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A review of strategies aimed at adapting livestock to volatile climatic conditions in Nigeria

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Abstract

Despite their crucial importance, limited information exists about how livestock are affected by climate change in Nigeria. Changing climatic patterns are manifested through occurrences like abrupt temperature increase, dwindling rainfall pattern, rise in spells of drought and flood. These conditions exert different effects across the geographical landscape of the country, which can broadly be classed as Semiarid, Sahel and Derived Savannah, respectively as well as Forest and Montane. Livestock provide humans with the full complement of amino acids, which are the only known natural suppliers of Vitamin B_{12} and equally supply iron, calcium, iodine and zinc. In addition, livestock accounts for 40% of Agricultural Gross Domestic Product and significantly contributes to enhancing rural livelihood. Stress conditions are induced in livestock by harsh weather conditions that reduce the feed available to them as well as impede growth rate and reproduction efficiency and disease incidence which may eventually result in death. In the light of the livestock benefits to humanity, it is necessary to devise means of making their climate resilient. Some of the proven strategies include animal genetic improvement for stress tolerance, growing disease resistant, early maturing and drought tolerant crops, selecting for and rearing climate tolerant animal species and breeds.

Keywords: Adapt, Livestock, Climate, Stress, Strategies

Un examen des stratégies visant à adapter le bétail aux conditions climatiques volatiles au Nigéria

Résumé

Malgré leur importance cruciale, il existe peu d'informations sur la manière dont le bétail est affecté par le changement climatique au Nigéria. Le changement des modèles climatiques se manifeste par des événements tels que l'augmentation brutale de la température, la diminution des précipitations, l'augmentation des périodes de sécheresse et d'inondation. Ces conditions exercent des effets différents sur le paysage géographique du pays, qui peuvent être globalement classés comme semi-aride, sahélien et savane dérivée, respectivement, ainsi que forêt et montagne. Le bétail fournit aux humains le complément complet d'acides aminés, qui sont les seuls fournisseurs naturels connus de vitamine B12 et fournissent également du fer, du calcium, de l'iode et du zinc. En outre, l'élevage représente 40% du produit intérieur brut agricole et contribue de manière significative à l'amélioration des moyens d'existence ruraux. Les conditions de stress sont induites chez le bétail par des conditions météorologiques difficiles qui réduisent les aliments disponibles pour eux et entravent le taux de croissance, l'efficacité de la reproduction et l'incidence des maladies qui peuvent éventuellement entraîner la mort. À la lumière des avantages de l'élevage pour l'humanité, il est nécessaire de concevoir des moyens de rendre leur résilient climatique. Certaines des stratégies éprouvées comprennent l'amélioration génétique animale pour la tolérance au stress, la culture de cultures résistantes aux maladies, à maturation précoce et à la sécheresse, la sélection et l'élevage d'espèces et de races animales tolérantes au climat.

Mots clés: Adaptation, Bétail, Climat, Stress, Stratégies

Introduction

The livestock sub-sector of the Agricultural Industry in Nigeria is affected by changing climatic conditions and other environmental hazards within all the ecological regions in the country. These conditions are hazardous and include but not limited to late onset of rainy season, higher than normal temperatures, flooding, salt water intrusion and windstorms. Late onset of the rainy season causes a lack of available water for livestock and reduces forage availability. Higher than normal temperatures leads to poor livestock health which reduces the market value of affected livestock thereby reducing farmers' income. Flooding leads to loss of livestock, destruction of livestock enclosures and outbreak of diseases. Windstorms impact fodder crops for livestock. Salt water intrusion leads to decline in livestock production as quality of fodder becomes poor due to salt water (Scholes, 1990,1993). This sub-sector is vulnerable to climate change hazards because livestock farmers in Nigeria are dependent on water to provide sufficient quantity and quality of fodder from rangeland and to provide drinking water for livestock. The high levels of poverty among livestock farmers and lack of economic alternatives for farmers and their household members combine to enhance the vulnerability of the livestock sub-sector. The main economic impact of climate change on livestock production is the loss of income that sustains pastoral livelihoods. Men are predominantly involved in livestock production therefore they have greater vulnerability to climate change impacts. However women are also affected because of their role in marketing milk products and indirectly through loss of family income from livestock. Despite the low adaptive capacity of livestock farmers to the impacts of climate change, historically, they have developed strategies to cope with and adapt to a region characterized by a variable climate. Communities dependent on livestock have over time faced harsh changes in environmental conditions and are therefore aware of the need to adopt different types of coping and adaptation strategies. These strategies include the use of forage obtained from hedgerows and compound farms, application of herbs to livestock diseases, migration of male and female youth to cities in search of jobs, drilling boreholes and water harvesting (e.g. from zinc roofs).

The debacle and likely prognosis

The livestock sub-sector is particularly susceptible to climate change due to the extent that livestock depend on water for survival. Shortage of rainfall, late onset of rains and rising temperature in the Sahel and Savanna will result in declining livestock production and productivity as well as increased incidence of diseases. In the Rainforest and Coastal zones, flooding and erosion will displace livestock farmers, destroy their assets and increase disease infestation in livestock farms. This trend will ultimately reduce animal protein supply in the country as much of the livestock production in Nigeria comes from these regions.

In the livestock subsector, the reduction of climate-related risks and adaptation to climate change will not be easy and will require long-term approaches unless a radical shift from current cultural norms of livestock management is introduced. Firstly, rangeland overgrazing and degradation must be halted and reversed to allow for recovery to full production potential. Planned and controlled range management programmes must be implemented, with grazing areas realistically divided into manageable blocks that allow for rotational grazing with managed rest periods. Re-seeding with palatable grass species will be required in some places with due consideration for likely competition with the native grass species and suitability for erosion control. Over the short term, interventions which reduce pressure on the rangelands will be required, such as fodder production and preservation, and the use of other supplementary feeds. A fodder production scheme could be introduced and encouraged on crop farm lands to boost livestock feed supplies and to relieve pressure on the local rangelands Fodder species could include dual purpose (food-feed) crops such as legumes, and sorghum, rather than only planting fodder for animals as these will be more attractive to farmers (Agyemang, 2010). Whilst indigenous cattle breeds are well suited to the current and future climate, livestock owners require basic training in herd management to optimize the breeds' genetic potential, such as introducing seasonal mating systems, providing for suitable weaning times, culling unproductive animals, and maintaining a manageable animal health programme year-round. Veterinary extension services should be made available. Development of abattoir facilities in towns would be in of support for planned culling programmes. Alternative livestock production such as intensive pig and poultry production schemes in the rural areas are desirable climate risk adaptation option, since no rangeland is and the animals are housed and thus protected from the elements.

Crop-Livestock integration can be an economically viable and environmentally sustainable option for climate change adaptation if introduced properly. For example, it is recommended that instead of introducing Irish potatoes (plant tops and vines do not have much feeding value for livestock), sweet potatoes should be encouraged (vines and leaves are used for feeding livestock) and legume introduction should not be limited to Pinto beans, but should also include dual purpose (food-feed) cowpea varieties to serve both household food security and livestock fodder needs. Any proposed drought resistant crop/tree species should try to consider dual purpose (food-feed) varieties. There is currently no policy framework programme for breeding and developing animals that are better adapted to climate changes such as heat, drought and high humidity. This problem needs to be addressed at a national level.

Existing governance, policies and programs

The recommendations for federal, state and local government and the private sector for improving livestock production are outlined in Agriculture in Nigeria: FMARD, 2000; Manyong *et al*., 2003). If implemented, these recommendations could make an important contribution to climate change adaptation in the agriculture sector.

The following adaptation actions are recommended for the livestock sub-sector:

Intensive livestock keeping: Keeping livestock in a confinement instead of free range (extensive) will help farmers adapt to climate change impacts like disease infestation. Government, private sector, and NGOs can help livestock farmers adapt to climate change by providing soft loans needed to initiate intensive livestock production.

Planting trees near livestock houses and on pasture land: This strategy will help farmers adapt to severe windstorms which are responsible for destruction of livestock houses and forage land.

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Greater support for insurance: Government should increase support for the Nigerian Agricultural Insurance Scheme and farmers should be encouraged to register with the

Table 1: Hazard- impact-vulnerability-adaptation matrix for livestock sub-sector

Climate Change Impacts	Climate Hazard	Determinants of Vulnerability	Adaptation Options
Eco-zone- Coastal/Rainforest Late onset & early cessation of rainy season Rising poor livestock health which reduces market value of affected livestock Reduced farmers' income and reduction in livestock production Destruction of fodder crops and livestock houses Sea level rise	Lack of availability of water for livestock Reduced forage availability Disease outbreaks and loss of pasture land from flooding & erosion Decline in livestock fodder and pasturelands	High dependence on water for livestock production Poverty Dependence on fodder from rangeland	Rainwater harvesting, digging of boreholes, use of forage obtained from hedgerows & compound farms, intensive livestock management Use of ethno-botanicals in treating livestock diseases, Building of culverts, Quarantine Planting of trees to serve as windbreaks
Ecozone – Savannah Late onset and early cessation of rain Rise in temperature Occasional increase in rainfall intensity	Reduced fodder production, heat stress, loss of pasture Heat stress, high disease burden, loss of pasture Outbreak of diseases like foot rot, destruction of livestock houses, flooding	Poverty Dependence on livestock production	Feed supplementation, shift to crop production especially to production of drought tolerant crops like millet and maize, drill boreholes, water harvesting (zinc roofs) Intensive livestock management, Migration to Fadama sites where there is moisture
			Use of ethno-medicine to treat animals, diversification into mixed farming
Eco-zone – Sahel Late onset of rain Rise in temperature	Drought and desertification More frequent droughts, heat stress and increased incidence of diseases	Lack of weather forecasting resources Poverty	Migration to Fadama sites where there is moisture

Adapted from Nwajuiba *et al.* (2011)

scheme. This will help farmers in the event the death of livestock due to flood, diseases and lack of water.

Developing improved livestock breeds: Government should increase support for livestock breeders in developing disease resistant species.

Building up measures to institutionalize Early Warning Systems: This will increase livestock farmers' ability to respond to climate related drought, flooding and disease impacts. Provision of potable water for livestock: Construction of dams, boreholes and wells are recommended to cater to the water needs of livestock management during the dry spells. Construction of embankment (dikes): This will help to reduce flooding caused by high rainfall events.

Culling of animals: Maintaining manageable herd size and removing diseased animals early will help reduce and control disease infestations.

Regular vaccination of livestock and cross border diseases surveillance: Vaccination can help reduce infections especially for migrating animals.

Encourage rainwater harvesting practices: This will help farmers adapt to shortage of water during dry spells and improve available forage on rangelands.

Other potential adaptation strategies involve land use decisions, animal feeding changes, genetic manipulation and alterations in species and/or breeds. In terms of mitigation, livestock is a substantial contributor to global non-CO_2 greenhouse gas emissions. Mitigation opportunities involve altered land use for grazing and feed production, feeding practices, manure treatment and herd size reduction. In addition, strengthening institutions that promote markets and trade, as well as local support programs can help both mitigation and adaptation. Succinctly, a combination of nutritional manipulation, breeding and good management techniques is needed in order to achieve desirable results. Some of the nutritional approaches include:

Forage species and stage of maturity

Both factors play significant roles as Benchaar *et. al* 2001 found out that the substitution of Timothy hay with Lucerne decreases methane emission by 21% (expressed as % digestible energy). Also, McCaughley *et. al*. (1999) observed that a 70:30 mix of Lucerne and grasses brought about 10% reduction in methane emission per unit product. It was concluded by the authors that the Methane reduction was due to intake of higher levels of lucerne intake which brought about a higher digestibility rate and increased passage of nutrients from the rumen. Furthermore, assuming there is an increased concentration of malate up to 3% of dry matter intake (DMI), the CH_4 decrease might be explained by the organic acid (malate). This characteristic effect on methanogenesis, however, is not typical of all legumes; for instance Clover (white or red) did not differ from Ryegrass on CH_4 emissions of growing Cattle (Beever *et. al,* 1985) or dairy Cattle (Van Dorland *et. al*, 2007). Inclusion of tannin rich legumes such as Sainfoin, Lotus, Sulla and certain shrubs in the diet also contributes to suppression of methanogenesis due to the presence of condensed tannins. Robertson and Waghorn (2002) observed that methane production from grazing dairy cows increased with forage maturity from 5% to 6.5% of Gross energy intake (in spring and summer, respectively). This was however not observed in other experiments; for example, cows grazing on a monospecific pasture of timothy at four stages of maturity over the grazing season (Pinares-Patin *et. al*,. 2003). A decrease in CH_4 with young fresh forages may be explained by a higher content of soluble sugars and linolenic acid. More generally, the correlation between forage quality and CH_4 emissions is low (Pinares-Patin *et. al*, 2007).

Level and nature of concentrates

An increase in the level of concentrates leads to a corresponding decrease in methane production as a proportion of energy intake or expressed by unit of animal product (milk and meat). Losses in methane appear to be relatively constant (6-7% of gross energy intake) for diets containing up to 40% concentrates while a rapid decrease (2-3% of gross energy intake) sets in when inclusion jerks up to 80%. Significant modification of rumen physico-chemical conditions and microbial populations has been found to result from the replacement of structural carbohydrates in forages (cellulose, hemi-cellulose) with non-structural carbohydrates in concentrates (starch and sugars). This is an offshoot of increased feed intake, higher rate of ruminal fermentation and accelerated feed turn over. A shift in volatile fatty acid production from acetate towards propionate occurs with the development of starch fermenting microbes which results in lower methane production. This is so because the relative proportion of ruminal hydrogen sources declines while hydrogen sinks increases. Concentrates rich in starch such as Maize, Wheat and Barley have a more important effect on low CH_4 production than fibrous concentrates e.g. Beet pulp. Beauchemin and McGinn (2005) measured CH_4 emissions from feedlot cattle fed starter and finishing diets containing maize (slowly degradable starch) or barley grain (rapidly degradable starch). Effect of grain source on CH_4 emissions was conditioned by the production phase. Expressed on the basis of Gross Energy intake, CH_4 emissions during the starter phase were not affected by grain source, whereas emissions were surprisingly less for the maize finishing diet than for the barley finishing period.

Level, nature and presentation of lipids

Dietary fat seems to be a promising nutritional alternative to depress methanogenesis without affecting other ruminal parameters. Martin *et. al*, (2009) summarised publications measuring in-vivo methane emissions where different lipid sources and forms were included in the diet. A total of 67 diets supplied with lipids, taken from 28 publications were kept for analysis; 29 results were obtained in open calorimetry chambers, 31 by the SF6 method and six by other methods; 33 were obtained on dairy cows, 13 on growing cattle and 16 on Sheep at maintenance and 5 on growing lambs. A mean decrease in CH_4 of 3.8% was observed for every 1% supplemental fat added. It was hypothesised that the fatty acids' effects depended on their nature. A decrease by 52% has been shown with a supplement of 5.8% linseed oil whereas a decrease by 37% has been observed with 6% soyabean lipids (Jordan et al., 2006a). Data are less numerous for monounsaturated fatty acids such as oleic acid (from rapeseed; five data) and saturated fats (from tallow; eight data), but these supplements result in decreases by 2.5% and 3.5% per percentage unit of added lipids, respectively. A decrease of 30% has been observed when 12% tallow was added to the diet. Recently, Beauchemin *et. al*, (2009) reported that CH_4 production in dairy cows was more affected by linseed and rapeseed (217% on average) than by sunflower seeds (210%). Woodward *et. al*, (2006) investigated in vivo the effect of fish oil, rich in C20:5 and C22:6, in association with other oils and reported a minor effect on methanogenesis. A common effect for all lipid sources is that unlike other feed constituents such as forages and cereals they are not fermented in the rumen, and thus the decrease in fermented organic matter leads to a decrease in methane. Among common sources of lipids, coconut oil suffers from a possible negative effect of medium-chain fatty acids on human health, due to an increase in myristic acid in milk. In contrast, polyunsaturated fatty acids are considered beneficial on human health and their use in diets, which results in a limited increase of these fatty acids in milk and meat, could thus be proposed as a way for CH_4 abatement provided that supplementation levels do not decrease feed efficiency or performance of animals.

Ionophores and organic acids

Ionophore antibiotics e.g. lasalocid and monensin are among the feed additives most commonly used to suppress methanogenesis and increase efficiency in ruminant production. Their mode of action often is directly on microbes wherein there is a shift in fermentation towards propionate production as against acetate. Ionophores also affect protozoa; the reduction and subsequent recovery in protozoal numbers perfectly matched CH_4 abatement – up to 30% and restoration to previous level in a cattle trial (*Guan et. al*, 2006). The effect on emissions range from no changes to up to, 25% reductions with persistency being also variable among studies, from long- to short-term (e.g. up to 6 months to a few days, respectively). These groups of additives are however not allowed in some countries including the European Union (where use of antibiotics has been banned since 2006). Organic acids (malate, fumarate and acrylate) have been assayed as diet additives. Fumarate and acrylate has been shown to be the most effective in vitro (Newbold *et al*., 2005). In contrast to the well-documented CH_4 production response to organic acids in vitro, responses to dietary supplementation in vivo remain inconclusive and highly variable. An exceptional decrease in methane production, up to 75%, has been shown with 10% encapsulated fumarate in the diet of lambs without any negative effect on animal growth (Wallace *et. al*, 2006). In contrast, encapsulated fumarate had no significant effect in another trial in dairy cows (McCourt *et al*., 2008). The high malate content in fresh forages (especially lucerne) at early growth stage, could lead to significant changes in rumen microbial fermentation.

Plant extracts (condensed tannins, saponins, essential oils): There is growing interest in the use of plant secondary compounds as a CH_4 mitigation strategy. Preparations from plants are seen as a natural alternative to chemical additives that have been banned or that may be negatively perceived by consumers. Most trials with plant extracts have been done in-vitro and the response of these molecules on methanogenesis is highly variable. Most positive reports concern the chemical families of tannins and saponins, and the heterogenous group of compounds known as essential oils. For tannin-containing plants, the antimethanogenic activity has been attributed mainly to the group of condensed tannins. Two modes of action of tannins on methanogenesis have been proposed in vitro by Tavendale *et. al*, (2005): a direct effect on ruminal methanogens and an indirect effect on hydrogen production due to lower feed degradation. Many plants contain tannins, and these are often tropical shrub legumes. Animal trials with plants or extracts of condensed tannin-containing Lotus corniculatus, Lotus pedunculatus and *Acacia mearnsii* reduced CH_4 production in small ruminants (sheep, alpaca, and goats) by up to 30% without altering digestibility (Pinares-Patin o *et. al*, 2003; Carulla *et. al*, 2005; Puchala *et. al,* 2005). More recently, Tiemann *et. al*, (2008) reported that the inclusion of the tannin-rich shrub legumes species *Callinadra calothyrsus* and *Fleming*a *macrophylla* in the diet reduced methane emissions in growing lambs by up to 24%, but this was associated with reduced organic matter and fibre digestibility. Notwithstanding, the effect of condensed tannins cannot be generalised and testing is necessary as high-tannin sorghum silage (De Oliveira *et. al*, 2007) or condensed tannin extract from *Schinopsis quebrachocolorado* (Beauchemin et al., 2007) seem not to be effective in cattle. Many biologically active molecules present in essential oils have antimicrobial properties that are capable of affecting rumen fermentations. Among them, it has recently been shown that garlic oil and some of its components decreased CH_4 production in vitro (Busquet *et. al*, 2005; Macheboeuf *et. al*, 2006). This was attributed to the toxicity of organosulphur compounds such as diallyl sulphide and allicin on methanogens. Additional research in vivo may be required to determine the optimal dose of the active compounds, to consider the potential adaptation of rumen microbes, the presence of residues in animal products as well as the potential anti-nutritional side-effects of such molecules. Palatability of these compounds could represent a practical issue. It has to be noted that sulphur-containing compounds are responsible for the described haemotoxic effects of onion and garlic on domestic herbivores (Rae, 1999; Pearson *et. al*, 2005).

Use of probiotics (Acetogens and yeast): The use of probiotics for the stimulation of rumen microbial populations capable of decreasing CH_4 emissions remains a potentially interesting approach. Reductive acetogenesis is a natural mechanism of hydrogen utilisation that coexists with methanogenesis in the gastrointestinal tract of many animals. This pathway is the dominant one in several hindgut-fermenting mammals (humans, rabbits, hamsters, rats) but also in foregut fermeners such as kangaroos (Klieve and Joblin, 2007). Acetate, the final product of the reaction, has an additional advantage of being a source of energy for the animal. However, in the rumen environment, acetogens are less numerous and efficient than methanogens in the competition for reducing equivalents. This is probably because acetogens need a higher concentration of hydrogen in the medium to reduce CO_2 into acetate than that required for methanogens to reduce CO_2 into CH_4. In addition, the former reaction is thermodynamically less favourable (Weimer, 1998). Attempts to increase the natural rumen population of acetogens have been assayed but without success (Demeyer *et. al,* 1996). The use of acetogens as probiotics has also been tested by several authors with and without the addition of methanogen inhibitors to favour competition (Nollet *et. al*, 1998; Lopez *et. al*, 1999). Results, so far, have been either unsatisfactory or not conclusive. The recent isolation from diverse gut environments of new species (Klieve and Joblin, 2007) with presumably a higher affinity for hydrogen than previously tested acetogens could offer a renewed prospect for this approach. Live yeast, the most commonly used probiotic in ruminant production, has not been extensively tested for their effect on CH_4 production (Chaucheyras-Durand *et. al,* 2008). However, yeasts are capable of showing great functional and metabolic diversity while some strains have been reported to decrease CH_4 production in vitro (review of Newbold and Rode, 2006). These results are yet to be confirmed in vivo. The mechanisms by which yeasts decrease methanogenesis has been proposed to be by increasing microbial synthesis (review of Newbold and Rode, 2006) and by stimulating reductive acetogenesis (Chaucheyras *et. al*, 1995).

Gaughan and Cawdell-Smith (2015) reviewed studies of Climate Change impacts on livestock production and reproduction, concluding that findings largely indicated detrimental effects. They argue that adaptation in the form of genetic manipulation, breed change and/or species change may be needed. Silanikove (2000) indicates a switch to goats from cattle may be in order as goats have been found to be better adapted to hotter conditions; goats possess skillful grazing behavior; and the goat digestive system is more efficient as the rumen can serve as a fermentation vat and water reservoir. One should note that animal physiology and genetics limit an animal's adaptive capacity and that livestock breeders can alter traits to enhance adaptation (Gaughan and Cawdell-Smith, 2015). Breeds and species changes are also possible adaptations. Seo *et al*. (2010) examined climate influence on choices among five primary South American livestock species. Their results suggest that as Climate Change shifts toward hotter and drier conditions, producers would reduce beef cattle, dairy cattle, swine and poultry but increase sheep. Zhang *et al*. (2013) examined breed choice between *Bos taurus*, *Bos indicus* and composite breeds in Texas, finding summer heat stress influenced breed selection, with heat stress increasing favoring *Bos indicus*, while reducing *Bos taurus* and composite breeds. Wu (2015) examined how Climate Change influences the distribution of yak breeds in China, finding breed incidence has mainly shifted northward or westward (which is upward in elevation), partly as a response to the thermal conditions. Animal incidence is also affected by climate "extremes". Seo (2015) found in Australia that under high temperature conditions, sheep production increases in arid ecosystems while beef cattle remain about the same. The study also predicts under hotter and more arid CC futures that crops will decrease and numbers of beef cattle and/or sheep will increase. They indicate this shift is due to increased comparative advantage of raising livestock and reduced prevalence of livestock diseases.

For small-ruminants, Seo (2016) found that, as the monsoon climate intensifies, Indian farm households would increase goat numbers. Finally, regional adaptation will be in order as a shift in livestock species and incidence will alter needs for supporting industries providing feed, animal and feed transport, animal slaughter and meat packing and final product transport (Steinfeld *et al*, 2007).

To summarize, different ruminant livestock species or breeds respond differently to climate alterations and that livestock producers can adapt to Climate Change by changing species or breeds. A major mitigation strategy involves reducing herd size or composition. Thornton *et al*. (2009) mention that the only effective way to reduce livestock CH_4 emissions in pastoral systems would be to reduce livestock numbers, as does Ripple *et al*. (2013). Also, Patra (2017) suggests that crossbreeding can be a mitigation strategy. For example, he estimates that if half of the indigenous cattle populations in India were replaced by crossbred cattle, then the carbon footprint of milk production could drop by 30% due to increased productivity.

Concepts for alleviating heat stress by environmental management have been narrowed to two strategies: altering the environment by providing shade in order to decrease exposure to solar radiation and/or evaporative cooling; secondly, directly cooling by using sprinkler or soakers to wet the animal. The implementation of a shade structure decreases solar heat load on animals. The environment surrounding the animals can then be further improved via increasing convection with fans or to decrease air temperature by evaporative cooling or by directly cooling using sprinklers and soakers.

Conclusion

Recommended roles for the federal government include:

There should be research and development of appropriate technology for agriculture, including biotechnology to continually increase the yield of agricultural production as well as find markets for the products.

Table 2: Policies, programs, adaptation options addressed, implementing agency and cost for the livestock sub-sector

Recommended Climate Change Adaptation (CCA) Policy Options	Proposed CCA Programmes	Eco-zones Addressed	CCA options addressed by proposed policies & progs.	Implementation Agency	Estimated Costs (₦)
Comprehensive review of national agricultural policies on pest and disease control; agricultural credit schemes	Mainstream CCA in animal disease control & surveillance programme Comprehensive review of National Agricultural Credit Grant Scheme	All	Regular vaccination of livestock and cross-border diseases surveillance Culling of Animals Intensive livestock keeping	Farmers and Government Agencies	200 Million
Maintenance of existing large dams & developing small dams, provision of borehole for livestock farmers' communities as a further effort in implementing National Agricultural Policy on Water Resources	Mainstream CCA in River Basin Development Programmes Encourage rainwater harvesting by Agricultural Extension agents	All Rainforests/ Coastal Zones	Provision of potable waterfor livestock Constructionof embankments Encourage rainwater harvesting practices	River Basin Development Authorities National Fadama Programme Communities NGOs	1 Billion
Increase national coordination of Agricultural Research Policy	Mainstream CCA in livestock development programme of the Federal Ministry of Agriculture	All	Develop improved hybrids of livestock species	Livestock Research Institutes	500 Million
Develop policy on Early Warning Systems for floods & disease outbreaks	Programmes on early warning systems for floods and other climate related disasters including disease outbreaks Encourage scientific and indigenous knowledge on weather forecasting	All	Building up measures to institutionalize Early Warning Systems for rainfall, drought, floods, & disease outbreaks	Nigerian Meteorological Agency (NIMET) & its affiliated agencies Communities	500 Million
Comprehensive Review of Agricultural Policy on Insurance	Mainstream CCA in Nigerian Agricultural Insurance	All	Greater supportfor Insurance	Nigerian Agricultural Insurance Corporation (NAIC)	250 Million

Adapted from Nwajuiba *et al.* (2011)

Table 3: Recommended Climate Adaptation and Mitigation Strategies for livestock reared in Developing Countries

Adaptation/Mitigation	Section	Developing Countries
Adaptation	Feed and Land Resources	Animal feed production: • Farm-level production adjustments • Introduce/revise insurance/credit schemes; enhance income diversification opportunities • Institutional changes such as introducing subsidies, strengthening markets and trade • Adopt new technologies Land use: • A move to livestock out of cropping • Increase the joint production of crops and animals
	Genetics/Breeds/Species	Ruminants: • Switch from cattle to goats • Increase sheep • Increase goats
	Trade and Local Institutions	Trade: • Trading can induce adjustments in regional production Local Institutions: • Local agriculture trad itional knowledge can be of essential help
	Disease	• Increase Disease Surveillance by improving Local and National Quarantine Services •Enforce incorporation of strict bio-security measures in farms • Select animal breeds resistant to ticks, drought, typanosomosis etc
Mitigation	Land Resources	Land Use: • Better management of existing protected area • Facilitate eco-services payment mechanisms • Improve grazing management • Legume sowing on pasturelands Land Use Change: • Intensify cattle ranching to avoid deforestation • Transition towards more efficient livestock production systems
	Fertilization	Nitrogen efficiency: • Increase Nitrogen efficiency during both feed production and livestock assimilation stages
	Enteric Fermentation	Nutrition: • Treat crop byproducts with urea in mixed crop-livestock systems
	Manure Management	CH_4 (Methane) • Reduce exposure of manure to water
	Livestock Numbers, Breeds and Mix	• Decrease herd size • Increase feeding efficiency, especially for swine and poultry Breeds and Mix: • Increase share of crossbred animals
	Market trade	Supply: • Shifts in regional production Demand: • Shifts in dietary preferences

Adapted from Zhang *et al*. (2017) with slight modifications

Also, there should be establishment and maintenance of an effective and robust national animal quarantine service. There should be establishment of an agricultural insurance scheme and collaboration with state and local governments for a well-trained and effective agricultural extension service delivery to all farmers. In addition there should be Government support to inputs, supply and distribution including improved breeds; and playing a larger role in the control of livestock pests and diseases of national and international significance.

Recommended roles for state governments include:

The promotion of all livestock products through the provision of more effective extension service as well as promotion of the production of inputs required to support livestock production. Also, there should be promotion of ranch development and access to water for livestock; contribute to training and manpower development. The promotion of the control of animal pests and diseases and promotion of appropriate institutions for administering credit to smallholders should also be included within the state Government's purview. There should also be maintenance of buffer stocks of agricultural commodities and investments in rural development infrastructure including rural roads and water supplies.

Recommended roles for local governments include:

There should be provision of an effective agricultural extension service and rural infrastructure. The mobilization of farmers for accelerated agricultural and rural development through cooperative organizations, local institutions and the communities and co-ordination of data collection at the primary levels should be done.

Recommended roles for the private sector include:

Investment should be encouraged in all aspects of livestock production such as livestock product storage, processing and marketing. There should also be provision of a favourable investment climate for the private sector in livestock input supply and distribution. In addition, production of commercial breeds under government certification and quality control should be encouraged. There should be provision of enterprise-specific rural infrastructure and rendering of support for research in all aspects of livestock production.

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