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(RESEARCH ARTICLE)

Detrimental characteristics of climate change on livestock production and reproduction

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Abstract

Agriculture and animal rearing are the most important resources of income for the farmers and indirectly have a big share in the economy of a country. Pakistan is one of the 16 regarding countries most vulnerable to environment change. Climate changes is one of the main threats affecting the sustainability of the livestock production system, which further leads to affects the other different factors associated with the animal health, production, reproduction and its adaptability. Dairy sector is the most susceptible segment to the climate change. A widely used as a parameter for the measurement of thermal stress in animals is temperature humidity index (THI). The health status of dairy animals and decreases in their milk production and reproductive performance are adversely affected by environmental stress, which results in the massive economic losses. Alteration in the temperature, humidity, rainfall and atmospheric carbon dioxide are expected via global climate change. The dairy sector is more prone to climate change and global warming where it is most often affected by the temperature and humidity such as temperature humidity index (THI). The combined effect of high temperature and high humidity results in adverse effects on reproductive performance of farm animals. Among the major environmental factors affecting the livestock production system includes temperature, relative humidity (RH), solar radiation, precipitation and wind speed. The heat stress play major role in the declining of fertility in lactating dairy cows and reducing the conception rate. The management strategies such as microclimatic modification, improved housing and management intervention, usage of fogger and sprinkler with or without fan, nutritional and feeding management, feeding strategies and changing in reproductive protocol like artificial insemination protocol are to be strictly followed to improve the adverse effects of heat stress on production and reproduction in dairy animals during the summer season.

Keywords: Agriculture and Animal Husbandry; Dairy Production; Reproduction and Health; Heat Stress and Temperature Humidity Index.

1. Introduction

Agriculture and Livestock sectors plays a central function in term of food security in the lives of people in developing nations. The major source of income for the farmers are animals rearing and agriculture, through which the economy of farmers are directly affected. Global demand for foods of animal origin is growing and it is apparent that the livestock sector will need to expand [1], so the sustainability in livestock production system is an important need. Livestock are adversely affected by the detrimental effects of extreme weather. Climatic extremes and seasonal fluctuations in herbage quantity and quality affects the well-being of livestock which leads to declines in production and reproduction efficiency [2]. Global climate change is expected to alter temperature, humidity, rainfall, atmospheric carbon dioxide. Among the different threats, climate change is one of the major threat affecting the sustainability of livestock production

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systems in tropical countries. Climate change affects different factors linked with animal health, production, reproduction and their adaptability to feasible environment. Dairy animals are more susceptible to climate change and global warming where it is mostly affected by the environmental stress such as temperature and humidity. The combined effect of elevated temperature and increased humidity results in adverse effect on productive and reproductive performance of farm animals, resulting in huge economic losses. Heat stress has adverse effects on the productive, reproductive and health performances of dairy animals and is a major contributing factor in the declining of fertility in lactating dairy cows [3]. A reduction from 20 to 30% in conception rate and in pregnancy rate in hot climatic condition [4]. Animals exposed to heat stress reduce feed intake and increase water intake, and there are changes in the endocrine status which in turn increase the maintenance requirements leading to reduced performance [5]. The heat gain becomes exceeds than heat lost from the body, when the air temperature reached above 25-37 °C, leads to induce the heat stress in a tropical climate [6]. The hot climatic conditions leads to an increase in the body surface temperature, rectal temperature (RT), respiration rate (RR) and pulse rate (PR) and decrease in feed intake, production and reproductive efficiency. It is estimated that the global average surface temperature would be increased to 1.4-5.8 °C by increase in temperature of earth per decade by 0.2 °C upto 2100. Temperature, relative humidity (RH), solar radiation, precipitation and wind speed (WS) are the major environmental factors affects livestock production system [7]. The improved housing and management intervention strategies leads to reduce the climatic negative impacts such as heat stress on production and reproduction of dairy animals. Different cooling system, nutritional and feeding management, microclimatic modification, diet manipulation and change in reproductive protocol (followed the artificial insemination protocol) exactly improve the dairy farm profitability. Cooling system is the most useful approach to increase both milk production and reproduction in dairy animals during the summer season.

2. Climatic zones of Pakistan

Agriculture sector being the back bone of the economy will be more probable stake holder of aftermaths of environmental changes. The environment and livestock production systems are closely related with each other [8]. The agriculture sector depends on the availability of the water for irrigation and annual precipitation. Based on the annual precipitation six Agro Ecological Zones (AEZ) has been defined by Quraishi et al. (1993) [9].

Table 1 Annual precipitation agri-ecological zones

S. No	Type of Area	Amount of Precipitation (mm)
1	Humid	>1000-2000
2	Sub-Humid(wet)	700-1000
3	Sub-Humid (dry)	>500-700
4	Semi-Arid(wet)	300-500
5	Semi-Arid(dry)	200-300
6	Arid	Less than 200

Source: Adopted from Quraishi et al., 1993.

Pakistan is one of the sixteen (16) regarding countries most vulnerable to environment change. Out of total 79.6 million hectares (MH), 29 % is cultivated area i.e. about 23 (MH), containing 19.54 (MH) are irrigated and 3.87 (MH) are rainfed. The irrigated area consumes about 80% of the country's freshwater. The 62% of the country areas are rangelands [9].

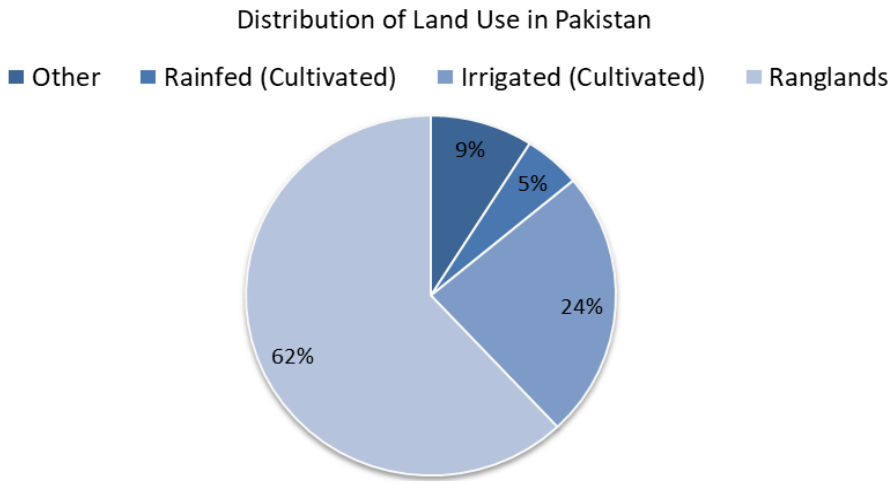

Figure 1 Showing the different Classification of the areas of Pakistan

3. Environmental factor leads to animal stress

Several environmental factors directly or indirectly effects on animals production performance. The production and reproduction intensity of animal about 58.3% and 63.3% directly affected by change in climatic condition [10]. Elevated environmental temperature leads to changes in the physiology of animal's body such as increase body temperature (>102.5 ºF), respiration rates (>70-80/minute) and blood flow [11]. The maintenance energy requirement may increase by 20-30% in animals under heat stress, which results in reduced feed intake and low energy level for productive functions such as milk production and increased loss of ions like sodium and potassium. This results shift in the acid-base balance and leads to metabolic alkalosis.

In perspective of climate change in Pakistan, it has further analyzed by [12] and concluded that annual mean surface temperature is on consistent rising trend since the beginning of 20th century. Charlotte (2011)[12.a] further added that the major risk from the climate change in South Asia is increased summer precipitation, intensity in temperate regions, increase flash-flood prone areas and further added that the arid and semi-arid regions would be drier in summer, which could lead to severe droughts.

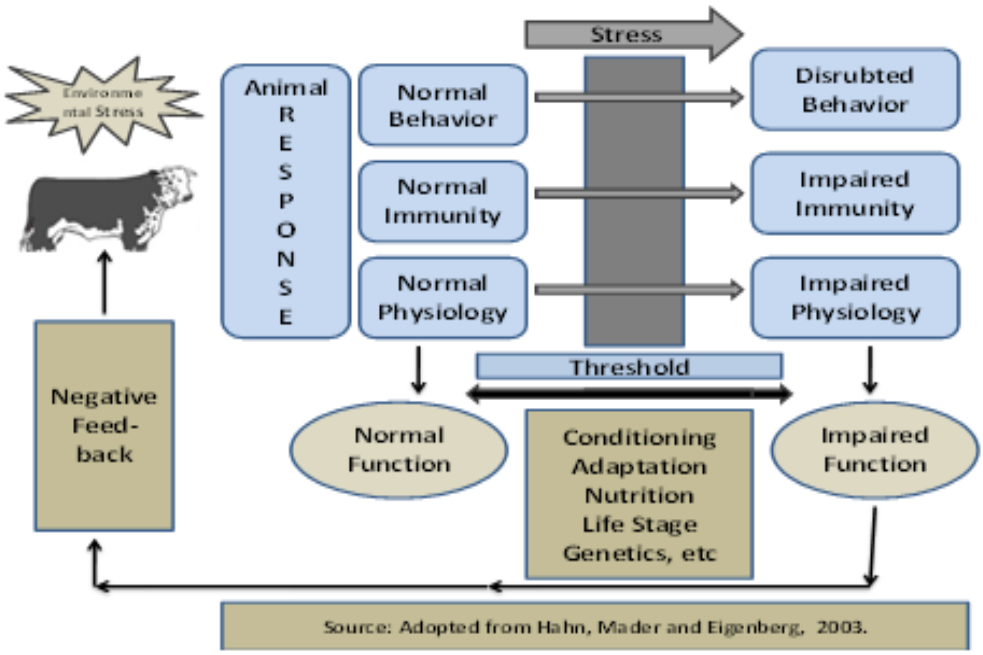

Figure 2 Showing the response of environmental stress on animal health

The climate change is affecting the animal productivity and health in all over the country especially in resource poor localities in the region. The detrimental effect of climate change adversely affecting the livestock production directly due to heat stress or indirectly due to changes incorporated in the ecosystem, leads to affecting the economy of peoples badly. Some of these may include reduced agricultural productivity, deteriorated health due to shortage of feed resources, water quality, global warming, shrinking glaciers, erratic weathers, river floods, disease prevalence, disrupted ecosystem and increase in the frequency of natural hazards and disasters [13]. The climate change affected the livestock in two ways (i) by affecting the forage production, (ii) directly affecting the livestock kept under different production systems. The losses suffered by the animals not only due to heat stress but also in the form of lower production and lower reproduction performance. Pakistan still suffers more than 30% Crude Protein and TDN deficiency for large and small ruminants in its feed balance. When ambient temperature reached to 32-47 ºC with a mean relative humidity of 33-75%, the physiological norms of the buffalo calves were significantly affected and their weekly body weight decreased as 43 kg as compared to 46 kg under open air tree shade than inside a shed with showers plus ceiling fans, body temperature is become higher 101.6 ºF than 101.0 ºF, respiration rate is become higher 28 to 26 per minute, and the pulse rate become increased to 53-54 per minute under treatment with open air tree shade as compared to inside with ceiling fans and showers. The effects on livestock production due to climate change become more deprived specially in a developing country like Pakistan where 35-40 million rural people derive their livelihood from livestock rearing [14].

3.1. Level of thermal stress assessment through temperature humidity index (THI)

Temperature-humidity index (THI) is a widespread and most precise indicator of stress assessment as temperature and humidity. Hot climatic environment lead to decline production and nutrient intake of dairy animal. During metabolizing of nutrient, the heat is generated which contributed to body temperature maintenance in a cold environment. However, in a hot climate, heat needs to be flow-out to maintain body temperature and normal physiological functions. That exposure of animals to hot climatic environment lead to severe changes in the biological functions which consist of decrease in feed intake and its utilization, disturbances in enzymatic activity, metabolism of water, protein, energy and mineral balances [15]. THI is widely used as index for the measurement of combine effects of atmosphere temperature and relative humidity and animal response. The production performance of cows is negatively correlated with temperature-humidity index. Milk yield of dairy animals become decline with 0.2 kg per unit increase in thermal humidity index (THI) when it exceeded 72 [16]. When the environmental temperature rises from the upper critical limit, the detrimental effects of heat stress on animals in terms of reduction in production of milk, changes in composition of milk and reduced reproductive performances are observed in cattle and buffaloes [17]. Numerous studies report the classification of different zones based on THI values whether the animals are comfortable or susceptible to heat stress.

Table 2 Classification of stress level based on THI values (Armstrong, 1994) [43].

THI	**< 72**	**73-78**	**79-88**	**89-98**	**> 98**
Stress Level	**None**	**Mild**	**Moderate**	**Severe**	**Danger**
Symptoms in Animals	Optimum productive and reproductive Performance	Increases respiration rate and rectal temperature, animals search for shade	Decrease dry matter intake, significantly increase water intake. Body temperature is increased and reproductive performances are severely affected specially in cattle and buffalo	The reproductive performances in animals are significantly decreased. Excessive panting and restlessness are observed	Heat stress is extreme and animals may die

THI (Temperature Humidity Index), **<** 72=absence of heat stress, 73 to 78=mild heat stress, 79 to 88= moderate heat stress, 89-98= severe heat stress and > 98=danger for animal.

4. Impact of climate change on production performance of dairy animals

The milk production and their composition in dairy animals especially of high genetic value animals is adversely affected by Climate change [18]. Increasing air temperature and THI value above the critical thresholds level leads to decreased

in dry matter intake (DMI) and milk yield and also cause disturbance in physiology of animal [19]. Several study reported that decrease in DMI by 0.85 kg per cow for every 1°C increase above the thermo-neutral zone and decline in milk production by 36% due to shift in post absorptive metabolism and partitioning of nutrient [20]. THI is negatively correlated to milk yield, an increase of THI value from 68 to 78, decreases DMI by 9.6% and milk production by 21% [21]. The negative relationship between rectal temperature and milk yield of animal is also reported by [22]. Decrease in milk yield by 4 lbs/d per cow for every 0.55 °C increase above the rectal temperature of 38.6 °C and decrease in milk yield 0.7 kg/day per cow when temperature was increased to 0.6 °F above the rectal temperature 102.4 °F [21]. Milk constituents are significantly affected by heat stress during summer season. Dairy breeds are more susceptible to heat stress than meat breeds, and higher milk producing animal had increased metabolic heat production and this causes more susceptibility to heat stress as compared to low milk producing animals [3]. Decrease in protein constituent show the reduction in casein, lactalbumin, IgG and IgA. Heat stress causes decline in dry matter intake and feed conversion efficiency which directly affects the body condition and resulting in low milk yield [23].

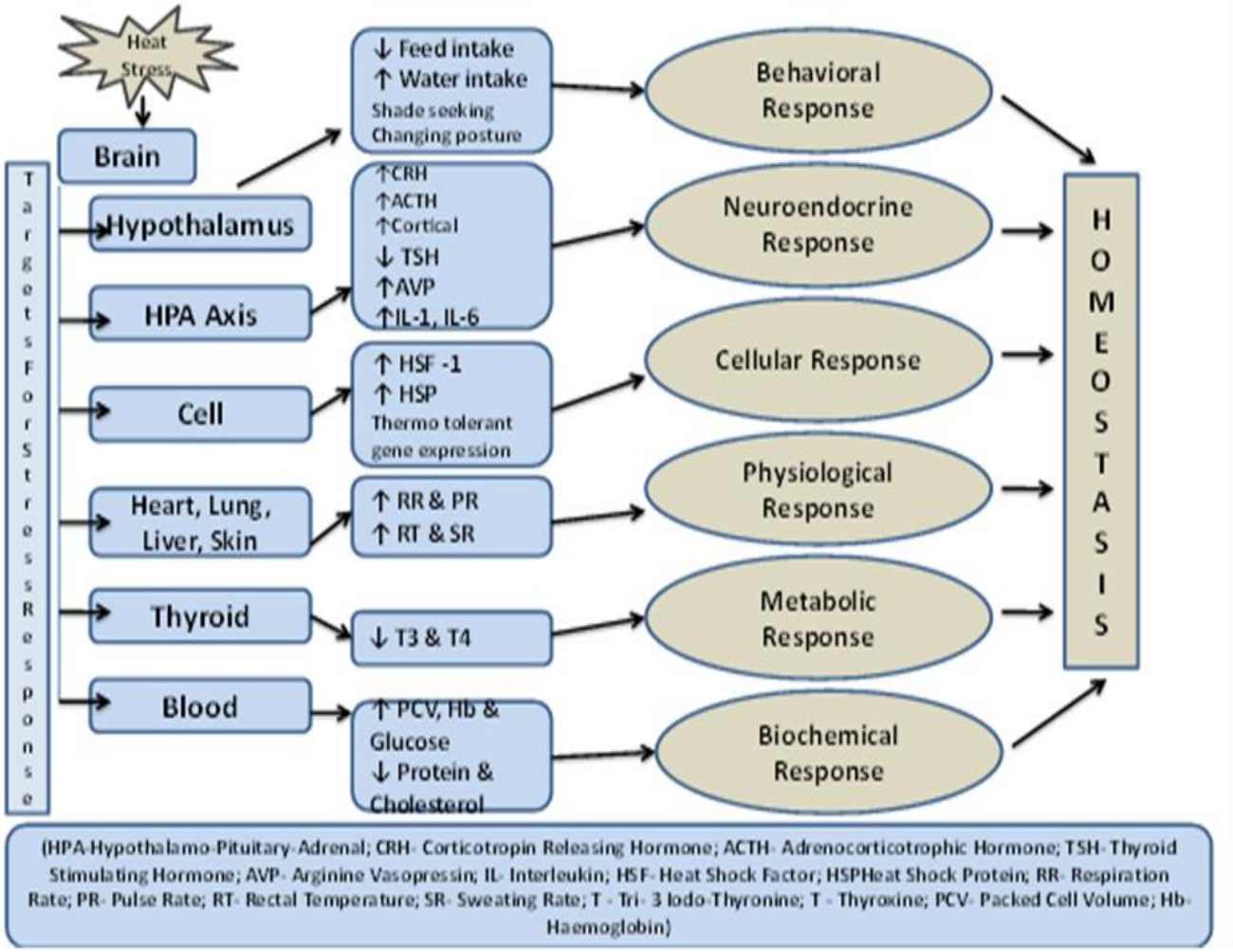

Figure 3 Different response output in response of heat stress on animal body.

5. Impact of climate change on animal reproduction

Climate change has a great impact on the reproductive activity of cattle and buffaloes [24]. High temperature combined with high level of relative humidity has negative effect on reproduction of cattle in summer season. Heat stress has negative effect on reproductive characters of cattle and buffaloes which can be quantified through formulating temperature humidity index (THI). Conception rates of lactating dairy animals have been declined with increased THI more than 72-73 in cattle [25] and 75 in buffalo [26]. The release of ACTH from anterior pituitary, which stimulate the release of cortisol and glucocorticoids from adrenal cortex occurs during heat stress condition. The release of luteinizing hormone is also inhibited by glucocorticoids. The hyperprolactinaemia, as a result of thermal stress inhibits the secretion of both FSH and LH at hypophyseal level [27].

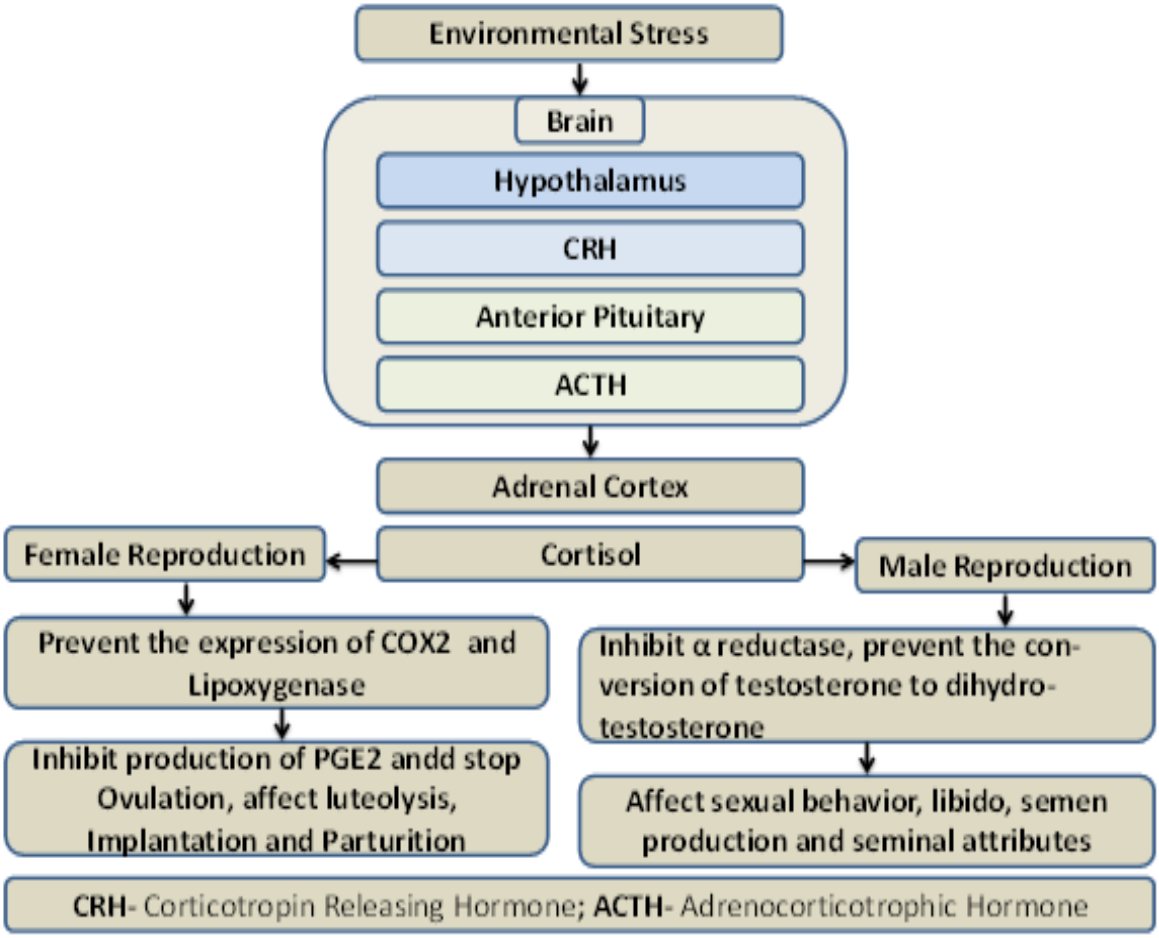

Figure 4 Response of environmental stress on reproductive activity**.**

6. Adverse impact of heat stress on health of dairy animals

Heat stress has directly and indirectly effects on health performance of animal leading to changes in body physiology, metabolism, hormonal and immune system. Increase in environmental temperature has a direct negative impact on voluntary feed intake and efficiency of feed utilization [28]. Lactating cows start to decline the feed intake at air temperature of 25-26 °C and reduces more rapidly above 30 °C in temperate climatic environment and at 40 °C it may decline by 40% in cattle, 8-10% in buffalo heifer and 22-35% in goat [29]. Increased environmental temperature may increase risk of metabolic disorders and health problems and change the basic physiological mechanisms resulting in decrease rumen motility and rumination [30]. Heat stress changes the metabolic patterns which results in decreased thyroid activity and reduces the metabolic heat production [31]. Incidence of lameness in animals increased with increase in ambient temperature [32]. This coincides with the change of climate as well the lameness prevalence is higher in hot climates as compared to cold climates [33]. These climatic and seasonal effects are also correlated to mastitis in dairy animals [34, 35]. Figure 5 describes the various impacts of climate change on livestock health, production and reproduction [36].

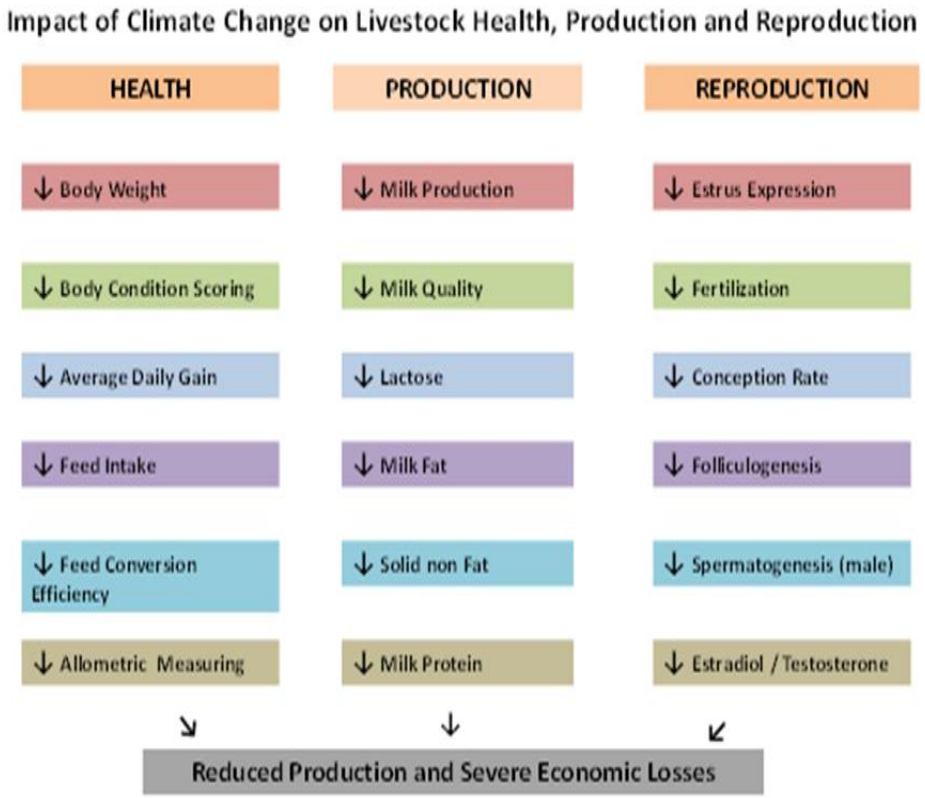

Figure 5 Summary about the effect of climate change on animal health, production and reproduction

7. Strategies to reduce the heat stress

Reduction of heat stress need a multidimensional and multidisciplinary approach. The management strategies via microclimatic modification, nutritional management, feeding strategies and artificial insemination protocol are the basics to reduce the adverse effects of heat stress in dairy animals. Furthermore, the modification of micro-environment, nutritional management and genetic improvement are the key components for sustainable livestock production under hot environment conditions.

7.1. Modification of micro-environment

Modification of micro-environment to improve heat flow-out mechanism to reduce heat stress is one of the most important action to be considered in hot environment. The most common approach to reduce/eliminate the heat stress is to modify environment near to cow surroundings through provision of shade, evaporative cooling system by use of fogger, mister or sprinkler with fan or without fan [37]. Advance reproductive performance of cows is easy to achieve by using effective cooling systems that combine evaporative cooling with tunnel ventilation or cross ventilation [38].

7.2. Nutritional management

Reduced dry matter intake with greater availability of key nutrients and to compensate for dietary heat increment while avoiding nutrient excesses. Lower DMI during hot weather reduces nutrients available for absorption, and absorbed nutrients are used less efficiently. Low-fiber, high fermentable carbohydrate diets lower dietary heat increment compared to high fiber diets. Although the metabolic energy of dairy animals increases in a hot environment, heat stress depresses feed intake. Therefore, the course to increase the nutrient density includes feeding of high quality forage, concentrates and use of supplemental fats in the diet of animals. During hot climate, dietary fat content in feed is to be increased to enhanced milk production efficiency and yield. Supplementation of niacin supportive to reducing of heat stress in cattle and supplementation with antioxidants during the heat stress period is an additional to improve fertility in buffaloes [39]. Both Vitamin C and Vitamin E have antioxidant properties. Antioxidant vitamins have proved to protect the biological membranes against the damage of ROS and the role of vitamin E as an inhibitor “chain blocker” of lipid peroxidation has been well recognized [40].

7.3. Genetic modification

The identification of heat tolerant animals within high producing breeds can be achieved by selecting them genetically for crossbreeding programme to improve genetic variation and cooling capability [41]. Cattle with lighter, thin skin, short hair and greater diameter of hair coat color are more adapted to hot environments as compared to darker colors and long hair coats [42]. Epigenetic regulation of gene expression and thermal imprinting of the genome can also be an efficient method to improve thermal tolerance.

8. Conclusion

Dairy industry facing major economical losses due to heat stress. Heat stress affects the production capacity, reproduction performance and health of animal through physiological changes. Environmental stress puts undesirable effects on health condition of dairy animals and decreases the milk production and reproductive performance of dairy cows resulting in massive economic losses. The most common method to reduce the heat stress in dairy animals by provision of shades, sprinklers, ventilation and evaporative cooling will be suitable for adapting to climates changes. Environmental modifications and nutritional management are the key elements to reduce the impact of heat stress on animal's performance during the hot climate. Wallowing and sprinkling are the most effective methods to reduce heat stress in case of buffalo during summer season. Strategies to reduce negative impact of heat stress of dairy animals by adopting cooling system, ration manipulation, change in reproductive protocol, use of antioxidant, buffers, yeast and hormones will ultimately leads to improve the economic status of dairy farmers.

In addition, Science and technology are lacking in thematic issues, including those related to climatic adaptation, dissemination of new understandings in rangeland ecology (matching stocking rates with pasture production, adjusting herd and water point management to altered seasonal and spatial patterns of forage production, managing diet quality, more effective use of silage, pasture seeding and rotation, fire management to control woody thickening and using more suitable livestock breeds or species), and a holistic understanding of pastoral management (migratory pastoralist activities and a wide range of biosecurity activities to monitor and manage the spread of pests, weeds, and diseases). Integrating grain crops with pasture plants and livestock could result in a more diversified system that will be more resilient to higher temperatures, elevated carbon dioxide levels, uncertain precipitation changes, and other dramatic effects resulting from the global climate change.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest amongst the authors.

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