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**Climate change and livestock: Impacts, adaptation, and mitigation**

**1. Introduction:** Human population is expected to increase from 7.6 to 9.6 billion by 2050 (UN, 2013). This represents a population increase of 33%, but as the global standard of living increases, demand for agricultural products will increase by about 70% in the same period (FAO). Meanwhile, total global cultivated land area has not changed since 1991, reflecting increased productivity and intensification efforts. Livestock products are an important agricultural commodity for global food security because they provide 17% of global kilocalorie consumption and 33% of global protein consumption. There is a growing demand for livestock products, and its rapid growth in developing countries has been deemed the ‘‘livestock revolution”. Worldwide milk production is expected to increase from 664 million tonnes (in 2006) to 1077 million tonnes (by 2050), and meat production will double from 258 to 455 million tonnes. Livestock production is likely to be adversely affected by climate change, competition for land and water, and food security at a time when it is most needed.

Global climate change is primarily caused by greenhouse gas (GHG) emissions that result in warming of the atmosphere (IPCC, 2013). The livestock sector contributes 14.5% of global GHG emissions, and thus may increase land degradation, air and water pollution, and declines in biodiversity. At the same time, climate change will affect livestock production through competition for natural resources, quantity and quality of feeds, livestock diseases, heat stress and biodiversity loss while the demand for livestock products is expected to increase by 100% by mid of the 21st century. Therefore, the challenge is to maintain a balance between productivity, household food security, and environmental preservation. There is growing interest in understanding the interaction of climate change and agricultural production and it is motivating a significant amount of research. There is still limited research regarding the impacts of climate change on livestock production (IPCC, 2014).

**2. Impact of Climate change on livestock**

Despite uncertainties in climate variability, the IPCC Fifth Assessment Report identified the increase in global average surface temperature by 2100, which is between 0.3C and 4.8C (IPCC, 2013). The potential impacts on livestock include changes in production and quality of feed crop and forage, water availability, animal growth and milk production, diseases, reproduction and biodiversity. These impacts are primarily due to an increase in temperature and atmospheric carbon dioxide (CO2) concentration, precipitation variation, and a combination of these factors. Regarding impacts of climate change on livestock production factors, the temperature affects most of the critical factors for livestock production, such as water availability, animal production, reproduction and health. Forage quantity and quality are affected by a combination of increases in temperature, CO2 and precipitation variation. Livestock diseases are mainly affected by an increase in temperature and precipitation variation.

**2.1. Quantity and quality of feeds**

Quantity and quality of feed will be affected mainly due to an increase in atmospheric CO2 levels and temperature. The effects of climate change on quantity and quality of feeds are dependent on location, livestock system, and species. Some of the impacts on feed crops and forage are:

* Increase of CO2 concentration will result in herbage growth changes, with greater effect on C3 species and less on grain yields. The effects of CO2 will be positive due to inducing partial closure of stomata, reducing transpiration, and improving some plants’ water-use efficiency. C4 species (which account for less than 1% of plants on Earth) are found in warm environments, and have higher water use efficiency than C3 plants. Temperature increases to 30–35 C could increase herbage growth, with larger effects on C4 species. However, the effects may vary depending on the location; production system used, and plant species.
* Changes in temperature and CO2 levels will affect the composition of pastures by altering the species competition dynamics due to changes in optimal growth rates. Plant competition is influenced by seasonal shifts in water availability. Primary productivity in pastures may be increased due to changes in species composition if temperature, precipitation, and concurrent nitrogen deposition increase.
* Quality of feed crops and forage may be affected by increased temperatures 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, which reduce digestibility and degradation rates leading to a decrease in nutrient availability for livestock. However as CO2 concentration rises forage quality will improve more in C3 plants than C4 plants. C3 plants also have greater crude protein content and digestibility than C4 plants.
* Extreme climate events such as flood, may affect form and structure of roots, change leaf growth rate, and decrease total yield.
* Impacts on forage quantity and quality depend on the region and length of growing season. An increase of 20C will produce negative impacts on pasture and livestock production in arid and semiarid regions and positive impacts in humid temperate regions. The length of growing season is also an important factor for forage quality and quantity because it determines the duration and periods of available forage. A decrease in forage quality can increase methane emissions per unit of gross energy consumed. Therefore, if forage quality declines, it may need to be offset (a consideration or amount that diminishes or balances the effect of an opposite one) by decreasing forage intake and replacing it with grain to prevent elevated methane emissions by livestock.

**2.2. Water**

Global agriculture uses 70% of fresh water resources, making it the world’s largest consumer. However, global water demand is moving towards increased competition due to water scarcity and depletion, where 64% of the world’s population may live under water-stressful conditions by 2025.

Water availability issues will influence the livestock sector, which uses water for animal drinking, feed crops, and product processes. The livestock sector accounts for about 8% of global human water use and an increase in temperature may increase animal water consumption by a factor of two to three. To address this issue, there is a need to produce crops and raise animals in livestock systems that demand less water or in locations with water abundance.

As sea level rises, more saltwater will be introduced into coastal freshwater aquifers. Salination adds to chemical and biological contaminants and high concentrations of heavy metals already found in water bodies worldwide and may influence livestock production. Water salination could affect animal metabolism, fertility, and digestion. Chemical contaminants and heavy metals could impair cardiovascular, excretory, skeletal, nervous and respiratory systems, and impair hygienic quality of production. There is a lack of research related to implications of reduced water availability for land-based livestock systems due to climate change. Therefore, it is important to consider water availability and appropriate mitigation strategies in the context of sustainable livestock production.

**2.3. Livestock diseases**

The effects of climate change on livestock diseases depend on the geographical region, land use type, disease characteristics, and animal susceptibility. Animal health can be affected directly or indirectly by climate change, especially rising temperatures. The direct effects are related to the increase of temperature, which increases the potential for morbidity (rate of disease in a population) and death. The indirect effects are related to the impacts of climate change on microbial communities (pathogens or parasites), spreading of vector-borne diseases, food-borne diseases, host resistance and feed and water scarcity. Temperature increases could accelerate the growth of pathogens and/or parasites that live part of their life cycle outside of their host, which negatively affects livestock. Climate change may induce shifts in disease spreading, outbreaks of severe disease, or even introduce new diseases, which may affect livestock that are not usually exposed to these type of diseases. Meanwhile, there is high probability that emergence of new diseases may act as a mixing vessel between human and livestock, facilitating combination of new genetic material and their transmissibility. This makes it difficult to estimate actual disease risk because of the dependence of diseases on animal exposure and interactions factors.

**2.4. Heat stress**

All animals have a thermal comfort zone, which is a range of ambient environmental temperatures that are beneficial to physiological functions. During the day, livestock keep a body temperature within a range of ±0.5C . When temperature increases more than the upper critical temperature of the range (varies by species type), the animals begin to suffer heat stress. Animals have developed a phenotypic response to a single source of stress such as heat called acclimation. Acclimation results in reduced feed intake, increased water intake, and altered physiological functions such as reproductive and productive efficiency and a change in respiration rate.

Heat stress on livestock is dependent on temperature, humidity, species, genetic potential, life stage, and nutritional status. Livestock in higher latitudes will be more affected by the increase of temperatures than livestock located in lower latitudes, because livestock in lower latitudes are usually better adapted to high temperatures and droughts. Heat stress decreases forage intake, milk production, the efficiency of feed conversion, and performance. Warm and humid conditions cause heat stress, which affects behavior and metabolic variations on livestock or even mortality. Heat stress impacts on livestock can be categorized into feed nutrient utilization, feed intake, animal production, reproduction, health, and mortality.

Livestock have several nutrient requirements including energy, protein, minerals, and vitamins, which are dependent on the region and type of animal. Failure to meet the dietary needs of cattle during heat stress affects metabolic and digestive functions. Sodium and potassium deficiencies under heat stress may induce metabolic alkalosis in dairy cattle, increasing respiration rates. Reduction of water intake may also decrease sweating and feed intake. One of the major causes of **decreased production in the dairy and beef industry** is heat stress and significant economic losses have been related to this. In the case of meat production, beef cattle with high weights, thick coats, and darker colors are more vulnerable to warming. Global warming may reduce body size, carcass weight, and fat thickness in ruminants. Heat stress on hens will reduce reproduction efficiency and consequently egg production because of reduced feed intake and interruption of ovulation. Egg quality, such as egg weight and shell weight and thickness may also be negatively affected under hotter conditions. Reproduction efficiency of both livestock sexes may be affected by heat stress. In cows, it affects oocyte growth and quality, impairment of embryo development, and pregnancy rate. Cow fertility may be compromised by increased energy deficits and heat stress. Heat stress has also been associated with lower sperm concentration and quality in bulls and poultry. Prolonged high temperature may affect metabolic rate, endocrine status, oxidative status, glucose, protein and lipid metabolism, liver functionality (reduced cholesterol and albumin, non-esterified fatty acids (NEFA), saliva production, and salivary HCO3 - content. In addition, greater energy deficits affect cow fitness and longevity. Warm and humid conditions that cause heat stress can affect livestock mortality and increases in temperature between 1 and 5 C might induce high mortality in grazing cattle.

**3. Biodiversity**

Biodiversity refers to a variety of genes, organisms, and ecosystems found within a specific environment and contribute to human well-being. Populations that are decreasing in genetic biodiversity are at risk, and one of the direct drivers of this biodiversity loss is climate change. Climate change may eliminate 15% to 37% of all species in the world. Temperature increases have affected species reproduction, migration, mortality, and distribution. The Intergovernmental Panel on Climate Change Fifth Assessment Report states that an increase of 2 to 3 \_C above pre-industrial levels may result in 20 to 30% of biodiversity loss of plants and animals.

**4. Agro-ecological zones (AEZ)**

Agricultural practices such as livestock production and management varies around the world. In order to describe thesevariabilities, The AEZ aredefined based on climate, landform, soils, land cover, and land use. In general, climate change impacts within an AEZ can be both negative and positive. For example, climate change impacts in a form of increase in CO2 level can improve the photosynthetic activity and the water use efficiency, which consequently increases crop productivity. Meanwhile, rise in average temperature can trigger plant diseases while increasing water stress, which consequently decreases crop productivity. These fluctuations in crop yields are indirectly affecting livestock productivity especially in rain fed systems. At the same time, higher temperatures will directly affect livestock production by changing the animals’ migration pattern and reproduction time. Therefore, livestock species with restricted habitat, small population, limited mobility, and low breeding rates will be the most vulnerable.

**Impact of livestock on climate change**

Livestock contribute 14.5% of the total annual anthropogenic GHG emissions globally. Livestock influence climate through land use change, feed production, animal production, manure, and processing and transport. Feed production and manure emit CO2, nitrous oxide (N2O), and methane (CH4), which consequently affects climate change. Animal production increases CH4 emissions. Processing and transport of animal products and land use change contributes to the increase of CO2 emissions.

Forests and natural habitats have been steadily converted to pasture and cropland since the 1850s. Agricultural land use change is related to two concepts: profit per unit of land and opportunity cost. Profit per unit of land refers to the willingness of farmers to manage a specific land use. Profit will vary depending on several factors, such as the land’s biophysical characteristics and price, access to markets,

inputs, and services. The opportunity cost concept compares the social and economic cost of different ways to use the same land area. Opportunity costs include private production costs and ecosystem service costs. Land use change affects the natural carbon cycle, which consequently releases high amounts of carbon into the atmosphere, increasing GHG emissions. Natural habitats, mainly forests, sequester more carbon in soil and vegetation than croplands and pasturelands. Deforestation, cultivated soils, and land degradation due to livestock production are the main source of CO2 emissions.

Livestock manure releases CH4 and N2O gas. The decomposition of the organic materials found in manure under anaerobic conditions releases methane. Liquid manure found in holding tanks releases more methane than dry manure.

**Adaptation and mitigation practices**

There are several climate change adaptation and mitigation recommendations that can be made based on the above discussion. Adaptation strategies can improve the resilience of crop and livestock productivity to climate change (USDA, 2013).

Mitigation measures could significantly reduce the impact of livestock on climate change.

* Livestock production and management systems. An adaptation such as the modification of production and management systems involves diversification of livestock animals and crops, integration of livestock systems with forestry and crop production, and changing the timing and locations of farm operations. Diversification of livestock and crop varieties can increase drought and heat wave tolerance, and may increase livestock production when animals are exposed to temperature and precipitation stresses. In addition, this diversity of crops and livestock animals is effective in fighting against climate change-related diseases and pest outbreaks.
* Agroforestry (establishing trees alongside crops and pastures in a mix) as a land management approach can help maintain the balance between agricultural production, environmental protection and carbon sequestration to offset emissions from the sector. Agroforestry may increase productivity and improve quality of air, soil, and water, biodiversity, pests and diseases, and improves nutrient cycling. Carbon sequestration can be achieved through decreasing deforestation rates, reversing of deforestation by replanting, targeting for higher-yielding crops with better climate change adapted.
* varieties, and improvement of land and water management
* Changes in mixed crop-livestock systems are an adaptation measure that could improve food security.
* Shifting locations of livestock and crop production could reduce soil erosion and improve moisture and nutrient retention.
* Changes in breeding strategies can help animals increase their tolerance to heat stress and diseases and improve their reproduction and growth development.
* Farmers’ perception and adaptive capacity. One of the limiting factors for these changes to succeed is the disposition and capability of farmers to recognize the problem and adopt climate change adaptation and mitigation measures.
* Soil organic carbon can be restored in cultivated soils through conservation tillage, erosion reduction, soil acidity management, crop rotations, higher crop residues, and mulching etc.