Research Article

Climate Change Related Factors Impacting Dairy Production in Pakistan

Muhammad Abdul Rahman[1*], Abdul Saboor[1], Gulnaz Hameed[1], Ghulam Bilal[2] and Farooq Tanwir[3]

[1]Department of Economics, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan; [2]Department of Animal Breeding and Genetics, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan; [3]Department of Sociology, University of Agriculture, Faisalabad, Pakistan.

Abstract | This study focuses on identifying critical environmental hazardous factors (CEHFs), threatening health and production of dairy production system in Pakistan under climate change scenario. Expert Judgment approach is employed to identify and then rank most significant CEHFs that are related to emerging security hazards to dairy system. These CEHFs are then stitched with existing body of literature to consolidate our findings. Results comprised key CEHFs affecting occurrence of security hazards to dairy production in the scenario of changing climate. Experts ranked lack of genetic research and fodder security on top among various critical factors that drive and increase occurrence of security hazards to health and production of dairy animals. Lack of labs to identify diseases, sensitiveness of buffaloes to temperature, slow and reduced weight gain and effect on birth and death rate are weighted high as threat to farm animal health while India-Pakistan ties on water, water scarcity, high water requirement for buffaloes and lack of innovation in processing of milk and milk products are other major threats to production from farm animals. The findings of this study can serve as basis of providing key elements for policy devising in order to have research based policy making and implementation with separate set of policy actions for small, medium and large farmers. Input price mechanism, regularization of dairy sector, separate policy measures for meat and dairy animals and preservation of local breeds are few optimistic policy options to safeguard Pakistan's dairy production system from environmental factor under climate change.

Received | July 24, 2019; **Accepted** | August 19, 2019; **Published** | November 02, 2019
***Correspondence** | Muhammad Abdul Rahman, Department of Economics, University of Arid Agriculture Rawalpindi, Pakistan; **Email:** mabdul.rahman@live.com
Citation | Rahman, M.A., A. Saboor, G. Hameed, G. Bilal and F. Tanwir. 2019. Climate change related factors impacting dairy production in Pakistan. *Pakistan Journal of Agricultural Research,* 32(4): 691-705.
DOI | http://dx.doi.org/10.17582/journal.pjar/2019/32.4.691.705
Keywords | CEHFs, Climate change, Dairy, Milk production, Pakistan

Introduction

There has been noticeable change in weather patterns globally over the past few decades (IPCC, 2007). This has resulted in today's most debatable phenomenon, 'the climate change'. It is an established reality that climate change has no borders and respect for mankind around the globe. Shifting patterns of climate are affecting several sectors of the economy, either directly or indirectly. The world has already witnessed year 2016 as the warmest, since birth of planet earth (Harvey, 2016). In Pakistan, warming has been on an increasing side. Mean temperature showed 0.24°C rise per decade from 1960 to 2007 (PMD, 2009). This trajectory, without any doubt, is a foreseeable future and even if the modest warming scenarios are considered, there will be a significant impact on dairy production system.

The impacts of climatic change on the dairy production

system are from both sides i.e. direct impacts on the farm animals (in terms of less production and health issues), and indirect impacts on the production of feed and fodder crops along with increased exposure to pathogens and the pests (Gauly et al., 2013).

On the other hand a rapid increased demand has been observed globally for animal products in relation to the increase in income in many countries (Haq and Ishaq, 2011), especially in China (Qian et al., 2011). The perception that dairy products have premium quality and nourishment gourmet food has also played a significant role in its high demand (Silanikove et al., 2010).

How dairy production is influenced?

The chief externality of changing climate is warming which hampers the functions of biological systems of dairy animals, if it increases above the optimal level. Dairy production systems are directly under the influence of warming. The excess heat produced as a result of warming creates heat stress in dairy animals that result immediately in the form of decreased milk production. In the course of continuous temperature increase above the thermo-neutral zone of animal, it undergoes inherit physiological changes to cool its body and to maintain a constant body temperature. This situation induces a condition where dry matter intake gets decreased while water intake increases i.e., dairy animal starts eating less and drinks more, are the most common behavioral changes when cattle are exposed to heat stress. In this manner, the energy reservoir of the animal starts spending more on cooling the body and low intake of food coupled with energy being spent on body cooling results in dramatic decrease in dairy production (West, 2003; Rhoads et al., 2009). Heat stress also impacts growth performance of farm animal and hence decreases meat production on the other hand due to low feed intake (Rowlinson, 2008) while ability to milk optimally is also affected by heat stress. Heat stress negatively impact milk secretion and milk synthesis, glucose uptake by the mammary gland and blood flow to the mammary glands (Rhoads et al., 2013).

From economic perspective, it is observed that losses in farm revenues cannot solely be attributed to decrease in the milk yield when the temperature index reaches the peak values. There are various factors that cause profit loss in dairy production system that includes impaired milk quality, increased health problems, reproductive issues and even death of the animal (Silanikove and Koluman, 2015).

This discourse is focused on studying the potential consequences of changing behavior of environmental factors under changing climate scenario on dairy production system in Pakistan. An effort will be made to evaluate the direct as well as indirect impacts of climate change on health and production of dairy production system in the country.

Materials and Methods

The scope of this study could be large employing extensive resources and intensive research methodology. However, that would not only take much time but also it is difficult to encompass this research in most sustainable and presentable manner. The aim here is to identify critical factors for isolating emerging security hazards on health and production of dairy animals that can be influenced by environmental factors under changing climate. It may cover a large number of factors belonging from inside and outside the dairy production system. Consequently, an expert judgment study is exercised to identify and then weigh chief factors using the knowledge and research sources of experts of this field.

Sample

Experts: Thirteen preselected dairy experts from Pakistan were approached and requested to participate in this expert judgment study. The selection criteria for experts comprised on their experience and knowledge of dairy sector including persons from government ministry, relevant government departments of climate change and dairy, experts involved rigorously in practical caring and holding of dairy animals, academia and NGO. The aim was to make this pool of expert's representation of various actors playing their role in Pakistan's dairy production system. The dairy farming system of Pakistan is different from other dairy productive nations due to the nature of small dairy animal holdings per household and there exists relatively short distance between various actors of dairy system. Another characteristic is the mixed dairy farming i.e. households has dairy herds comprising variety of animals belonging to different species. This, itself is one of the security hazards as each animal then demands separate set of actions to cater its need on the farm that may increase the herd keeping cost or may reduce the production of dairy products. In the changing climate scenario, situation may get worse for Pakistan's dairy sector system. Therefore, the characteristics of the Pakistan's dairy production system are discussed below before moving ahead in this discourse.

Pakistan's dairy system structure: Pakistan's Dairy sector functions under the widespread umbrella of livestock sector. It is pivotal in nourishing socio-economic development. Over 8 million families are dependent on livestock rearing and production (for dairy and meat purposes) which enables them to earn 35-40 percent of their income The sector has a chief share in livelihoods of the rural households and marginalized communities. During fiscal year 2018-19, this sector contributed 11.2 percent to the overall GDP and 60.5 percent to the agriculture as value added. At constant cost factor of 2005-06, there has been tremendous increase in Gross Value Addition of livestock sector from Rs.1384 billion during 2017-18 to Rs.1440 billion in 2018-19 (GoP, 2019).

At regional arena, Pakistan ranks second in carrying second largest population of dairying animals in South Asia (138.12 million heads) after India (517.08 million heads) and also annual growth rate of dairy sector is positive, depicting a healthy environment to flourish dairy in Pakistan (Siddiky, 2017). Globally, Pakistan is the 4th largest milk producer of the world (Pakistan Today, 2017) and in the South Asian region it ranks second. In addition to this, production of milk per cow and per buffalo is highest in Pakistan followed by India in the region (Siddiky, 2015).

As per FAO, world milk production has shown dramatic increase of more than 50 percent during past three decades from 500 million tons of milk produced in 1983 to 769 million tons production in 2013 (FAO, 2016). It is also a fact that most of this production increase has been seen in the developing countries. Pakistan produces 54 billion kg milk annually (Siddiky, 2017; Memon, 2017). Large dairying animals like cattle and buffalo produce 96 percent of milk while rest is collectively produced by camel, sheep and goat. This small amount of milk is not sold as such rather mixed with buffalo and cow milk and sold in the market or in some cases, used domestically (Memon, 2017).

Despite having fourth largest milk production rank globally, Pakistan never gained a comparative advantage in global arena from this white gold. The sector is facing many socio-economic and environmental challenges. About 35 million of population mainly poor and marginalized earned 40 percent of additional income from this sector (Shahid et al., 2012) or there are more than 7.5 million farming families which are mostly landless peasants and smallholders are directly engaged in livestock farming (Khan, 2018).

The productivity of milk per animal has decreased and increase in gross milk production is mainly attained by increased number of dairying animals (population) in the country which is critically unsustainable in the changing climate scenario. A careful analysis of empirics presented in government documents show that during last 3 decades, population growth of dairy animals is consistent at 9 percent annually, where during the decade 1996-2006, milk production increase only 7 percent and it lowered to 6 percent during the next decade (2006-2016) (GoP, 2019). Hence productivity of dairy herd is a serious question mark. The changing climate will surely play its role in this regard in near future as dairying sector is one of those sectors that depends heavily on climatic parameter from both input and output side i.e. climate change will pose threat to fodder crops and on the health and production of dairy animals.

Expert judgment approach

We used Expert Judgment technique here. In this technique, judgment is obtained against specific set of expertise. The expertise is usually acquired in a precise knowledge area, a particular discipline or in an industry. Such expertise may be obtained from individual or any group that has specialized skills, knowledge, education training or experience (PMI, 2013). The advantage of this approach lies in the fact that data requirement is not necessary. It does not need to elaborate the statistical expertise or tools. Forecasting can be made with ease and swiftly using this approach. In other words, it is a practical forecasting technique especially when time series data over several years is missing or not available. On the other hand, its demerit is that it relies a lot on judgment and intuition and in case the expert is not fully sensitized about his/her participation in the research, the findings may get disturb. So the researcher employing this technique should be fully aware of such shortcoming and approach the experts taking prior time and choose those experts who are willingly participating in the research to minimize biasness (FAO, 2019). This technique is quite useful in management related studies where resource management is prime objective.

Our study employed expert judgment approach as dairy sector is one of the good examples of resource management to obtain optimal dairy yield. The success

of dairy sector relies on managing and allocating the resources as per need/demand. In changing climate scenario, this technique is helpful in identifying the critical factors (in our study, CEHFs) that are threatening health and production of dairy animals. It is pure qualitative approach and the critical factors identified here can be used further in quantitative studies by gathering data for identified factors and using statistical inference for estimation. So the findings of this study will surely open new arenas for future researches especially for quantitative studies.

Expert judgment approach here consisted of two-steps:

- Identification of critical environmental hazardous factors (CEHFs) by three experts from academia having expertise in agriculture and livestock sector. Based on their research and literature review, a comprehensive pool of factors was developed.
- Ranking of the identified CEHFs by experts.
- Stitching ranked CEHFs with the findings of related studies.

Identification of critical environmental hazardous factors (CEHF): Three experts from academia having rigorous research background in agriculture and livestock system of Pakistan were approached for individual interviews. The aim here was to identify and compose a list of CEHFs that are threat to the health and the production side of the dairy sector. The production side included the input production i.e. the fodder production and the output production i.e. the output produced by the dairy sector in the changing climatic conditions of Pakistan. The exercise performed in this phase resulted in a gross list of factors on paper that are then ranked by the same experts in the next phase.

Ranking of the identified CEHF by the dairy experts: In second phase, ranking of the identified CEHFs was exercised to rank most significant factors impacting the occurrence of hazards to health and production of dairy production system in changing climate scenario. Ranking is carried out in such a manner that all ten experts ranked identified factors for their relevancy by giving a score to each of these factors out of 10 i.e. each identified factor should not get more than 10 score from one expert and at the end, each factor is ranked out of 100 score. A higher score means higher relevance than a lower score. The factors which were recurrently ranked by the experts and with the highest total score were identified as the most significant factors affecting the occurrence of environmental hazards to health and production of dairy animals as a result of climate change.

Stitching of the ranked CEHF with the findings of related global studies: In last phase, identified and then ranked CEHFs were stitched with the literature review in a fashion that the factors identified and ranked by our experts were matched with the findings of the related previous studies to consolidate and provide a strong base to our findings.

Results and Discussion

Table 1 shows a list of identified common critical environmental hazardous factors (CEHFs) threatening health and production of the dairy production system in Pakistan which are expected to be affected by climate change. The identification is carried out by using expert judgment approach by interviewing individual experts. A list was generated for numerous factors, which was reduced significantly after selection of those factors that were identical in nature in all expert responses. These factors were divided into two categories. First category shows critical environmental hazardous factors that are threat to heath of animals. Second categorization is established on the basis of threat to production to dairy production system in Pakistan from the identified hazardous factors.

Table 2 shows results after the identified CEHFs were weighed by 10 experts. The weighing of each factor was carried out by asking the experts to rank identified factors out of 10. This means, each factor had got 10 score out of which each expert gave it a score depending on the relevancy in impacting the health and production of dairy production system in prevailing changing climatic scenario. As each factor is ranked 10 times by 10 individual experts, each factor is scored out of 100 cumulatively at the end for analysis. A highest score for a factor illustrated that, that individual factor is more relevant in impacting health or production of dairy production system in Pakistan in prevailing changing climatic conditions. Figure 1 and 2 were also sketched and presented after Table 2, highlighting findings in a more illustrative manner.

Table 3 is the core part and heart of this study. It presented identified and ranked CEHFs in one column and in the parallel column; each CEHF is

Table 1: *Identification of critical environmental hazardous factors to health and production of dairy system in Pakistan.*

Identified critical environmental hazardous factors	Threats to health	Threats to production
	Slow and reduced weight gain	Fodder security
	Effect on birth and death rate Sensitiveness of buffaloes to temperature	India-Pakistan ties on water
	Climate induced disasters	Lack of baseline studies on dairy sector
	Introduction of new diseases	Unchecked/over grazing
	Local level poor cross breeding	Water scarcity
	Disease transfer	Two extended dry periods in the country
	Showering of water on animal in hot temperature	Protein content loss
	Lack of genetic research	High water requirement for buffaloes
	Lack of labs to identify diseases	Changing cropping pattern
	Poor feed management carrying diseases	Poor genetic pool of breeds
	Crowding in farm	Lack of genetic up-gradation
	Effect on conception rate	Increased used of additives and preservatives
	Fertility problems	Lack of innovation in processing of milk and milk products
	Fluctuating humidity impact	High import of milk and milk products
		Humidity fluctuates dairy production

Table 2: *Ranked critical environmental hazardous factors to health and production of dairy system in Pakistan.*

Ranked critical environmental hazardous factors	CEHF threatening health	Score	CEHF threatening production	Score
	Lack of genetic research	76	Fodder security	85
	Lack of labs to identify diseases	74	India-Pakistan ties on water	83
	Sensitiveness of buffaloes to temperature	71	Water scarcity	83
	Slow and reduced weight gain	69	High water requirement for buffaloes	77
	Effect on birth and death rate	65	Lack of innovation in processing of milk and milk products	76
	Introduction of new diseases	65	Lack of genetic up-gradation	73
	Fertility problems	61	Poor genetic pool of breeds	70
	Poor feed management carrying diseases	56	High import of milk and milk products	68
	Effect on conception rate	56	Lack of baseline studies on dairy sector	59
	Climate induced disasters	55	Changing cropping pattern	55
	Fluctuating humidity impact	54	Unchecked/over grazing	50
	Disease transfer	53	Increased used of additives and preservatives	45
	Local level poor cross breeding	51	Protein content loss	39
	Crowding in farm	43	Humidity fluctuates dairy production	39
	Showering of water on animal in hot temperature	35	Two extended dry periods in the country	28

stitched with the literature review. Stitching was carried out in a fashion that at least one study is stitched with our findings from expert judgment analysis. The aim was to provide scientific base and consolidation to each factor so that uniqueness is created that can set pathways for future researches in similar manner.

CEHFs threatening health

Lack of genetic research in dairy sector has placed this factor on top of the list (s=76). Experts viewed that Government is more eager on importing high yielding varieties and semen for artificial insemination from west and especially Australia rather than investing in research and development to help genetic researches in developing and improving indigenous breeds that

can cope better in local conditions. Lack of genetic marketing is another factor and poor breeding practices are also sort of hindrances that the country's genetic pool of livestock is poor and even 'pure' breeds are unavailable. Local level poor cross breeding (s=51) is another hindering factor that threats not only animal health in achieving desired traits but also its adaptability is shaken in adapting to changing climate. Cross breeding that lack scientific approach results in poor traits in terms of production and coping with the environmental factors (Cassell, 2009; Farooq, 2016).

Moving ahead in the analysis, a higher score was given by the experts to lack of labs (s=74) designated especially for testing livestock virus strains are not present in the country. Experts were of the view that it's a dilemma that without identifying true cause of a disease, farm animal is vaccinated expensively but animal does not recover. One of the experts highlighted that *Mokhar* is a disease in dairy animals and it has 8 stains i.e. 8 different types of viruses for example Russian, French etc. In Pakistan vaccine is either available against Russian, French or for other 2-3 strains. The non-availability of labs causes the failure for the farmer to identify exact strain of virus that has infected his animal. So even when the animal is vaccinated, it is of no use. Policy level intervention is required in this case because it requires handsome budget and manpower training and in changing climate scenario where environmental threats are ever higher than before, this factor need government level intervention (Jabbar, 2018).

Table 3: *Literature stitching to identified and ranked CEHFs by experts.*

CEHFs threatening health	Literature stitching	CEHFs threatening production	Literature stitching
Lack of genetic research	Farooq, 2016	Fodder security	Höglind et al., 2013; Downing et al., 2017; Hanna et al, 2018
Lack of labs to identify diseases	Dr. Jabbar, 2019	India-Pakistan ties on water	Johnson, 2019; Slater 2019
Sensitiveness of buffaloes to temperature	Hammami et al., 2013; Khaqan et al., 2016; Seerapu et al., 2015	Water scarcity	Thornton et al., 2009; Tubiello et al., 2007
Slow and reduced weight gain	Downing et al., 2017; White et al., 2003	High water requirement for buffaloes	Upadhyay, 2010
Effect on birth and death rate	Upadhyay, 2010; Lacetera, 2019; Bernabucci, 2019	Lack of innovation in processing of milk and milk products	Wynn et al., 2006; Farooq, 2016; Asayehegn et al., 2017
Introduction of new diseases	Das et al., 2016; Rhoads et al., 2013; Downing et al., 2017; Lacetera, 2019	Lack of genetic up-gradation	Rauw and Raya, 2015; Garner et al 2016; Jabbar, 2019
Fertility problems	Hansen, 2009; Upadhyay, 2010; Sadiq, 2019; Escarcha, 2019	Poor genetic pool of breeds	Khan et al., 2013
Poor feed management carrying diseases	Spiegel et al., 2012; Gauly et al., 2013; McKenzie, 2017	High import of milk and milk products	Peculiar CEHF
Effect on conception rate	Upadhyay, 2010	Lack of baseline studies on dairy sector	Peculiar CEHF
Climate induced disasters	Nardone et al., 2010; Chari, et al., 2017; Escarcha, 2019	Changing cropping pattern	Gauly et al., 2013
Fluctuating humidity impact	Hatfield, 2008; Lacetera, 2019	Unchecked/over grazing	Soussana et al., 2010
Disease transfer	Kataktalware et al., 2016	Increased used of additives and preservatives	Science Daily, 2019; Davison, 2013
Local level poor cross breeding	Cassell, 2009	Protein content loss	Downing et al., 2017; Hill and Wall, 2015
Crowding in farm	Parameswaranaik et al., 2017	Humidity fluctuates dairy production	Hatfield, 2008; Mauger et al., 2015; Hill and Wall, 2015
Showering of water on animal in hot temperature	Chen et al., 2013; Naheed et al., 2015; Kataktalware et al., 2016	Two extended dry periods in the country	Peculiar CEHF

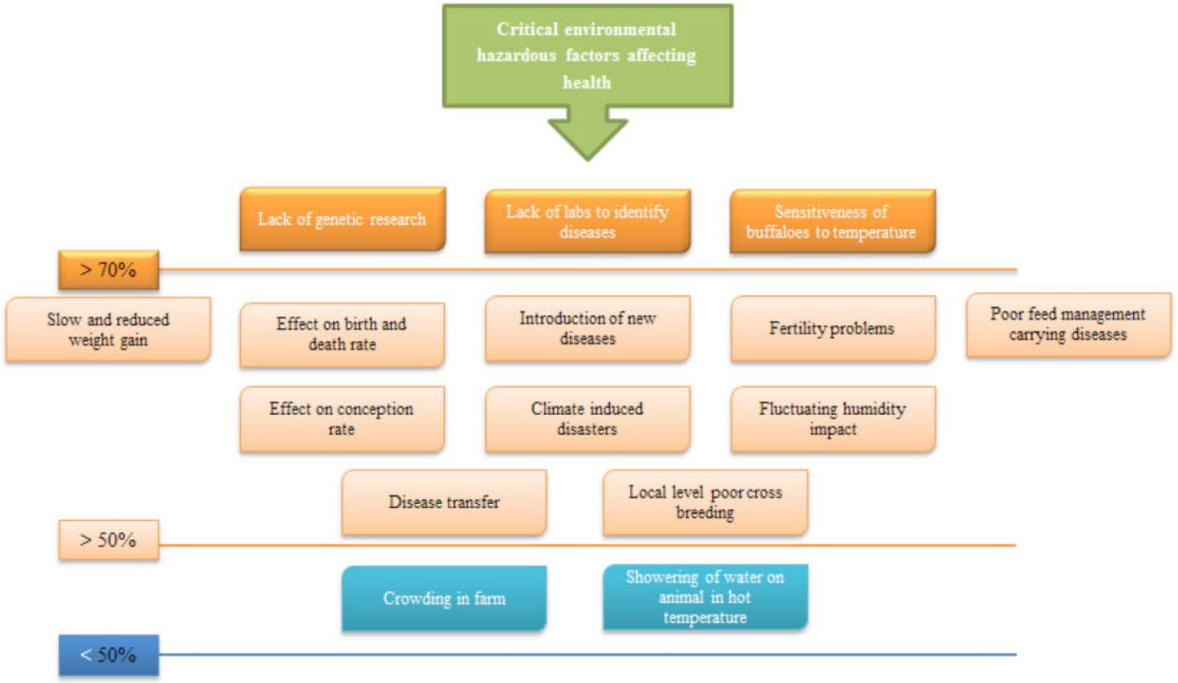

Figure 1: *CEHFs affecting health.*

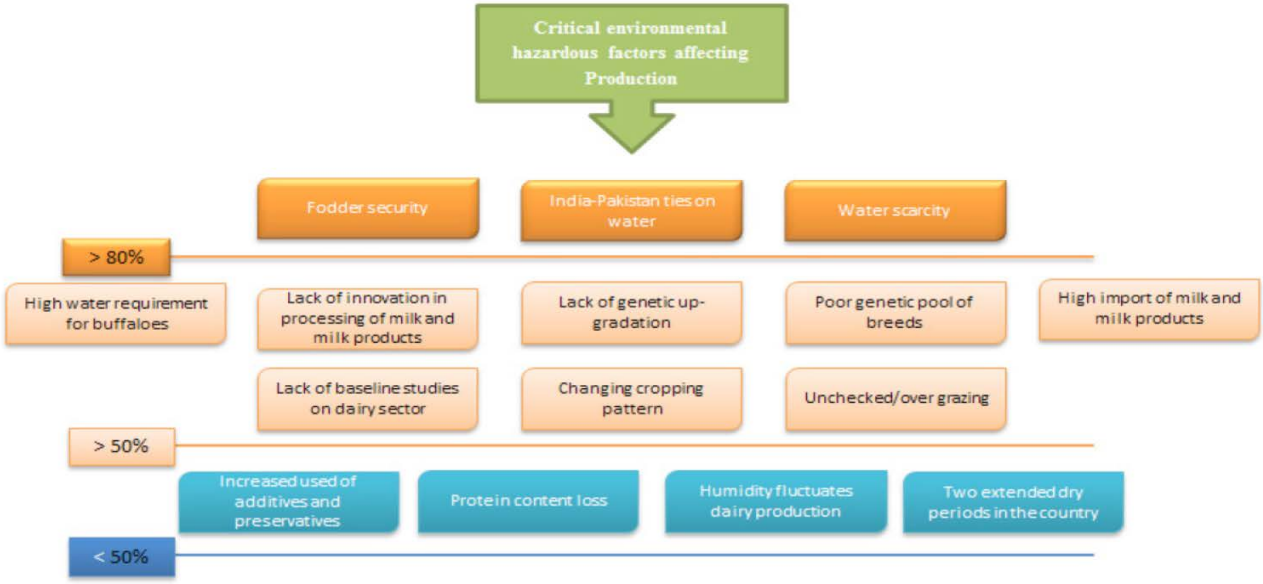

Figure 2: *CEHFs affecting production.*

The next chief hazardous factor identified and verified by experts, that can impact health of the animal is the sensitiveness of buffaloes to temperature (s=71). Pakistan has large herds of buffaloes (40.5 million) (GoP, 2019). Buffalo milk is preferred over cow milk. The color of buffalo is itself a threatening factor. It is black and in high temperature, animal heat up quickly. This results in low dairy production along with increased water requirement. This on one side reduces the economic returns from the animal and on the other side increases the cost of holding the animal in warm condition (Upadhyay and Ashutosh, 2009; Hammami et al., 2013; Seerapu et al., 2015; Khaqan et al., 2016; Jabbar, 2019).

Slow and reduced weight gain (s=69) is positioned at number 4. Warming induces loss in body weight of animal as animal enters into the phase of stress and its intake gets less. Due to less intake of feed, body weight starts to increase slowly and in worse cases animal become so weak that production is significantly reduced. Daily addition of recommended 800 grams a day in animal's body weight is compromised due to warming that obviously impact the productivity of animals. Evidence show that warming increases respiration rate, rectal temperature and heart rate

which directly affect feed intake thereby, reduces growth rate, milk yield, reproductive performance, and even death in extreme cases. There are several studies that concreted the theory that dairy breeds of animals are typically more sensitive to heat stress as compared to meat breeds. They need to acclimatize and adjust their body functions more than meat breeds to have sustainable growth as well as milk production (White et al., 2003; Rhoads et al., 2013; Das et al., 2016; Downing et al., 2017). Similarly, heat stress also affects the birth rate in dairy animals. Fluctuation in environmental factors like increase in temperature creates heat stress that has severe effect on birth and death rate (s=65). Increased temperature induces heat stress which undoubtedly impacts animal health and its welfare negatively. There is a demand of efficient heat reduction systems in the dairy farms in order to cater increasing warming to help dairy animals to perform optimally under heat stress (St-Pierre et al., 2003). It is an established fact that such environmental circumstances can disturb livestock health by triggering oxidative stress, metabolic disruptions and immune suppression which results in infections and more alarmingly, death of the animal. It is also reported that heat stress due to rise in temperature in buffaloes may root negative impacts like lower and desynchronized endocrine activities which effect conception rate (s=56), eventually hitting the production side of dairy cattle. Hence heat stress is one of the core issues that should be addresses on high priority especially in the changing climatic scenario that is creating warming globally (Upadhyay, 2010; Lacetera, 2019; Bernabucci, 2019).

The change in climate also favors introduction of new varieties of diseases that doesn't exist in a specific location before. Experts also mentioned this factor as "introduction of new diseases" (S=65) and increased frequency of disease transfer (s=51) among the farm animals is a serious concern in changing climate scenario. This is because changing behavioral patterns of climatic parameters though sometimes eliminate certain type of diseases and their pathogens but on the same merit facilitates new diseases to arrive and impact animal in a different way. Many researchers accept that animal diseases will get augmented in changing climate. This will not only influence sustainable food supply but also trade, commerce and health sectors will be next victim globally especially in developing nations. The impact of climate change on disease distribution is more of an indirect sort of impact that follows intricate pathways and is difficult for the farmers especially in developing world to explore them easily. Warming also increases the rate of disease transmission in livestock (Rhoads et al., 2013; Das et al., 2016; Kataktalware et al., 2016; Downing et al., 2017; Lacetera, 2019). Introduction of new diseases results in the shape of health issues and increases the fertility problems (s=61) that may get aggravated in these circumstances. Decreased animal fertility, longevity and general fitness are reduced along with reduced birthing rates. Another alarming result is increase in aging of the animal at first calving in cattle. Buffaloes which normally conceive in cooler parts of the year are impacted from fertility aspect as warming is disturbing seasonal patterns. Generally, in Pakistan, warming is on a rise and even in winter season; optimum winter temperature is not achieved thus fluctuating the fertility of the animals (Hansen, 2009; Upadhyay, 2010; Sadiq, 2018; Escarcha, 2019).

Introduction of new diseases (s=65) impacts dairy production system in two ways. One is discussed earlier where there is a serious concern on the health of animal. Another way of disease impact is on the feed of the animals. Poor feed management leading to outbreak of diseases (s=56) is another hazardous factor that impacts the health of animal. Raw materials, silage, pastures, manufacturing of compound feed and storage are more susceptible to climate change and worse situation aggravates if proper management is not practiced. It is also established that climate change is likely to introduce new diseases, pest and insects on crops. From this perspective, farmers need to be vigilant (Spiegel et al., 2012; Gauly et al., 2013; McKenzie, 2017).

Climate induced disasters (s=55) is another serious CEHF that threats health and overall welfare of dairy production system. Experts viewed that majority of Pakistan lies on the flood plains. On the other hand, erratic rainfall is another recurring activity that is happening frequently in Pakistan and is mainly due to climate change. In the event of a disaster cause by any reason, people tend to safeguard themselves and their families first and in many instances they don't have much time to even proper safeguard their own wellbeing. The livestock is directly impacted in this scenario. Numerous studies have reported that unusual weather events such as floods cyclones and droughts directly hit animal stocks mainly by increasing the morbidity and death rates (Nardone et al., 2010; Chari et al., 2017; Escarcha, 2019).

Like temperature, fluctuating humidity impact (s=54) is another serious CEHF identified and verified by

our experts. Globally, the temperature–humidity index couple's temperature and humidity into a single variable and derives a single value for them. This is considered a useful tool in predicting the impacts of environment on the farm animals. It is an established fact that 80 and 70 values for temperature–humidity index are the daily maximum and minimum values above which heat-induced death rate increases. It is also studied that fluctuation in temperature-humidity index favors birth of new insect types that impact the health of dairy animals directly (Hatfield, 2008; Lacetera, 2019). Furthermore, experts also ranked crowding in farm (s=43) another threat to animal health. Keeping less animals or appropriate herd size according to farm carrying capacity increases productivity and efficiency of dairy animals. Overcrowding elevates heat stress in dairy animals that results in less production (Parameswaranaik et al., 2017). Lastly, showering of water on animal in hot temperature (s=35) is ranked last by the experts. In Pakistan, it is a general practice to cool the animals in the hot weather. Though it is an advantageous technique, however, if not properly managed, it increases the chances of disease spread in the farm. Moreover, wet condition favors more parasitic attack on the skin of the farm animal, if the wasted feed and dung is not removed properly. In humid conditions, showering can also cause fever in animals impacting health and lowering production (Chen et al., 2013; Naheed et al., 2015; Kataktalware et al., 2016).

CEHFs threatening production

Fodder security (s=85) is the chief emerging problem in the dairy production system of Pakistan as identified by the experts that is threat to production not only to the fodder crops but also the production from farm animals depends on fodder security. The climatic pattern is changing and there are established studies where climate is impacting the cash crops in Pakistan. Fodder security is something that is significantly neglected in case of Pakistan. A wise option here is to explore for the adaptive varieties of fodder that can withstand climate change. Similarly, milk production is at risk due to quantity and quality of feed that is going to be produced under these fluctuating circumstances. Increased frequency along with increased duration of heat stress and heavy rains are likely to harm fodder crops (Höglind et al., 2013; Downing et al., 2017; Hanna et al., 2018). Changing cropping pattern (s=55) due to change in environmental factors is also impacting fodder security. Dairy sector in Pakistan is totally different than other countries of the world. It is 72 percent dependent upon the residues of the crops unlike other countries. Farm animal are being fed 72 percent on the residues. Climate change is likely to change cropping pattern and harvesting period is likely to be squeezed which will directly affect the residues availability (Sadiq, 2018). Climate change is likely to introduce new diseases, pest and insects on crops. This will also affect the cropping pattern and farmers need to be vigilant (Gauly et al., 2013). Another trajectory in which fodder security is a growing problem is unchecked/over grazing (s=50). There is a lack of management of large grazing areas in Pakistan. Proper management and governance of these lands is required so that animal can get some food from these lands during scarcity periods. Over grazing under threat of changing climate can increase pace towards fodder insecurity and ultimately production of fodder as well as animal farm production will suffer. Well-managed grazing can improve soil organic carbon and nitrogen content; hence provide sustainable feed production (Soussana et al., 2010; Ahmad, 2018).

Another serious factor identified by experts is of political nature. Fodder security problem is going to aggravate due to India-Pakistan ties on water (s=83). Water scarcity (s=83) is another serious concern emerging globally and in case of Pakistan, the situation is alarming. Country will not only face shortage of water due to climate change, but its ties with India on water issue are also crucial. Both countries have Indus Water Treaty of 1960 according to which water of rivers flowing between two countries were divided. However, flow of rivers between two countries is such that they enter into Pakistan from Indian side and hence India has comparative advantage in disturbing its flow mainly due to political reasons and its own increasing water demand (Johnson, 2019; Slater, 2019). Thus in these prevailing circumstances water shortage will impact the fodder crops and scientists are of the view that climate change will create water scarcity issues for animal consumption and hence performance of dairy production system is at risk (Thornton et al., 2009; Tubiello et al., 2007).

High water requirement for buffaloes (s=77) is another threat to production aspect identified by the experts for Pakistan. Lactating buffaloes are subtle to heat stress. They are not able to uphold core temperature of their bodies within thermo neutral zone. This is because of particular specie characteristics mainly the 'black body color' and more affiliation to water for their production and reproduction. In the scenario, where water scarcity is insight due to climate change (Thornton et al., 2009) the production performance of

buffaloes has serious challenges. They not only needed water to cool down their bodies more than cows, but sufficient amount of water is needed for maintaining optimum dairy performance along with reproduction aspect (Upadhyay, 2010).

Lack of innovation in processing milk and milk products (s=76) has raised grave question marks in Pakistan. Experts viewed that milk requires special treatment as soon as it is obtained from animal body. Poor processing and transportation of milk creates huge loses along with deterioration of milk quality. Transportation and processing though have different trajectories in terms of analysis and impact on milk quality, however, processing of milk started right after it is obtained from farm animals as milk is a fragile and perishable commodity. The containers in which it is initially collected are of low quality i.e. poor in withstanding the fluctuation in climatic conditions. Poor skills and knowledge of farmers in this regard is another serious concern. There is a good lesson from Kenya regarding innovation in milk processing to adapt to changing climate where variety of ways (mainly technology implementation) are adopted to process milk under changing climate where warming is chief factor impacting the quality of milk (Wynn et al., 2006; Farooq, 2016; Asayehegn et al., 2017).

Lack of genetic up-gradation (s=73) and poor genetic pool of breeds (s=70) in Pakistan are serious and significant CEHFs identified by experts. These factors are significantly linked to the lack of genetic research (s=76) that is discussed in CEHF threatening health. However, in case of production, impact is serious. One of the experts highlighted that Australians took our *Sahiwal* cow breed and Neli Ravi buffalo to their country and modified it. Now it is producing around 28-30 kg average of milk whereas in our country it is still producing 13-14 kg. They updated these breeds and increased the production of meat. Their animal of 2.25 years age weighs around 16 mounds whereas our animal of same age weighs not more than 8 mounds. Genetic up-gradation is dire need of time to cope the animals not only with global standards of production but also to withstand fluctuating environmental factors (Khan et al., 2013; Rauw and Raya, 2015; Garner et al., 2016; Jabbar, 2018).

Increased used of additives and preservatives (s=45) is another CEHF threaten production aspect of dairy production system. With increased warming, farmers as well as milk distributors are compelled to add additives and preservatives in fresh milk to increase shelf life. The added substances are not only harmful for milk itself to deteriorate its quality but also it has established negative impacts on humans after consumption. In changing climatic scenario, policy level intervention is required here by imposing ban or regulating the use of such substances in milk (Science Daily, 2019; Davison, 2013). Protein content loss (S=39) is also a serious hazardous factor demanding special consideration. This is because it is impacted by addition of additives and preservatives. Dairy animals also aid mankind by converting non-consumable crops by humans into edible protein. Increased warming also affects amino acids in the protein content of milk and lack of proper processing and transportation system aggravates this situation. It is an established fact that increased temperature-humidity index reduces protein content of milk (Hill and Wall, 2015; Downing et al., 2017).

Humidity fluctuates dairy production (s=39) and alters optimum production from dairy production system. Changes in humidity especially increase in its level due to climate change is expected to influence milk production and increase spread of diseases. It also affects reproduction in dairy animals and impacts negatively. It is also noted that high moisture in farm environment creates humidity impact and when it couples with temperature, it affects the feed intake negatively. There is evidence that moisture management is also critical in controlling emergence of new diseases (Hatfield, 2008; Mauger et al., 2015; Hill and Wall, 2015).

Peculiar CEHFs identified in this study

3 CEHFs were also identified from expert judgment approach that is peculiar in nature to Pakistan's context. These included high import of milk and milk products (s=68), lack of baseline studies on dairy sector (s=59) and two extended dry periods in the country (s=28). These three peculiar CEHFs can be regarded as the starting points for future researches. Though first of the three CEHFs are out of the canvass of climate change, but their linkage has multi-dimensional impact. Similarly, the extension of dry periods in the country is serious consequences of climate change as identified by the experts.

Sadiq (2018) highlighted with empirics that on one end, it is claimed that Pakistan is 4th largest milk producer but on the other hand, we are also importing Rs. 300 billion of powdered milk. It is claimed that 50 billion liters of milk is produced each year in Pakistan and domestic demand is 20 billion liters, in that case

where is rest of milk going? These are serious policy gaps and need to be addressed with responsibility. Pakistan is already facing extreme trade deficits and in case climate change starts to impact dairy sector severely, we need to address these issues seriously, otherwise import of milk will not only impact food security of the country, but also the trade imbalances will increase (Sadiq, 2018).

Jabbar (2018) was of the view that it is a dilemma in Pakistan that policies are crafted on table without following demands of the modern day policy making techniques. There is huge shortage of baseline studies in Pakistan's dairy sector. Without a baseline study, no policy measures can be taken to target any component of this sector effectively. A comprehensive and multi-dimensional approach is needed to explore various underpinnings of dairy production system in Pakistan and it's inter as well as outer linkages with other fields of sciences so that not only production aspect of the system is enhanced but also the system as a whole has the capacity to withstand any change especially, climate change (Jabbar, 2018).

Ahmad (2018) and Sadiq (2018) showed serious concerns over one of the visible impact of climate change in Pakistan i.e. extension of seasonal dry periods. Generally, there are two water scarcity periods in Pakistan that exist from decades and are June-July. But now this has shifted to May-July. Then there is a dry spell from 15th December to end of January in which availability of fodder to animal is too less and water is also scarce. These two scarce patterns are induced in our country due to climate change. With the passage of time, the scarcity is increasing. The alteration in these two periods is not only impacting cropping pattern of Pakistan, resulting in late crop maturing and delayed fodder availability, but also the heating period of female farm animals is distrusting resulting in difficulty in conceiving and birth rates (Ahmad, 2018; Sadiq, 2018). So these three peculiar CEHFs need special attention in the policy making corridors.

Conclusions and Recommendations

Expert judgment approach not only resulted in identification and ranking of critical factors in the most neglected dairy sector of Pakistan, but also it inquired experts to suggest policy recommendations based on their wisdom and research/experience of dairy sector situation. This helped in comprising a list of targeted and significant set of policy actions for policy makers to consider while crafting policy measures for various segments of dairy sector. These are presented below.

- Research based policy making and then effective implementation is dire need of time.
- The government should start treating dairy as an industry rather than a sector as only then optimal allocation of resources can be made along with attracting local and foreign investment.
- Not all the demands pertaining to different players of dairy sector can be made through single set of policy frame. To cater this, separate policy actions are needed for small, medium and large dairy farmers. Same should be followed for milk and meat animals as both needs different sets of policies to function.
- Farmers are the most important stakeholders in dairy sector. They must be consulted during policy devising.
- A government assisted program is needed to preserve local dairy breeds as most of the local breeds are mixed by crossing with other local species and foreign imported semen or breeds. This has reduced capacity of such breeds to sustain warming.
- Input price mechanism is needed to be introduced by the government as followed in cropping sector.
- Like cropping sector, dairy sector needs to be regularized first for optimal functioning of policy implementation.
- The cropping sector is under serious threat due to climate change and the fodder crops are facing the same. Farmers need to upgraded through technology transfer and training for hay and silage making for enduring fodder security.
- Grazing lands are also under pressure for sustainability under climate change scenario. Free and open grazing is further challenging the grazing lands and this needs effective policy and management in this regard.
- The extension department as well as agricultural universities should be involved in farmers training programs to cope themselves and their dairy animals in changing climate. The talent of research students can be used in disseminating outcomes of research through farmer's days in organized at district or if possible at *tehsil* level.
- Farm insurance needs to be included in policy devising to attract investment in dairy sector and also giving boost and confidence to small farmers to expand their farm thus play their role in economic uplifting of the country.

Author's Contribution

Muhammad Abdul Rahman: Main author.
Abdul Saboor: Conceived the idea and supervision.
Gulnaz Hameed: Refining the research methodology and techniques.
Ghulam Bilal: Subject related supervision in the field of dairy sciences.
Farooq Tanwir: Technical supervision during finalization of this paper.

References

Ahmad, T. 2018. Key informant interview with author.

Asayehegn, K., A. Iglesias, B. Triomphe, P. Pedelahore and L. Temple. 2017. The role of systems of innovation in adapting to climate change: The case of the Kenyan coffee and dairy sectors. J. Innov. Econ. Manage. 2017/3 (No 24). https://doi.org/10.3917/jie.pr1.0015

Bernabucci, U. 2019. Climate change: impact on livestock and how can we adapt. Anim. Front. 9(1): 3-5. https://doi.org/10.1093/af/vfy039

Cassell, B. and J. McAllister. 2009. Dairy crossbreeding research: Results from current projects. Va. Cooperat. Ext. Publ. 404-094. (http://www.creativegeneticsofca.com/procross.htm).

Chari, F. and B. S. Ngcamu. 2017. An assessment of the impact of disaster risks on dairy supply chain performance in Zimbabwe. Cogent Eng. 4: 1-14. https://doi.org/10.1080/23311916.2017.1409389

Chen, J.M., K.E. Schütz, and C.B. Tucker. 2013. Dairy cows use and prefer feed bunks fitted with sprinklers. J. Dairy Sci. 96: 5035–5045. https://doi.org/10.3168/jds.2012-6282

Das, R., L. Sailo, N. Verma, P. Bharti, J. Saikia, Imtiwati and R. Kumar. 2016. Impact of heat stress on health and performance of dairy animals: Rev. Vet. World. 9(3): 260–268. https://doi.org/10.14202/vetworld.2016.260-268

Davison, K. 2013. Effects of a commercial feed additive on production losses during acute heat stress conditions in mid-lactation Holstein dairy cows. Master Thesis. Fac. Graduate Sch. Univ. Missouri.

Downing, M.M.R., A.P. Nejadhashemi, T. Harrigan and S.A. Woznicki. 2017. Climate change and livestock: Impacts, adaptation, and mitigation. Clim. Risk Manage. 16: 145-163. https://doi.org/10.1016/j.crm.2017.02.001

Escarcha, J.F., J.A. Lassa and K.K. Zander. 2019. Livestock under climate change: Sys. Rev. Impacts Adapt. Clim. 6(54): 1-17. https://doi.org/10.3390/cli6030054

FAO. 2016. Food Outlook. (www.fao.org).

FAO. 2019. Use of expert judgment. (http://www.fao.org/3/T4240E/T4240E14.htm).

Farooq, U. 2018. Key informant interview with author.

Farooq, U. 2016. Milk supplies in Pakistan: Issues and challenges facing the dairy economy. conference paper: milk supplies in Pakistan: Quantity, quality and legal framework, at enter of policy studies, COMSATS Inst. Inf. Tech. (CIIT), Islamabad.

Garner, J.B., M.L. Douglas, S.R.O Williams, W.J. Wales, L.C. Marett, T.T.T. Nguyen, C.M. Reich and B.J. Hayes. 2016. Genomic selection improves heat tolerance in dairy cattle. Sci. Rep. 6: 34114. https://doi.org/10.1038/srep34114

Gauly, M., H. Bollwein, G. Breves, K. Brugemann, S. Danicke, G. Das, J. Demeler, H. Hansen, J. Isselstein, S. Konig, M. Loholter, M. Martin-sohn and C. Wrenzycki. 2013. Future consequences and challenges for dairy cow production systems arising from climate change in central Europe. Rev. Anim. 7: 843-859. https://doi.org/10.1017/S1751731112002352

GoP. 2019. Economic survey. Ministry of finance, GoP, Islamabad Pakistan.

Hammami, H., J. Bormann, N.M. Hamdi, H.H. Montaldo and N. Gengler. 2013. Evaluation of heat stress effects on production traits and somatic cell score of Holsteins in a temperate environment. J. Dairy Sci. 96: 1844-1855. https://doi.org/10.3168/jds.2012-5947

Hanna, M., K. Janne, V. Perttu and K. Helena. 2018. Gaps in the capacity of modern forage crops to adapt to the changing climate in northern Europe. Mitig., Adapt. Strateg. Glob. Change. 23: 81-100. https://doi.org/10.1007/s11027-016-9729-5

Hansen, P.J. 2009. Effects of heat stress on mammalian reproduction. Philos. Trans. R. Soc. Lond. B Biol. Soc. 364: 3341-3350. https://doi.org/10.1098/rstb.2009.0131

Haq, Z. and M. Ishaq. 2011. Economic growth and agric. food import performance of emerging economies and Next-11. Afr. J. Bus. Manage. 5: 10338–10344.

Harvey, F. 2016. 2016 locked into being hottest year on record, NASA says. The Guardian. (https://

www.theguardian.com/environment/2016/oct/18/2016-locked-into-being-hottest-year-on-record-nasa-says).

Hashmi, A. 2018. Key informant interview with author.

Hatfield, J.L., A.A. Gitelson, J.S. Schepers and C.L. Walkhall. 2008. Application of spectral remote sensing for agronomic decisions. Pap. Nat. Res. 257. https://doi.org/10.2134/agronj2006.0370c

Hill, D.L. and E. Wall. 2015. Dairy cattle in a temperate climate: the effects of weather on milk yield and composition depend on management. Animal. 9(1): 138-149. https://doi.org/10.1017/S1751731114002456

Höglind, M., S.M. Thorsen and M.A. Semenov. 2013. Assessing uncertainties in impact of climate change on grass production in Northern Europe using ensembles of global climate models. Agric. For. Meteorol. 170: 103-113. https://doi.org/10.1016/j.agrformet.2012.02.010

Hussain, R. 2018. Key informant interview with author.

IPCC. 2007. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate. Cambridge Univ. Press Cambridge, U.K.

Jabbar, A. 2019. Key informant interview with author.

Johnson, K. 2019. Are India and Pakistan on the verge of a water war? Foreign policy. (https://foreignpolicy.com/2019/02/25/are-india-and-pakistan-on-the-verge-of-a-water-war-pulwama-kasmir-ravi-indus/).

Kataktalware, M.A., S. Nazar, G.L. Devi and K.P. Ramesha. 2016. Adaptation and mitigation strategies for sustainable dairy production under changing climate scenario. S. Nautiyal, R. Schaldach, R. Raju, H. Kaechele, B. Pritchard and K. Rao (eds.). Climate Change Challenge (3C) and social-economic-ecological interface-building. Environ. Sci. Eng. Sprin. Cham. https://doi.org/10.1007/978-3-319-31014-5_31

Khan, A.F. 2018. Reviving dairy sector. Dawn. (https://www.dawn.com/news/1400370).

Khan, M.J., A. Abbas, M. Naeem, M.M. Ayaz and S. Akhtar. 2013. current issues and future prospects of dairy sector in Pakistan. Sci. Tech. Dev. 32(2): 126-139.

Khaqan, S.H., Z. Mustafa, A. Mukhtiar and G.A. Siyal. 2016. Ricardian analysis on climate change and its impact on livestock husbandry in tehsil Faisalabad, Pakistan. Int. J. Livestock Res. 6(2): 10-19. https://doi.org/10.5455/ijlr.20160209014031

Khurshid, R.A. 2018. Key informant interview with author.

Lacetera, N. 2019. Impact of climate change on animal health and welfare. Anim. Front. 9(1): 26-31. https://doi.org/10.1093/af/vfy030

Mauger, G., Y. Bauman, T. Nennich and E. Salathé. 2015. Impacts of climate change on milk production in the United States. Prof. Geographer. 67(1): 121-131. https://doi.org/10.1080/00330124.2014.921017

McKenzie, R. 2017. Get your farm ready for global warming. Grainews. (https://www.grainews.ca/2017/02/10/adapting-your-prairie-farm-to-changing-climate-conditions/).

Memon, N.A. 2017. Pakistan has strong infrastructure of dairy sector. (http://www.foodjournal.pk/2017/March-April-2017/PDF-March-April-2017/Dr-Noor-Exclusive-on-Milk.pdf).

Naheed, S., I. Raza, T. Hassan, M.Z. Anwar and A. Fatima. 2015. Impact of climate change on livestock composition in Pothwar region, Pakistan. Sci. Tech. Dev. 34(4): 270-273. https://doi.org/10.3923/std.2015.270.273

Nardone, A., B. Ronchi, N. Lacetera, M.S. Ranieri and U. Bernabucci. 2010. Effects of climate changes on animal production and sustainability of livestock systems. Livestock Sci. 130: 57-69. https://doi.org/10.1016/j.livsci.2010.02.011

PMD. 2009. Impact of climate change over Pakistan. Islamabad, Pakistan: Alam, M.T.

Pakistan Today. 2017. January 16. Pakistan fourth largest milk producing country in world. Pakistan Today. (https://www.pakistantoday.com.pk/2017/01/16/pakistan-fourth-largest-milk-producing-country-in-world/).

Parameswaranaik, J., A.P. Verma and M.N. Sawant. 2017. Adaptation strategies of dairy farmers to combat climate variability in Karnataka State, India. Int. J. Curr. Microbiol. Appl. Sci. 6(11): 3091-3094. https://doi.org/10.20546/ijcmas.2017.611.362

PMI. 2013. A guide to the project management body of knowledge. PMBOK Guide, 5th Edition.

Qian, G., X. Guo, J.J. Guo and J.G. Wu. 2011. China's dairy crisis: impacts, causes and policy implications for a sustainable dairy industry. Int. J. Sustain. Dev. World Ecol. 18: 434–441.

https://doi.org/10.1080/13504509.2011.581710

Rauw, W.M. and L.G. Raya. 2015. Genotype by environment interaction and breeding for robustness in livestock. Front. Genet. 6: 310. https://doi.org/10.3389/fgene.2015.00310

Rhoads, M.L., R.P. Rhoads, M.J. VanBaale, R.J. Collier, S.R. Sanders, W.J. Weber, B.A. Crooker and L.H. Baumgard. 2009. Effects of heat stress and plane of nutrition on lactating Holstein cows: I. Production, metabolism, and aspects of circulating somatotropin. J. Dairy Sci. 92(5): 1986-97. https://doi.org/10.3168/jds.2008-1641

Rhoads, R.P., L.H. Baumgard, J.K. Suagee and S.R. Sanders. 2013. Nutritional interventions to alleviate the negative consequences of heat stress. Adv. Nutr. 4(3): 267-276. https://doi.org/10.3945/an.112.003376

Rowlinson, P. 2008. Adapting livestock production systems to climate change, temperate zones. In P. Rowlinson, M. Steel, A. Nefzaoui (eds.). Proc. Livestock Glob. Clim. Change Conf. Cambridge Univ. Press, Tunisia, pp. 61-63.

Sadiq, N. 2019. Key informant interview with author.

Science Daily. 2019. Seaweed feed additive cuts livestock methane but poses questions. Science Daily. (https://www.sciencedaily.com/releases/2019/06/190617164642.htm).

Seerapu, S.R., A.R. Kancharana, V.S. Chappidi, and E.R. Bandi. 2015. Effect of microclimate alteration on milk production and composition in Murrah buffaloes. Vet. World. 8: 1444-1452. https://doi.org/10.14202/vetworld.2015.1444-1452

Shahid, M.Q., M. Abdullah, J.A. Bhatti, K. Javed, M.E. Babar, M.A. Jabbar and I.A. Zahid. 2012. Machine milking performance of Nili Ravi buffaloes on different pre-milking stimulation practices. J. Anim. Plant Sci. 3(3): 284-287.

Siddiky, M.N.A. 2017. Dairying in south Asian region: Opportunities, challenges and way forward. SAARC J. Agric. 15(1): 173-187. https://doi.org/10.3329/sja.v15i1.33164

Siddiky, M.N.A. 2015. SAARC dairy outlook. SAARC Agric. Centre, Dhaka, Bangladesh.

Silanikove, N., G. Leitner, U. Merin, and C.G. Prosser. 2010. Recent advancesin exploiting goat's milk: quality, safety and production aspects. Small Rumin. Res. 89: 110–124. https://doi.org/10.1016/j.smallrumres.2009.12.033

Silanikovea, N. and N. Koluman. 2015. Impact of climate change on the dairy industry in temperate zones: Predications on the overall negative impact and on the positive role of dairy goats in adaptation to earth warming. Small Ruminant Res. 123: 27-34. https://doi.org/10.1016/j.smallrumres.2014.11.005

Slater, J. 2019. India wants to use water as a weapon against Pakistan. A 59-year-old treaty stands in the way. The Washington Post. (https://www.washingtonpost.com/world/2019/02/22/indias-threats-pakistan-offer-hint-future-water-wars/?noredirect=onandutm_term=.751ceecd49ac).

Soussana, J.F., A.I. Graux and F.N. Tubiello. 2010. Improving the use of modeling for projections of climate change impacts on crops and pastures. J. Exp. Bot. 61: 2217-2228. https://doi.org/10.1093/jxb/erq100

Spiegel, M.V.D., H.J. van der Fels-Klerx and H.J.P. Marvin. 2012. Effects of climate change on food safety hazards in the dairy production chain. Food Res. Int. 46: 201-208. https://doi.org/10.1016/j.foodres.2011.12.011

St-Pierre, N.R., B. Cobanov and G. Schnitkey. 2003. Economic losses from heat stress by US livestock industries. J. Dairy Sci. 86: 52-77. https://doi.org/10.3168/jds.S0022-0302(03)74040-5

Suleri, A.Q. 2018. Key informant interview with author.

Tariq, I. 2018. Key informant interview with author.

Thornton, P.K., J. van de Steeg, A. Notenbaert and M. Herrero. 2009. The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. Agric. Sys. 101: 113-127. https://doi.org/10.1016/j.agsy.2009.05.002

Tubiello, F.N., J.F. Soussana and S.M. Howden. 2007. Crop and pasture response to climate change. Proc. Nat. Acad. Sci. USA. 104: 19686-19690. https://doi.org/10.1073/pnas.0701728104

Upadhyay, R.C. 2010. Annual milk production loss due to global warming. Animal physiology. Nat. Dairy Res. Inst. (NDRI), Press Trust India, New Delhi, India.

Upadhyay, R.C. and S.S.V. Ashutosh. 2009. Impact of climate change on reproductive functions of cattle and buffalo. In P.K. Aggarwal (ed.). Glob. Clim. Change India. Agric. Indian Counc. Agric. Res. New Delhi. pp. 107-110.

West, J.W. 2003. Effects of heat-stress on production in dairy cattle. J. Dairy Sci. 86:

2131–2144. https://doi.org/10.3168/jds.S0022-0302(03)73803-X

White, N., R.W. Sutherst, N. Hall and P.W. Wilson. 2003. The vulnerability of the Australian beef industry to impacts of the cattle tick (Boophilus microplus) under climate change. Climatic Change. 61(1-2): 157-190. https://doi.org/10.1023/A:1026354712890

Wynn, P., D. Harris, R. Moss, B. Clem, R. Sutton and P. Doyle. 2006. Report on dairy mission to Pakistan. Aust. Center Int. Agric. Res. Aust.

Zia, S. 2018. Key informant interview with author.