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Strategies to Improve Livestock Genetic Resources to Counter Climate Change Impact

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Abstract

Global diversity of livestock in the form of many different species and breeds in a variety of production environments is indicative of the fact that it has developed over time in sync with the ecosystem. The developing world is particularly enriched with livestock breed portfolio. Natural selection has mainly acted on fitness including adaptability and reproductive success, whereas selection practised by livestock keepers and animal breeders has been need based. As against highly structured breeding programmes and intensive selection in developed world, livestock of developing world have largely been subjected to differential selection pressures in the form of their ability to survive in harsh production environments and challenged inputs. The last few decades have witnessed large-scale erosion of livestock genetic diversity. Climate change (CC) through its direct and indirect effects including its mitigation measures is believed to have influenced the erosion. Faster loss of animal genetic diversity poses greatest threat to the sustainability of the sector. The presence of varied livestock species and their breeds with widely variable performances offers the opportunity for genetic improvement. In the absence of it, we risk progress in this sector. Reorientation of livestock breeding is required to address the issues of CC. Although resource-use efficiency is imperative, careful trade-off between livestock production, productivity and

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adaptability will be required. Breeding strategies for livestock genetic resources to counter CC impact will not be fundamentally different in the future. Natural stratification of species and breeds of livestock shall be an important guide in the design. Appropriate policy framework, large-scale cooperation in knowledge and resources and awareness will be crucial.

Keywords

Adaptability • AnGR • Breeding strategy • Conservation • Genetic improvement • Production system • Sustainability

Animal agriculture continues to remain as one of the most important sources for income generation and tool for nutritional security, livelihood and poverty alleviation in developing and least developed countries. Growth trend of industrial and organised mode of animal production in developed countries also confirms its ever-increasing and important role in food security. The livestock sector as a whole is dynamic and has grown over the period facing newer challenges, developing suitable strategies to curtail and circumvent it. Key ingredient in facing the challenges with resilience has been the flexibility of operation and diversity of production and production system. The swiftness of the production system to adjust has been the cornerstone that has been possible because of the many factors, one of the key of which is the diversity of gene pool in the form of many different livestock species and breeds of a species including crossbred and synthetic population. The dynamic livestock sector embraces for a relatively newer challenge – climate change (CC). Not only the livestock species but also its production system has evolved over hundreds of years facing climatic and weather variables and extremes. It may not be illogical to think that the sector will match the demands of CC through structural and functional change including its organic function. The key question that remains to be answered is the preparedness in the face of CC so that livestock production and productivity are not grossly affected. What is largely unexplored because of absence of authentic data and sufficient experimentation is whether the variable and veritable gene pool will continue to deliver the same goods and services with incremental growth without major change in case CC outpaces the inherent and serial adaptability of the livestock production and production system.

The pillar of the livestock improvement to meet the burgeoning needs of humankinds has been the improvement of genetics. The genetic improvement of livestock has been a function of natural selection and human intervention. Whereas fitness and adaptability have shaped the course of natural selection, livestock keepers and animal breeders have brought improvement through application of their wisdom, science and technologies. Although rate of genetic gain is slow and steady, it is relatively permanent and thus indispensable. The predominant motive in artificial selection has been need based; however, societal as well as ecological values of livestock might not have been overlooked while practising selection by their keepers. Key ingredient for selection to be effective and useful is variation in the population. The diversity and variability in the phenotype and genotype of livestock offers the opportunity for genetic improvement. The last few decades have witnessed unparallel loss of livestock genetic diversity for varied reasons. CC through its direct and indirect effects is supposed to have accelerated the erosion. Faster loss of animal genetic diversity poses greatest threat to the sustainability of animal agriculture directly and thereby to nutritional security and livelihood of its keepers along with high impact on the ecosystem.

In the following section, attributes of livestock genetic resources in interaction with climate and CC, analysis of practised breeding strategies and resultant priority of livestock genetic improvement issues with respect to climate resilience are discussed.

25.1 Interplay of Animal Genetic Resources (AnGR) and Climate (Change)

The diversity of livestock species and its many different breeds including the ones developed by its rearers and breeders is sufficiently indicative of the interplay of animal genetic resources (AnGR) with climate. Natural distribution pattern of livestock species and breeds has been a function of the ecosystem. Climate being an integral part of the ecosystem influencing production and reproduction, nutrient availability and disease pattern, the diversity of livestock species was ensured. Thus, the course of evolution has been in no stage insulated from the interaction with climate and its variables. Thirty-three mammalian and avian livestock species are described by Food and Agriculture Organization's (FAO) Domestic Animal Diversity Information System (DAD-IS). When we look at a particular livestock species, another discernible feature is the natural stratification of livestock breeds by climatic zones suiting to the macro-environment and based on production system and practice. FAO's global assessment of livestock breed diversity puts the figure to 7,040 local breeds and 1,051 transboundary breeds (FAO 2009). Developing countries host about two-thirds of breed portfolio. Further variability is explained by the selective expression of gene(s) depending on the climate and weather variables.

Livestock species has equally undergone the course of natural evolution determined by the fitness acting on selective reproductive success. Since the onset of domestication, humankind has used it to suit their diverse needs. Although the predominant motive has been the improvement in production and productivity, nontangible factors like sociocultural and environmental service have also importantly influenced livestock species and breed biodiversity portfolio. In the process, livestock has acquired necessary physical and physiological changes. When looked to the cellular level, it has resulted in differential display of genes, their action and interaction. In many cases, it has resulted in signature conformation with novel gene mutations.

25.1.1 Significance of Climate Change for the Management of AnGR

Livestock breeds have been conscientiously developed along with the climatic variables naturally. Whenever farming needs have defined the breeding objective, a healthy balance of production and productivity, feed efficiency, general vigour, disease tolerance and longevity has got predominance on macro-scale. Thus, both natural and artificial selection have largely been in sync with climate and production system so that it can produce goods and offer services and at the same time withstand climatic stress. For industrial or landless production system, other traits except production and productivity have not received due attention because of easy access to inputs. There are notable exceptions like the beef industry which has imbibed functional traits serially.

It is now well understood that the diversity of livestock species and breed portfolio offers the opportunity for facing challenges more effectively and helps in risk mitigation. In this connection, it is worthwhile to note that maximum livestock diversity is observed in developing and least developed countries with a variety of production systems like smallholder, mixed crop-livestock and pastoral offering diverse production, sociocultural and environmental services. In developed world, the portfolio has become limited suiting to industrial needs of milk, meat, egg and fibre. Thus, whereas local breeds along with traditional breeding system dominate developing and poor countries, limited transboundary breeds with global reach developed through scientific well-structured breeding programmes are mostly seen in developed countries. Traditional production system is largely not protected for environmental variables and open grazing is popular in contrast to large-scale intensive production system which is mostly protected against environmental variables through shelter and control of microenvironments. Heterogeneous plant communities with widely variable nutritive values, crop residues, pasture feeding and low-quality forage characterise the feed type available to livestock in majority of the developing and poor countries as against concentrate, cereal, easily digestible fodder and good pasture in developed world which is largely not influenced by seasonal variability. When it comes to disease and parasitic challenges, tropical world is more unfavourable to its livestock as compared to temperate world.

The direct challenges posed by climatic variables like high temperature, humidity and restricted access to potable water and the indirect challenges such as low-quality feed and fodder, increased diseases and mortality have resulted in the development of livestock breeds which are well adapted in tropical world. Most of them can thrive well and produce a wide variety of goods and services. The range of goods include milk, meat, egg, wool and fibre, skin and hides, draught power and transport, manure for soil fertility and bio-fuel. The definition of the broad-based role of tropical and traditional livestock production system also includes a range of sociocultural services like insurance and asset function during emergencies, religious role, heritage, alternative system of medicinal use, sports and recreation, social status of owner and a host of environmental services like efficient use of crop by-products and residues, weed and shrub control, dispersal of seeds and constituent of cultural landscapes.

However, when enumerating the role and contribution of livestock by commonly agreed and easily comparable economic terms, it is by and large restricted to traded products only like milk, meat and egg. This has resulted in considerable undervaluation of it as a humankind asset function. Even in the absence of complete capture of the true value of the product and services offered by livestock resources, it is accepted beyond doubt that the genetic diversity of AnGR is vital for adapting production systems to future changes.

The relevance of maintaining diversity in AnGR for the present and the future remains with the fact that animals must be genetically well matched to production environments in which they are (to be) kept and able to meet the demands for products and services. Altered scenario under CC may require adjustment of breeding objectives and/or adaptation of husbandry practices, but genetic diversity always remains as a prerequisite for adapting production systems to future changes.

It may be appreciated that the projected challenges associated with CC like thermal stress, poor nutrition and increased disease risk will not be fundamentally different than what the livestock faces today specially for the tropical world. It becomes a major concern for the conditions that changes outpace the adaptability and/or the future portfolio of genetic diversity no longer offers the option to adapt because of being already lost.

Livestock rearing being one of the oldest professions of humankind gave rise to diverse production environment and systems. For all reasons, livestock husbandry has matched the expectation of nutritional security and livelihoods. However, ever-increasing demand for animal products with human population explosion led to unparallel demand leading to the so-called livestock revolution. The sector being dynamic has kept the pace, and CC for all purpose may add another layer of influence. Livestock revolution saw globalisation of livestock production led by the industrialised system of production in developed world. More than 90 % of genetic material exports originate from developed countries, and share of trade from developed to developing countries increased from 20 to 30 % between 1995 and 2005 (Gollin et al. 2008). The industrial system of livestock production produces 55, 68 and 74 % of global pork, eggs and poultry meat production, respectively, utilising internationally sourced animal genetics and feed and large-scale use of sophisticated technologies (FAO 2003; Steinfeld et al.

2006). Most of the developing and poor countries in the pursuit of purchasing genetic progress as short-cut instead of developing suitable animal germplasm using native genetic resources of their own has imported genetic materials of high producing ability which has otherwise been developed for production environments of developed world based on high-inputs. This led to the spread of elite and restricted genetic base to the world over, the so-called international transboundary breeds.

As compared to industrial livestock production, majority of the developing and poor countries basically harbours smallholder production along with pastoral system of livestock rearing with a host of native livestock breeds known for their resilience. These native breeds have always been a cultural entity rather than a defined class of homogenous population. The so-called livestock-based development programmes in developing and poor countries based on import of genetic progress led to severe erosion of their own livestock diversity. Although developing countries host about two-thirds of breed portfolio, about 9 % of reported breeds are extinct and 20 % are currently classified as being at risk globally. The risk status of 36 % of breeds is unknown (FAO 2009). About 31 % of cattle breeds, 35 % of pig, 38 % of chicken and 33 % of horse breeds are currently at risk or already extinct (FAO 2009).

Although short- and medium-term gain of importer countries can never be denied, its long-term effect has already shown vulnerability whereby the improved livestock struggles to retain its superiority with relatively poor inputs and services in different production environments.

The growing dichotomy between large-scale intensive livestock production and smallholder mixed crop-livestock or pastoral system of livestock production further adds uncertainty and vulnerability to future changes. These may warrant redefining the role and value of AnGR in broadest possible term including its sociocultural and environmental value. Most native livestock breeds of developing and poor countries produce at low to medium level with challenge inputs – poor feed, fodder and pasture, high disease incidences and worm load and higher mortality. However, sufficient within-breed variation exists, allowing exploit of additive genetic variation through selective breeding.

More perplexing is the fact that livestock production both contributes to and is affected by CC. Eighteen per cent of global GHG emissions are attributed to livestock via land use and land-use change which includes grazing, feed crop production, manure management and enteric fermentation (FAO 2006a, 2010a).

Although it is widely understood that CC will affect the product and services rendered by diverse livestock species and breeds, regrettably it is yet to be integrated to the adaptation and mitigation strategies of CC. One of the biggest challenges in quantifying the role of CC on livestock is the absence of quality data and appropriate model. Although adaptation traits are widely covered, in many a case, they are restricted to anecdotal evidences and detailed data of it along with thermo-neutral zone (TNZ) is not available. Again, because of globalisation of animal genetics, mainly by international transboundary breeds, the geographical distribution of the breed(s) is overlaid by diverse production systems. Further, they often have similar environmental envelopes since several species have been domesticated in the same region. Another bigger void is that many stakeholders do not consider CC as a possible threat to the long-term sustained use of livestock biodiversity and the product and services thereof.

25.1.2 Challenges Associated with Climate Change to AnGR

As discussed earlier, selection in general has largely been in sync with climate and production system so that it continues to produce goods and services in the presence of predictable stresses with time horizon of its development. However, many a different factors influence it. There is a wide variation in adaptability of different livestock species and breeds to stressors. Most native animals of tropical countries have remarkable ability to adapt to environmental stressors. However, fast dilution of native germplasm, large-scale transboundary movement of narrow pool of *superior* animal genetics ignoring genotype and environment interaction (GEI), and absence of sharing of knowledge are widening the vulnerability of AnGR. The range, scale and possible magnitude of the influence of stressors are continuously updated, and the present paradigm of knowledge may not be in the advanced stage of understanding their impact. In the following section, challenges posed by most possible stressors are discussed.

25.1.2.1 Direct Effect

Direct effect of CC that is likely to affect livestock diversity and the product and services offered by the livestock significantly in long-term horizon is heat stress. Temperature is predicted to increase globally in certainty with reduction in precipitation in many parts of the world, more so for the already arid regions (IPCC 2007). It will result in increased heat stress to livestock. Heat stress continuously challenges the homeostasis of livestock, and appetite and FI become the first casualty. When lifetime production of animal is considered, it is significantly affected because of reduction in fertility and increased mortality. Milk production, fertility and longevity in Holstein-Friesian cattle are reported to decline as temperature increases (West 2003). A modelling exercise for the Great Plains region of the United States indicated substantial declines in beef, dairy and pig productivity in parts of the study area (Mader et al. 2009). For most of the species, body temperature beyond 45–47 °C is considered to be lethal. Effect of heat stress on animal production and productivity will be variable based on climatic region, production system and speciation distribution. Livestock of arid region are supposed to be affected by highest degree. Monogastric species being less thermotolerant than ruminants will suffer more in areas with increased thermal stress.

Response of animals to any stress including thermal is a function of fitness and adaptation. Wide variability in adaptation of livestock to thermal stress is observed which is governed by morphological and physiological features. Morphological characteristics of the skin, viz. colour, thickness, concentration of sweat glands and hair coat, number of hairs per unit area, length and diameter of the hair, angle of the hair to the skin surface and degree of pigmentation, vary between temperate and tropical livestock. Physiological features like respiration rate, endocrinological profile and metabolic heat production in interplay with morphological features determine the response to heat stress. However, the underlying principle covering complex interaction of physiological, genetic and behavioural factors for combating heat stress is yet to be understood clearly (McManus et al. 2008).

Tropical livestock in general withstand thermal stress better than their temperate counterparts like zebu cattle (FAO 2006b). There are some other species which are uniquely distributed like camelids in arid areas and yaks in harsh high altitudes. CC will be a greater threat to the geographically isolated or restricted livestock species and breeds through extreme weather events (EWE) like flood, drought and hurricanes. This particular area is so less documented although heavy mortality and extreme stress are quite common with disasters. Temperate livestock of developed world that are dominant in industrialised mode of production are insulated from the climatic variables and are generally not well adapted. At the same time, their metabolic heat production is higher. Livestock of developing and least developed countries which has been imported from developed world will face increased threat of heat stress because of ignoring GEI and production environments.

The first and most convenient way of combating heat stress, i.e. shelter management, will be imperative. Other sophisticated measures as used in industrialised system of production will not be feasible in small-scale and traditional production resulting in increased heat stress. Temperate livestock may continue to enjoy the benefits of manipulations of micro-environments till the time associated inputs for maintaining it become limited and uneconomic because of CC.

Although adaptation traits in general have low heritability, they will become more relevant in

CC scenario. In homogenised and stable production environments, they may not show any appreciable genetic gain indicating towards selection limit (Hill and Zhang 2009). But with change in production environments associated with CC, they are likely to be responsive because of change in existing fitness profile and increase of heterozygosity.

25.1.2.2 Indirect Effect

Direct effect of CC on livestock interacts with the other induced changes in the agroecosystem like altered feed and nutrient availability as well as disease epidemiology. Intervention to counteract CC and policy measures are also likely to influence the livestock diversity and its produce. For many parts of the world, indirect effects of CC may influence the livestock production more pronouncedly than through direct effect.

25.1.2.2.1 Feed and Nutrition

CC has every potential to affect the availability of livestock feed in a host of ways and may pose major challenges for the livestock sector as a whole as well as specific production systems. These in turn will affect AnGR. It is well known that climate directly affects the quality and quantity of the forages. Higher temperatures increase lignifications and decrease the digestibility. It is likely that CC will induce a shift from C3 to C4 grasses (Morgan et al. 2007). Further, it may increase shrub coverage in some grasslands (Christensen et al. 2004). Plant species have differential capacities to spread in response to CC. Just like livestock breeds, plant species that flourish in limited environments are more likely to be affected by climate-related agroecosystem changes than generalist species that can survive in a variety of different environments (Foden et al. 2008). By taking advantage of it, generalist or colonising species will expand their ranges leading to increased range being invaded by otherwise uncommon weeds, pests, pathogens or disease vectors.

In fact, the increases in temperature in temperate areas may benefit early season plant growth and thereby productive forage species may get an upper hand. It may be conducive for keeping high-performance livestock breeds that require good nutrition. Contrary to this, already semiarid areas are likely to experience lower rainfall. Wide variability in rainfall pattern along with frequent droughts may further accentuate the problem of shorter growing period that is likely to happen in many parts of the tropics (IPCC 2007; Thornton and Herrero 2008). This will lengthen the duration of nutritional stress. Animals may have to walk longer distances in search of feed and cope with less availability of potable water. This in turn will result in overgrazing in relatively less affected areas and newer disease and parasites challenges. The areas where winter will be more severe will limit the grazing of animals because of ice and snow cover like the *dzud* disasters that occur from time to time in Mongolia (Pilling and Hoffmann 2011).

Industrial livestock production system is largely characterised by globally sourced economic feed inputs. Escalation of cost of inputs like grain (Rowlinson 2008) which may or may not be because of CC will pose a serious challenge and may force shift in production portfolio as has been witnessed in Southeast Asian countries such as Indonesia (Sudaryanto et al. 2001). This may force increased focus on exploitation of locally available feed resources (Holechek 2009) and better nutrient utilisation.

Large differences in response to nutritional stress are observed among different livestock species and breeds. For example, camels do not show much susceptibility to heat stress-induced nutritional challenges unlike other species. On the other hand, *Bos indicus* perform relatively better with low-quality forages although feed conversion efficiency is higher in *Bos taurus* with good-quality feeds. Small ruminants perform better with low-quality feed and forages when compared across species. Even species and breed differences exist with diet selection which may be a function of their metabolic profile (Blench 1999). The degree of influence of nutritional stress on production and reproduction and underfeeding induced mobilisation of body reserves vary among species and breeds and may have a genetic basis (Hall 2004). However, anecdotal evidences dominate over scientific revelation with respect to differential response to nutritional stress.

25.1.2.2.2 Diseases and Parasites

Many infectious diseases especially that are vector-borne are significantly influenced by climate. The disease-causing pathogens, vectors and hosts and their interaction are directly as well as indirectly affected by climate. Thus, CC is likely to affect spatial and temporal distribution of diseases including influence on their intensity. Incidences and distribution of many vector-borne diseases including bluetongue, dengue, leishmaniasis and trypanosomiasis have significantly changed during the recent past (de La Rocque et al. 2008). However, sufficient reasons do not exist to ascribe their rise to CC. The dynamic interaction of climate with constituents of diseases may see geographical expansion of vector-borne infectious diseases like bluetongue and Rift Valley fever to those places where it is less likely to occur otherwise. It indeed may influence the transmission and course of diseases (Rogers and Randolph 2006).

However, simply expansion of a range of a disease-causing pathogens or vectors does not necessarily result in disease transmission to a larger scale (de La Rocque et al. 2008). In fact, larger population movement and increased trade may have contributed more to the atypical spread and intensity of diseases than direct effect of CC which might have helped disease cross their classical barriers such as deserts and oceans.

Seasonal influences on disease incidences may be more pronounced in the future. Specific short-term weather events and seasonal rainfall are known to trigger outbreaks of many diseases like African horse sickness, anthrax, bluetongue, peste des petits ruminants and Rift Valley fever (Van den Bossch and Coetzer 2008). It may be of considerable significance since the frequency of EWE such as floods and droughts is expected to rise with CC (IPCC 2007).

Although the diversity of AnGR plays a pivotal role in adapting production system to the changes including climate-induced, it in turn is vulnerable to these changes. The threat may operate in two ways: disease epidemics may cause death of a large number of animals and control measure including the much-used culling of animals may cause severe depletion of livestock strength in affected areas. The effect is more pronounced when a breed or species is geographically isolated or has limited distribution. The loss of livestock in large scale because of culling as a means of control measure has been due to diseases like African swine fever, avian influenza, classical swine fever, contagious bovine pleuropneumonia and foot-and-mouth disease in recent times. The majority of the livestock death for the referred diseases has been due to culling and not because of disease epidemics. It may be noted that these diseases are not largely known to be influenced by CCs. However, it may be so that CCs may have influenced the disease epidemics through indirect means by their influence on management system and general immune status. To cite an example of the threat that culling measures cause to the diversity, a sizeable portion of poultry genetic resources has been lost in Tripura state of India because of mass culling to combat avian influenza.

Irrespective of the control measures, CC and seasonally influenced increased incidences and range of diseases will see preference for livestock species and breeds that are disease resistant or tolerant. Many livestock breeds, mainly from developing countries, are reported to be resistant or tolerant to trypanosomiasis, tick burden, tick-borne diseases, internal parasites, dermatophilosis or foot rot (59 cattle, 33 sheep, 6 goat, 5 horse and 4 buffalo breeds) (FAO 2007a). However, underlying physiological and genetic mechanisms including causal mutations associated with differential response to diseases for the above-referred livestock breeds are yet to be deciphered in most cases and thus considered to be largely anecdotal.

25.1.2.2.3 Deviation from Normal Species and Breed Stratification

Natural stratification of species and breeds exists ensuring environmental and production niche. Generally, local breeds adapt well, and thus, species and breed substitution becomes relevant only when changes in climate condition outpace the adaptability both naturally and through man-made measures. Species substitution by increased use of dromedaries because of climate and vegetation changes has already been witnessed in parts of Africa (Gouro et al. 2008). The same has happened at breed level also. However, movement of species and breeds because of CC may be considered both as a threat and opportunity. Herd portfolio comprising multiple species and breeds is a common strategy in traditional livestock farming for production as well as environmental niche and is considered to be more CC resilient. Along with it, popularity of small ruminant like sheep and goat is a measure of CC resilience in small farms of developing world (Seo and Mendelsohn 2007). However, globalisation of breeding programmes and purchase of genetic gain have affected resilience to varying degree in different parts of the world.

Impact of CC may be exacerbated by environmental degradation and CC adaptation may prove to be more costly. A classical case of it is explained by Zhang and Hong (2009) whereby local ruminant breeds are reported to be affected because of restriction imposed on grazing with the objective of reducing rangeland degradation in provinces of western China.

Many studies predict that farmers will switch from cattle and chicken to goat and sheep (Herrero et al. 2008; Seo and Mendelsohn 2008). Some other studies model that ruminants will increase in rangelands as long as there is sufficient vegetation growth (Seo and Mendelsohn 2008). It is predicted that livestock keeping will replace cropping in marginal mixed crop-livestock systems as they become ecologically and socially more marginal (Jones and Thornton 2009). By contrast, shift of livestock populations from rangeland-based grazing to mixed systems is predicted based on improved feeding of crop by-products by Herrero et al. (2008). Indian experience reveals that farmers who keep livestock along with agriculture farming are more successful in handling drought-induced distress.

The concept of climatic envelopes as applicable for wildlife is not so straightforward in livestock species because of very high human intervention. It is simply because of the fact that the breeds' capacity to survive is not simply a function of adaptation but also of management and socio-economic and cultural strength.

25.1.2.2.4 Impact of Climate Change Mitigation Measures on AnGR

Emission of greenhouse gasses (GHG) occurs throughout the production chain of livestock although enteric methane emission is primarily the focus. Discussion and efforts to curtail it include reduction in animal numbers, resource-use efficiency, increasing productivity and feed conversion efficiency, enrichment of feed and a host of technologies. Emission rate is highly variable and depends on the composition of animals and the nature of the production system. Monogastric animals such as pig and chicken have better feed conversion efficiency and produce less methane than ruminants. Within species, breeds and lines that have been continuously subjected to rigorous selection generally have better feed conversion ratio (FCR) with high production performance in input-intensive production system. Across the species, these superior animals dominate the global genetics. On the other hand, in traditional livestock rearing, the animals have mostly been subjected to different selection pressures with focus on their ability to survive in harsh production environments or low input. These adapted animals when judged through feed conversion efficiency may not be very efficient, but they provide a range of products and services many of which are not accounted for in economic terms while assessing their output and productivity. Thus, in the absence of a broad-based definition of the output, there is an increased tendency of branding them as polluter. However, if emission along the whole production chain is considered, carbon footprint of an input-intensive production system may be less impressive because of heavy reliance on fossil fuels and problems with the management of manure. Moreover, efficiency shall not only be measured in terms of converting feed inputs to human food but also of differences in the animal's ability to use feedstuff that cannot otherwise be used by humans. Thus, any regulatory framework with market-based core values may result in sidelining production systems that are deemed to be high emitters of GHGs resulting in the decline of associated AnGR diversity. Further, promoting animals that may not adapt well to stressful production environments may result in compromise in fertility and survivability which will render the system unsustainable.

As has been told, GHG emission depends on the production system. For example, GHG emission per unit of meat produced is less with intensive feedlot systems than extensive grazing systems when beef cattle production is considered. Intensive and mixed farming dairy production has lower emission than grassland-based systems as has been reported by Gerber and Vellinga (2009) who also reported on life-cycle assessment of global GHG emissions per kilogramme of fat- and protein-corrected milk (FPCM). While comparing milk and beef production, milk protein can be produced with less methane emission than beef (Williams et al. 2006). Thus, dairying might become the major focus of cattle production, and beef may become a by-product of dairying in an intermediate GHG reduction scenario (Hoffmann 2010). This may see prominence of dual-purpose breeds and crossbreeding (Flachowsky and Brade 2007).

Grazing system which is particularly popular in traditional livestock rearing possesses the highest contrasting feature. On one side, it results in high methane production because of low-quality forages consumed by the ruminants. On the other, it is the backbone of animal production in developing world which ensures livelihoods to large numbers of livestock keepers who are mainly resource poor. More interesting is the fact that grazing systems mainly involve the lands that are otherwise unsuitable for crop production. This means that animal products are derived without direct competition with crops for human consumption. The concept of ‘human edible return’ as suggested by Gill and Smith (2008) may be a better indicator for assessing livestock efficiency. This may also partly substantiate that livestock keeping provides an alternative to more damaging types of land use. However, increasing trend of restricting extensive grazing specially in dryland areas may pose severe threat to associated AnGR diversity. In the same vein, the suggestion of lowering stocking rate for promoting carbon sequestration does not match with popular and increasing trend of livestock grazing as a tool in wildlife and landscape management.

25.1.3 Climate Change and Production System

The influence of CCs on production system is exerted through its direct and indirect effects and explained in earlier sections. The change in the organic nature of the production system because of CC is discussed here. In the face of CCs, the livestock keepers have the option of either adapting their animals to the changed environments or changing the production environment without many changes in the animal genetic portfolio. Since livestock species and breeds that we see today have evolved over many generations assimilating environment and production challenges, breeding programme to maintain animal genetic portfolio so that it continues to render the same goods and services may not be fundamentally different from what we practise today. However, the process may not be smooth. It may witness shift of choice of the species and breeds either locally or regionally affecting the production system. Technologies available for the intensive animal production system may not be readily available and economic to the smallholder production system. Further, the rate of technology adoption varies greatly both by choice and capacity. This will result in further vulnerability of traditional and pastoral systems.

25.2 Adaptability of AnGR and Breeding Strategies to Counteract Climate Change

Adaptation is a dynamic process, wherein living beings are modified phenotypically over the significant course of time as a response to several environmental stimuli which modulate the genomic expression of the organism to suit the needs of time. An interesting thing about the adaptation of the organisms to environmental stimuli is that the information obtained from external stimuli is learned by living systems that in turn help to change the genetic and phenotypic expression that finally inherits in the subsequent generations. AnGR have faced a lot of challenges in the past and the way ahead is tougher. The challenge of CC comes with varying degrees of problems and those need to be counteracted systematically. The most trusted method to bring the change in the livestock is rigorous selection for the desired traits. However, the selection for adaptability in the era of changing climate seems to be the most difficult path to tread.

25.2.1 Adaptability of AnGR in Place

AnGR play a very important role in our life due to complete dependence of mankind on them. Throughout the course of evolution, AnGR have modified themselves according to the need of mankind through the process of domestication and selection, although it was by and large for the benefit of man. The Intergovernmental Panel on CC (IPCC) has defined ‘adaptation’ as ‘initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected CC effects’ (Hoffman 2010). Adaptation includes all activities that help people and ecosystems reduce their vulnerability to the adverse impacts of CC and minimise the costs of natural disasters. There is no one-size-fits-all solution for adaptation; measures need to be tailored to specific contexts, such as ecological and socio-economic patterns, and to geographical location and traditional practices (IFAD 2013a). Adaptability is then a measure of potential or actual capacity to adapt, for example, if one breed is used in different environments. Adaptation traits are usually characterised by low heritability. In relatively stable environments, such traits have probably reached a selection limit; however, they are expected to respond to selection if the environment shifts, resulting in change of fitness profiles and increase in heterozygosity (Hill and Zhang 2009). Many generations of natural selection and human-controlled selective breeding and husbandry, in a wide range of production environments, have given rise to great genetic diversity among the world’s livestock. Breeds and populations that have been exposed to climatic extremes, heavy disease and parasite challenges, poor-quality feed, high elevations or difficult terrain have often developed adaptations that enable them to thrive where other animals struggle to survive. Although advances in feeding, housing and veterinary care have increasingly enabled the establishment of production systems that isolate animals from such stresses, locally adapted animals remain essential to many livestock-keeping livelihoods especially in marginal areas (Pilling and Hoffman 2011).

While CC is a global phenomenon, its negative impacts are more severely felt by poor people in developing countries who rely heavily on the natural resource base for their livelihoods (IFAD 2013a). Rural poor communities rely greatly for their survival on agriculture and livestock keeping that are among the most climate-sensitive economic sectors. Livestock producers have traditionally adapted to various environmental and climatic changes by building on their in-depth knowledge of the environment in which they live. However, the expanding human population, urbanisation, environmental degradation and increased consumption of animal source foods have rendered some of those coping mechanisms ineffective (Sidahmed 2008). In addition, changes brought about by global warming are likely to happen at such a speed that they will exceed the capacity of spontaneous adaptation of both human communities and animal species (IFAD 2013b). Research on production systems and local and indigenous knowledge systems during the last 10–15 years has yielded ample evidence that in many cases the locally available breeds represent the ‘best fit’ in terms of adaptability to the physical and animal husbandry environment. If this is the case for the production system(s) under consideration, and unless there is clear evidence for the benefit of using an exotic breed, a decision to use the locally available AnGR would be a reasonable outcome of the decision-making process (FAO 2010a). AnGR have been modulating the phenotype according to the change in climatic factors, but at a very slow pace. However, in today's CC era, the need to change is altogether different and demands a fast rather very fast pace that seems to be difficult from every perspective.

25.2.2 Adaptability of Production Systems in Place

Production systems in modern era are highly specialised. Production environments, and the intensities and purposes of production, vary greatly within and across countries. Developed countries have objective-oriented and result framework-documented production systems, whereas in developing and underdeveloped part of the world, still the production systems are integral to their livelihood and stakeholders are mostly ignorant about the business model of the production system, say, for example, sheep husbandry in India. Indian shepherd considers his sheep as an integral part to his livelihood and thus does not pay much attention to the modes of rapid revenue generation through better science and economics. Sheep husbandry in India is with the people who are poor, and also it is the lifeline for them as it helps in sustaining their livelihood. Proper marketing and technical inputs for feeding, breeding and health are usually based on age-old wisdom rather than modern scientific knowledge. That results in sociological animal husbandry practices rather than scientific practices. However, this type of production system has one advantage that it can be shifted to any kind of system as the need arises. On the contrary, the highly specialised production systems of developed world have a very little scope to deviate from their existing systems. Therefore, to study the adaptability of the production systems, it is necessary to first characterise the environment associated with the production system. FAO (2010a) has detailed pointwise the crux of characterising the environment associated with the production system as given below:

- Briefly characterise the nature – including major seasonal features – and the state of ecosystems affected by the production system. Consider groundwater, forest and forest habitat, other flora, wild fauna and soil.
- Are components of the ecosystem sensitive to changes in livestock management?
- Are components of the production system sensitive to the possible effects of global CC?
- Is there evidence that the production system causes environmental damage?
- How does the production system enhance ecosystems (e.g. providing organic fertiliser or maintaining habitats)?
- Do constraints or opportunities result from interactions between the production system and the environment? Are some of these constraints seasonal?

Animal agriculture systems have been categorised on the basis of agro-ecological opportunities and demand for livestock commodities. In general, these systems are shaped by prevailing biophysical and sociocultural environments, and without external inputs, they have traditionally been mostly in sustainable equilibrium with such environments. Many of these systems that are the result of a long evolution are currently under pressure to adjust to rapidly evolving socio-economic conditions; large intensive livestock production units, in particular for pig and poultry production, have emerged over the last decades in many developing regions in response to the rapidly growing demand for livestock products. Several researchers have classified the production systems according to the criteria of existing systems (Steinfeld et al. 2006) such as: (1) integration with crops, (2) relation to land, (3) agro-ecological zone, (4) intensity of production and (5) type of product. These criteria have been used by several authors to classify the systems in several categories; however, the basic remains the same. In the future, production will increasingly be affected by competition for natural resources, particularly land and water, by competition between food and feed and by the need to operate in a carbon-constrained economy. Developments in breeding, nutrition and animal health will continue to contribute to increasing potential production and further efficiency and genetic gains (Thornton 2010).

Although varied natures of the production systems that involve animal, land and man exist and are best suited to the existing conditions, the challenges of the future are demanding. It has always been said that the adaptation of the livestock and also of the production systems to the agro-ecological niches they are placed in is a product of several years of slow change. However, the rapid change due to increased human activities leading to sudden rise of temperature in the last few decades and expected changes in the future if the trend continues (it shall continue!) pose several threats in pipeline. The first steps in adapting production systems to the effects of CC are likely to involve attempts to alter husbandry practices rather than to make major changes in the utilisation of AnGR, such as introducing new breeds or adjusting breeding strategies (Pilling and Hoffman 2011). However, the sudden replacement of the breeds or changes in the breeding objectives does not seem to be the only options as they too need a significant amount of time. Various technologies can be used to protect animals from the direct effects of rising temperatures. Similarly, vaccinations and other preventive measures can be used against many of the diseases and parasites that may spread into new areas as a result of CC (Pilling and Hoffman 2011). Every so-thought-out remedy seems to come with challenges. The biggest one is, suppose the alternate strategy fails in an event of threat due to CC, then what? People round the world are working for this, and many a times, boomerang to the roots seems to be the best solution.

In most of the African and Asian countries, the sociological mode of livestock keeping is in practice since ages. The least change in the animal husbandry practices helped the communities in this region to maintain the diversity of the livestock to a good extent. All the livestock from cattle, sheep, goat, poultry, pig, etc. have many different breeds, which are important not only for their product but also for traits like heat tolerance, disease resistance, longevity, aesthetic value and many more. This diversity will be the only solution to the challenges of tomorrow.

25.2.3 Breeding for Climate Change Adaptation and Mitigation

Nature has possibly already created every alternative for future threats; the need is to identify them, act swiftly and respect the nature and the resources it gives to us. Breeding is a science that has mimicked the process of evolution (selection for desired adapted traits) through man's interference. How can breeding be useful for the process of adaptation in the era of CC is a tough question. Not only this but also mitigating the effects of CC on animal productivity and production by breeding strategies is also a function of imagination and positive projections as we do not have sufficient scientific data as of now. An adaptive trait is an aspect of the developmental pattern which facilitates the survival and/or reproduction of animals in a certain succession of environments (Dobzhansky 1956). Fitness is an important trait for any species which centres on the adaptation of individual species in a given environment to propagate their genes in subsequent generations. Livestock keepers throughout the world have been practicing animal husbandry and breeding in unfavourable environment for centuries. As a result, many breeds of the unsympathetic environment have developed many adaptive traits that enhance survivability. Today, with advancement in the scientific acumen, efforts are needed for enhancing the competence of breeding for harsh environments and also for making the future planning and execution for developing strains which can withstand the unforeseen climatic changes (Naskar et al. 2012). In the following few sections, we will discuss in detail the breeding strategies for adaptation to CC mitigating the challenges posed by CC in the near future.

To sustain the traits of local importance and to have improvement in these traits, a very good practice of keeping a community bull usually owned by temple in a village was adopted since ages in India. These days, there has been decline in this concept as penetration of crossbreeding and other means has increased in villages of interior India too. However, looking into the old concept of keeping community bull in each village, it seems that it has greatly helped in improving the desired traits of interest in the flock of cattle in that region. Today, characterising the traits of interest as far as CC is concerned and reviving the concept of community bull, wherever local breeds or strains need conservation, can very well be practised. WoDaaBe of Niger is another example of cultural habits of exchange of germplasm (Kratli 2007). In livestock-keeping communities, social interactions often involve animals. Friendships are sealed with animal loans; marriages involve the payment of a bride price; animals are offered as wedding gifts; disputes and compensation claims are settled with animals. These and other traditional practices, such as animal exchanges, herd splitting and herding contracts (known locally among the WoDaaBe of Niger as *mafisa*, *haBBana*'*e* and *bulisana*, respectively), entail numerous movements of animals. The cultural customs are therefore of direct relevance to animal breeding. While breeding is rarely the primary motivation for such customs, they influence breeding because any movement of animals from one herd or flock to another implies an exchange of genetic material.

The continuing approach of breeding strategy will be explored further, but before that, it is essential to understand whether we have enough groundwork for adopting a proper and successful breeding policy. According to FAO (2010b), livestock policy is indispensable for formulating a breeding policy. To cite a case, reference may be made to the enactment of the same in United Republic of Tanzania in 1991. In 2003, a second attempt led to the presentation of a draft animal breeding policy. However, the Ministry of Agriculture realised that no livestock policy was yet in place and gave priority to establishing one, which was done in 2006. In March 2008, an FAO workshop on policies and strategies for the development of AnGR was held in Dar es Salaam, with the objective of revitalising the draft animal breeding policy. A new task force was given the job of reformulating the policy. Similar cases in other countries, such as Burundi, illustrate that before formulating a breeding policy, it is important to establish a comprehensive livestock policy that defines livestock development objectives and associated strategies (FAO 2010a). Another example where clear-cut directives are issued for breeding the indigenous cattle of Africa is the case of N'Dama cattle (ICAR/FAO 2000). The directors of the livestock/veterinary services and of the research organisations dealing with livestock in Gambia, Guinea, Guinea-Bissau, Senegal and Sierra Leone made the following qualitative statement on breeding goals: The N'Dama will remain the cattle breed of choice for the low-input system from the Gambia southwards. Throughout the region, the breed is regarded as triple purpose (for milk, meat and traction), and emphasis for improvement will be on milk and meat without the loss of disease resistance and other adaptive traits. This type of straightforward approach is very urgently required in countries where local germplasms are fast disappearing due to dilution of the germplasm.

25.2.3.1 Developing a Suitable Breeding Strategy

Throughout the world, breeding programmes for improving the productivity of the livestock are in progress. These strategies use the already set rules and knowledge about the basic principles of genetics. Many programmes go for strict adoption of within-breed selection with stringent selection criteria for a trait of economic interest. Selection or straight breeding implies genetic improvement based on variation among individuals within the population. This approach brings a permanent change in the structure of the population but with relatively slow rate. Another approach is crossbreeding, where two different breeds are crossed and improver breed bring fast genetic improvement in the receptor breed. Crossbreeding can also be used for mixing two desired traits of interest in the population. Biotechnological techniques are also in use these days to enhance the productive and reproductive performance at a faster rate. In a few instances, biotechnological tool has been integrated with the breeding programmes that has resulted in reduced generation interval and enhanced productivity (Mishra et al. 2007).

According to FAO (2010a), among the many factors that must be considered in the development of a breeding programme are the animal species involved; the types of traits considered; the availability, accessibility and affordability of different breeds; the production environment; the time frame for the planned genetic improvement (improvement through straight breeding usually takes longer than through crossbreeding); and the infrastructure of the livestock sector and the resources allocated to the programme.

For successful initiation of any breeding programme, it is essential to identify the trait of interest that needs to be improved in the targeted population. In an event of probable global warming and CC, there shall be shift in the traits of interest from productivity to adaptability and fitness. What we expect from the challenge of CC is again the shift of stress to animal from production to balance between production and traits of fitness. It will be a tough task not only for the livestock but also for the stakeholders especially breeders and farmers associated with the animal husbandry with regard to how to keep the balance between these two contrasting traits. CC poses a great threat to the AnGR. Threats are numerous starting from effect on individual animals to the population as a whole. The change in the pattern of disease occurrence and distribution, geographical disease barrier erosion, heat stress as a common factor demanding more heat-tolerant individuals, scarcity of the food resources and water as a general factor, overall decline in the production level of the animals as a compensatory mechanism for stress tolerance, reproductive disturbances and loss of animal genetic diversity at population level will be a few among the many effects of CC on AnGR (Naskar et al. 2012). The overall increase in temperature will have its impact on the physiological stress and thermoregulatory control, nutrition and disease status of the animals.

25.2.3.1.1 Heat Tolerance

The challenge ahead is to manage the livestock genetic resources amiably in accordance with the expected change in the climate. Among the many stressors in animal production system, heat stress is one important factor that needs most attention. Heat stress is known to alter the physiology of livestock, reduce male and female reproduction and production and increase mortality (Hoffman 2010). Livestock's water requirements increase with temperature. Heat stress suppresses appetite and FI; thus, feeding rations for high-performing animals need to be reformulated to account for the need to increase nutrient density. Body temperatures beyond 45–47 °C are lethal in most species. Heat stress is an important factor in determining specific production environments (Zwald et al. 2003). There are several factors that determine the differences for the heat tolerance in livestock. Some species are more tolerant than others; same is the case with breeds within species. We do not have a concrete scientific data to comment on the fact that how the selection for production affects the heat tolerance in animals; however, it is well established that temperate breeds perform better in production, whereas tropical breeds are better for heat tolerance. A good volume of literature is available on adaptation differences between zebu and taurine cattle (Frisch 1972; King 1983; Burns et al. 1997; Prayaga et al. 2006). *Bos indicus* is generally more heat resistant than *Bos taurus* (Burns et al. 1997). When we talk about the heat tolerance level of *Bos indicus*, it is a result of hundreds of years of adaptation and evolution to the harsh climate of Asian, Arab and African countries.

In an event of increase in the climatic temperature, there will be a need to incorporate the trait of heat tolerance in the breeds which are less resistant to heat stress. Current trend in which genetic selection in dairy cow is primarily influenced by milk yield is likely going to give rise to increase in 'elite' germplasm with increased susceptibility to heat stress (Naskar et al. 2012). Genetic adaptation to adverse environmental conditions including heat stress is a slow process and is the result of natural selection over many generations (Ames and Ray 1983). Good environment favours high production whereas bad environment hampers it. Production of any kind, milk or meat characteristics or wool traits requires congenial environment to have better GEI (Naskar et al. 2012). Selecting animals for heat tolerance needs a new understanding by livestock holders and development agencies.

Adaptation traits are usually characterised by low heritability. Selection on the basis of observation of heat stress seems to be difficult and costly. Crossbreeding for heat tolerance per se needs to be traded carefully vis-à-vis production. In Brazil, Indian cattle breeds have been used for genetic improvement that involves the use of Nellore cattle. Now, this move seems to be a good option, where a breed with trait for heat tolerance is used for enhancing productivity. However, where the industries are based on high milk yielding ability of the cattle, whole animal crossbreeding will not be useful. In such instances, use of molecular markers or transgenic approaches for incorporating the heat tolerance genes seems suitable. Heat shock protein 70 (Hsp70) are ubiquitously expressed proteins which protect animals against heat shock (HS) or stress, whether extreme hot or cold. These proteins virtually exist in all living organisms including microorganisms. They are an important part of the cell's machinery for protein folding and help to protect cells from stress. Finding the polymorphism at genetic level for Hsp70 and their correlation with the observed heat stress resistance are useful tools for discovering sturdy animals. There are reports where it was recorded that the polymorphisms in the bovine HSP90AB1 gene were associated with heat tolerance in Thai indigenous cattle (Charoensook et al. 2012). Another gene 'slick' was identified as a gene that improves heat tolerance in dairy cattle. The discovery is very important to the beef cattle industry, since it should greatly facilitate the slick gene's introgression, into other economically important breeds, such as Holstein or Angus, to improve their heat tolerance (Olson et al. 2003). Cattle with slick hair were observed to maintain lower rectal temperature (RT). The gene is found in Senepol cattle and Criollo (Spanish origin) breeds in Central and South America. This gene is also found in a Venezuelan composite breed, the Carora, formed from the Brown Swiss and the Venezuelan Criollo breed. The decreased RT observed for slick-haired crossbred calves compared to normal-haired contemporaries ranged from 0.18 to 0.4 °C. Liu et al. (2010) examined the genetic polymorphism of the ATP1A1 gene in Holstein cows. Nucleotide substitution of G to A at position 14,103 in exon 14 and C to T at position 14,242 in intron 14 of the bovine ATP1A1 gene was identified having a significant correlation between ATP1A1 gene polymorphism and the coefficient of heat tolerance ($P < 0.01$) and with respiratory rate ($P < 0.01$).

For many breeds of sheep, goat, buffalo, pig and poultry, several genes are responsible for heat tolerance. However, in each breed, selection for heat tolerance does not seem logical. In the breeds of tropical climate, especially in Asia, Africa, etc., the livestock are adapted to the harsh climate. In the future, if the temperature rises (if it rises significantly!), then the breeds will probably adapt to those changes, as has been the case in the past. In breeds where commercialisation has reached to its peak such as in pig and poultry in the Western world and in-house production systems are used, it will be cheaper and efficient to provide micro-climate that controls the outside temperature than to change the genetic structure of the population for heat tolerance.

25.2.3.1.2 Production, Productivity and Feed Efficiency

Production and productivity of the livestock are very important criteria for profitable animal husbandry practices. To increase the production of the livestock, efforts have been made in recent past through several genetic improvement programmes, where milk yield; beef yield; live weight gain in sheep, goat and pig; egg quality and quantity; and several other traits have been improved significantly. In the era of CC, the production and productivity of the animals will be at stake, as the changing climate will pose a threat in terms of stressors that negatively influence the productivity of the livestock. An experiment for fine wool production by crossbreeding was adopted in the semiarid region of Rajasthan, India, in which Rambouillet and Russian Merino were crossed with the local breeds to evolve a fine wool breed called Bharat Merino. However, it was seen that the harsh environment in the semiarid region posed constraints for this genotype to fully exhibit its potential. These animals were then shifted to a subtemperate region (Mannavanur, south India) where already a flock of Bharat Merino sheep was maintained, which resulted in better performance of the genotype (Gowane et al. 2010). It reflects the importance of climate on the productivity of animals and the extent to which it can affect breeding programmes.

Milk productivity in dairy farming is a reflection of interactions between the production potential of the livestock, nutritional knowledge, veterinary care, availability of technologies, investment, active extension service, research as well as readiness to agree and accept innovations (Naskar et al. 2012). Productivity also depends on the kind of nutritional input given to the animals. All livestock production depends on access to the feed and water that animals need to survive, produce and reproduce. The future of livestock production systems, and of the associated AnGR, depends on the continued productivity of various feed-producing areas – all of which are potentially affected by CC (Pilling and Hoffman 2011).

In any breeding programme, the main target for improving the production and productivity must be complimented with the parameters that take into consideration the feed efficiency of the animals such as high FCR, reduced age at maturity, reduced mortality, as they all have a significant say in the productivity per unit in animal husbandry practices. Assuming that future dairy systems may become more reliant on pasture than grain feeding, Hayes et al. (2009) proposed to select sires whose daughters will cope better with low feeding levels and higher heat stress. They identified markers associated with sensitivity of milk production to feeding level and sensitivity of milk production to THI in Jersey and Holstein. Because feed-efficient animals are also more cost-effective and productive, the Australian beef industry now includes net feed efficiency as an integral part of its breeding programme (Beef CRC). Indian zebu cattle, sheep, goat and other species mostly rely on pasture feeding than on grains. These animals are mostly very efficient in effective utilisation of low-quality feed and require very less input. However, selective breeding to increase the feed efficiency may not be widely applicable specially in extensive system of production and small-scale holding. The breeds of different agro-climatic zones worldwide are evolved and adapted to the locally available feed resources that have in turn changed the physiology of the livestock for feed efficiency. Today, the option open for CC situation is management of the AnGR for feed efficiency; herein, change in the feeding systems can be suggested.

One such desired change where feeding system, if manoeuvred, can result in significant reduction is in the methane production from the livestock. Methane gas is a potent greenhouse gas produced in the rumen of livestock during the normal process of feed digestion and represents a significant loss of feed energy that increases feed costs. For example, a lactating dairy cow produces about 400 g of methane each day. These methane losses quickly add up. In 1 year, the amount of methane a dairy cow produces is equivalent to the greenhouse gas emissions from a mid-sized vehicle driven 20,000 km. Because methane production increases as the animal eats more feed, improving feed conversion efficiency, the amount of feed consumed per kilogramme of milk produced or weight gained, decreases methane output. Diets that are more digestible lower the amount of methane emitted per product produced. It may also be possible to breed more efficient cattle that produce less methane. Many strategies such as feeding oils and oilseeds, higher grain diet, legumes, rumen modifiers or animal selection for reduced methane production are suggested for reduced methane production. In India, animals are reared on different feeding systems/diets comprising locally available roughage and feed ingredients according to the animal physiological needs in different AERs of the country. Enteric CH_4 emission estimated for Indian livestock using animal population of 2003 was 9.10 Tg, wherein indigenous cattle and buffalo had the major contribution (Singh et al. 2012). Nutritional intervention in Indian livestock for reduced methane emission is suggested.

Location-specific nutritional interventions can be taken up for altered dietary composition to reduce CH_4 production.

25.2.3.1.3 Disease Tolerance and Resistance

In animal production system, disease tolerance and disease resistance are two different aspects. In the disease tolerance, animal is inflicted with the attack of parasite; however, it has a mechanism by which the negative effects of the disease are not exhibited on the production and reproduction performance of the animal. Disease resistance defines a case wherein the animal's immune system does not allow the antigen to enter the system, and thus, the animal is protected from the disease. In farm animal science, tolerance to infections is sometimes termed disease resilience (Albers et al. 1987). Resistance is different from tolerance. Disease resistance is the *host trait* that prevents infection or reduces the number of pathogens and parasites within or on a host. For animal production system, both disease resilience and resistance traits are important.

There is considerable variation among individuals in the response to infectious disease and vaccination, a significant proportion of which can be shown to be genetic (Davies et al. 2009). Identifying the causal genes involved in disease resistance is no straightforward. Parasitic diseases like gastrointestinal (GI) nematodes and trypanosomiasis are worldwide an important cause of reduced production efficiency in ruminants and partly even limited livestock production in some regions of the world. GI nematodes are among the most important infections faced by livestock, especially affecting poor keepers (Perry et al. 2002). A potential alternative to alleviate the problems is breeding for disease resistance. Extensive research on the genetics and breeding for worm resistance has been carried out in Australia, New Zealand, South Africa (de Greef 2009) and also in India (Singh et al. 2009). Tick counts, faecal worm egg counts (FEC), RT and coat scores have been used as indicator traits of adaptability of beef cattle to assess the suitability of particular genotypes to tropical environment. Singh et al. (2009) evaluated Avikalin (Rambouillet x Malpura) breed of sheep for faecal egg count at naive and exposed stage of natural infection (predominantly *Haemonchus contortus*), and two divergent lines were created by selecting progenies from sires with low (R line) and high (S line) mean faecal egg count (FEC). The performance of selected animals from both lines was compared over the years, and no untoward effects on different performance traits were observed.

Climate affects vectors, pathogens, hosts and host-pathogen interactions from the level of cellular defence to that of the habitat. Hoberg et al. (2008) provide an overview of predicted responses of complex host-pathogen systems to CC. CC may affect the spatial distribution of disease outbreaks and their timing and intensity. Outbreaks of African horse sickness, peste des petits ruminants, Rift Valley fever, bluetongue virus, facial eczema and anthrax are triggered by specific weather conditions and changes in seasonal rainfall profiles (Hoffman 2010). Climatic effects on host-vector and host-parasite population dynamics will further the geographic expansion of vector-borne infectious diseases to higher elevations and higher latitudes and affect the transmission and course of the diseases (Rogers and Randolph 2006). One example is availability of mosquitoes *Culicidae* (vector for disease like malaria) in the higher altitudes of the Himalayan ranges at 7,500 ft high in Mukteshwar. It is evident that mosquitoes were never seen at that height due to low temperatures; however, due to increase in the average temperature, the presence of these vectors is felt which is dangerous with regard to the spread of dreaded diseases like malaria, yellow fever, etc. in the virgin areas. FAO (2007a) lists breeds, mainly from developing countries, that are reported to be resistant or tolerant to trypanosomiasis, tick burden, tick-borne diseases, internal parasites, dermatophilosis or foot rot (59 cattle, 33 sheep, 6 goat, 5 horse and 4 buffalo breeds). Trypano-tolerant N'Dama cattle respond more rapidly and with a greater magnitude to infection compared to the trypano-susceptible Boran cattle. Gorman et al. (2009) showed major gene expression differences exist between cattle from trypano-tolerant and trypano-susceptible breeds. Breeding for disease resistance in the era of CC is increasingly being looked at as a promising option and several experiments are going on worldwide. The use of new molecular techniques to identify the candidate genes and then the use of transgenic technique to introgress this gene of interest (if found a major gene) in the animals are in waiting.

25.2.3.2 Conservation

The Global Plan of Action for AnGR (FAO 2007b) recognises the significance of CC and the need for conservation programmes and strategies to account both for gradual environmental changes in livestock production systems and the effects of disasters and emergencies. Genetic diversity signifies a unique resource to respond to the present and future needs of livestock production and human needs. Nevertheless, livestock diversity is shrinking rapidly. Among the domesticated populations, it is estimated that one to two breeds are lost every week (Schearf 2003). However, the impact of these losses on the global or the local diversity remains undocumented. According to the State of the World's AnGR, 20 % of all reported breeds are at risk of extinction; however, the population status of many breeds is still unknown, and the problem may thus be underestimated. Most developing countries and some developed countries do not currently have AnGR conservation strategies or policies in place. Without strategically planned interventions, using both in situ and ex situ conservations, erosion will continue and may accelerate (FAO 2007b). There is an urgent need to document the diversity of our livestock genetic resources and to design strategies for their sustainable conservation. Looking at this problem from a bigger perspective, the mission is massive, and it has prompted the Food and Agriculture Organization and other international organisations to develop databases [ILRI Domestic Animal Genetic Information System (DAGRIS) and DAD-IS]. In India, the National Bureau of Animal Genetic Resources (NBAGR) has also developed an information system on AnGR of India (AGRI-IS) to inventorise and monitor trends in breed characteristics and population.

There are several reasons for losses of the genetic diversity of domestic animals; however, CC remains one of the most important criteria. To conserve the available genetic resources is a task ahead so that the resources shall be available for sustainable use and management for the future generations. The Global Plan of Action for AnGR and the Interlaken Declaration (FAO 2007b) have prioritised some points wherein appropriate conservation measures should ensure that farmers and researchers have access to a diverse gene pool for further breeding and research. This genetic diversity provides an essential resource to cope with the impacts of CC, pest and disease outbreaks, and new and growing consumer demands. Strategic and considered investment in the conservation of AnGR is of critical importance, and international collaboration is essential to halt the serious decline of these resources.

In situ conservation programmes are the best options, wherein the resources are available and chances of strengthening the resources are high. Many genetic improvement schemes worldwide also involve in situ conservation as a major objective. In situ measures facilitate continued co-evolution in diverse environments and avoid stagnation of the genetic stock. In situ conservation measures are best based on agroecosystem approaches and ideally should be established through economically viable and socially beneficial sustainable use (FAO 2007b). There are several instances where these programmes need extra input from the agencies that run these programmes. In developing countries like India, mostly these programmes are run by government agencies and thus completely funded. However, here too, for successful accomplishment of these programmes, participatory approach of workers with the real stakeholders is necessary. On farm programmes, active participation of the farmers along with the research workers is mandatory for in situ conservation programmes.

Ex situ conservation basically refers to conservation away from the home tract and production system where the resources are developed. This category involves both maintenance of live animals and cryopreservation. Improvement and natural selection also lead to disturbance of the

Hardy-Weinberg (HW) equilibrium in such populations. Cryopreservation on the other hand is for future use, when probably the breeds shall be extinct, or a specific desired character goes missing. Semen, ova, embryos, tissue, etc. for potential future use are cryopreserved. The Global Plan of Action recognises that global or regional facilities may play a role in ex situ conservation. Many stakeholders express support for the idea of their countries' participation in such endeavours, with regional initiatives being the most popular option (FAO 2010b). Cryopreservation of domestic animal embryos has become an integral part of embryo biotechnology especially programmes related to germplasm conservation (Fahning and Garcia 1992; Dobrinsky 2002). The transfer of germplasm resources as embryos rather than animals on hoofs is economical, warrants less risk of disease transmission and possesses added advantage of allowing exotic stocks to develop in recipients well adapted to local conditions. The prospect that CC will bring more frequent catastrophes and major disruptions to livestock production probably increases the significance of establishing back-up ex situ collections of AnGR and the importance of situating these collections in dispersed locations (Pilling and Hoffman 2011).

25.2.3.2.1 Characterisation

AnGR which are available today are a product of several centuries of evolution and adaptation to the local agro-climatic zones in which they are located. In an event of probable catastrophes or threat of CC, there is a possibility to shift these resources to new locations where safe livelihood is assured along with matching production systems. In such a case, it becomes mandatory to have complete knowledge of the genetic and phenotypic characteristics of the AnGR before taking any major decision with regard to shift in the production system or place or any other factor. Many breeds in the developing and underdeveloped countries are yet to be characterised and posses a worth information with regard to traits of importance. There are several breeds which are important for disease resistance traits, feed efficiency traits, heat tolerance traits, etc., and all these breeds must be characterised for their probable future use.

Assessments of the risk posed to AnGR by climatic and other disasters require knowledge of the geographical distribution of breeds and populations. Prioritisation and planning of conservation programmes and measures to promote sustainable use of AnGR require knowledge of the respective breeds and of their production environments, demographics and geographical distributions (Pilling and Hoffman 2011). Detailed advice on phenotypic and molecular characterisation and on surveying and monitoring of AnGR is provided in the respective draft FAO guidelines (FAO 2010c, d, e). Ideally, such studies and surveys should be part of cohesive national strategies addressing countries' needs for AnGR-related data and information (Pilling and Hoffman 2011). The potential effects of CC should be taken into account in the development of such strategies, both in terms of the information targeted and in terms of the frequency with which monitoring surveys need to be repeated (FAO 2010c). Such strategy shall help for better planning and help for mitigating the challenges that will be posed by CC.

25.2.3.2.2 Funding and Sustainability

The conservation and characterisation programmes are in majority funded by government agencies worldwide. As per Global Plan of Action for AnGR (FAO 2007b), implementation will require substantial and additional financial resources and long-term support for national, regional and international AnGR programmes and priority activities, provided such incentives are consistent with relevant international agreements. The process should encourage and support the participation of governments and all relevant stakeholders. Regional and international collaboration will be crucial.

CC represents an increasing threat to so many planet species – including our own. Science tells us now is the time to act. Targets and promises need to be put into action – before it is too late. WWF-UK has engaged itself in conservation activities especially those related to wildlife and nature. There are many agencies worldwide that are setting an example of this type. Barring these agencies, public funding remains a major source for conservation programmes. Large-scale awareness programmes of civic societies for conservation of livestock are an important prerequisite for success. The public funding can still raise an issue as to why taxpayer's money needs to be spent on animal conservation. Awareness regarding the impact of CC on human life and its association with the livestock has to be studied and advertised to the public in detail through media, discussions, print and several other avenues. The need for conserving the golden gene pool for tomorrow must come within, and for that, awareness is essential. In many countries including India, a very good example of such initiative is the tiger conservation programme. The government has initiated and successfully carried out the awareness among the people regarding the need and utility of conserving the tiger and also other wildlife. This has not only resulted in public funding but also has attracted a lot of private funds too. Conservation of domestic animal biodiversity in an era of CC is a much gigantic task than conserving wildlife. This is so, because the threats are largely unknown and probable impacts cannot even be imagined. A concerted effort to raise the fund like collaboration with other organisations such as multi-government funding, private funding, FAO, World Bank, etc. may be essential.

25.2.3.3 Planning Altered Species and Breed Stratification

To decide whether the breeding programmes will be carried out on the locally available breed or alternate breeds remains the choice of stakeholders and beneficiaries. Looking into the probable effects of CC, it is very much possible that in temperate parts of the world, introduction of new germplasm which can tolerate the effects of CC may be practised. Ideally, decisions as to which breed should be introduced and for what use should be based on an evaluation of the alternative breeds and their crosses in the production environment in which it is planned to be introduced. Although introduction of the new breeds in different production systems is still an option, it must be looked at very cautiously. Traits of interest such as heat tolerance, disease resistance, efficient feed and water consumption and also better production have to be incorporated in an index. The planning with regard to the use of crossbreeding, transgenic approach or just introduction of new breeds as such should also consider the available production system and adaptability of the new germplasm in such environment. Introducing a new breed to a new environment however has a lot of issues surrounding it, but one important thing is to avoid the negative consequences of it. Australia maintains a strict policy on importing alternative breeds of sheep. One policy objective is to protect the quality of its wool clip, where one black fibre per million is sufficient to reduce value considerably. Therefore, the proportion of black fibres in the fleece is a critical attribute of an imported breed. A second policy objective is to keep scrapie (a sheep disease) out of the country. Therefore, no breeds that might introduce the disease are considered for importation (FAO 2010b).

Breed stratification according to the landscape of the production system is also essential. An example of breed stratification for sheep in India based on the user's purpose, interest, availability of the resources and objective of the breeding system has been described by Shinde et al. (2013). The alternate species or breed stratification is a demand-based choice. In general, all species will be adversely affected by global warming and there will be fewer animals per farm as a result. The livestock business that demands more input and amiable environment is likely to be affected first, an example being the beef cattle industry. Sheep and goat are the animals of the future. Throughout the world, they have very high population growth rate in spite of heavy consumption. CC is expected to determine a decrease in beef cattle and an increase in sheep and goats. This change of species from large ruminant to small ruminant is very much possible in India, Africa, Asian countries and also in the Western world, if the situation arises. Smallholder farmers who are able to switch to sheep and goats may not be as vulnerable to higher temperatures as large-scale farmers who cannot make this switch. Farm size can shape the way farmers respond to CC. Smallholder farmers are diversified, relying on dairy cattle, goats, sheep and chickens, while large-scale farmers specialise in dairy and especially beef cattle. As a result of CC, large-scale farmers are likely to shift away from beef cattle and chickens in favour of dairy cattle, sheep and goats. Livestock keeping will be a safety valve for smallholder farmers if warming or drought causes their crops to fail (Seo and Mendelsohn 2006).

25.2.4 Matching AnGR with Production Systems

Matching AnGR with production systems means looking for the optimal breed to satisfy the needs of the production system (FAO 2010b). As it has been discussed earlier, the locally adapted and available breeds throughout the world are the best choice as far as their utility, adaptability and future use are concerned. This is so, because the available production system has forced the livestock resources to mould or modify themselves to existing situations and any deviation from this combination of AnGR and production system does not seem viable. Farmers or the stakeholders who are involved in the animal husbandry practices know well how and why the livestock they keep best suits their need and the need of production system.

A beautiful example in this context is the case of Indian Chilika buffalo (FAO 2010b). Chilika buffaloes are prevalent in the islands and periphery of Chilika Lake on the coast of eastern India (Khurda, Ganjam and Puri districts in the state of Orissa). The animals are well suited to the backwaters of the lake and enter the knee-deep waters to feed on weeds and grasses, generally during the night. During the daytime, they rest on the shore, under the trees. The Chilika buffaloes have an important ecological role – their dung and urine support zooplankton, which support the lake's fish population, which in turn supports livelihoods around the lake. Other breeds are not well adapted to the local production system, and introduced animals have proved unable to meet the multiple roles performed by the Chilika buffaloes. Murrah buffaloes or Murrah-Chilika crosses, for instance, do not survive in this environment, because they are less well adapted to the humid conditions and due to the absence of non-saline drinking water. Now, this must be seen very seriously, as to how the real stakeholders of the AnGR know the importance of the resources, and these criteria must be given due weightage while deciding on the importance of breeds, their conservation programmes and related issues.

Another example of matching production system with AnGR is given here in the context of sheep in the semiarid region of Rajasthan, India. In India, several efforts for introducing the crossbreeds of sheep with exotic inheritance of Rambouillet or Merino ram were made in the semiarid region of Rajasthan. However, the acceptability of the farmers for these crosses was not high in spite of their high production potential. Ultimately the crossbreeds of sheep were finally shifted to the temperate regions. The production system available in the semiarid region of Rajasthan demands exhaustive grazing of the sheep that demands covering distance of 30 miles or so per day in the harsh climate. Such demand can only be met by locally evolved and adapted breed 'Malpura'. Since the last 10 years, rainfall pattern in this area has changed drastically, and it is receiving hardly 400 mm of rainfall per year. This has resulted in the scarcity of resources available in the field due to which farmers have started taking their sheep on migration as an alternative strategy. Migration has become common during drought season (Rathore 2004). Malpura sheep was in between crossed with the Marwari sheep from arid region during migration, which resulted in the production of crossbreeds which are sturdier, have long legs and are best for migration purpose. These sheep are now preferred whenever farmers need to go on migration. Kheri sheep is a product of farmers' own intellect, where need-based intervention yielded the desired results (Gowane and Arora 2010).

FAO (2010b) has published guidelines regarding how to proceed for matching AnGR with production systems that involve the following tasks:

1. Define the overall breeding goal for the production system of interest.
2. Collate available information on experiences in the conduct of breeding programmes.
3. Collate available information on the roles and characteristics of locally available breed(s).
4. Examine possible alternative breeds.
5. Decide whether the breeding programme will be based on locally available or alternative breeds.
6. Conduct a feasibility study for the introduction of alternative breeds and take a decision.
7. Prepare the germplasm introduction plan.
8. Implement the germplasm introduction plan.

These tasks may be of use for planning introduction of new breeds to the different agro-climate or production systems and to assess the impact of such intervention. However, for any step to be executed, the views of local prime stakeholder must be given due importance in decision making.

25.3 Genetic Tools for AnGR to Counteract Climate Change

25.3.1 Genes of Importance to Counteract Climate Change

Selection of animals with improved thermal tolerance is one of the ways to counteract the harsh effect of CC. The primary impact of CC is the rise in ambient temperature. Although several reports are available on the adverse impact of heat stress on livestock production, the reports pertaining to genes involved in heat stress adaptation are very meagre. The following section will provide information on genes involved in thermotolerance in livestock.

25.3.1.1 Heat Shock Factors (HSF)

At cellular level during the onset of increased cell temperature, a transcription factor family known as the HSF has been considered as important first responders (Page et al. 2006). HSFs are known to interact with specific DNA sequence in the promoter HS elements. The HS element is a stretch of DNA located in the promoter region of susceptible genes containing multiple sequential copies (adjacent and inverse) of the consensus pentanucleotide sequence 5′-nGAAn-3′ (Morimoto 1998) mostly found in HSP genes. These transcription factors coordinate the cellular response to thermal stress and affect the expression of a wide variety of genes including HSPs (Akerfelt et al. 2007). A total of four HS factors have been identified so far (Morimoto 1998), out of which three, viz., HSF-1, HSF-2 and HSF-4, are found in mammalian systems and HSF-3 is present in avian systems. In cattle, the HSF-1 gene has been mapped to chromosome 14 (Winter et al. 2007). During HS, HSF-1 is activated by thermal stress and found mainly in the nucleus in trimeric form (Sarge et al. 1993) which binds to the HS elements and is primarily involved in elevated gene expression level of HSPs (Pirkkala et al. 2001).

25.3.1.2 Heat Shock Proteins

Many candidate genes for thermal tolerance have been identified, out of which HSPs are the major responders during thermal stress. HSPs were originally identified as proteins whose expression was markedly increased by HS (Lindquist 1986). HSPs are usually expressed in normal cells too to play important functions in normal cell physiology. Their numbers in cells are increased when an animal is subjected to various stressors such as heat, cold and oxygen deprivation. The HSP40, HSP60, HSP70 and HSP90 families of proteins are the example of the first biochemical activity group. The second biochemical activity is regulation of cellular redox state. HSP32, better known as heme oxygenase-1 (HO-1), is an example of this group (Otterbein and Choi 2000). The third principal biochemical activity of HSPs is the regulation of protein turnover (Parsell and Lindquist 1993). Ubiquitin, which is expressed in unstressed cells, up-regulated by HS, is a classical example of this group.

Patir and Upadhyay (2007) indicated that thermal exposure of Murrah buffaloes caused induction of HSP70 and declined the immune status of buffalo heifers. HSP70.1 and HSP70.3 in mouse (Huang et al. 2001) and HSP72 in human

(Fehrenbach et al. 2001) have been identified as candidate genes for thermal resistance. Gaughan et al. (2009) studied the effect of chronic heat stress on plasma concentration of secreted HSP70 in growing feedlot cattle and found that its concentration is a reliable indicator of chronic stress. Prostaglandin A1 (PGA1) induces HSP synthesis in bovine mammary epithelial cells resulting in protection against cellular stresses (Collier et al. 2007). Zhang et al. (2002) identified polymorphisms of the regulatory and coding regions of the HSP70 gene associated with different heat tolerance capabilities in broiler chickens. A functional promoter and 3′-UTR variants of highly conserved inducible HSP70.2 gene in pigs significantly affected mRNA stability and cell response to stress (Schwerin et al. 2001, 2002).

Sodhi et al. (2013) identified several distinct nucleotide changes in HSP70.1 gene of 14 diversified Indian zebu cattle breeds and six buffalo breeds. They also identified four microsatellite markers within the buffalo HSP70.1 gene and three microsatellites within the bovine HSP70.1 gene that could further be evaluated as molecular markers for thermotolerance. Basiricò et al. (2011) investigated the association between inducible HSP70.1 single nucleotide polymorphisms (SNPs) and HS response of peripheral blood mononuclear cells (PBMC) in dairy cows and suggested mutations in the 5′-UTR region of inducible HSP70.1 may be useful as molecular genetic markers to assist selection for heat tolerance. While analyzing the heat and cold challenge responses in terms of expression of different HSP family genes and HSP70 protein in the PBMC of goat, increased levels of expression of *HSP27* in both heat and cold stress conditions was reported by Mohanarao et al. (2013).

Mehla et al. (2014) through microarray study in four Sahiwal heifers exposed to heat stress demonstrated that gene expression changes through activation of HSF-1 and HSPs. An experiment of both induced in vitro and environmental stress conditions by Deb et al. (2014) indicated that Sahiwal cattle may express higher levels of Hsp90 than Frieswal cattle to regulate their body temperature and increase cell survivality under heat stressed conditions.

25.3.1.3 Halothane Gene in Pigs

Porcine stress syndrome (PSS) gene is associated with a condition called malignant hyperthermia induced by environmental stressors. PSS gene is commonly referred to as halothane (HAL) gene, because this condition can be triggered by exposing pigs to the anaesthetic halothane gas. This is a major gene inherited on single locus with two alternate alleles, dominant (N) and recessive (n). Pigs possessing recessive allele are more sensitive to stress conditions. Homozygous recessive (nn) genotype is associated with production of PSE pork characterised by its pale colour, lack of firmness, dripping of exudates from cut surfaces and denaturation of muscular proteins (Monin et al. 1999). Malignant hyperthermia in nn pigs is a muscular disorder characterised by an abnormal response to stress, exercise and anaesthetics (Klip et al. 1986; Monin et al. 1999). Different HAL genotypes produce different amounts of HSP70, suggesting a role for dominant HAL gene (N) in promoting cell survival in response to stressful conditions (Khazzaka et al. 2006). Successful introgression of halothane normal allele into a Pietrain line that otherwise had a high frequency of the halothane-positive allele is reported (Hanset et al. 1995).

25.3.1.4 Slick Hair Gene in Cattle

The slick hair gene is found in Senepol cattle and Criollo (Spanish origin) breeds in Central and South America. Studies have shown that Senepol cattle and their crosses with Holstein, Charolais and Angus animals are as heat tolerant as Brahman cattle. This has been attributed to the slick hair coat of Senepol cattle, which is thought to be controlled by a single dominant gene and has been mapped on bovine chromosome 20 (Mariasegaram et al. 2007). These breeds have been developed from crossbreeding of N'Dama cattle to include favourable heat stress traits. However, origin of slick hair gene in Senepol remained uncertain. Cattle with slick hair were observed to maintain lower RT. The effect of the *slick hair* gene on RT depended on the degree of heat stress and appeared to be affected by age and/or lactation status. The decreased RT observed for slick-haired crossbred calves compared to normal-haired contemporaries ranged from 0.18 to 0.4 °C (Olson et al. 2003).

25.3.1.5 Nramp1 Gene

Natural resistance-associated macrophage protein 1 (Nramp1) has been identified as a major gene in many species (Vidal et al. 1993) expressed in late endosomes of macrophages. Nramp1 regulates antimicrobial activity of macrophages (Barton et al. 1995). In mouse, a point mutation in the coding region of the gene Nramp1 causes a single amino acid change from Gly to Asp at position 169, and it results in a susceptibility phenotype of mice in the early phases of infection with *S. enterica* serovar *Typhimurium*, *Leishmania donovani* or various species of *Mycobacterium* (Vidal et al. 1995). $(GT)_n$ microsatellite polymorphism at 3′-UTR of Nramp1 has been found to be associated with resistance/susceptibility to *Brucella abortus* (Adams and Templeton 1998; Barthel et al. 2001), salmonella and paratuberculosis (Pinedo et al. 2009) infection in cattle and buffalo (Ganguly et al. 2008). This gene holds promise in disease resistance which may be relevant in changing climatic situations to combat many diseases in the future.

25.3.1.6 Other Genes

Recently, many genes have been reported to be involved in heat stress and affected by HS and interact with HSPs. With the help of gene chip arrays, it has become possible to screen the expression of thousands of sequences simultaneously. Several gene chip array experiments have been performed that specifically examined the role of HS on gene expression. An experiment reported in 1996 (Schena et al. 1996) used an array containing 1,000 genes to examine changes in gene expression in human T cells and demonstrated the feasibility of using this technology to identify new candidate heat-responsive genes. Approximately 50 genes not traditionally considered to be HSPs have been found to undergo changes in expression in response to heat stress (Sonna et al. 2002). There are many genes with known physiological functions which are induced by cold stress. p53 and p21 are the most important genes to play significant role in cell physiology during cold exposure (Matijasevic et al. 1998; Ohnishi et al. 1998). Many genetic factors apart from the slick hair gene have been identified which influence the colour pattern of the cattle and hence may be useful in differential selection and performance under different heat stress conditions. The spotted locus in Hereford cattle and Kit locus on bovine chromosome 6 are few of the examples and have been extensively studied (Fontanesi et al. 2010). A cDNA microarray analysis found 140 transcripts to be upregulated and 77 downregulated in the Sahiwal cattle blood after heat treatment (Mehla et al. 2014).

Several genes have been identified in poultry which play a major role in heat tolerance. Naked neck (Na) a dominant gene responsible for reducing feather cover and sex-linked recessive gene for dwarfism (dw) responsible for reduced body size and thereby reduced metabolic heat output are few of the examples. The frizzle (F) gene is another important gene related to the economic performance of the stock under hot humid conditions.

25.3.1.7 Emerging Technologies Shaping the Future of Livestock Breeding

As we know, a vast natural variation exists in our livestock population that will form the basis for further genetic improvement and selection by including new traits to meet the challenges in the coming decades. Following are new technologies which will be the limelight in the future to accelerate genetic gains in livestock to cope with the threats of CC.

25.3.1.8 Genomic Selection

Genomic selection (GS) is a marker-assisted selection (MAS) method, in which high density-markers covering the whole genome are used simultaneously for individual genetic evaluation via genomic estimated breeding values (GEBVs). GS is based upon linkage disequilibrium between the markers and the polymorphisms present in various traits of importance (Meuwissen et al. 2001). Hayes et al. (2013) described the method of exercising GS. The equation that predicts breeding value from SNP genotypes must be estimated from a sample of animals, known as the reference population, that have been measured for the traits and genotyped for the SNPs. This prediction equation can then be used to predict breeding values for selection candidates based on their genotypes alone. The candidates are ranked on these estimated breeding values, and the best ones are selected to breed the next generation.

GS is advantageous over selection based on phenotype because meritorious animals in GS can be identified early with genomic prediction. There are many traits which are difficult or expensive to measure like GHG emissions, feed efficiency, disease inheritance, reproductive traits like fertility, etc. Large dairy ruminants are traditionally selected on the basis of progeny testing as merit of breeding bulls is evaluated on the milk production of his daughters. An advantage of GS is that generation interval can be reduced to 2 years and also result to almost double the rate of genetic gain (Pryce and Daetwyler 2011). Due to the above reasons, GS has got wide and rapid acceptance among dairy industries in all over the world. However, GS in beef cattle is adopted at lower pace due to reasons that reference population in beef cattle is smaller than dairy cattle. In addition, as compared to few dairy breed, there are several beef breeds of importance around the world. Requirement of sufficient reference population to achieve expected accuracy of genomic breeding value in beef cattle is challenging; therefore, international collaborations are required to pool reference population across countries (Hayes et al. 2013). However, accuracy is compromised in this case due to differences in linkage disequilibrium phases between SNPs and causative mutations across breeds (Daetwyler et al. 2012a).

GS is also being practised in meat, wool and dairy sheep (Duchemin et al. 2012). Daetwyler et al. (2011) utilised available 50,000 ovine SNPs to predict estimated breeding values for wool and meat traits in sheep. The effects of all SNP markers in a multi-breed sheep reference population of 7,180 individuals with phenotypic records were estimated to derive prediction equations for GEBVs for greasy fleece weight, fibre diameter, staple strength, breech wrinkle score, weight at ultrasound scanning, scanned eye muscle depth and scanned fat depth. Breeding value of 540 industry sires was used as a validation population and the accuracies of GEBVs were assessed according to correlations between GEBVs and sheep breeding values. Results showed that accuracy of GEBVs will increase with the increase in size of reference population.

In meat sheep, genomic predictions have been made for health attributes in lambs; Daetwyler et al. (2012b) predicted carcass and novel meat quality traits in a multi-breed sheep population that included Merino, Border Leicester, Polled Dorset and White Suffolk sheep and their crosses. Further, there are already some promising estimates of the accuracy of genomic predictions for feed conversion efficiency in chickens, dairy cattle and pigs. Pryce et al. (2012) postulated a term residual feed intake (RFI) which is the difference between actual and predicted FI that may be a useful selection criterion for greater feed efficiency. A group of DNA markers explaining genetic variation in RFI would enable cost-effective GS. In their study, eight SNPs with large effects on RFI were located on chromosome 14 at around 35.7 Mb, and these may be associated with the gene NCOA2, which is known for controlling energy metabolism. Genomic prediction of female fertility with high accuracy is also available to be used for GS (Wiggans et al. 2011). Improvement in FI and feed efficiency of livestock is strongly associated with methane emission levels. It is suggested that genomic predictions of FI may be used as indirect GS for low methane emission (Haas et al. 2012). FI plays an important economic role in beef cattle and is related with feed efficiency, weight gain and carcass traits. The genome-wide association study (GWAS) for dry matter intake (DMI) and RFI of Nellore cattle was studied in which three SNPs surpassed the threshold of Bonferroni multiple tests for DMI and two SNPs for RFI. These markers are located on chromosomes 4, 8, 14 and 21 in regions near genes regulating appetite and ion transport and close to important QTL as previously reported to RFI and DMI, indicating that two processes are important in the physiological regulation of intake and feed efficiency (Santana et al. 2014).

GS can also be exercised to improve performance of animals in heat stress conditions. To select cattle adapted to changing environments, Hayes et al. (2009) conducted a GWAS to detect SNPs associated with the sensitivity of milk production to environmental conditions and validated many markers located on chromosomes 9 and 23, associated with sensitivity of milk production to feeding level and sensitivity of milk production to temperature humidity index (THI). There is a need to identify signatures of selection related to heat stress and individual genes associated with mechanisms to fight climate challenges by the use of genomics (Rothschild and Plastow 2014). Many genes in the insulin pathway have been identified and associated with the capacity of camel to go long periods of time without water in hot dry environments (Jirimutu et al. 2012). Huson et al. (2013) and Elbeltagy et al. (2014) examined many possible signatures of climatic stress in sheep and goats. Similar study to examine stressed chickens has revealed many significant genomic differences by Lamont et al. (2013) which could be possible genomic markers to select avian in the future. Similarly, a novel SNP in the ATP1A1 gene has also been associated with heat tolerance traits in dairy cows (Liu et al. 2010).

There are some diseases which are present in wild counterparts of domesticated animals without any serious effect, but have deleterious effect in domesticated livestock species. African swine fever is one of the examples which is present in warthogs without any serious consequences but is deadly in domesticated pigs. Comparison of genomic sequences of indigenous pigs to that of domesticated pigs to determine regions of susceptibility/resistance will lead to open a new approach to GS (Mujibi et al. 2014). Such efforts also may provide targets for genome editing or other modifications to create resistant or more tolerant animals that could be utilised in these environments.

Assembling large number of reference populations will be the major challenge in implication of GS in the coming future. In this process, very large number of phenotyped individuals will be required to make accurate predictions. International collaborations to increase the size of reference populations and to find the economical ways for genomic screening will decide the future of GS.

25.3.1.9 Significant Quantitative Trait Loci of Climate Change Adaptation in Livestock

A quantitative trait locus (QTL) is a genomic region that is associated with or modulates the variation in a measurable phenotype (Williams et al. 1998). In particular, certain QTLs may account for a comparatively large portion of the variance in different complex traits, which could be analysed by studying the pattern when separating alleles are derived from opposing spectrums at a major QTL (Williams et al. 1998). The identification of specific genomic regions that affect economically important traits in farm animals holds great interest for the livestock industry as it aims at incorporating genomic markers linked to QTL into breeding programmes, by making use of MAS (Anderson 2001). In the search of QTL and major genes, different approaches have been investigated including genome-wide scans using relatively high density panels of microsatellites or SNP markers across the genome together with genome-wide association studies or candidate gene approaches (Ron and Weller 2007; Hayes and Goddard 2010). Liu et al. (2010) studied the polymorphism of ATP1A1 gene of Holstein cows and identified two SNPs out of which AC genotype was associated with heat tolerance and has a potential as genetic marker in future breeding to combat with CC. Dikmen et al. (2013) performed a GWAS for RT during heat stress in Holstein cow and identified SNPs. The largest proportion of SNP variance (0.07–0.44 %) was explained by markers flanking the region between 28,877,547 and 28,907,154 bp on *Bos taurus* autosome (BTA) 24. These SNPs could prove useful in genetic selection and for identification of genes involved in physiological responses to heat stress. Significant QTLs have been identified on chromosome 5 related to stress and anxiety (Tarricone et al. 1995; Roberts et al. 1995; Dai et al. 2009). Thermal stress on bovine mammary development by microarray technique has been evaluated

(Collier et al. 2006). Study revealed an overall upregulation of genes associated with the stress response and protein repair. Four QTLs in pig have been identified with significant effect (Lilja et al. 2000). They are present on chromosomes 2, 6, 8 and 12 and are responsible for induction of IL-2 activity, phagocytic capacity and mitogen induced proliferation. Two significant and two suggestive Marek's disease QTLs were detected in four chromosomal regions, explaining 11–23 % of the phenotypic and 32–68 % of the genetic variation in Marek's disease in poultry (Vallejo et al. 1998). QTLs associated with resistance to avian coccidiosis to GGA1 were mapped by using 119 microsatellite markers (Zhu et al. 2003).

Genetic variation associated with nematodes resistance has been utilised by implementation of marker-assisted breeding value estimation (MA-BVE) using dense maps covering the entire genome (Meuwissen et al. 2001). The interest in the MA-BVE approach is solely in the breeding value of the candidates with the objective to estimate the breeding value with the highest possible accuracy using all phenotypic and genomic information.

25.4 Conclusion

CC adds another layer of uncertainty to the ever-evolving and dynamic livestock sector. Although AnGR and the goods and services rendered by it are affected by direct and indirect effects of CC, it has largely not been integrated in their actual context because of highly concentric focus on present human needs ignoring environmental costs. The lion share of the veritable goldmine of AnGR in the form of many different livestock species and breeds is concentrated in developing and least developed countries, most of which are with the smallholder and pastoralist. It is them who will be most affected by CC.

Undoubtedly resource efficient livestock production will be key to secure the future. Industrial and commercial production will be better able to handle the direct effects of CC through their access to technologies and manipulation of micro-environments. But smallholder and pastoralist livestock production system will face significant challenges in addressing it. In the absence of appropriate, accessible and affordable technologies to counteract CC-induced challenges, the diversity of the production system, AnGR and breed portfolio is likely to be restricted. Further, the inherent structural variability in livestock production along with its differential ability to absorb changes may not allow assimilation of resource-use efficiency at every stratum. This may result in the growing dichotomy between industrial and smallholder livestock production.

In all probability, resource-use efficiency will be measured increasingly through feed conversion efficiency of livestock in immediate and medium terms. This will see altered preference for livestock species as well as breeds. The species and breed portfolio in CC scenario will vary locally as well as regionally. Superior FCR of monogastrics will put them in comparative advantage over cereal-fed ruminants (Hoffmann 2010). However, ruminants may increase in rangelands with sufficient vegetation growth (Seo and Mendelsohn 2008). On the other hand, small ruminants are likely preferred in extensive systems of production (Herrero et al. 2008; Seo and Mendelsohn 2008). The typical outlook of FCR may not help in traditional livestock production; instead, 'human edible return' as suggested by Gill and Smith (2008) may be a better indicator for assessing efficiency. Fertility and longevity of livestock will be more important in the future, and more selection pressure on them along with FCR will be expected. However, key to the climate-resilient livestock production will be the adaptability of the animals to their production environments. This will require careful trade-off between production, productivity and adaptability since they are not favourably related. Although adaptive traits are characterised by low heritability like fertility, significant prominence of fitness traits is expected. This will entail overcoming problems associated with measuring the phenotypes relevant to adaptation and better understanding of its physiology and genetics.

Breeds of livestock species that dominate industrial production have been developed through highly structured breeding programmes and intensive selection for years. Narrow pool of these highly developed animal genetics will continue to catalyse global trade of animal products. As against this, local breeds that predominate traditional livestock production have largely not been placed under any structured breeding and genetic improvement programmes although they have been subjected to differential selection pressures in the form of their ability to survive in harsh production environments and low input. If the common trend of purchasing genetic gain for quick results, through import of *superior* livestock genetics, continues in developing countries instead of developing their own production environment-specific livestock breeds, it will see raising stocks largely not in sync with production environments, thus increasing vulnerability and further marginalization of local and adapted breeds. Of course recent trends of increasing focus on local superior livestock germplasm and its promotion as an alternative to import of *superior* genetics and mutual share may not go unnoticed in many developing countries like India.

Understanding the dynamics of CC and animal production in the *most* comprehensive manner and appropriate modelling to counteract or absorb it shall be the most important step towards ensuring prioritisation of research and developmental goals which shall also help create awareness among all stakeholders including policy planners. Central to the development of climate-resilient animals are characterisation of the AnGR in a broad-based manner and its valuation in the context of its environmental niche and scientific understanding of adaptability. Most tropically adapted breeds that reside in developing countries are largely under-characterised. It shall be an important priority.

Breeding strategies for livestock genetic resources to counter CC impact will not be fundamentally different than what is practised today. Between the choice of matching genetics with environment and vice versa, the norm and practice shall be system specific. Natural stratification of species and breeds of livestock shall be an important guide in the design. Efficient livestock production ensuring diversity of gene pool, fitness for the production environments and optimum fertility that shall also meet sociocultural needs and have low environmental footprint shall be the desirable shape for sustainability. A healthy combination of higher production and productivity with heat resilience, fertility, disease tolerance and challenged nutrition will require flexibility of breeding indices. Irrespective of the scale, GEI may not be ignored.

Large-scale transboundary movement of superior animal genetics and specially considering its relative ease may not match well when cooperation and share of knowledge, expertise and resources are considered with respect to broad-based use of AnGR. A positive change in this regard is desired. Promotion of breed societies will be indispensible, and performance recording of livestock of smallholder production system will be increasingly important for the improvement of AnGR in the CC era.

Although livestock is an important pillar for livelihood, nutritional security and poverty alleviation in most of the developing and poor countries, enabling policies and long-term commitment for its sustainable growth have mostly been missing. Continuation of treating this as an allied sector of agriculture in many parts of the developing world undermining its significant contribution to agricultural GDP and the potential it holds has restricted its growth path and will not help in the long run. A sound policy framework for animal breeding, commitment for long-term investment and close cooperation between stakeholders and partners regionally, nationally and internationally are the need of the hour to ensure that livestock continues to progressively provide diverse goods and services even in the face of looming uncertainties posed by CC.

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