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Climate Change Impacts on Animal Production and Contribution of Animal Production Sector to Global Climate Change: A Review

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ABSTRACT

Global demand for animal products is extremely increasing in the future period, which mainly because of improvement in the global standard of living. In the meantime, global climate change is a pressure to animal production due to the impact on quality of forages, water availability, animal and milk production, animal health, animal reproduction and biodiversity. This paper reviews the impacts of climate change on animal production and converse contributions of animal production sector to global climate variation and specific climate change adaptation and mitigation strategies in animal production sector. Global climate change will affect animal production and consequently food security mainly in tropical regions. This paper also reviewed that, converse contribution of animal production sector in emission of GHGs to the atmosphere for global climate change. Therefore, global climate change adaptation, mitigation practices and policy frameworks are critical to protect animal production.

Key words: Adaptation, Animal production, Climate change, Green house gas, Mitigation.

Global demand for animal products is expected to increase extremely in the future period, which mainly because of advancement in the global standard of living. Animal products are an important agricultural commodity for global food security since they provide 17% of global kilocalorie consumption and 33% of global protein consumption (Rosegrant *et al*., 2009; Mottet *et al*., 2017). This sector contributes to the livelihoods of 1 billion poorest populations and 1.1 billion employs in the world (Hurst *et al*., 2005). There is an increasing demand for animal products in developing countries (Thornton, 2010; Wright *et al*., 2012). For instance, worldwide milk production will be increased from 664 million tonnes (2006) to 1077 million tonnes and meat production will double from 258 to 455 million tonnes by 2050 (Alexandratos and Bruinsma, 2012).

Animal production is adversely affected by climate change, competition for land and water and food security at a time when it is most needed (Garnett, 2009; Thornton, 2010; Kovats *et al*., 2014). For that reason, the challenge is to maintain a balance between productivity, household food security and environmental preservation (Wright *et al*., 2012). According to Intergovernmental Panel on Climate Change (IPCC) (2013), the global climate change is mainly caused by greenhouse gas (GHG) emissions that result in warming of the atmosphere. Animal production sector contributes 14.5% of global GHG emissions (Gerber *et al*., 2013) and it may increase land degradation, air and water pollution and declines in biodiversity (Steinfeld *et al*., 2006; Reynolds *et al*., 2010; Bellarby *et al*., 2013).

There is an increasing interest in understanding the interaction of climate change and animal production (Aydinalp and Cresser, 2008). However, there is limited research and review has been conducted regarding the impacts of climate change on animal production and contribution of animal production in green house gases (GHG) emission to the atmosphere for climate variation (IPCC, 2014). Therefore, this paper reviews the impacts of climate change on animal production and food security and animal production sector's contribution to climate alteration. The objectives are to: (1) address the impacts of climate change on animal production; (2) describe the impacts of animal production sector on climate change and (3) sum up climate change adaptation and mitigation strategies.

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Impact of climate change on animal production

The impact of climate change on animal production includes changes in production and quality of forages (Rowlinson, 2008; Thornton *et al*., 2009; Stokes *et al.,* 2010; Chapman *et al*., 2012 ; Polley *et al*., 2013; Mottet *et al*., 2017), water accessibility (Nardone *et al*., 2010; Henry *et al*., 2012), animal growth and milk production (Aydinalp and Cresser, 2008; Henry *et al*., 2012), diseases (Thornton *et al*., 2009; Nardone *et al*., 2010), reproduction (Olori *et al*., 2002; Nardone *et al*., 2010) and biodiversity (Reynolds *et al*., 2010). These impacts are primarily due to an increase in temperature and atmospheric carbon dioxide (CO_2) concentration, precipitation variation and a combination of these factors (IFAD, 2010; Henry *et al*., 2012; Polley *et al*., 2013). Generally, climate change affects animal production through a negative impact on- quantity and quality feeds, water accessibility, animal reproduction and health, heat stress, biodiversity as explained below:-

Quantity and quality of feeds

Chapman *et al*. (2012) described that, quantity and quality of feed will be affected largely due to an increase in atmospheric temperature and CO_2 levels. Climate change consequences on animal feeds quantity and quality are dependent on location, animal production system and species (IFAD, 2010). Similarly, Sanz-Saez *et al*. (2012); Craine *et al*. (2017) noted that, increasing global temperature and declining precipitation results decreased forage or grass crude protein content and increased the ratio of digestible organic matter to crude protein (nitrogen) content.

On the other hand, Hatfield and Prueger (2011); Thornton *et al*. (2015) noted that, increasing CO_2 concentration will result in changes herbage growth, with greater effect on C_3 species (temperate plants) and less on grain yields. C_4 (tropical plants) forage species are found in hot environments has higher water use efficiency than C_3 plants. Temperature changes and CO_2 levels will affect the composition of pastures by altering the species competition dynamics due to changes in optimal growth rates (Howden *et al.,* 2008; McKeon *et al.,* 2009; IFAD, 2010; Thornton *et al*., 2015). Quality of forages may be affected by increased temperature and dry conditions due to variations in concentrations of water-soluble carbohydrates and nitrogen. Temperature increases may increase lignin and cell wall components in plants (Polley *et al*., 2013), which reduce digestibility and degradation rates (IFAD, 2010; Polley *et al*., 2013), leading to a decrease in nutrient availability for animals (Thornton *et al*., 2009). In general, impacts of climate change on forage quantity and quality depend on the region and length of growing season (Thornton *et al*., 2009; Polley *et al*., 2013). Temperature increase leads a decrease in forage quality can increase methane emissions per unit of gross energy consumed (Benchaar *et al*., 2001).

Water accessibility

Climate change impacts will have a substantial effect on global water availability in the future. This will not only influence animal drinking water sources, but it also affects their feed production systems and pasture yield (Thornton *et al*., 2008; Thornton *et al*., 2009; Gaughan, 2017). Animal production sector accounts for about 8% of global human water use and an increase in temperature may increase animal water consumption so, to address this issue, there is a need to produce crops and raise animals that demands less water or in places with water abundance (Nardone *et al*., 2010).

Animal diseases

Increasing temperature may increase exposure and vulnerability of animals to parasites and different diseases (Tubiello *et al*., 2008; McKeon *et al*., 2009; Henry *et al*., 2012), especially vector borne diseases (Tabachnick, 2010). Many important animal diseases are affected directly or indirectly by weather and climate. These links may be *spatial* (with climate affecting distribution) or *temporal* (with weather affecting the timing of an outbreak), or may relate to the *intensity* of an outbreak (Baylis and Githeko, 2006). Understanding the complex interactions between pathogens, vectors, host and climate is difficult due to the multivariate nature of climate change and the non linear thresholds in both disease and climate processes (Patz *et al*., 2008; Mills *et al.,* 2010). Therefore, the ability to predict the effect of climate change on disease is difficult to achieve (Randolph, 2008; Mills *et al.,* 2010; Tabachnick, 2010).

Heat stress

Though, animals can keep their body temperature within a range of ±0.5°C during the day (Pörtner and Knust, 2007; Henry *et al*., 2012; Pasqui and Di Giuseppe, 2019); when temperature increases more than the upper critical temperature of the range (varies by species type), the animals begin to suffer heat stress and their normal behavioral, immunological and physiological functions are potentially impacted (Nienaber and Hahn, 2007; FAO, 2017). The stress response is influenced by species, breed and previous exposure and health status, level of performance, body condition, mental state and age factors. In addition, when animals are exposed to thermal stress, metabolic and digestive functions are often compromised due to altered feeding activity (Mader, 2003). These effects could potentially result in changes in types of animals and genotypes that are used (Gaughan *et al*., 2009).

Warm and humid conditions cause heat stress, which affects behavior and metabolic variations on animals or even mortality. Generally, heat stress have a significant negative influences on animals-feed nutrient utilization (Mader, 2003), feed intake (Mader and Davis, 2004; Thornton *et al*., 2009), animal production (Kadzere *et al*., 2002; Berman, 2005; Summer *et al*., 2019), reproduction(Wolfenson *et al*., 2000; Hansen, 2007; Naqvi *et al*., 2012), health (Bernabucci *et al*., 2006; Nardone *et al*., 2010; Lacetera, 2019) and mortality (Sirohi and Michaelowa, 2007; Howden *et al*., 2008). Thus, all of these influences lead to economic loss (St-Pierre *et al*., 2003).

Biodiversity destruction

Decreasing (loss) of populations in genetic biodiversity is mainly due to by change in climate (UNEP, 2012). Climate change may eradicate 15% to 37% of all species in the world (Thomas *et al*., 2004). Animals' reproduction, migration, mortality and distribution is affected by temperature increases (Steinfeld *et al*., 2006). The loss of genetic and cultural diversity in farm animals occurred as a result of climate change (Ehrenfeld, 2005). An increase of 2-3°C in pre-industrial levels may result in 20-30% loss of biodiversity of plants and animals (IPCC, 2007; IPCC, 2014). Around 16% of livestock breeds (buffalo, cattle, goat, pig, sheep and horse) were lost in 2000 (Thornton *et al*., 2009). In addition, from 7,616 farm animals breeds reported, 20% were at risk and almost one breed per month was being extinguished (FAO, 2007).

Agro-ecological zones

Agro ecological zones (AEZs) are broadly classified into five categories such as tropics, subtropics, temperate, boreal and arctic (FAO, 1996). Climate change variations and impacts on animal production are not necessarily associated with the AEZs or even can be significantly different within an AEZ, which makes it difficult to generalize the impacts of climate change on AEZs. Higher temperatures will directly affect animal production by changing their migration pattern and reproduction time. Therefore, animal species with restricted habitat, small population, limited mobility and low breeding rates will be the most vulnerable (Steinfeld *et al*., 2006).

The majority of worldwide animals are found in tropics and subtropics AEZs, especially in arid or semi-arid regions, where climate conditions hamper animal productivity and yield; even though the largest numbers of farm animals are found in the tropics and subtropics AEZs, the largest productivity is found in the temperate AEZs (Herrero *et al*., 2012). On the other hand, in the boreal AEZs, the impacts of climate change on crop and animal productions are generally positive (Bajz¡elj and Richards, 2014).

Impact of animal production on climate change

Animal production sector contributes 14.5% of global greenhouse gases (GHG) emissions and they influence climate through land use change, feed production, animal production, manure and processing and transport. Feed production and manure emit CO_2, nitrous oxide (N_2O) and methane (CH_4), which consequently affects climate change (IPCC, 2007; Gerber *et al*., 2013). This sector often associated with negative environmental impacts such as land degradation, air and water pollution and biodiversity destruction (Steinfeld *et al*., 2006; Reynolds *et al*., 2010; Thornton and Gerber, 2010; Bellarby *et al*., 2013). An increase in animal production is expected to derive from a declining natural resource base, which will cause further environmental damage with no proper natural resources management (Thornton and Herrero, 2010a).

GHG emissions

Animal production has a great contribution for GHG emissions while, the production of beef (41%) and milk (29%) is responsible for the majority of the emissions at global level; whereas, pork and poultry eggs contribute 9 and 8% of the emissions of the sector respectively (FAO, 2006; FAO, 2013). The primary GHG emissions are CO_2 (27%), CH_4 (44%) and N_2O (29%) (Gill and Smith, 2008; Gerber *et al*., 2013). This sector contributes GHG emission directly and indirectly to the atmosphere through animal physiology, animal housing, manure storage, manure treatments, land application and chemical fertilizers (Dourmad *et al.,* 2008; Casey *et al*., 2006; Opio *et al*., 2011; Henry *et al*., 2012; Mottet *et al*., 2017). Direct emissions from animal sources include enteric fermentation, respiration and excretions (Jungbluth *et al*., 2001). Indirect emissions refers to emissions derived from feed crops, manure application, farm operations, animal products processing, transportation and land use allocation for animal production (IPCC, 1997). Enteric fermentation is the largest contributor of the sector's emissions (39.1%,) followed by manure management, application and direct deposit (25.9%), feed production (21.1%) land use change (9.2%), post-farm gate (2.9%) and direct and indirect energy (1.8%) (Gerber *et al*., 2013). However, contribution to GHG emissions varies depending on the type of farming system and region.

Adaptation practices

It involves production and management system modifications, breeding strategies, institutional and policy changes, science and technology advances and changing farmers' perception and adaptive capacity (Rowlinson*,* 2008; IFAD, 2010; USDA, 2013). Adding oil supplements to ruminant animal diets particularly for dairy cattle is important for reducing enteric methane (Eckard *et al*., 2010; Martin *et al*., 2010; Grainger and Beauchemin 2011; Moate *et al*., 2011). Likewise, net reduction of animal numbers should be appropriate for inclusion as an offset method for reducing both methane and N_2O emission (Eckard *et al*., 2010). In a study by FAO (2008), Thornton *et al*. (2008), Sidahmed (2008), the following have been identified as ways to increase adaptation in the animal production sector:

Animal production and management systems

Resourceful and affordable adaptation practices have to be developed for rural poor produces that are not able to buy expensive adaptation technologies. Providing natural (low cost) shade instead of high cost air conditioning is more applicable to rural poor producers; lower number of farm animals having more productive animals will cause more efficient production and lesser emission of GHG (Batima, 2006). An adaptation which is the modification of production and management systems involves diversification of farm animals and crops, integration of animal farming systems with forestry and crop production and changing the timing and locations of farm operations (IFAD, 2010).

Diversification of farm animals and crop varieties can increase drought and heat wave tolerance and may increase animals production when animals are exposed to temperature and precipitation stresses. In addition, this diversity of crops and animals is effective in fighting against climate change related diseases and pest outbreaks (Kurukulasuriya and Rosenthal, 2003; Batima, 2006; IFAD, 2010). Generally, change in animals herd composition (large animal versus small animal, *etc*.) and improved management of water resources through the introduction of simple techniques for localized irrigation (*e.g.* drip and sprinkler irrigation), accompanied with infrastructure to harvest and store rainwater, such as small superficial and underground dams, tanks connected to the roofs of houses *etc.* will an effective adaptation practices for thermal global climate changes.

Breeding strategies

Changes in breeding strategies can help animals to increase their tolerance to heat stress, diseases and improve their reproduction and growth development (Rowlinson, 2008; Hoffmann, 2008; Henry *et al*., 2012). Therefore, the challenge is in increasing animal production while maintaining the valuable adaptations offered by breeding strategies (Thornton *et al*., 2008). In addition, policy measures that improve adaptive capacity by facilitating implementation of adaptation strategies will be vital (USDA, 2013).

Mitigation measures

According to a study by FAO (2008), mitigation of GHG emissions in the animal production sector can be accomplished through a variety of activities such as: different animal feeding management, manure management (collection, storage, spreading), management of feed crop production. On the other hand, Gerber *et al*. (2013) noted that, there is potential to reduce animal production sector GHG emissions through the implementation of different technologies and practices if we widely used. Generally, technical options for mitigating the impact of farm animals on climate change are listed as follows:

Carbon sequestration

Considering the importance of rangelands in land uses, herders and pastoralists could play a crucial role in soil carbon sequestration (Tennigkeit and Wilkes, 2008). Therefore, environmental friendly rangeland practices have a relevant potential to sequester carbon. On the other hand, Milchunas and Lauenroth (1989); FAO (2008) reported that, gazing can either have a positive or negative impact on rangeland vegetation and soils, depending on climatic characteristics of rangeland ecosystems and grazing history and effectiveness of management. Carvalho *et al*. (2004) noted that, carbon sequestration can be achieved through decreasing deforestation rates, reversing of deforestation by replanting targeting for high yielding crops with better climate change adapted varieties and improvement of land and water management (Steinfeld *et al*., 2006).

Similarly, Steinfeld *et al*. (2006) explained that, soil organic carbon can be restored in cultivated soils through conservation tillage, erosion reduction, soil acidity management, double-cropping, crop rotations, higher crop residues, mulching and more improving pasture management can also lead to carbon sequestration by incorporating trees, improving plant species, legume inter seeding, introducing earthworms and fertilization (Conant *et al.,* 2001; Conant and Paustian, 2002). In addition, grass productivity and soil carbon sequestration could be improved by increasing grazing pressure in grasslands that have a lower amount of grazing animals than the livestock carrying capacity (Holland *et al*., 1992; Tennigkeit and Wilkes, 2008).

Improving diets to reduce enteric fermentation

The composition of feed has some effect on the enteric fermentation and emission of CH_4 from the rumen or the hindgut (Dourmad *et al*., 2008). Also the amount of feed intake is related to the amount of waste product. The higher proportion of concentrate in the diet results in a reduction of CH_4 emission (Yan *et al*., 2000). Increasing dietary fat content, in previous findings by Beauchemin *et al*. (2008); Martin *et al*. (2010) described that, one per cent increase of dietary fat can decrease enteric methane emissions between 4 to 5%, on the other hand, in a study conducted by Hristov *et al*. (2013), providing higher quality forage ply a great role in reduction of methane emissions because it increases digestibility, increasing protein content of feed can also improve digestibility and reduce overall methane emissions per unit of product (ICF International, 2013), providing supplements such as feed antibiotics, which tend to increase weight gain and reduce feed intake per metric ton of meat produced, can reduce enteric fermentation (Boadi *et al*., 2004) and the use of anti-methanogens is directly reduces methane emissions in the rumen (EPA, 2013). Differently, in another study done by ICF International (2013) described that, there is high uncertainty in the efficacy of these practices to the initial reductions of enteric fermentation achieved are only temporary.

Improving manure management

Improving management of animal manure through different mechanisms such as covered storage facilities and anaerobic treatment is important. The amount of GHG emission from manure (CH_4, N_2O and CH_4 from liquid manure) will depend on the temperature and duration of the storage. Therefore long term storage in high temperature will result higher GHG emissions. In the case of ruminants, pasture grazing is an efficient way to reduce CH_4 emission from manure, because no storage is necessary; once manure deposited on pasture can produce nitrous oxide emissions, the mitigation measures are often difficult to apply because of the manure dispersion on pasture (Swamy and Bhattacharya, 2006; FAO, 2008; Gerber *et al*., 2008; Dickie *et al*., 2014). Therefore, most mitigation practices involve shortening storage duration, improving timing and application of manure, used of anaerobic digesters, covering the storage, using a solids separator and changing the animal diets (ICF International, 2013).

In a study conducted by Dickie *et al*. (2014) described that, using other storage and handling practices can also reduce GHG emissions, such practices include reducing storage time, improving housing and waste management systems to handle manure and removing bedding from manure by using a solids separator. Hess *et al*. (2006); Dickie *et al*. (2014) also reported that, GHG emissions can be reduced by balancing dietary proteins and feed supplements. If protein intake is reduced, the nitrogen excreted by animals can also be reduced. Supplements such as tannins are also known to have the potential to reduce emissions. Tannins are able to displace the nitrogen excretion from urine to feces to produce an overall reduction in emissions.

More efficient use of fertilizers

As Dickie *et al*. (2014) explained that, nitrogen use efficiency can be improved by applying the required amount that the crop will absorb and when it needs the nutrients and placing it where the plant can easily reach it. Regular soil testing can be a part of a nutrient management plan depending on the region and crop and improve efficiency of nitrogen use. Plant breeding and genetic modifications can reduce the use of fertilizers by increasing a crop's nitrogen uptake (Dickie *et al*., 2014). On the other hand, Denef *et al*. (2011) described that, increasing the use of organic fertilizers would also decrease emissions because organic fertilizers do not produce as much nitrogen oxide as synthetic fertilizers Furthermore, fertilizer technology has improved through regulating the release of nutrients from the fertilizer and inhibiting nitrification to slow the degradation of the fertilizer and maintain the nutrients available for the plant. However, these technologically advanced fertilizers are more costly than the other practices mentioned above (Dickie *et al*., 2014). In the case of pasturelands, the use of synthetic nitrogen can be reduced by combining legumes with grasses. Legumes fix nitrogen through Rhizobium bacteria; therefore, the need for supplementary nitrogen is reduced (USDA-NRCS, 2007).

Shifting human dietary trends

Particularly in high income regions, dietary shifts could make a significant difference to emissions and other environmental impacts related to farm animals production. Using a number of diet and animal production scenarios, scientists in Sweden calculated the impacts of food production on land use and GHGs in 2030. They found that reducing meat consumption by 25% in high income regions and reducing food waste would be more successful than intensifying animal production in order to increase productivity per animal (Wirsenius *et al*., 2010). Similarly, in findings by Stehfest *et al*. (2009) noted that, a reduction in meat consumption may significantly reduce GHG emissions and Further analysis is needed to identify the best regional and global strategies for diet and what opportunities, costs and benefits could be derived from dietary shifts. But, mitigation measures need public policy support to be effective (Dickie *et al*., 2014).

CONCLUSION

Global climate change will affect animal production and productivity and consequently food security mainly in tropical regions. Conversely, animal production sector has its own contribution in global emissions of GHGs and they influence climate through land use change, feed production, animal production, manure and processing and transport. Therefore, global climate change adaptation, mitigation practices and policy frameworks are critical to protect animal production. But, the effectiveness of these practices in reducing emissions is uncertain and more research is needed concerning effective mitigation practices related to enteric fermentation. For instance, if we want effective adaptation and mitigation measures to address climate change and animal production, these measures must be scaled up through policy development including farmers and understanding their perceptions on food security improvement and environmental conservation by promoting widespread practice adoption.

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