Livestock
Thematic Papers
Tools for project design

Livestock and climate change

Evidence from the Intergovernmental Panel on Climate Change (IPCC, 2007) is now overwhelmingly convincing that climate change is real, that it will become worse, and that the poorest and most vulnerable people will be the worst affected.

The International Fund for Agricultural Development (IFAD) acknowledges climate change as one of the factors affecting rural poverty and as one of the challenges it needs to address.[1]

While climate change 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. Rural poor communities rely greatly for their survival on agriculture and livestock keeping that are amongst the most climate-sensitive economic sectors.

The IPCC predicts that by 2100 the increase in global average surface temperature may be between 1.8° C and 4.0° C. With increases of 1.5° C to 2.5° C, approximately 20 to 30 per cent of plant and animal species are expected to be at risk of extinction (FAO, 2007b) with severe consequences for food security in developing countries.

Responses to climate change include (i) adaptation,[2] to reduce the vulnerability of people and ecosystems to climatic changes, and (ii) mitigation,[3] to reduce the magnitude of climate change impact in the long term. However, neither adaptation nor mitigation alone can offset all climate change impacts. To respond to this threat it will be necessary to focus both on mitigation, to reduce the level of emission of gases contributing to global warming, and on adaptation, to support local communities in dealing with the impacts.

1 The IFAD Strategic Framework 2007-2010 is available on line at www.ifad.org/sf/. For further details consult: "IFAD/GEF partnership on climate change: Fighting a global challenge at the local level" available at www.ifad.org/climate/

2 Adaptation includes all activities that help people and ecosystems reduce their vulnerability to the adverse impacts of climate change and minimize 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: a key player in adaptation to climate change, available at www.ifad.org/operations/gef/climate/ifad_adaption.pdf)

3 Mitigation activities are designed to reduce the sources and enhance the sinks of greenhouses gases in order to limit the negative effects of climate change. (IPCC Fourth Assessment Report: Working Group III.)

IFAD
Enabling poor rural people
to overcome poverty

At present, very few development strategies promoting sustainable agriculture and livestock related practices have explicitly included measures to support local communities in adapting to or mitigating the effects of climate change. Activities aimed at increasing the resilience of rural communities will be needed to raise their capacity to adapt and to respond to new hazards.

At the same time, while small scale agricultural producers and livestock keepers, especially poor farmers, are relatively small contributors to greenhouse gas (GHG)[4] emissions, they have a key role to play in promoting and sustaining a low-carbon rural path through proper agricultural technology and management systems.

This thematic paper analyses some of the key issues linking climate change and development practices in livestock and farming systems.[5] It draws on knowledge gained from IFAD-supported projects and programmes, and documents some of the experiences and the lessons learned in addressing livestock and climate change. The paper also briefly examines the following:

- The effects of climate change on livestock and fisheries.
- Adaptation and mitigation strategies in the livestock sector.
- Livestock and soil carbon sequestration.
- Gender issues in relation to livestock and climate change.

The paper builds on these concepts and strategies to provide recommendations for project design, together with possible solutions promoting both adaptation and mitigation activities in development projects.

The effects of climate change on livestock and fisheries

The possible effects of climate change on food production are not limited to crops and agricultural production. Climate change will have far-reaching consequences for dairy, meat and wool production, mainly arising from its impact on grassland and rangeland productivity. Heat distress suffered by animals will reduce the rate of animal feed intake and result in poor growth performance (Rowlinson, 2008). Lack of water and increased frequency of drought in certain countries will lead to a loss of resources. Consequently, as exemplified by many African countries, existing food insecurity and conflict over scarce resources will be exacerbated.[6] The following sections provide an overview of the effects of climate change on both livestock and fisheries.

The effects of climate change on livestock

In pastoral and agropastoral systems, livestock is a key asset for poor people, fulfilling multiple economic, social and risk management functions. The impact of climate change is expected to heighten the vulnerability of livestock systems and reinforce existing factors that are affecting livestock production systems, such as rapid population and economic growth, rising demand for food (including livestock) and products,[7] conflict over scarce resources (land tenure, water, biofuels, etc). For rural communities, losing livestock assets could trigger a collapse into chronic poverty and have a lasting effect on livelihoods.

The direct effects of climate change will include, for example, higher temperatures and changing rainfall patterns, which could translate into the increased spread of existing vector-borne diseases and macroparasites, accompanied by the emergence and circulation of new diseases. In some areas, climate change could also generate new transmission models.

---

4 The main greenhouse gases are: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N20). Less prevalent but very powerful greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). Further details available online at www.ifad.org/climate/

5 Annex 1 briefly describes how climate change could alter the output potential of agriculture worldwide.

6 See Annex II for more information about the impact of climate change on livestock management in Africa.

7 Globally, livestock products contribute approximately 30 per cent of the protein in human diets (Gill and Smith, 2008), and this contribution is only expected to increase (FAO Stats).

Table 1

Factor	Impacts
Water:	Water scarcity is increasing at an accelerated pace and affects between 1 and 2 billion people. Climate change will have a substantial effect on global water availability in the future. Not only will this affect livestock drinking water sources, but it will also have a bearing on livestock feed production systems and pasture yield.
Feeds:	Land use and systems changes As climate changes and becomes more variable, niches for different species alter. This may modify animal diets and compromise the ability of smallholders to manage feed deficits.[8] Changes in the primary productivity of crops, forage and rangeland Effects will depend significantly on location, system and species. In C4[9] species, a rise in temperature to 30-35° C may increase the productivity of crops, fodder and pastures. In C3[10] plants, rising temperature has a similar effect, but increases in CO_2 levels will have a positive impact on the productivity of these crops. For food-feed crops, harvest indexes will change, as will the availability of energy that can be metabolized for dry season feeding. In semi-arid rangelands where the growing season is likely to contract, productivity is expected to 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. For example, higher CO_2 levels will affect the proportion of browse species. They are expected to expand as a result of increased growth and competition between each other. Legume species will also benefit from CO_2 increases and in tropical grasslands the mix between legumes and grasses could be altered. Quality of plant material Rising temperatures increase lignifications of plant tissues and thus reduce the digestibility and the rates of degradation of plant species. The resultant reduction in livestock production may have an effect on the food security and incomes of smallholders. Interactions between primary productivity and quality of grasslands will require modifications in the management of grazing systems to attain production objectives.
Biodiversity (genetics and breeding):	In some places there will be an acceleration in the loss of the genetic and cultural diversity already occurring in agriculture as a result of globalization. This loss will also be evident in crops and domestic animals. A 2.5° C rise in global temperature would determine major losses: between 20 and 30 per cent of all plant and animal species assessed could face a high risk of extinction. Ecosystems and species display a wide range of vulnerabilities to climate change, depending on the imminence of exposure to ecosystem-specific critical thresholds, but assessments of the effects of CO_2 fertilization and other processes are inconclusive. Local and rare breeds could be lost as a result of the impact of climate change and disease epidemics. Biodiversity loss has global health implications and many of the anticipated health risks driven by climate change will be attributable to a loss of genetic diversity.
Livestock (and human) health:	Vector-borne diseases could be affected by: (i) the expansion of vector populations into cooler areas (in higher altitude areas: malaria and livestock tick-borne diseases) or into more temperate zones (such as bluetongue disease in northern Europe); and (ii) changes in rainfall pattern during wetter years, which could also lead to expanding vector populations and large-scale outbreaks of disease (e.g. Rift Valley fever virus in East Africa). Temperature and humidity variations could have a significant effect on helminth infections. Trypanotolerance, an adaptive trait which has developed over the course of millennia in sub-humid zones of West Africa, could be lost, thus leading to a greater risk of disease in the future. Changes in crop and livestock practices could produce effects on the distribution and impact of malaria in many systems, and schistosomiasis and lymphatic filariasis in irrigated systems. Heat-related mortality and morbidity could increase.

Adapted from Thornton et al., 2008.

8 For example, in parts of East Africa, maize is likely to be substituted with crops more suited to drier environments (sorghum, millet); in marginal arid southern Africa, systems could convert from mixed-crop livestock to rangelands-based systems.

9 C4 plants possess biochemical and anatomical mechanisms to raise the intercellular carbon dioxide concentration at the site of fixation; this reduces, and sometimes eliminates, carbon losses through photorespiration. C4 plants inhabit hot, dry environments and have a very high rate of water-use efficiency, which means that there can be up to twice as much photosynthesis per gram of water as there is in C3 plants. However, C4 metabolism is inefficient in shady or cool environments. Less than 1 per cent of the earth's plant species can be classified as C4.

10 C3 plants, which account for more than 95 per cent of earth's plant species, use rubisco to make a three-carbon compound as the first stable product of carbon fixation. C3 plants flourish in cool, wet and cloudy climates, where light levels may be low, because the metabolic pathway is more energy efficient and, if water is plentiful, the stomata can stay open and let in more carbon dioxide. Carbon losses through photorespiration are high in C3 plants.

These effects will be evident in both developed and developing countries, but the pressure will be greatest on developing countries because of their lack of resources, knowledge, veterinary and extension services, and research technology development.[11]

Some of the indirect effects will be brought about by, for example, changes in feed resources linked to the carrying capacity of rangelands, the buffering abilities of ecosystems, intensified desertification processes, increased scarcity of water resources, decreased grain production. Other indirect effects will be linked to the expected shortage of feed arising from the increasingly competitive demands of food, feed and fuel production, and land use systems.

In a recent paper, Thornton et al. (2008) examined some of the direct and indirect impacts of climate change on livestock and livestock systems. These are summarized in Table 1.

The effects of climate change on fisheries

Climate change represents a threat to the sustainability of capture fisheries and aquaculture development. The consequences of gradual warming on a global scale and the associated physical changes will become increasingly evident, as will the impact of more frequent extreme weather events.

Until recently, production trends in aquaculture and capture fisheries had remained similar to those already in place at the start of the decade. The capture fisheries sector was regularly producing between 90 and 95 million tons per year, and aquaculture production was growing, albeit at a measured pace. However, the substantial increases in energy and food prices, which were first seen in 2007 and continued into 2008, coupled with the threat of climate change, mean that the conditions for capture fisheries and aquaculture are changing.[12]

The effects of increased pressure on fisheries (environmental pollution, environmental degradation resulting from unsustainable aquaculture practices, intensive exploitation of marine resources), together with future climate change, will have a bearing on a very large number of fisheries in different socio-economic and geographical contexts.

Kibuka-Musoke (2007) identifies both positive and negative impacts of climate change on fisheries:

- *Positive impacts*. The projected climate change will generally be positive for aquaculture, which is often limited by cold weather. Since many of the changes will entail warmer nights and winters, there should be longer periods of growth and growth should be enhanced. The cost of making structures ice-resistant and of heating water to optimum temperatures should also be lowered. By developing appropriate technologies, farmers can use flooded and saline areas no longer suitable for crops to cultivate fish. Farmers can also recycle water used for fish culture to moderate swings between drought and flood.
- *Negative impacts.* Climate change will have a negative impact on fisheries both directly and indirectly. Fisheries will be impacted by changing water levels and flooding events; temperature changes will cause a shift in the range of fish species (in different geographical areas) and a disruption to the reproductive patterns of fish. Rising sea levels could also affect important fishery nursery areas. Warming can increase disease transmission and have an influence on marine pathogens. Because of their comparatively small or weak economies, a number of countries that are heavily dependent on fish have low capacity to adapt to change (World Fish Center, 2007). These countries include Angola, Mali, Mauritania, Niger, Senegal and Sierra Leone. Other vulnerable countries in Africa are Malawi, Mozambique and Uganda. Beyond Africa, it is the countries in Asia with river-dependent fisheries, including Bangladesh, Cambodia and Pakistan, that are most at risk.

---

11 The effects of rising temperatures vary, depending on when and where they occur. A rise in temperature during the winter months can reduce the cold stress experienced by livestock remaining outside. Warmer weather reduces the amount of energy required to feed the animals and keep them in heated facilities (FAO, 2007b).
12 FAO, 2008a.

A number of IFAD projects currently promote a more sustainable utilization of fisheries resources and value adding through diversification activities. (See the example of the Republic of Mauritius summarized in case study 1.)

In particular, fishing communities in Africa will be most vulnerable to climate change because of their elevated level of exposure to risk and low adaptive potential. The inland fisheries of Africa play a crucial role in supporting the livelihoods and food security of millions of people across the world: approximately 30 to 45 million people depend on fish for their livelihoods (the World Fish Center, 2007). Fisheries also provide a safety net offering protection against the effects of the unpredictability of agricultural product prices. In this sense, fisheries could, depending on local circumstances, support the adaptation of some coastal communities.

Region-specific ecosystem-based approaches are needed to address the impact of climate change on fisheries and fishing communities. While it is important to have an understanding of both the regional and the global impact that climate change will have on fishing communities in developing countries, it is essential that context-specific vulnerability assessments are carried out to inform the development of locally tailored strategies to support fishing communities in adapting to a changed environment.

Meeting the challenge: adaptation and mitigation livestock strategies

Livestock can play an important role in both mitigation and adaptation. Mitigation measures could include technical and management options in order to reduce GHG emissions from livestock, accompanied by the integration of livestock into broader environmental services. As described in the section below, livestock has the potential to support the adaptation efforts of the poor. In general, livestock is more resistant to climate change than crops because of its mobility and access to feed. However, it is important to remember that the capacity of local communities to adapt to climate change and mitigate its impacts will also depend on their socio-economic and environmental conditions, and on the resources they have available.

The sections below provide a brief overview of adaptation and mitigation activities that could be used in the livestock sector.

Case study 1:
Promoting the sustainable use of fisheries resources
The Rural Diversification Programme in the Republic of Mauritius – IFAD

Over-fishing in lagoons has a destructive effect on the coral reef and the marine life it supports. To increase the incomes of small-scale fishers and relieve pressure on depleting marine resources, the Rural Diversification Programme in the Republic of Mauritius helps provide incentives for fishermen to abandon lagoon fishing. It encourages fishing beyond the lagoon, with small-scale fishers using fish aggregating devices (FADs) to attract fish in deeper seas.

To back up the introduction of FADs, the programme includes training in fishing techniques, boat handling and other safety measures, to assist fishermen in making the transition from net fishing in the lagoon to fishing in the open sea under very different conditions. Women involved in octopus fishing on Rodrigues Island have been trained to fish without damaging the reef, and received assistance in finding alternative income-generating activities. The programme supports the Government in the sustainable management of marine resources and builds the capacity of the Fisheries Training and Protection Services to monitor FAD fisheries and other fishing activities. It also helps build institutional capacity to support poor people's rural enterprises through training, improving access to financial services and strengthening grassroots organizations.

A follow-up programme, the Marine and Agricultural Resources Support Programme (MARS), will continue promoting non-fishing activities to reduce the unsustainable (for the national budget) payment of bad weather allowances to fishermen when they are unable to fish because of weather conditions. This programme is also expected to reduce the strain on fisheries resources, and improve agricultural productivity and food security.

Livestock adaptation strategies

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, urbanization, 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.

The following have been identified by several experts (FAO, 2008; Thornton, et al., 2008; Sidahmed, 2008) as ways to increase adaptation in the livestock sector:

Production adjustments. Changes in livestock practices could include: (i) diversification, intensification and/or integration of pasture management, livestock and crop production; (ii) changing land use and irrigation; (iii) altering the timing of operations; (iv) conservation of nature and ecosystems; (v) modifying stock routings and distances; (vi) introducing mixed livestock farming systems, such as stall-fed systems and pasture grazing.

Breeding strategies. Many local breeds are already adapted to harsh living conditions. However, developing countries are usually characterized by a lack of technology in livestock breeding and agricultural programmes that might otherwise help to speed adaptation. Adaptation strategies address not only the tolerance of livestock to heat, but also their ability to survive, grow and reproduce in conditions of poor nutrition, parasites and diseases (Hoffmann, 2008). Such measures could include: (i) identifying and strengthening local breeds that have adapted to local climatic stress and feed sources and (ii) improving local genetics through cross-breeding with heat and disease-tolerant breeds. If climate change is faster than natural selection, the risk to the survival and adaptation of the new breed is greater (Ibid.).

Market responses. The agriculture market could be enhanced by, for example, the promotion of interregional trade and credit schemes.

Institutional and policy changes. Removing or introducing subsidies, insurance systems, income diversification practices and establishing livestock early warning systems – as in the case of IFAD-supported interventions in Ethiopia (see case study 2), and other forecasting and crisis-preparedness systems – could benefit adaptation efforts.

Science and technology development. Working towards a better understanding of the impacts of climate change on livestock, developing new breeds and genetic types, improving animal health and enhancing water and soil management would support adaptation measures in the long term.

Capacity building for livestock keepers. There is a need to improve the capacity of livestock producers and herders to understand and deal with climate change increasing their awareness of global changes. In addition, training in agroecological technologies and practices for the production and conservation of fodder improves the supply of animal feed and reduces malnutrition and mortality in herds.

Livestock management systems. Efficient and affordable adaptation practices need to be developed for the rural poor who are unable to afford expensive adaptation technologies. These could include (i) provision of shade and water to reduce heat stress from increased temperature. Given current high energy prices, providing natural (low cost) shade instead of high cost air conditioning is more suitable for rural poor producers; (ii) reduction of livestock numbers – a lower number of more productive animals leads to more efficient production and lower GHG emissions from livestock production (Batima, 2006); (iii) changes in livestock/herd composition (selection of large animals rather than small); (iv) improved management of water resources through the introduction of simple techniques for localized irrigation (e.g. drip and sprinkler irrigation), accompanied by infrastructure to harvest and store rainwater, such as tanks connected to the roofs of houses and small surface and underground dams.[13]

13 IFAD, 2009.

Case study 2:

Early warning systems
The Pastoral Community Development Project in Ethiopia – IFAD

The project aims to improve the prospects of achieving sustainable livelihoods among herders living in arid and semi-arid lowlands. It seeks to harmonize the development of Ethiopia's lowlands and its more fertile highlands, and reduce vulnerability to drought and the risk of local conflict.

The first phase of the project (2004-2009) was a response to drought and to the need to create sustainable livelihoods for herders. In partnership with the World Bank, the project established early warning systems and disaster preparedness plans, through a participatory approach to programming, implementation and monitoring. The objective was to strengthen the resilience of the rural poor and increase their ability to cope with external shocks, while making them less vulnerable to drought and other natural disasters, thus indirectly promoting climate change adaptation. Initial activities included strengthening the institutional capacity of indigenous social organizations.

The disaster-preparedness and contingency fund (DPCF) will be created in the second phase, with separate 'windows' for early response and disaster-preparedness investment financing. Through the disaster-preparedness strategy and investment programme (DPSIP) subcomponent, the project will identify local needs for long-term regional disaster-preparedness and mitigation. Under the DPCF, each region will receive DPSIP grants to finance disaster-preparedness investments.

Mitigation of livestock GHG emissions

Unmitigated climate change will, in the long term, exceed the capacity of natural and human systems to adapt. Given the magnitude of the challenge to reduce GHG concentrations in the atmosphere, it is imperative to receive the contribution of all sectors with significant mitigation potential. Agriculture is recognized as a sector with such potential, and farmers, herders, ranchers and other land users could and should be part of the solution. Therefore, it is important to identify mitigation measures that are easy to implement and cost effective in order to strengthen the capacity of local actors to adapt to climate change.[14] The livestock production system contributes to global climate change directly through the production of GHG emissions,[15] and indirectly through the destruction of biodiversity, the degradation of land, and water and air pollution. There are three main sources of GHG emissions in the livestock production system: the enteric fermentation of animals, manure (waste products) and production of feed and forage (field use) (Dourmad et al., 2008). Indirect sources of GHGs from livestock systems are mainly attributable to changes in land use and deforestation to create pasture land. For example, in the Amazon rainforest, 70 per cent of deforestation has taken place to create grazing land for livestock. In general, smallholder livestock systems have a smaller ecological footprint[16] than large-scale industrialized livestock operations.

Mitigation of GHG emissions in the livestock sector can be achieved through various activities, including:

- Different animal feeding management.
- Manure management (collection, storage, spreading).
- Management of feed crop production.

The contribution the livestock sector can make to the reduction of emissions varies. Possible mitigation options include (FAO, 2008b)

Selection of faster growing breeds. Improvements could be made to livestock efficiency in converting energy from feed into production and losses through waste

14 See case study 4 on IFAD activities in Mongolia.

15 According to "Livestock's Long Shadow" (FAO, 2007a). livestock is responsible for 18 per cent of global warming. Livestock contributes 9 per cent of all GHG emissions measured in CO_2 equivalents, 65 per cent of human-induced nitrous oxide (which has 296 times the global warming potential of CO_2), and 20 per cent of methane (which has 23 times the global warming potential of CO_2).

16 The ecological footprint is a means of evaluating human demand on the earth's overall ecosystem. Ecological footprints measure human demand (for energy and air) against the planet's capacity to regenerate resources and provide services. The measurement is based on the area of biologically productive land and sea needed to regenerate the resources consumed by the human population and to absorb and render harmless the corresponding waste.

products can be reduced. Increasing feed efficiency and improving the digestibility of feed intake are potential ways to reduce GHG emissions and maximize production and gross efficiency, as is lowering the number of heads. All livestock practices – such as genetics, nutrition, reproduction, health and dietary supplements and proper feeding (including grazing) management - that could result in improved feed efficiency need to be taken into account.

Improved feeding management. The composition of feed has some bearing on enteric fermentation and the emission of CH_4 from the rumen or hindgut (Dourmad, et al., 2008). The volume of feed intake is related to the volume of waste product. The higher the proportion of concentrate in the diet, the lower the emissions of CH_4 .

Better waste management. Improving the management of animal waste products through different mechanisms, such as the use of covered storage facilities, is also important. The level of GHG emissions from manure (CH_4, N_2O, and CH_4 from liquid manure) depends on the temperature and duration of storage. Long-term storage at high temperatures results in higher GHG emissions. In the case of ruminants, pasture grazing is an efficient way to reduce CH_4 emission from manure because no storage is necessary. It is possible not only to mitigate GHG emissions

Case study 3:
Biogas: an environmentally-friendly alternative energy source – IFAD
The West Guangxi Poverty-Alleviation Project in the People's Republic of China and the Gash Barka Livestock and Agricultural Development Programme in Eritrea

(i) The IFAD-supported West Guangxi Poverty-Alleviation Project (2000-2007) was designed to improve and sustain the livelihoods of poor rural people while rebuilding and conserving natural resources.

The project promoted the use of biogas as a source of household energy within remote communities in West Guangxi where fuelwood is in short supply and rural electricity unavailable. Biogas units can be used to convert human and animal waste into a mixture of methane and carbon dioxide that can be used for lighting and cooking.

Each household received training to build its own plant to channel waste from the domestic toilet and nearby shelters for animals, usually pigs, into a sealed tank. The waste ferments and converts naturally into gas and compost, resulting in improved sanitary conditions at home. The poorest households, with only one pig, built small units that could produce enough gas for lighting in the evening. Households with two or more pigs built larger units capable of producing gas for both cooking and lighting.

The Guangxi project has become a catalyst for other initiatives in the region. To date, 2.73 million biogas tanks have been built in villages, benefiting about 34.2 per cent of the rural households in Guangxi. It is estimated that 7.65 million tons of standard coal and 13.4 million tons of firewood are saved each year in Guangxi through the use of biogas.

The double bonus of energy and compost motivated poor people to adopt this technology in significant numbers. The project provided more than 22,600 biogas tanks serving almost 30,000 households in more than 3,100 villages. As a result, 56,600 tons of firewood can be saved in the project area every year, equivalent to the recovery of 7,470 hectares of forest.

(ii) The IFAD-supported Gash Barka Livestock and Agricultural Development Programme is piloting a household-level biogas plant.

The pilot initiative included the design, construction and installation of the biogas plant, which is now operational. The selected family has several cows kept semi-intensively. The household uses methane gas for cooking and lighting, and digested residues as organic fertilizers in their fields. Current practice dictates that farmers collect animal dung, dry it and burn it as fuel. IFAD and the Government are considering expanding this initiative (once the pilot has been evaluated) to about 150,000 households, provided additional resources are available.

In addition to securing access to cleaner fuel and fertilizers for poor households, IFAD and the Government are looking into the possibility of claiming carbon credits through this project, under the "Clean Development Mechanism" set up by UNFCCC. Participation in the voluntary market for emission reductions is also under consideration.

but also to create an opportunity for renewable energy. (See IFAD-supported activities in China and Eritrea described in case study 3.)[17]

Grazing management. One of the major GHG emission contributions from livestock production is from forage or feed crop production and related land use. Proper pasture management through rotational grazing would be the most cost-effective way to mitigate GHG emissions from feed crop production. Animal grazing on pasture also helps reduce emissions attributable to animal manure storage. Introducing grass species and legumes into grazing lands can enhance carbon storage in soils.

Lowering livestock production and consumption. Lowering the consumption of meat and milk in areas with a high standard of living is a short-term response to GHG mitigation.

Livestock grazing and soil carbon sequestration

Experts[19] have estimated that the soil contains carbon more than twice the quantity in the atmosphere and demonstrated that enhancing carbon sequestration by soils could make a potentially useful contribution to climate change mitigation. The Royal Society (2001) suggested that terrestrial vegetation and soils

Case study 4:

Strengthening pastoralists' resilience and capacity to adapt to climate variability and extremes – IFAD activities in Mongolia[18]

The livestock and natural resource management component of the Rural Poverty Reduction Programme (RPRP) implemented by IFAD in Mongolia was designed to increase livestock productivity, improve rangeland management and strengthen herder resilience to natural calamities. In a country where climate hazards have substantial effects upon animal husbandry and crop production – effects that are clearly increasing in frequency and magnitude as a consequence of global warming – IFAD is building the adaptive capacity of pastoralists through a series of interventions.

The organization of herder groups and Rangeland Management and Monitoring Committees (RMMCs), designated to formulate the local natural resource management maps and associated development plans, has a significant positive impact on pasture and livestock management through the joint decision-making and collaborative management it allows. RMMCs play a key role in representing the interests of herders in the planning and regulation of local land use at the government level. Herder groups and RMMCs are considered of pivotal importance by project beneficiaries and local government in preparing for and responding to natural calamities such as drought and dzud.

Additionally, IFAD assistance in winter fodder production improves preparedness for harsh climatic conditions, thus substantially raising survival rates and livestock performance. The establishment of a dzud emergency fund contributes to enhancing the resilience of herder households and their ability to respond to unusual weather phenomena, thereby mitigating the worst effects on the poorest. Remote unused and underused pasture is now accessible thanks to the rehabilitation and construction of new wells. This strategy allows the use of rangeland that would otherwise be inaccessible in winter and spring, and results in better climate risk management.

The RPRP laid the foundations for increasing the resilience of the ecosystem and herders' livelihood systems to current climate variability and extreme events. However, these measures might not be sufficient to reduce the risks associated with more pronounced climate change.

IFAD is currently developing an intervention funded by the Global Environment Facility and based on the achievements and the lessons from the RPRP by adopting a two pronged approach that focuses on: (i) building the capacity of RMMCs to address climate change and (ii) supporting activities that will allow herders to manage their natural resources and build the resilience of their livestock system in a context of greater vulnerability to climate variability. These activities include: improving natural resource management to take into account climate change impacts; climate-proofing the pasture water supply; and introducing a tailored index-based insurance to better respond to climate change risk in the livestock sector.

17 Concerning the generation of carbon credits through soil conservation initiatives, there is no approved methodology yet by the UNFCCC to calculate the amount of carbon sequestration when sustainably improving the different livestock husbandry systems.
18 IFAD, 2009 (draft).
19 FAO, 2009.

absorb approximately 40 per cent of global CO_2 emissions from human activities.[20]

Considering the importance of rangeland in land use (accounting for about 40 per cent of the total land surface area), herders and pastoralists could play a crucial role in soil carbon sequestration. Across the world there are between 100 million and 200 million pastoralist households occupying 5,000 million hectares of rangelands, in which 30 per cent of the world's carbon stocks are stored (Tennigkeit and Wilkes, 2008). Therefore the carbon sequestration potential offered by environmentally sound rangeland practices is significant.

Global studies have found that grazing can have either a positive or negative impact on rangeland vegetation and soils, depending on the climatic characteristics of rangeland ecosystems, grazing history and effectiveness of management (Milchunas and Lauenroth, 1989). Common grazing management practices that could increase carbon sequestration include: (i) stocking rate management, (ii) rotational, planned or adaptive grazing, and (iii) enclosure of grassland from livestock grazing.

Stocking rate management. Conventional rangeland science suggests that sustainable management of grassland can be achieved by grazing livestock at stocking rates that do not exceed the grassland carrying capacity.

Rotational, planned or adaptive grazing. Many grasslands increase biomass production in response to frequent grazing, which, when managed appropriately, could increase the input of organic matter to grassland soils. However, there have been few studies of the effects of rotational grazing on soil carbon stocks. Two published reports indicate that rotational grazing would have limited impacts on soil carbon stocks, despite the benefits for livestock production and vegetation. Site-specific planned and adaptive grazing is likely to be more effective in managing soil carbon, but no published reports have been identified (Tennigkeit and Wilkes, 2008).

Enclosure of grassland from livestock grazing. The effects of closing off land from livestock grazing vary in relation to the type of land. The Conservation Reserve Program run by the United States Department of Agriculture and the 'Return Grazed Land to Grass' Program in the People's Republic of China are large-scale interventions that support the closing off of degraded grasslands from livestock grazing for given periods of time.

Grazing intensity should be properly regulated to enhance carbon sequestration. It is important to note that methane emissions, grazing intensity and increase in woodland cover are all interrelated issues. Therefore GHG emissions should be considered in conjunction with carbon sequestration when analysing the impacts of livestock on GHG emissions and climate change. It has been suggested (FAO, 2009b) that a sustainable livestock distribution could be operated, including a rotational grazing system combined with a seasonal use of land. The proposal is based on the hypothesis that a reduced grazing intensity would result in increased soil carbon stocks.

However, Gifford (FAO, 2009a,b) demonstrates that the situation is more complex and the interaction among these elements is not entirely linear for the following four reasons:

- The woody component has high above-ground carbon stocks and high deep-soil carbon stocks.
- Wildfires contribute to the loss of carbon stocks.
- The reduction in grazing land for native herbivores can be partially offset by the expanding population of unmanaged herbivores (e.g. kangaroos in Australia).
- Floods and desert storms contribute to the shifting of vast quantities of topsoil characterized by high carbon stocks.

Given the complexity of the interaction between grazing and soil carbon sequestration and the associated environmental, social and economic issues, therefore, reducing grazing intensity does not necessarily imply an increase in soil carbon stocks.

When analysing the effect of grazing on rangeland carbon stocks, the following three factors should be taken into account:

- Overgrazing does not mean soil degradation; the two terms should not be confused or considered as synonyms.

---

20 The same study estimated that the global stocks of carbon in above ground vegetation amount to about 550 petagrams (pg), 1,750 pg in the soil (including peat) and about 800 pg in the atmosphere. Further details are available at www.royalsoc.ac.uk

- Overgrazing can contribute both to an increase in ecosystem carbon stocks (e.g. from wood thickening) and to a decrease in soil carbon stocks (i.e. soil degradation).
- There is a weak basis for estimating carbon sequestration potential from grazing: few data exist on the impact of changed grazing intensity on soil carbon stocks.

Finally, Conant (2002) demonstrates that grazing management drives change in soil carbon stocks by influencing the balance between what goes into the soil (inputs) and what comes out of it (outputs): effective livestock management systems that adopt better feeding practices and use specific agents and dietary additives have a positive effect on food security (enhancing productivity and meat quality) and soil carbon stocks.[21]

Gender issues considered in relation to livestock and climate change

While it is not within the scope of this paper to address gender issues in detail, it is important to note that climate change will create different opportunities and challenges for men and for women. In many countries the role of women in livestock production systems is significant. In general, women are often responsible for most livestock nurturing activities and play an active role in on-farm livestock duties such as feeding, watering, fodder collecting, stable cleaning, milking and milk processing, caring for small and sick animals, poultry raising, wool work and traditional animal health care. Men are generally responsible for marketing, shearing, animal feed purchasing, procuring veterinary services, and herding. While men's tasks are seasonal, most women's tasks are daily (Nassif, 2008).

Women are already affected by several issues that make them more vulnerable to food insecurity and environmental change, and have a bearing on their capacity to reduce poverty. FAO (2007c) recognized that the following key issues have an impact on women: i) denial of land rights and land tenure security, ii) biased government attitude towards women, iii) lack of access to information and new knowledge, iv) lack of credibility and access to market and financial services, v) very limited share of political power and presence in lobbies, and vi) lack of opportunity for their voice to be heard.

Climate change is likely to intensify existing inequalities and have different effects on the capacity of women and of men to cope with additional stresses. In view of their role as the most significant suppliers of family labour and efficient managers of household food security (IFAD, 2009), more emphasis needs to be placed on ensuring that any adaptation and mitigation strategies developed take into account these differences and the increased needs of women. Supporting the empowerment of women is a means of building community resilience to climate change (IFAD, 2009).

Key issues for project design

The previous sections explored some of the key issues linking livestock and climate change. The following have been identified as key elements that should be taken into account to support the design of development interventions:

- *Collaborative management of natural resources.* Participatory approaches to sustainable management of land, forest and natural resources are essential to the development of long term sustainable strategies. Decision making processes should be designed in such a way that they include all concerned stakeholders (farmers, pastoralists, herders).
- *Community involvement in adaptation strategies.* Successful adaptation strategies cannot be developed in isolation. Community involvement in the identification of new solutions is key to ensuring the long-term sustainability of interventions. At the same time, adaptation strategies need to take into account cross-cutting issues (e.g. environment, health, social factors such as increased migration, conflict).
- *Incentives and tailored responses.* Financial incentives and regulations for improving natural resource management and livestock production systems through proper pasture and land management, in addition to feeding management, can be used to encourage GHG mitigation and adaptation. The introduction of tailored

21 Conant and Paustian, 2002.

index-based insurance schemes and rural finance initiatives is important in helping livestock keepers cope better with climate change risks.

- *Subsidies.* When subsidies or other such incentives are incorporated into development activities, their possible effects need to be carefully considered. While in some instances (for example, promoting the introduction of heat-resistant breeds and subsidizing vaccinations to reduce vulnerability to new diseases) they could support adaptation strategies, in others incentives could negatively affect adaptation and mitigation strategies.
- *Risk management mechanisms.* Proper risk management mechanisms and preparedness measures need to be put in place to cope with the impacts of more frequent and extreme climatic events. Preparedness measures, early warning systems and other risk mitigation activities (such as strengthening infrastructures, insurance systems and forecasting) are needed to reduce the impact of severe weather events and prevent loss of livestock.
- *Awareness and education.* Information about climate change is a crucial component of adaptation. It is important to ensure that knowledge is shared with local communities. An understanding of the patterns of variability of current and projected climate and seasonal forecasts is essential in anticipating shocks and losses, and in enabling external agencies to provide targeted assistance to herders.
- *Mitigation.* Efforts to support measures to mitigate GHG emissions should focus on reforestation, improved grazing management, restoration of degraded lands, livestock manure management, better feeding management, improved energy and feed efficiency, selection of more productive animal breeds, and transhumance practices.
- *Innovation, research and technology development.* Promoting the development of and improved access to technologies, and sharing knowledge of sustainable and climate friendly farming practices is vital. Country-specific research is needed to inform the development of adaptive strategies. To increase the resilience of developing countries, there needs to be a sharper focus on 'the development of improved crop varieties and animal breeds, as well as more sustainable and integrated management of crops, animals and the natural resource base that sustain their production, while providing other vital services for people and the environment' (IFAD, 2009).
- *Gender dimension.* Adaptation and mitigation strategies should consider the different roles of women and men and how they will be affected by climate change. Climate change clearly offers an opportunity to rethink gender inequality and to involve both women and men in finding innovative solutions to common environmental challenges.
- *Indigenous knowledge.* Local communities and indigenous peoples have an in-depth understanding of their environment and a vast experience in adapting to climate variability. This knowledge is key to the development of effective adaptation and mitigation strategies.

Annex I
Climate change and agriculture

Over a billion people worldwide live in extreme poverty, and three quarters of them are in rural areas. Agricultural production based on natural resources is the main source of livelihood for more than 800 million malnourished and food-insecure people. Agriculture is therefore the main instrument to be used in lifting the rural poor out of poverty in developing countries. In many rural communities, livestock is often the only asset the poor have, but it is also highly vulnerable to climate variability and extremes.

There is significant evidence of increased global average air (by 0.7° C) and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (by 25 cm). Human activities result in the emissions of four long-lived greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and halocarbons. The global increase in carbon dioxide concentrations is primarily due to the use of fossil fuels (IPCC, 2007).

While climate change is a global phenomenon, its negative impacts are more severely felt by poor people in developing countries. Although agricultural producers, especially small-scale poor farmers, are relatively small contributors of GHG emissions, proper agricultural technology and management systems are crucial to promote and sustain a low-carbon rural path. Livestock production will not be excluded from the impact of climate change. Approximately 20-30 per cent of plant and animal species are expected to be at risk of extinction if increases in global average temperature exceed 1.5-2.5° C (FAO, 2007). As a result of climate change, the potential for food production is projected to decrease because of high mortality, less productivity and more competition for natural resources. Globally, this would then increase the risk of hunger, especially for those in poor rural communities.

In addition to the changing climate, there are many other factors simultaneously affecting livestock production systems, such as rapid population and economic growth, and increased demand for food (including livestock products). Globally, livestock products contribute approximately 30 per cent of the protein in human diets (Gill and Smith, 2008), and this contribution is only expected to increase (FAO Stats). How livestock keepers can take advantage of the increasing demand for their products and how the livestock assets of the poor can be protected in the face of globalization and climate change is uncertain.

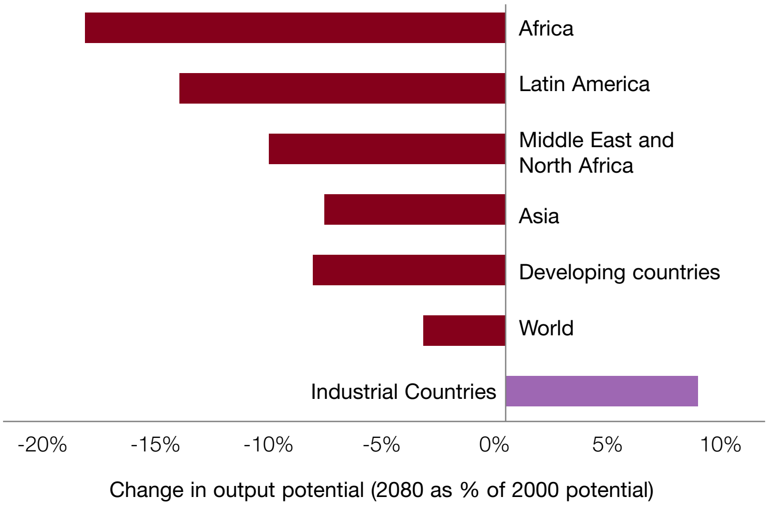
Climate change impacts on agriculture are expected to be predominantly negative. Also, the impacts of climate change on agricultural production and livestock are difficult to measure and distinguish from other changes occurring in the natural and human environment. There are many non-climatic drivers that are interconnected with climate change impacts, such as migration, overgrazing of pasture, change in livestock management, and change in human and livestock population.

The following are the main characteristics of climate change impacts on rural livelihood and agriculture systems:

- *Distribution of impacts and vulnerabilities*. Impacts differ across regions and continents. Those in the weakest economic position are often the most vulnerable to climate change. There is increasing evidence of greater vulnerability among the poor and the elderly in developing countries. According to the Department for Environment, Food and Rural Affairs (DEFRA) of the United Kingdom, climate change threatens about 850 million poor people as a result of the increasing limitation of natural resources for food production and the extinction of animals through climate disasters and disease.
- *Aggregate impacts*. Collectively, the effects of climate change produce a greater impact. For example, warmer temperatures will bring about the extinction of animal species through heat stress, which in turn will lead to reduced food diversity and a shortage of food production. Increased malnutrition and other adverse health impacts will then follow.

Figure 1

Change in agricultural output potential due to climate change: 2000-2080



Source: World Resources Institute (2007)

- *Risk of extreme weather events*. The increased frequency of events such as hurricanes, tornadoes, droughts and flooding is likely to result in higher vulnerability in both developing and developed countries. However, the impact on fragile states will be greater.

Contribution of agriculture to climate change
Although the contribution to climate change of gas emissions from agricultural sources appears to be proportionally lower than emissions from fossil fuel use, according to the IPCC Fourth Assessment Report, by 2020 sub-Saharan Africa, the Middle East and North Africa are expected to experience emission growth. For the most part, this will be the result of agriculture being intensified and extended to marginal lands to satisfy a higher food demand.

In East and South Asia, rapid population and economic growth will entail lifestyle changes and a shift in diet, particularly towards more meat consumption, which in turn will require more livestock. Therefore, according to the IPCC, animal sources (enteric fermentation and manure management) are expected to be one of the major causes of non-CO_2 emissions in the region.

According to FAO, by 2030 it is estimated that rice production will have increased by only 4.5. per cent (IPCC, 2007); methane emissions from this sector are not expected to represent a major threat in the coming years.

In Latin America and the Caribbean emissions of CO_2 and N_2O, in particular, are expected to increase because of possibly extended land use, changes in land use activities, the growing size of cattle populations and greater user of fertilizers in cropland areas.

Estimated contributions from agricultural sources are listed below (FAO, 2006).

- CO_2: 25 per cent from natural resource sources (20 per cent – deforestation; 5 per cent - biomass burning).
- CH_4: 70 per cent from anthropogenic sources (20 per cent - domestic ruminants; 20 per cent - biomass burning; 20 per cent - rice production/wetlands; 10 per cent - other waste products).
- N_2O: 75 per cent from crop production sources (44 per cent - tillage; 22 per cent - fertilizer; 9 per cent - biomass burning).

It follows that sustainable agricultural systems can be used to encourage both adaptation and mitigation of climate change.

Annex II

The impact of climate change on livestock management in Africa

(Seo and Mendelsohn, 2006)

The African continent is subject to drought and food insecurity. Even before climate change issues became evident, serious concerns had been raised about agriculture in Africa, which has the slowest rate of productivity increase in the world. Nevertheless, agriculture remains the backbone of most African economies (Hussein, Calvosa and Roy, (2008). The sector is the largest domestic producer across the continent and employs between 70 and 90 per cent of the total labour force. In addition, agriculture supplies up to 50 per cent of household food requirements and up to 50 per cent of household incomes. Most of the income is generated by beef cattle, dairy cattle, goats, sheep and chickens. Altogether these five animals generate 92 per cent of the total revenue from livestock.

A model has been developed to study the sensitivity of African animal husbandry decisions to climate (Seo, S. and Mendelsohn, R., 2006). A survey of over 5,000 livestock farmers in ten countries reveals that the selection of species, the net income per animal, and the number of animals on a farm are all highly dependent on climate. As climate warms, net income across all animals will fall, but especially across beef cattle. The fall in relative revenues also causes a shift away from beef cattle towards sheep and goats.

In general, all species will be adversely affected by warming and there will be fewer animals per farm as a result. Beef cattle are especially vulnerable. Climate change is expected to determine a decrease in beef cattle and an increase in sheep and goats. Consequently, it is anticipated that farmers will switch from beef cattle as temperature rises. The net profitability of livestock will be reduced and farmers will reduce their investments in livestock accordingly. Many climate change predictions suggest that African livestock will be damaged as early as 2020. Even small changes in temperature will be sufficient to have a relatively substantial effect on beef cattle operations, which potentially could lead to protein deficiency or other health issues. In contrast, 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. In these circumstances, smallholder farmers in Africa are better able to adapt to climate change than their larger, more modern counterparts.

Precipitation also plays an important role in climate change. Scenarios with less precipitation are predicted to be less harmful. Although pasture and ecosystems are more productive with more precipitation, lower precipitation may help reduce animal diseases that are quite significant for livestock in Africa. As long as there is sufficient moisture to support grasslands, a reduction in precipitation from high to moderate levels appears to be beneficial for livestock. Increasing precipitation results in a lower probability of beef cattle, dairy cattle and sheep being selected and a higher probability of goats and chickens being chosen.

Farm size can shape the way farmers respond to climate change. Smallholder farmers are diversified, relying on dairy cattle, goats, sheep and chickens, while large scale farmers specialize in dairy and especially beef cattle. As a result of climate change, large-scale farmers are likely to shift away from beef cattle and chickens in favour of dairy cattle, sheep and goats. Owners of commercial livestock farms are more able to adapt to warming or precipitation increases by switching to heat-tolerant animals and crops. Livestock keeping will be a safety valve for smallholder farmers if warming or drought causes their crops to fail.

Acknowledgments

This paper has benefited from inputs and materials provided by: S.Mwanundu (IFAD), I.Firmian (IFAD), S.Donato (IFAD/GECC), A.Benhammouche (IFAD) and E.Oehninger (IFAD).

Responsibility for its content rests entirely with the authors and does not necessarily reflect the position of the International Fund for Agricultural Development.

References

AIACCC – Mongolia Government, GEF, UNEP, 2006. *Final Report for Assessment of Impacts and Adaptation to Climate Change*, Project No: 06.

Allison, H. E., Adger, W. N., Badjeck, M., Brown, K., Conway, D., Dulvy, N.K., Halls, A., Perry, A., and Reynolds, J.D., 2005. *Effects if Climate Change on the Sustainability of Capture and Enhancement Fisheries Important to the Poor: analysis of the vulnerability and adaptability of fisherfolk living in poverty*. Fisheries Management Science Programme Department for International development, University of East Angela.

ANSP, *Climate Change in Mongolia*.

ARD, 2008. *Generating Global Public Good to Promote Sustainable Pro-poor Growth in the Livestock Sub-Sector*.

Batima, P., 2007. *Climate change vulnerability and adaptation in the livestock sector of Mongolia*. Assessments of impacts and adaptations to climate change. International START Secretariat, Washington DC, US.

Brooks, N., 2006. *Climate Change, Drought and Pastoralism in the Sahel*. Discussion note for the World Initiative on Sustainable Pastoralism.

Cohen, R.D.H., Sykes, C.D., Wheaton, E.E. and Stevens, J.P., 2002. "*Evaluation of the effects of Climate Change on Forage and Livestock Production and Assessment of Adaptation Strategies on the Canadian Prairies*". University of Saskatchewan, Saskatoon.

Conant R.T. and Paustian K. 2002. Spatial variability of soil organic carbon in grasslands: implications for detecting change at different scales. In Environmental Pollution 116: pp. 127-135.

Dourmad, J., Rigolot, C., and Hayo van der Werf, 2008. *Emission of Greenhouse Gas: Developing management and animal farming systems to assist mitigation*. Livestock and Global Change conference proceeding. May 2008, Tunisia.

FAO, 2009a. *Enabling agriculture to contribute to climate change mitigation*. FAO, Rome.

FAO, 2009b. *Carbon sequestration in grasslands: technical, economic and policy issues*. Draft briefing paper. FAO, Rome.

FAO, 2008a. *The state of world fisheries and aquaculture*. FAO, Rome.

FAO, 2008b. *Climate-related Transboundary Pests and Diseases Including Relevant Aquatic Species*. Expert meeting, FAO. February, 2008.

FAO. 2007a. *Livestock's Long Shadow: environmental issues and options*. FAO, Rome.

FAO. 2007b. *Adaptation to Climate Change in Agriculture, Forestry, and Fisheries: perspective, framework and priorities*. FAO, Rome.

FAO, 2007c. Report on Evaluation of the FAO Emergency and Rehabilitation Assistance in the Greater Horn of Africa

FAO. 2005-2008. *Issues Fact Sheets - Fisheries and global climate change*. Text by John Everett and S.M. Garcia. In FAO Fisheries and Aquaculture Department [online]. Rome. Updated 27 May 2005. [Cited 15 Oct 2008].

Gill, M. and Smith, P., 2008. *Mitigating Climate Change: the role of livestock in agriculture*. Livestock and Global Change conference proceeding. May 2008, Tunisia.

Gommes, R. and Fresco, L.O., *Everybody Complains About Climate: what can agricultural science and the CGIAR do about it?*. FAO, Rome.

Hanson, J.D., Baker, B.B., and Bourdon, R.M., 1993. *Comparison of the Effects of Different Climate Change Scenarios on Rangeland Livestock Production" Agricultural Systems*. V. 41, p. 487-502.

Hatfield and Jonathan Davies, 2006. *Global Review of the Economics of Pastoralism* IUCN, Nairobi, 2006.

Hoffmann, I. 2008. *Livestock Genetic Diversity and Climate Change Adaptation*. Livestock and Global Change conference proceeding. May 2008, Tunisia.

Holdren P. John, 2008. *Meeting the Climate-Change Challenge*. Washington DC.

Hussein, K., Calvosa C., Roy R. and the Global Environmental Facility Unit/IFAD, 2008. *The Effects of Climate Change on Small Holder Farmers in West and Central Africa*. Published for the 10th Meeting of the Africa Partnership Forum, April 2008, Tokyo, Japan.

id21 Insights. V.72, Feb 2008.

IFAD, 2009. (Draft) *Comprehensive Report on IFAD's Response to Climate Change Through Support to Adaptation and Related Actions*

IFAD, 2008a. *Making Difference in Asia and the Pacific*. IFAD, Feb 2008.

IFAD, (Text by Rota A., Calvosa C.). 2008b. *Livestock and Farming System:* learning note.

IFAD, 2007. *West Guangxi Poverty-Alleviation Project*
http://operations.ifad.org/web/ifad/operations/country/project/tags/china/1153/project%20overview

IFAD, 2004. T*he Pastoral Community Development Project in Ethiopia*.
http://operations.ifad.org/web/ifad/operations/country/project/tags/ethiopia/1237/project%20overview

IFAD, 2002. *The Gash Barka Agricultural and Livestock Programme*.
http://operations.ifad.org/web/ifad/operations/country/project/tags/eritrea/1097/project%20overview

IFAD, 2000. *The Mauritius Rural Diversification Programme*
http://operations.ifad.org/web/ifad/operations/country/project/tags/mauritius/1093/project%20overview

IFAD, Rural Poverty Knowledge Base: Livestock and Rangeland Knowledgebase. www.ifad.org

ILRI, 2008. *Women and Livestock: Global Challenge Dialogue*.

IPCC, 2001. *Climate Change*.

IPCC, 2007. Fourth Assessment Report.

Kibuka-Musoke, D., 2007. Issue paper II. African Partnership Forum, OECD.

Lancelot, R., La Rocque, S., and Chevalier, V., 2008. *Bluetongue and Rift Valley Fever in Livestock: a climate change perspective with a special reference to Europe*, the Middle East & Africa. Livestock and Global Change conference proceeding. May 2008, Tunisia.

Maldhari J.A., 2008. *The Gender Issues in Pastoralism Trends and Capacity Building*. Presented by Pastoral People's Movement of India. MARAG.

Milchunas,D. and Lauenroth, W. 1989. *Quantitative effects of grazing on vegetation and soils over a global range of environments*. In Ecological Monographs 63, Vol. 4: 328-366.

Nassif, F. 2008. *The Gender-Livestock-Climate Change connection: local experiences and lessons learned from Morocco*. Presentation at the Livestock and Global Climate Change conference, Hammamet, Tunisia. BSAS, 2008.

Nori, M. and Davies J. 2007. *Change of Wind or Wind of Change: Climate Change, adaptation and pastoralism*. IUCN, Nairobi 2007.

Punsalmaa B., 2006. *Climate Change Vulnerability and Adaptation in the Livestock Sector of Mongolia*. AIAAC, project No. AS06. Washington, USA.

Rowlinson, P., 2008. *Adapting Livestock Production Systems to Climate Change – Temperate Zones*. Livestock and Global Change conference proceeding. May 2008, Tunisia.

Royal Society, 2001. *The role of land carbon sinks in mitigating global climate change*. Policy document 10/01.

Seo, S. and Mendelsohn, R., 2007. *An Analysis of Livestock Choice: adapting to climate change in Latin American farms*. World Bank Policy Research Working Paper No. 4164.

Seo, S. and Mendelsohn, R., 2006. *The Impact of Climate Change on Livestock Management in Africa: a structural Ricardian analysis*. CEEPA Discussion Paper No. 23, Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Sidahmed, A. 2008. *Livestock and Climate Change: Coping and Risk Management Strategies for a Sustainable Future*. In Livestock and Global Climate Change conference proceeding, May 2008, Tunisia.

Silbyl N. and Yianna L., 2007. *People-Centred Climate Adaptation: Integrating gender issues*. FAO, Rome.

Skinner, R.H., 2008. *High biomass removal limits carbon sequestration potential of mature temperate pastures*. In Journal of Environmental Quality, Vol. 37, 1319-1326.

Tennigkeit, T. and Wilkies, A. 2008. *Carbon finance in Rangelands*. ICRAF.

Thornton P. and Herrero M., 2008. *Climate Change, Vulnerability, and Livestock Keepers: Challenges for Poverty Alleviation*. In Livestock and Global Climate Change conference proceeding, May 2008, Tunisia.

Thornton P., Herrero M., Freeman A., Mwai O., Rege E., Jones P., and McDermott J., 2008. "*Vulnerability, Climate Change and Livestock – Research Opportunities and Challenges for Poverty Alleviation*". ILRI, Kenya.

Thornton PK, Jones PG, Owiyo T, Kruska RL, Herrero M, Kristjanson P, Notenbaert A, Bekele N and Omolo A, with contributions from Orindi V, Otiende B, Ochieng A, Bhadwal S, Anantram K, Nair S, Kumar V and Kulkar U. 2006. *Mapping Climate Vulnerability and Poverty in Africa*. Report to the Department for International Development, ILRI, Nairobi. p.171.

Tietjen, B. and Jeltsch, F., 2007. *Semi-arid Grazing Systems and Climate Change: a survey of present modelling potential and future needs*. In Journal of Applied Ecology, V.44, p. 425-434.

Turnpenny, J.R., et al. 2001. *Integrated models of livestock systems for climate change studies. 2. Intensive systems.* Global Change Biology. V7, p. 163-170.

UNEP and UNFCCC, 2003. *Climate Change: information kit*. July, 2003.

Watson, B. 2008. *Climate Change: An environmental, development and security issue*. Livestock and Global Change conference proceeding. Tunisia.

Wit de J., Oldenbroek, J.K., Kulen van H., and Zwart, D., 1995. *Criteria for Sustainable Livestock Production: a proposal for implementation*. Agriculture, Ecosystems and Environment., V.53: p.219-229.

Wood, C. and Knipmeyer, C.K., 1998. *Global Climate Change and Environmental Stewardship by Ruminant Livestock Producers*. National Council for Agricultural Education, USA.

World Bank, 2007. *Climate change adaptation in Africa: a microeconomic analysis of livestock choice*. World Bank Policy Research Working Paper No. 4277, July 2007.

World Fish Center, 2007. *Fisheries and aquaculture can provide solutions to cope with climate change*. Issues brief, 1701.

World Resources Institute. 2007. *EarthTrends: Environmental Information.* Available at http://earthtrends.wri.org . Washington DC: World Resources Institute.

Contact
Antonio Rota
Senior Technical Adviser on
Livestock and Farming Systems
Technical Advisory Division
Tel: +39 06 5459 2680
a.rota@ifad.org

Authors
Chiara Calvosa
Consultant,
Technical Advisory Division
c.calvosa@ifad.org

Delgermaa Chuluunbaatar
Associate Technical Adviser
Technical Advisory Division
d.chuluunbaatar@ifad.org

Katiuscia Fara
Project Coordinator,
Environment and NRM
Technical Advisory Division
k.fara@ifad.org

International Fund for
Agricultural Development
Via Paolo di Dono, 44
00142 Rome, Italy
Telephone: +39 06 54591
Facsimile: +39 06 5043463
E-mail: ifad@ifad.org
www.ifad.org
www.ruralpovertyportal.org

These materials can be found on IFAD's
website at www.ifad.org/lrkm/index.htm

November 2009