trade offs are likely to become increasingly important between breeding for increased productivity in meat, milk etc and other traits such as disease resistance and adaptability. However, if animal genetic resources are to continue contributing substantially to improve livelihoods and meeting market demands, measures to mitigate the effects of climate change on livestock production will be critical. The choice of adapted species will be an insurance against future challenges to uncertainties of climate variability. A clear understanding of the need to match the goat type to the physical, biological and economic setup will drive the animal improvement processes. Smallness in goats as a trait may be promoted in future because of its advantage on resources requirement and greater refuge sites than do larger goat breeds. However, smaller size is likely to be disadvantaged by high mass specific metabolic rate, high water turnover and less capacity to store heat. Goat improvement research should do away with compromising adaptive traits on the expense of productivity alone. Breeding objectives should consolidated the ability of goats to cope with climate variability even better than before, but at the same time sustaining production. Compromising adaptational traits on the expense of productivity alone may be counterproductive in the animals ability to survive and produce in stressful environment. Adaptation to harsh semi tropical environmental conditions and the ability of animals to reproduce and produce in stressful environment is a vital component of livestock production in the context of climate change.

6. Implications

Livestock capacity decline as a result of use of ill adapted livestock species in the context of climate change offer a compelling task to adopt mitigation strategies to maintain and improve livestock production in the harsh semi arid tropics. Goat population in the semi arid tropics is presenting different forms of adaptability to different ecological conditions, which warrant greater attention in their utilization. Their ability to survive, reproduce and produce in harsh semi arid tropics is enough a testimony for sustainable livestock production. Goats have proved beyond doubt that, there are a resilient livestock genetic resource as indicated by their ability to thrive in these areas. Hence, it is imperative that goats are used to counteract the negative effects of climate change in livestock production. This is on the understanding that use of adapted livestock species is one of the solutions to mitigating the negative effects of climate change. The choice of livestock species to rear becomes crucial in the context of unpredictable climate effects. It needs not to be emphasized that environmental stressors caused by climate change are a serious threat which are undermining livestock production. Some of the known environmental stressors include high ambient temperature, low nutritional value of forage and emerging of new disease and parasites. It is assumed that goats due to their adaptive capacity to harsh environmental conditions are likely to make a valuable contribution despite the unavoidable negative influence of climate change on livestock production. However, there is need to improve the understanding of general adaptation of livestock to such changing production environments, although the measurement of adaptation is complex and difficult. From the distribution nature of goats in the tropics, it points to the fact that goats are able to survive in a wide range of environmental conditions characterized by prolonged drought, feed and water scarcity. They can walk long distances in search of water and forage, and utilize course forage for their production and survival. In view of these parameters, livestock production systems could be only sustainable in long term, if adaptive species such as goats are promoted to counteract the adverse environmental effects. It is suffice to mention that the focus on use of adapted livestock species should be supported by appropriate research to consolidate species adaptive capacity to the unfavorable environmental conditions. Adaptive features of goats such as feeding behavior and disease tolerance should be further investigated and understood through climatic change simulation studies. Goats attributes which were not considered important in breeding, such as outstanding adaptability, disease resistance and low maintenance cost may be valuable to mitigate the negative effects of climate change in future. Goats are smaller animals which have less maintenance requirement which will be paramount in the event of scarce feed resources. The ability to graze and browse a wide range of forage species which may be unpalatable will be a necessary adaptive characteristic in sustainable livestock production. Water shortage is one of the major components of climate change, as a result structural characteristics which enable animals to walk for long distances to look for water and feed need to be incorporated in future

improvement programs. The choice of goat production in this regard may increase the adaptive capacity of livestock producers because they have a greater effect on the ecosystem than any other animal species. It is suffice to suggest that in any future livestock production strategies or research, there is need for gradually modification to actual respond to crisis that are associated with climate change by choosing the adaptive livestock species such as goats. Promoting livestock species which are ill adapted in harsh semi arid tropics will be a recipe for a disaster. This will have long term negative effects on livestock productivity in semi arid tropics. It should be acknowledged that goats represents a group of animal genetic resources resilient to climate variability, hence should not only be conserved for future use, but be incorporated in main stream livestock production activities to serve the increasing population. Intensified research on behavior of goats under unfavorable conditions may be a vital springboard to embark upon their improvement in the context of climate change. This can be achieved through application of modern scientific knowledge gathered through simulation studies on heat stress and water deprivation, which are major components of climatic variability. Research which put emphasis on making goat production systems better cope with the negative impact of climate change than before are critical. This means goats deserve greater attention considering their adaptive capacity in the event of uncertainties of climate change. Given the considerable hardy characteristics of goats their promotion will go a long way to improve livestock productivity and at the same time act as a coping strategy in response to the adverse effects of climate change in the semi arid tropics. The rich adaptable morphological, physiological and behavioral characteristics could be exploited for future goat breeds improvement programs in semi arid tropics.

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