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Threats of climate change on livestock products: A review

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Abstract
Global demand for livestock products is expected to double by 2050, mainly due to improvement in the worldwide standard of living. Meanwhile, climate change is a threat to livestock production because of the impact on meat and milk production, livestock diseases, animal reproduction and biodiversity. Climate change is a major and important threat to the survival of many species in many parts of the world. Previous work has shown that a wet-bulb temperature (*TW*) of 35°C can be considered an upper limit on human survivability. On the basis of an ensemble of high-resolution climate change simulations also has been project that extremes of *TW* in South Asia are likely to approach and, in a few locations, exceed this critical threshold by the late 21st century under the business-as-usual scenario of future greenhouse gas emissions. The livestock sector which will be the most sufferer of climate change is itself a large source of methane emissions contributing about 18% of total enteric methane. In Indian subcontinent, an estimated annual loss due to direct thermal stress on livestock is about 1.8 million tonnes of milk (2661.62 crores) in the country. In the case of meat production, beef with high weights, thick coats, and darker colors are more vulnerable to warming. Strong negative effects of the hot season (average temperature of 34.3 ± 1.67 °C and 48.8 ± 7.57% relative humidity) have been reported on body size, carcass weight and fat thickness in ruminants, pigs and broilers and on the quality characteristics of beef meat, in particular, higher ultimate pH, lower Warner–Bratzler shear force and darker meat in heat-stressed beef cattle. Though the reduction in GHG emissions from livestock industries are seen as high priorities but strategies for reducing these emissions should not reduce the economic viability of livestock enterprises. Hence, reducing the total area where high milk and meat yielding livestock may be economically reared.

Keywords: climate change, methane, mitigation, livestock products

Introduction

Livestock production is one of the most important parts of Indian agrarian economy and this sector provides sustainability and stability to the national economy by contributing to farm energy and food security. Livestock sector not only provides essential protein and nutrition to human diet through milk, eggs, meat and by products such as hides and skin, blood, bone and fat etc., but also plays an important role in utilization of non-edible agricultural by-products. During the last decade, the annual growth rate of livestock production has maintained a compounded growth rate of more than 5.0%.

However, in future the situation is likely to change due to global warming as Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report [1] anticipated rise in temperature between 1.8-4.0 ^{0}C over the entire country. Many of the developing countries tend to be especially vulnerable to extreme climatic events as they largely depend on climate sensitive sectors like agriculture and forestry. Atmospheric concentrations of GHGs have risen by about 39% since pre-industrial era and Methane (CH_4) concentration has more than double during this period [2]. The consequences of climate change phenomena are now visible everywhere and considered as the serious long term threat to animal farm industry [3] because the increase in wet-bulb temperature (*TW*) reduces the living beings ability to cool itself [4]. *TW* is defined as the temperature that an air parcel would attain if cooled at constant pressure by evaporating water within it until saturation point. It is a combined measure of temperature and humidity. High values of *TW* imply hot and humid conditions and vice versa. Cattle exposure to *TW* of around 36.5 °C for even a few hours (>6 hrs.) will result in death even for the fittest of animal under shaded, well-ventilated conditions [5].

According to the recent global historical reanalysis records from 1979 to 2015, the largest TW_{max} rarely exceeds 31°C in the current climate [6]. However, three extensive regions where values exceed 28°C are Southwest Asia (Persian/Arabian Gulf and Red Sea), South Asia (Indus and Ganges river valleys) and eastern China. Future TW_{max} around the Persian/Arabian Gulf region is likely to exceed the *TW* threshold for human survivability by the end of the century under a business-as-usual (BAU) scenario of atmospheric greenhouse gas (GHG) concentrations (fig. 1) [7]. In summer 2015, *TW* in the Bandar Mahshahr, Iran Persian/Arabian Gulf, reached nearly 35°C, suggesting that the threshold may be breached sooner than projected [8]. In this study, we shift our attention to the region of South Asia, here defined as Pakistan, Nepal, India, Bangladesh, and Sri Lanka. The northern part of this region is the second hottest after Southwest Asia.

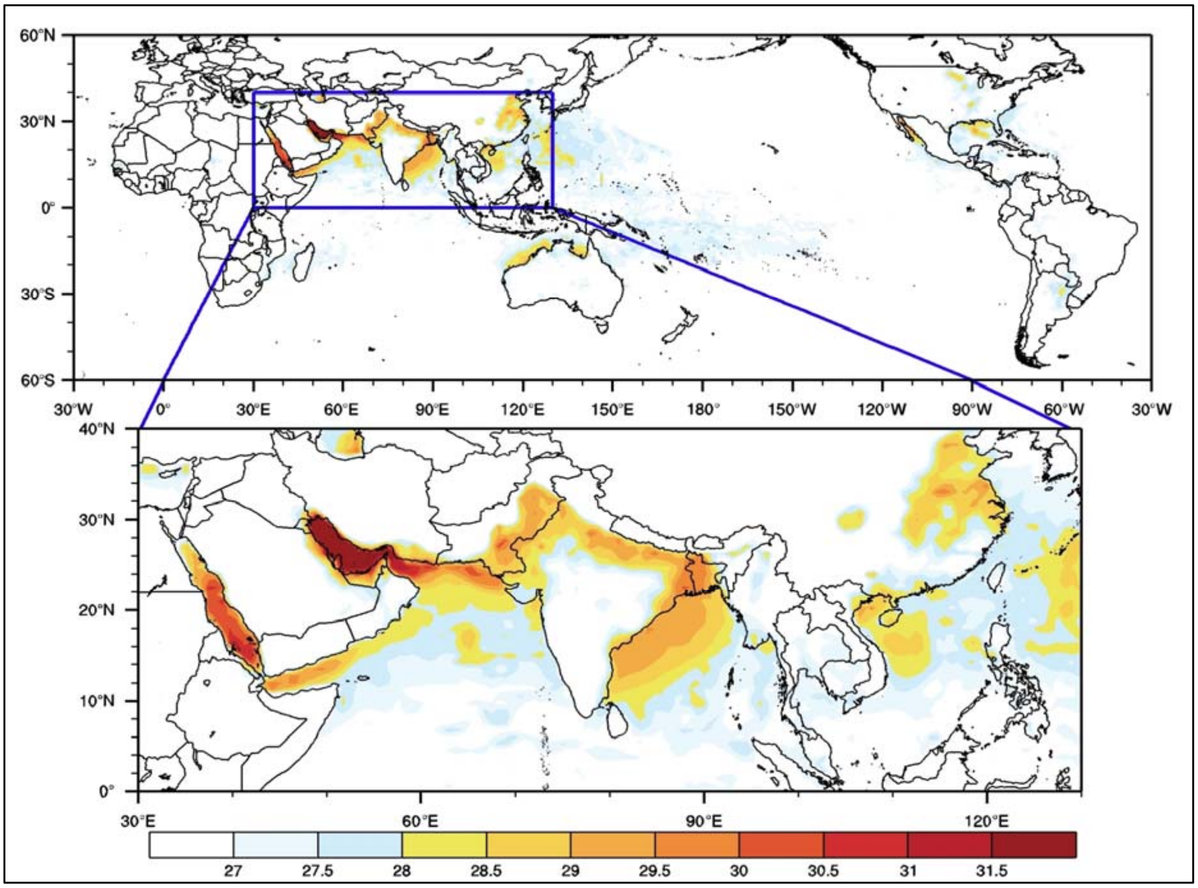

Fig 1: Spatial distribution of highest daily maximum wet-bulb temperature (TW_{max}, ^{0}C) in modern record (1979-2015).

Heat waves and their impacts on human and animal health are combined consequences of high temperatures and humidity (*TW*) and the vulnerability of the population. However, studies that are based on higher-resolution simulations are generally focused on North America and Europe [9,10] but the most detrimental human and livestock impacts of climate change on heat waves could potentially be those in developing nations (in much of India and Pakistan) because of the vulnerability of their populations [11,12,13]. For example, severe heat waves resulting in thousands of deaths to humans and livestock were reported around Odisha (eastern India) in 1998, Andhra Pradesh in 2003, and Ahmadabad and other parts of Gujarat (western India) in 2010 [14]. In particular, the fifth deadliest heat wave in recorded history [15] affected large parts of India and Pakistan, claiming around 3500 lives in 2015 [16]. Climatologists reported that the large positive departure of maximum temperature during the heat wave periods largely coincides with the areas (particularly in Uttar Pradesh, Bihar, and Odisha) where *TW* is projected to approach or exceed the survivability threshold under the Representative Concentration Pathway 8.5 scenario [17].

Independent factors mechanism

The most severe projected hazard from heat waves will experience in some of the fertile valleys of the Indus and the Ganges because of the following three independent factor mechanisms.

1. The monsoon system from the surrounding warm Arabian Sea and Bay of Bengal transports warm and humid air masses into the Indus and Ganges valleys.
2. Surface elevations in these valleys are generally lower than 100 m above sea level, and hence, surface air is generally warmer than surrounding higher-elevation areas.
3. Much of the valleys are irrigated, which tends to enhance *TW* over irrigated areas because of modifications in the surface energy balance (Im *et al*., 2014).

These three factors add together to favor higher *TW* conditions in the valleys compared to the surrounding regions.

Effects of independent factors mechanism

Studies of detection and attribution of recent climate change indicates increase in the frequency and magnitude of related heat stress to the projected late 21st century due to anthropogenic GHGs, which will likely impose significant risk and negative impact on human and livestock health [18]. In this regard, these findings have significant implications to the ongoing considerations regarding climate change policy. In the absence of serious mitigation, some of the most severe hazards associated with climate change will fall on some of the most vulnerable areas. In these areas, such as South Asia, air conditioning is not currently available as a safe haven to the livestock production. At the regional scale, India's GHG emissions have been increasing rapidly in recent decades because of rapid economic and population growth and high dependence on coal used for energy generation. Despite their relatively low GHG per capita emissions, India (and more so China) is responsible for much of the recent rise in global emissions.

Roll of livestock production in GHG emissions

The livestock sector which will be most sufferer of climate change is itself a large source of methane emissions contributing about 18% of total enteric CH_4 budget [19]. Ruminant livestock such as cattle, buffalo, sheep and goats contributes the major proportion of total agricultural emission of methane. Emission of CH_4 is responsible for nearly as much radiative forcing as all other non-CO_2 GHGs combined [20].

Recent estimation of GHGs production from livestock indicates that the total CH_4 emitted due to enteric fermentation and manure was 9.37 Tg annum^{-1} for the year 2003 [1]. Both small and large ruminants were the main contributors (98%) to the enteric CH_4 emission and more than 90% of the total CH_4 emission from enteric fermentation is being contributed by the large ruminants (cattle and buffalo) [21]. Higher methane production results from higher energy requirement and feed intake which depends on the livestock characteristics (age, weight and species). Total emission of methane from Indian livestock ranged from 7.26 to 10.04 MT year^{-1} considering different categories of ruminants and type of feed resources available in different zones of the country [22].

Livestock manure management is also a significant source of CH_4 emission [21]. The total global CH_4 emissions from livestock manure management have been estimated as 9.3 Tg year^{-1} [23], of which the developed countries contribute about 52%.

Roll of climate change on livestock Production

Among the environmental variables affecting animals, heat stress seems to be one of the intriguing factors making animal production challenging in many geographical locations in the world [24]. However, new knowledge about animal responses to the environment continues to be developed, managing animals to reduce impact of heat stress till the environmental conditions reach to the TW_{max} remains a challenge [25]. Upadhyay *et al*. [26] started animal stress level due to temperature rise using Temperature Humidity Index (THI) in India. Climate change had negative impact on milk production and lactation length and infertility in Nepal.

Effects on production and reproduction

An estimated annual loss due to direct thermal stress on livestock is about 1.8 million tonnes of milk (2661.62 crores), that is, nearly 2% of the total milk production in the country. Ravagnolo and Misztal [27] reported milk yield decline by 0.2 kg per unit increase in *TW* when *TW* exceeded 72. The Scientific Committee on Animal Health and Animal Welfare [28] suggested that the higher threshold temperature for beef cattle is 30 °C with relative humidity below 80% and 27 °C with relative humidity above 80 %. Strong negative effects of the hot season (average temperature of 34.3 ± 1.67 °C and 48.8 ± 7.57% relative humidity) have been reported on the quality characteristics of beef meat [29]. In particular, these authors reported higher ultimate pH, lower Warner–Bratzler shear force and darker meat of *m. longissimus thoracis* in heat-stressed beef cattle when compared with muscle samples collected during the cool season. Moreover, the increase in milk yield increases sensitivity of cattle to thermal stress and reduces the threshold temperature (*TW*) at which milk losses occur [30]. The extent of decline in milk yield were less at mid lactation stage than both late or early stage and decline in yield varied from 10 -30% in first lactation and 5-20% in second or third lactation in Murrah buffaloes [26]. Milk production traits in ewes seem to have a higher negative correlation with the direct values of temperature or relative humidity than *TW*. High air temperatures even affect goats, reducing milk yield and the content of milk components.

In the case of meat production, beef cattle with high weights, thick coats, and darker colors are more vulnerable to warming [31]. Global warming may reduce body size, carcass weight, and fat thickness in ruminants [32]. The same is true in pig production, where larger pigs will have more reduction in growth, carcass weight, and feed intake [31].

The poultry industry may also be compromised by low production at temperatures higher than 30 °C [33]. Tankson *et al*. [34] stated that heat stress on birds will reduce body weight gain, feed intake and carcass weight. Similarly heat stress on hens will reduce egg production and egg quality [31, 35, 36].

Heat stress due to high ambient temperature accompanied with excess humidity during summer months causes infertility in most of the farm species and have adverse effect on reproductive performance of farm animals. During hot dry (March- June) and hot humid (July- September) seasons, the *TW* values exceeds 80 in most parts of India. The pattern of estrus varies among cattle and buffaloes. Most of the buffaloes exhibit sexual activity during cooler parts of the year, when the *TW* generally remains < 72 [37]. An increase in uterine temperature of 0.5 °C above average is associated with a decline in conception rate of 12.8% [38].

Reproductive processes in male animal are very sensitive to disruption by hyperthermia with the most pronounced consequences being reduced quantity and quality of sperm production and decreased fertility. Sperm production (ejaculate volume, sperm concentration and total sperm number) and percentage of normal sperm cells decreased during the hot season in *B. indicus* bulls in Africa [39].

Dairy cows experiencing heat stress during late gestation had calves with lower birth weights and produced less milk than cows not exposed to heat stress [40]. Scrotal circumference, testicular consistency, tone, size and weight are decrease in hot summer in the sub tropics than those of the same breeds of buffalo reared under temperate environmental conditions [41].

Mitigation Strategies

The global CH_4 emissions from livestock production are expected to increase 60% by 2030, if its emissions grow in direct proportion to projected increases in livestock numbers [42]. Reducing the increase of GHG emissions from livestock production should therefore be a top priority, because it could curb warming fairly rapidly [43].

Several options have been considered for mitigating methane production by the livestock [44]. All approaches points towards either reduction of methane production per animal or

reduction per unit of animal product [45]. Generally the methane mitigation strategies can be grouped under three broader headings viz., managemental [46], nutritional [47] and advanced biotechnological strategies [43].
Global analyses have clearly shown that non-CO_2 greenhouse gas (GHG) emissions are inversely related to animal productivity [48]. Increase in animal productivity can be achieved through improvements in animal genetics, feeding, reproduction, health, and overall management of the animal operation. In many parts of the world, reduction in animal numbers was the single most influential mitigation strategy that significantly reduced the C footprint [49]. Increasing milk yield per animal in India from the national average of 3.6 liter per day to up to 9.0 liter per day was possible using currently available feed resources by removing unproductive and stray cattle and this would potentially reduce CH_4 production in the country from 2.29 to 1.38 Tg year^{-1} [50].
There are a number of nutritional technologies for improvement in rumen efficiency like, diet manipulation, direct inhibitors, feed additives, propionate enhancers and hormones [51]. Bell *et al*. [52] demonstrated that improvements in feed efficiency and milk production can significantly reduce GHG emissions and land use of the dairy herd. However, selection for high milk production and decreased productive life, increased death rate, and decline in fertility need to be avoided [53]. Field experiments in India showed that dietary manipulation through increased green fodder decreased methane production by 5.7% [54].
In India, the possibility of capturing or preventing emissions from animal manure storage is limited as it is extensively used as fuel in the form of dry dung cakes or spread in field. Animal wastes including manure account for more than 25 million tonnes methane emission globally per year. Separation of manure solids and anaerobic degradation pre-treatment can mitigate CH_4 emission. Though the reduction in GHG emissions from livestock industries are seen as high priorities but strategies for reducing these emissions should not reduce the economic viability of livestock enterprises. Hence, reducing the total area where high yielding dairy cattle may be economically reared.

Conclusion
The livestock production system is sensitive to climate change and at the same time itself a contributor to the phenomenon, climate change has the potential to be an increasingly formidable challenge to the development of the livestock sector. Responding to the challenge of climate change requires formulation of appropriate long term adaptation strategies and mitigation options for the livestock sector. Factors affecting variability in enteric CH_4 production requires urgent attention and efforts to decrease the uncertainty in GHG emission inventories. It is very essential to identify viable GHG reduction strategies. First, much more clarity is needed concerning the benefits of livestock, the negative impacts they can have on greenhouse-gas emissions and the environment, and the effects of climate change on livestock system. Although the reduction in GHG emissions from livestock industries are seen as high priorities, strategies for reducing emissions should not reduce the economic viability of enterprises.

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