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Livestock and climate change: the key actors and the sufferers of global warming

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ABSTRACT

There are many agents of climate change. Livestock are one of them. Livestock contibutes to climate change by adding to greenhouse gases (GHGs). At the same time, livestock are one of the worst sufferers of the climate change. This paper discusses how the GHG emissions from livestock sector are phenomenol for climate change and how the climate change is affecting the performance of this sector and what could be the potential impact of this sector on public health. Livestock are more sensitive to climate change than cropping systems. Crossbred cattle are still more sensitive than their indigenous counterparts. There are strategies of reducing impact of climate change on livestock and improve their overall performance. Improved and effective management of natural resources and livestock sector would be phenomenal for reducing methane emission by changing the physiological processes inside rumen. There is need to formulate a policy to replace livestock products with better and more nutritive alternatives of which there is enormous scope in this world. Imposition of carbon taxes on meat industry would also help reduce carbon emissions from livestock sector.

Key words: Climate change, Greenhouse gas (GHG) emissions, Livestock, Methane, Rumen fermentation

Climate change is looming large and intensifying itself unabatedly with every successive year setting new records of its thermodynamics. Soaring of global temperatures carry serious consequences to the whole life. Accelerated melting of polar ice, rapidly receding Himalayan glaciers, rising of sea levels, vicious weather cycle, increased rate of species extinction, etc. are some of the visible symptoms of ongoing climate change. Climate change in the 21st century, in fact, is emerging as one of the most critical human concerns. A number of international protocols have cropped up since humanity began realizing the impacts of global warming, but the climate change trends continue to advance threatening the living planet with grave consequences.

Basic anthropogenic causes of climate change are: (i) excessive carbon emissions (carbon dioxide, methane, fluorinated gases – including chlorofluorocarbons, infamous for their depletion of the upper atmosphere's protective ozone layer – and nitrous oxide); and (ii) reduced carbon sequestration. Greenhouse gases due to disrupted global carbon budget are scientifically the most important source of climate change. There is also a third and relatively less discussed anthropogenic source: "black carbon"—essentially soot and other small carbon particles from combustion—potent enough to change the reflectivity of the earth's surface (as and when reflective sea ice melts and is replaced by heat absorbing ocean water) also contribute to warming (Asian Development Bank 2009). While excessive carbon emissions into the atmosphere are largely attributable to excessive dependence on non-renewable and polluting sources of energy, mainly the fossil fuels, reduced carbon sequestration is largely owing to declined forest covers on land and due to marine pollution.

The other (non-human) species that could also be accused of climate change includes all domesticated farm animals, the livestock. However, here too human species is a big player. All livestock populations of the world play in the hands of human beings. Therefore, whatever happens due to them or happens to them is all anthropogenic in nature. The way we manage livestock is excessively detrimental to our environment. Livestock's contribution to climate change, in fact, goes to the anthropogenic category of climate order disruption. According to a World Watch report, the lifecycle and supply chain of domesticated animals raised for food was vastly undermined as a source of greenhouse gases (GHGs), and in fact, account for at least half of all human-caused GHGs (Goodland and Anhang 2009).

Livestock accentuate the processes leading to climate change by adding to carbon emission mainly through methane production directly owing to rumen fermentation and indirectly through the degradation of their wastes. They also contribute to reduced carbon sequestration in various ways; by causing ecological degradation of forests, rangelands and pastures.

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Livestock sector in global economy

Numerous farming communities in the world, especially those dwelling in the highlands and mountains of the world, and those who are landless in rural settings, are livestock dependent. Economically the livestock are not a big global player (Steinfeld *et al.* 2006), but they play a critical role in the socioeconomic and cultural life of the majority of livestock dependent people the world over. For the majority of the poor in Asia and Africa, livestock serve as a major source of food, nutrition and livelihood security. For millions of marginal and small farmers, livestock serve as a source of draught power and transport and have no alternative source of energy (Singh 1998, Partap and Singh 2002, Singh and Gautam 2004, Singh and Partap 2000, 2002, 2005).

Livestock sector of the world employs some 1.3 billion people and creates livelihood for about one billion of the poor across the world apart from contributing to about 40% agricultural gross domestic product (Steinfeld *et al.* 2006). With about 521 million livestock, India's livestock sector is the biggest in the world. India stands first with 16.1% of the world's cattle and 57.9% of the world's buffaloes, second with 16.7% world's population of goats and third with 5.7% world's population of sheep, according to FAOSTAT (Sirohi and Michaelowa 2007).

Managing such large livestock populations poses a challenge to the earth's climate system as well as to the livestock sector itself. In the times of climate change, therefore, livestock sector needs to be handled with utmost care. We need to reduce the impact of livestock sector on climate, on the one hand, and have to protect the climate sensitive sector from the negative impact of climate change, on the other.

Rumen microbial ecosystem

Ruminant animals have to rely upon their rumen microbial ecosystem to derive energy and nutrients from the lignocellulosic fodders that comprise bulk of livestock feeds. Bioconversion of the recalcitrant lignocellulosic feeds accomplished by a consortium of microorganisms (bacteria, protozoa and fungi) gives rise to volatile fatty acids, which serve as energy sources for the ruminants (Kamra 2004). The rumen microbial ecosystem (Hobson 1988), contains bacteria (1,010–1,011 cells/ml representing more than 50 genera), ciliate protozoa (104–106/ml from 25 genera), anaerobic fungi (103–105 zoospores/ml, representing 5 genera) and bacteriophages (108–109/ml).

The ruminants are capable to subsist on the lignocellulosic feeds due to the rumen microbial ecosystem (the largest part of a ruminant's stomach) but not the non-ruminant animals and human beings. Rumen microbial ecosystem has many ecological and economic attributes. The ecological attributes include ruminants' role in accelerating nutrient cycles in a farming system, which helps the farmers effectively manage nutrient cycles and soil fertility. In the absence of microorganisms inhabiting rumen ecosystem, biodegradation of lignocelluloses available plentifully in nature would be very slow and farmers cannot wait for so long to replenish their soils with the nutrients lost from the field with the harvest of a crop. When the nutrients contained in lignocellulose pass through the rumen ecosystem, they could be availed by the farmers (as organic manure) at short intervals. In farming systems, such as in the Himalayan mountains, ruminants are fed on forest-based fodders quite high in lignocellulosic compounds. Thus, the nutrients from a relatively more stable ecosystem (a forest) are transferred to a relatively more fragile ecosystem (cultivated land) through dung/ organic manure. In this way, the livestock contributes to ecological integrity of a farming system.

Owing to the ruminants, the necessary nutrient inputs can be produced within a farming system itself. This reduces farmers' dependence on market system for the purchase of chemical fertilizers. Since livestock are fed on the parts of the plants which are non-consumable by human beings, they do not compete with human beings for their nutrition as the non-ruminant animals would do. In a rumen ecosystem, energy of the lignocellulosic feeds is captured for transformation into many livestock products of economic importance, such as milk, fibre and labour. A farming system would function even in the absence of livestock. But the livestock captures some energy to be converted into products of economic importance which would have gone waste. Thus livestock help diversify economic pathways benefitting the society in several ways.

Fermentation in the rumen ecosystem, however, costs the health of the environment to a certain extent. Despite the several ecological and economic attributes, the rumen ecosystem is infusing GHGs, mainly methane, in the atmosphere at an alarming rate, and this is becoming a matter of great concern.

Livestock-environmental interactions: current scenario

Livestock in human socio-economic systems play a major role in land use change (overgrazing, deforestation, increased use of cultivated land for feed and fodder production) underlying climate change that connects livestock with the global N and C cycles. Considering emissions along the entire commodity chain, livestock currently contributes about 18% to the global warming effect. FAO's widely cited 2006 report *Livestock's Long Shadow* has elaborated on how livestock are increasingly becoming a burden to the environment (Steinfeld *et al.* 2006). Some of the major findings are presented in Table 1.

FAO estimates that of the worldwide emissions, 7,516 million metric tonne/year of CO_2 equivalents (CO_2e), or 18% are contributed by buffaloes, cattle, sheep, goat, camels, horses, pigs and poultry (Steinfeld 2006). However, the World Watch analysis showed that livestock and their by-products actually account for at least 32,564 million tonne of CO_2e/year, or 50% of annual worldwide GHG emissions (Goodland and Anhang 2009). This analysis included data relating to GHG emissions, which were either

Table 1. Livestock contributions to environmental disruption

Land degradation	The single anthropogenic user of land;
	The total area occupied by grazing equivalent to 26% of the ice-free terrestrial surface of the planet;
	The total area devoted to feed/fodder production equal to 33% of total arable land;
	Expansion of livestock as a key factor in deforestation in many regions of the world;
	About 20% of the pastures and rangelands (73% rangelands in dry areas) degraded through overgrazing, compaction and erosion triggered by livestock.
Water	Livestock as key player in increasing water use (about 8% of global human water use, mostly for irrigation of fodder/feed crops);
	One of the largest sources of water pollution contributing to eutrophication, “dead” zones in coastal areas, degradation of coral reefs, human health problems, emergence of antibiotic resistance, etc.;
	Animal wastes as a major source of water pollution.
Biodiversity	Livestock account for about 20% of the total terrestrial biomass and 30% of the Earth’s land surface which was once inhabited by wildlife;
	Livestock as major drivers of deforestation, land degradation, environmental pollution, sedimentation of coastal areas and facilitation of invasion by alien species; etc. – all leading to biodiversity erosion at a faster pace;
	Out of 825 terrestrial eco-regions (identified by WWF), some 306 reported to be threatened by livestock;
	As many as 35 global hotspots of biodiversity identified by Conservation International face serious level of habitat loss due to livestock;
	Most of the world’s threatened species are on account of habitat loss with livestock as a major threat, according to an analysis of World Conservation Union (IUCN).
Atmosphere and Climate	Livestock responsible for 18% GHG emissions measured in CO_2 equivalent – a higher share than transport;
	Livestock sector accounting for 9% of anthropogenic CO_2 emissions;
	Emission of 37% of anthropogenic CH_4 (with 23 times the global warming potential (GWP of CO_2);
	Emission of 65% N_2O (with 296 times GWP of CO_2);
	Responsible for 64% anthropogenic NH_3 emissions contributing significantly to acid rain and acidification of ecosystems.

Source: Most of the information is based on Steinfeld *et al.* (2006).

uncounted or overlooked, or misallocated (Table 2).

Global warming potential (GWP), i.e. the capacity of GHG to trap heat in the atmosphere, is different for different GHGs. GWP compares warming potency of GHGs to CO_2 (with GWP=1). The widely accepted GWP value for CH_4, using a 100-year timeframe, is 25. However, Goodland and Anhang (2009) argue that GWP value of CH_4 is 72 using a 20-year timeframe, which appears to be more appropriate “because of both the large effect that CH_4 reductions can have within 20 years and the serious climate disruption expected within 20 years if no significant reduction of GHGs is achieved.” IPCC also supports this GWP value of CH_4.

Livestock contributes about 9% of total carbon dioxide (CO_2) emissions, but 37% of methane (CH_4), and 65% of nitrous oxide (N_2O). The latter will substantially increase over the coming decades, as the pasture land is currently at the maximum expanse in most regions; future expansion of the livestock sector will increasingly be crop-based (Mohammed and Awan 2012).

Annual methane production per cattle head in India (35 kg) is much lower that of a European cattle head (95 kg for a cow in Germany) as revealed by Crutzen *et al.* (1986). Despite this fact, India’s contribution to the annual global methane budget is the highest, which is only owing to its huge livestock population (Sirohi and Michaelowa 2007). Lower intake level and quality of feed intake are mainly responsible for lower level of methane production by Indian cattle. Higher level of methane production by European cattle is attributable to their higher energy requirement and higher feed intake. NRC (1996) established that the energy requirement of Asian cattle (*Bos indicus)* is 10% less than that of its North American or European cattle (*Bos taurus)*. Dependence of Indian livestock largely on poor quality roughage of low digestibility helps emit less methane in

Table 2. Uncounted, overlooked and misallocated livestock-related GHG emissions

	Annual GHG emissions (CO_2e)	Percentage of worldwide total
FAO estimate	7,516	11.8
Uncounted in current GHG inventories		
1. Overlooked respiration by livestock	8,769	13.7
2. Overlooked land use	≥2,672	≥4.2
3. Undercounted CH_4	5,047	7.9
4. Other four categories	≥5,560	8.7
Subtotal	≥22,048	≥34.5
Misallocated in current GHG inventories		
5. Three categories	≥3,000	≥4.7
Total GHGs attributable to livestock products	≥32,564	≥51

Source: Goodland and Anhang (2009).

comparison to the European or North American cattle dependent on high quality feed of high digestibility value (Sirohi and Michaelowa 2007).

Methane emissions through livestock waste management at global scale are estimated at 9.3 Tg/year (Scheehle 2002) with more than 52% contribution of developed countries. Livestock waste management in India is better than that in the Western countries as it leads to comparatively much lower levels of methane production (Sirohi and Michaelowa 2007). Nitrous oxide emissions (GWP=296) from manure management in India were estimated to be 0.017 Tg/year and are projected to increase to 0.022 Tg/year by 2020 as cited by Sirohi and Michaelowa (2002) based on the report of Scheehle (2002).

Livestock as a victim of climate change

So far we have looked into how livestock is contributing to global warming. Livestock sector, however, is not only a driver of climate change; it is also a sufferer, like many other sectors.

Physiology of livestock responds to physical, chemical, biological and climatic stimuli from their surroundings, thereby altering the functioning of their body accordingly. Overall performance of livestock – feed conversion efficiency, growth, reproduction, draught power output, milk and wool production, etc. – is influenced by the climate both directly and indirectly. Examples of Direct changes are listed in next paragraph (Sirohi and Michaelowa 2007).

Hot and humid environmental conditions due to alteration in temperature range cause heat stress in cows inducing behavioural and metabolic changes, thereby declining their productivity. Vulnerable animals die of extreme climatic events, however of short duration (summer heat waves or snow storms, for instance). Abnormal increase in temperature during summer results in reduced conception rate to the extent of 36%.

The indirect effects of climate driven changes in animal performance result mainly from alterations in the nutritional environment (Sirohi and Michaelowa 2007). Examples of Direct changes are listed in next paragraph

Changes in climate would affect the quality and quantity of forage produced. The impact of climate change on pastures and rangelands may include deterioration of pasture quality towards poorer quality subtropical C4 grasses in temperate regions as a result of warmer temperatures and less frost. Alterations of temperature and precipitation regimes may result in a spread of disease and parasites into new regions or produce an increase in the incidence of disease, which, in turn, would reduce animal productivity and possibly increase animal mortality.

The effect of temperature on livestock production is multifactorial. Maintenance of appropriate temperature range is conducive to optimum or potential production. A drastic change in temperature range, on the other hand, would induce inappropriate changes in animal physiology affecting production to a significant extent.

With the continuous increase in GHG accumulation and consequent soaring of temperature more of the living species on the Earth might face increasing risks of extinctions. According to IPCC (2007) estimates, approximately 20 to 30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increase in global average temperature exceed 1.5° to 2.5°C.

Vulnerability of crossbred cows to climate change

Crossbreeding of Indian cows with European bulls is central to our livestock development policy. As a result, 17.5% dairy cattle in India are crossbred (Sirohi and Michaelowa 2007). Nearly 4 decades ago this proportion was almost negligible. However, crossbred cows are highly vulnerable to increase in temperatures. Productivity of crossbred dairy cows is lower in areas where mean annual temperature is higher (Table 3).

Average annual temperature has negative correlation (r = -0.66) with average daily milk yield (Sirohi and Michaelowa 2007) indicating that rise in atmospheric temperature is likely to lower the production potential of crossbred cows.

Sirohi and Michaelowa (2007) have further emphasized this relationship through seasonal changes in air temperature and milk productivity. Milk productivity decreases after the

Table 3. Average annual temperature and milk productivity of crossbred cows in selected districts of India (Sirohi and Michaelowa 2007)

District	Average annual temperature (°C)	Average daily milk yield per crossbred cow (l)
Kurnool	29.05	3.02
Anantpur	28.61	3.21
Chennai	28.27	4.65
Ahamadabad	27.86	5.56
Cuttack	27.72	3.15
Rajkot	27.14	5.28
Thiruvanathpuram	27.1	5.65
Jodhpur	27.09	3.27
Kolkatta	26.98	5.48
Balasore	26.88	3.57
Nagpur	26.85	3.29
Hyderabad	26.1	4.86
Patna	25.58	3.5
Jaipur	25.17	5.45
Aurangabad	25.04	3.78
Lucknow	25.01	4
Agartala	24.86	5.5
Bhopal	24.85	6.01
Pune	24.79	6.28
Ranchi	24.33	6
Guwahati	24.21	5.85
Bengaluru	23.8	6.34
Ludhiana	23.5	7.58
Ambala	23.45	6.44

Table 4. Seasonal variation in air temperature and productivity of crossbred cows

Region/District	Seasonal normal temperature (°C)			Seasonal milk yield (l/day)		
	Winter	Summer	Rainy	Winter	Summer	Rainy
South India						
Thiruvananthapuram	26.93	28.35	26.74	5.68	5.62	5.70
Belgaun	22.50	27.12	23.50	3.72	3.50	3.64
North India						
Karnal	15.87	30.80	28.87	10.30	8.47	9.10
West India						
Akola	23.04	32.01	27.71	3.96	3.80	3.86
Kota	19.5	31.88	29.33	3.07	2.83	2.93

Source: Sirohi and Michaelowa (2007).

onset of summer due to increased temperature, but the same recovers after decrease in temperature upon the onset of rainy season (Table 4).

Not only the productivity of crossbred cows decreases with an increase in the atmospheric temperature, draught power output of crossbred bullocks is also likely to be decreased. Crossbred cattle as such is more vulnerable and less adapted to climate change.

Impact of climatic factors on livestock

Mohammed and Awan (2012) have compiled information based on reviews of Thornton *et al.* (2007, 2008). Feed, water, biodiversity and health cover would be affected in several ways on account of climate change consequently resulting in declined production performance of the livestock (Table 5).

Changing climate and spurt in livestock diseases

Climate imposes restrictions on vectors, environmental habitats and disease causing agents, and also helps check several livestock diseases (Stem *et al.* 1989). But it is true of the normal climate pattern. When climate deviates from its normal order, its protective attributes are compromised. High probability of spread of diseases and parasites among livestock in new areas, with alterations of temperature and precipitation regimes is there. A spurt of diseases, in turn, would have a corresponding decline in animal productivity and an increase in animal mortality.

Zoonotic diseases are transmitted from animals to people in several ways. Some diseases are acquired by people through direct contact with infected animals or animal products and wastes. Other zoonoses are transmitted by

Table 5. Some of the impacts of climate change on livestock and livestock systems (taken from broader reviews in Thornton *et al.* 2007, 2008)

Factor	Impacts
Water	Increasing water scarcity is an accelerating condition for 1-2 billion people. Coupled with population growth and economic development, climate change impacts will have a substantial effect on global water availability in the future.
Feeds	Land use and systems change
	As climate changes becomes more variable, species' niches change (plant and crop substitution); may modify animal diets and compromise the ability of smallholders to manage feed deficits. For example: in parts of East Africa, maize being substituted by crops more suited to drier environments (sorghum, millet); in marginal arid southern Africa, systems converting from a mixed crop-livestock to rangeland-based.
	Changes in the primary productivity of crops, forages and rangeland
	Effects depend significantly on location, system and species. For food-feed crops, harvest indices will change and so will the quantity of stover and availability of metabolic energy for dry season feeding. In the semi-arid rangelands where contractions in the growing season are likely, rangeland productivity will decrease.
	Changes in species composition
	As temperature and CO_2 levels change, optimal growth ranges for different species also change. Species alter their competition dynamics, and the composition of mixed grasslands changes. Proportion of browse in rangelands will increase in the future as a result of increased growth and competition of browse species due to increased CO_2 levels (Morgan *et al.* 2007). Legume species will also benefit from increases in CO_2 and in tropical grasslands, the mix between legumes and grasses could be altered.
	Quality of plant material
	Increased temperatures increase lignification of plant tissues and thus reduce the digestibility and the rates of degradation of plant species.

(Contd...)

(concluded table 5)

Factor	Impacts
	Resultant reduction in livestock production may have impacts on food security and incomes of smallholders.
	Interactions between primary productivity and quality of grasslands will demand modifications in grazing systems management to attain production objectives.
Biodiversity	In some areas, loss of genetic and cultural diversity in agriculture, in crops as well as domestic animals, will accelerate, which is already occurring as a result globalization (Ehrenfeld 2005).
	A 2.5°C increase in global temperature above pre-industrial levels will see major losses: 20-30% of all plant and animal species assessed could be at high risk of extinction (IPCC 2007).
	Ecosystems and species show a wide range of vulnerabilities to climate change, depending on the imminence of exposure to ecosystem-specific, critical thresholds, but assessments are fraught with uncertainty related to CO_2 fertilisation effects etc.
Livestock (and human) health	Major impacts on vector-borne diseases will be realized; e.g., expansion of vector populations into cooler areas (higher altitude areas, such as malaria and livestock tick-borne diseases) or into more temperate zones (such as bluetongue disease in northern Europe).
	Changes in rainfall pattern may also influence expansion of vectors during wetter years, leading to large outbreaks of disease (Rift Valley Fever virus in East Africa).
	Helminth infections are greatly influenced by changes in temperature and humidity. Climate change may affect trypanotolerance in sub-humid zones of West Africa could lead to loss of this adaptive trait that has developed over millennia and greater disease risk in the future.
	Effects (via changes in crop, livestock practices) on distribution and impact of malaria in many systems and schistosomiasis and lymphatic filariasis in irrigated systems (Patz *et al.* 2005).
	Increases in heat-related mortality and morbidity (Patz *et al.* 2005).
	Climate variability impacts on food production and nutrition can affect susceptibility to HIV/AIDS as well as to other diseases (Williams 2004).

vectors; while others are transmitted through the consumption of contaminated food or water (Table 6).

The proliferation of zoonoses and other animal diseases may result in an increased use of veterinary drugs that could lead to increased and possibly unacceptable levels of veterinary drugs in foods (FAO 2008).

Climate change and zoonotic diseases

Climate change leading to some abnormal and unexpected meteorological patterns might aggravate health problems for livestock. An appropriate environment for the emergence and spread of new diseases is set in. Transfer of animal pathogens to human beings is most likely in such

Table 6. Examples of some zoonotic agents that are expected to be affected by climate change and their mode of transmission

Causal agent	Host	Mode of transmission to humans
Virus		
Rift Valley fever virus	Multiple species of livestock and wildlife	Blood or organs of infected animals (handling of animal tissue), unpasteurized or uncooked milk of infected animals, mosquito, hematophagous flies.
Nipah virus	Bats and pigs	Directly from bats to humans through food in the consumption of date palm sap (Luby *et al.* 2006). Infected pigs present a serious risk to farmers and abattoir workers
Hendra virus	Bats and horse	Secretions from infected horses
Hantavirus	Rodents	Aerosol route from rodents. Outbreaks from activities such as clearing rodent infested areas and hunting.
Rotavirus	Humans	Faecal-oral route; spread through contaminated water and also by infected food-handlers who do not wash their hands properly.
Hepatitis E virus	Wild and domestic animals	Faecal-oral; pig manure is a possible source through contamination of irrigation water and shellfis in coastal waters
Bacterium		
Salmonella	Poultry and pigs	Faecal/oral
Campylobacter	Poultry	Faecal/oral

(Contd...)

(concluded table 6)

Causal agent	Host	Mode of transmission to humans
E. coli O157	Cattle and other ruminants	Faecal/oral
Anaerobic spore-forming bacteria	Birds, mammals and livestock	Ingestion of spores through environmental routes, water, soil and feeds. This has been associated with outbreaks of anthrax in livestock and wild animals, blackleg (*Clostridium chauvoei*) in cattle and botulism in wild birds after droughts.
Yersinia	Birds and rodents with regional differences in the species of infected animal. Pigs are a major livestock reservoir.	Handling pigs at slaughter is a risk to humans
Listeria monocytogenes	Livestock	In the northern hemisphere, listeriosis has a distinct seasonal occurrence in livestock probably associated with feeding of silage.
Leptospirosis	All farm animal species	Leptospirae shed in urine to contaminate pasture, drinking water and feed
Protozoan		
Toxoplasma gondii	Cats, pigs, sheep	Cat faeces are a major source of infection. Handling and consuming raw meat from infected sheep and pigs pose a zoonotic risk.
Cyptosporidium and Giardia	Cattle, sheep	Faecal-oral transmission. Oocysts are highly infectious and with high loadings; livestock faeces pose a risk to animal handlers
Parasites		
Tapeworm (*Cysticercus bovis*)	Cattle	Faecal-oral
Liver fluke (*Fasciola hepatica*)	Sheep, cattle	Eggs are excreted in faeces, and life cycle involves lymnaeid snail hosts. Human cases generally associated with the ingestion of marsh plants such as watercress.

environment. The zoonotic disease specific patterns in climate change are likely to influence the livestock sector and public health by: increasing livestock susceptibility to diseases; increasing the range of abundance of vectors; and prolonging the transmission cycles of vectors.

Exposure of animals to intense heat, humidity, droughts or cold may predispose them to complex bacterial syndromes, for example mastitis. Milk from the dairy animals suffering from mastitis, particularly when it is in subclinical state with no visible symptoms, would pose health problems for milk consumers if the pasteurization is incomplete or faulty. Drake *et al.* (2007) and Paz *et al.* (2007) have worked on aquatic animals' susceptibility to climate change. Warm waters can trigger disease outbreaks imposing heavy economic losses to fish farmers. This is particularly true for introduced aquaculture species, or if engineered fish lack the innate abilities to deal with new strains of pathogens, or if the fish farmers have to rely heavily on chemicals to control diseases. In some areas, some species may already be near their upper temperature tolerances (Mohammed and Awan 2012).

Climate change led to variations in temperature and rainfall could significantly alter the range, seasonality and incidence of many zoonotic diseases (CDC 2008).

Because of the sensitivities of vectors to climatic factors, ecological changes such as variations in rainfall and temperature could significantly alter the range, seasonality and incidence of many zoonotic diseases (CDC 2008). Examples of diseases influenced by climate change and variability include Rift Valley fever, bluetongue, as well as tick-borne diseases (Mohammed and Awan 2012). Some of the striking cases of sensitivities of vectors to climatic change are mentioned below.

Increased night temperatures resulting in enhanced vector flight activity (Purse *et al.* 2005); Greater competence in supporting replication and transmission of viral pathogens (Baylis and Githeko 2006); Spell of drought followed by rainfall providing breeding sites for midge and mosquito vectors with possible outbreaks of vector-borne livestock diseases (Baylis and Githeko 2006); Increase in the range and distribution of arthropod vectors with changes in rainfall patterns, and expansion in the range of ticks with decreasing rainfall (Trape *et al.* 1996); Increased rainfall helps snail hosts of livestock parasites to proliferate.

Climate change might lead to a spurt in the food-borne zooneses and animal pests with possible increase in the use of veterinary drugs (FAO 2008). Unacceptable levels of veterinary drugs in foods might have an adverse impact on public health.

Length of the vectors' transmission cycle owing to climate change might enhance the incidence of human infection. A glaring example is that of the West Nile Virus, a vector-borne zoonosis whose transmission cycle is prolonged by the early onset of spring. Human infections from West Nile Virus become more likely as the population of mosquitoes (that bite both birds and humans) increases.

In temperate regions, mosquito activity is relatively shorter (between spring and autumn season). However, an earlier onset of spring would prolong the cycle, thereby increasing incidence of human infection (Greer *et al.* 2008).

Livestock and agriculture sustainability

Despite their enormous contribution to GHGs, livestock cannot be condemned as the major actors of climate change. We cannot also reach any decision to get rid of their role in farming systems. In fact, ecological contributions of livestock as vital inputs for sustainability in agriculture must be appreciated. In our farming systems, livestock play a role which is so critical for the very sustainability of agriculture. They contribute to the diversification of agriculture, manuring of soils and enrichment of agro-biodiversity. As suppliers of draught power, livestock renders services vital for agricultural operations, such as ploughing, levelling, puddling, inter-culture operations, transport of agricultural produce, etc. which involve no use of polluting sources of energy, i.e. petrol or diesel (Partap and Singh 2002, Singh 1998, Singh and Partap 2002, 2005).

Livestock connect two ecosystems, viz. a forest and an agroecosystem – by allowing nutrient flows from more stable forest ecosystems to more fragile agroecosystems through manure. Further, they help recycle the nutrients of the fodders obtainable from croplands through manure. Thus, they contribute to maintain soil fertility in the agroecosystems. This role of livestock strikes what we call ecological integrity of an agroecosystem (Singh and Bohra 2005, Singh and Gaur 2008, Singh *et al.* 2014), which is a prerequisite and a key to realize sustainability in agriculture.

If a system is ecologically sound, it contributes to enhance carbon sequestration, a phenomenon that counters carbon emission. A livestock-dependent farming system is ecologically sound and sustainable and, therefore, fortifies carbon sequestration into plant biomass and soils.

Mitigation measures

Mellino (2016) curses 'world's meat addiction' for increased GHGs from the livestock sector. The global demand of meat is skyrocketing and intensive animal agriculture is leading to shocking environmental consequences. Earlier Goodland and Anhang (2009) had also warned of increased consumption of animal products. Effective strategy must involve replacing livestock products with better alternatives which would help to reduce at least 12.5% GHG emissions to the atmosphere. Governments of the world must develop policy to impose heavy carbon taxes on meat industry.

Alternative nutritional management practices (Beede and Collier 1986, West 1999) and improvement in rumen efficiency (Moss 1994) would led to significant curtailment on GHG emissions. Diet manipulation, direct inhibitions, feed additives, probiotics, methane oxidizers, propionate enhancers, defaunation and hormones are the parts of many promising nutritional technologies available that help reduce methane production considerably (Moss 1994). Carbon emission reduction potential of these technologies ranges between 6–32% (Sirohi and Michaelowa 2007). Methane reduction is of the order of 15–32%, depending on the ratio of concentrate in ruminants' diet (Singh and Madhu Mohini 1999). As much as 21% methane mitigation from use of additive monensin (De and Singh 2001), 8.7% from urea-mollases supplementation (Srivastava and Garg 2002) and 5.7% through increased green fodder (Singhal and Madhu Mohini 2002) was observed in experiments.

Livestock impact on GHG production can be compensated significantly by transforming livestock production systems into ecologically sound and sustainable systems. The livestock plays a role in enhancing carbon sequestration, turning soils fertile by increasing their carbon contents, and in maintaining nutrient cycles – thus striking ecological integrity of the farming systems.

CONCLUSION

Climate change is likely to have a phenomenal impact on livestock sector, including a big jolt to rural economy based on crop-livestock mixed farming systems, both directly and indirectly. The direct impact would include a stress on the physiology of the animals affecting their ethology and adaptation mechanisms and thereby their production performance.

The indirect climate change impact on livestock sector would emanate from climate change impact on vegetation in forests/rangelands and on croplands. A spurt in pests of various sorts is also very likely with ongoing trends in climate change and warming of the globe which are likely to add to stress on livestock to adversely affect their performance and increase morbidity and mortality in their population. Zoonotic diseases' spread might be of perilous proportions for public health.

There is likelihood that new indicators, which could be referred to as indicators of unsustainability, have emerged during the period of climate change. These indicators could be measured on the basis of oral history, secondary literature and field experience. Livestock linkages with other sectors/ farming system components are also likely to be affected due to warming of the climate. Quantification of the flows through these linkages is feasible and would provide an understanding of the overall performance of the livestock-mediated farming system, especially in mountain areas of the country.

Some more data need to be generated to bridge the gap to assess climate change impact of livestock sector, such as livestock-based production systems and their characteristics; current livestock population and composition; dynamics of livestock population and composition; livestock breeds and their traits, productive and reproductive performance of various species and breeds; livestock linkages in agro-ecosystems—their analysis and quantification; dynamics of change in livestock sector—identification and quantification of negative indicators at resource base, production flows, and management bases over a period of about 40–50 years; livestock adaptation strategies based on local resource base, technologies and institutional policies.

Ways and means to respond to climate change have been existing in the traditional management systems involving livestock as an integral part, which could be identified, augmented and implemented. Further, appropriate strategies involving natural resource management and nutritional technologies vital for enhancing adaptation mechanisms and long-term measures to mitigate climate change could be evolved. We should leave no stone unturned to develop and implement such strategies, which are not only necessary but an imperative of our times.

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