  

The role of Small-Scale Livestock Farming in Climate Change and food security

THE ROLE OF SMALL-SCLAE LIVESTOCK FARMING IN CLIMATE CHANGE AND FOOD SECURITY

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Foreword

This study was conducted as part of the Development Education Project AP UE DCI-NSA ED/2010/247, co-funded by the European Commission. The program is being deployed between 2011-2013 in five countries, by as many members of the VSF-Europa network, namely: Agronomes et Vétérinaires Sans Frontière (France), SIVTRO (Italy), VSF Belgium, VSF Czech Republic and VSF Norway.

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The initiative aims to sensitize students, general public, farmers and policy makers to the importance of Small Scale Livestock Farming in the context of climate variability. The study shows that small-scale livestock farming has the potential to adjust to climate change, especially in some specific regions of the world. Moreover, due to its specific functions, small-scale farming can be considered as an important way to mitigate carbon emissions from the whole livestock sector.

This study can be considered as a take-off for a campaign that will run for over 3 years and will raise the awareness of and mobilize support for small-scale livestock farming.

The original text was slightly changed by the editors. Its full version is available for download at ***www.smallscalefarming.org***

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Executive Summary

Since the FAO Livestock's Long Shadow Report in 2006, there has been mounting research on the role of livestock in food security, the growth in the livestock sector, and its impact on climate change (CC). As of 2000, the livestock sector has been estimated to account for 18% of man-made GHG emissions.

Other authors instead suggest that this value is largely underestimated, as livestock production seems to make up 51% of total GHG emissions. In any case, the livestock sector is a major contributor of GHG emissions and therefore one of the targets of any mitigation policy. In addition, the livestock sector absorbs 58% of direct human appropriation of biomass, 70% of agricultural land (from which 33% is designed to feed crop production) and 30% of land globally. Unfortunately, only few attempts were made to address the issue of livestock and CC, and differentiate within it different categories of livestock farming systems, so to inspire specific policy measures to deal with these farming systems according to their different category.

This report aims at contextualizing the role small-scale livestock farming (SSLF) plays in the CC debate and at highlighting its potential contribution to food security. The two major hypotheses arising from the study are: **a.** SSLF can contribute to CC mitigation and needs to be integrated into the difinition of policy measures; **b.** actions taken by local communities, mostly based on traditions and local knowledge, can serve as a reliable set of CC mitigation measures while contributing to global food security. The questions the report tries to address can be summarized as follows: **(i)** how sustainable are small-scale livestock farming systems and can they contribute to CC mitigation; **(ii)** how efficient are SSLF practices in producing animal source foods needed by growing population and in responding to future food security challenges; **(iii)** how successfully SSLF communities have traditionally adjusted to climate variability and how their strategies can help better respond to CC. As part of the report we will illustrate how SSLF, and more specifically pastoralism, fit into the new solutions.

To address the above issues, the report provides a new categorization of livestock production systems, going beyond conventional categories. Our attempt is to integrate the classification process with livestock farming systems' multiple inputs and to link the above process to each type of production system, so as to add a food system approach to the categories. Subsequently the report critically reviews the existing literature on livestock production and mitigation alternatives. Finally, based on four case studies, it presents the adaptation measures undertaken by small-scale livestock farming communities in Turkana (Kenya), Alaotra Lake (Madagascar), Khar-o-Touran (Iran) and Huancavelica (Peru), and illustrates key socio-economic drivers that intensify CC's effects and undermine their adaptation capacity.

Categories of livestock farming

It is well known that livestock farming is one of the highest contributors to GHG emissions. However livestock farming can be practiced in multiple ways. In this report, we propose three main categories of livestock farming: small-scale livestock farming (SSLF), which includes pastoralism, small ranching, backyard pig and poultry production, and small mixed farming (both irrigated and rain-fed); medium-scale livestock farming (MSLF) with the highest variability of farming types, including large ranching and large mixed farming (both irrigated and rain-fed); and finally, large-scale livestock farming

(LSLF) mainly consisting in landless industrial production. The classification is made on the basis of four variables, namely: farm **size**, use of **external inputs**, use of **land**, and the most typical **supply market** the farm has access to.

The SSLF approach is applied holistically to specific socioecological contexts. Its main objective is to evaluate the resilience of the system. The system is characterized by small farms, limited use of inputs, primary role of extensive grazing and by supplying mostly local and informal markets. The MSLF approach is more reductionist as it is focused on the farm or on the animal. Its main objective is to optimize the system productivity. It is characterized by medium-scale farms, moderate use of inputs and prevailing use of arable land, with access to local, regional and global markets. The LSLF approach is based on economies of scale, under chrematistic premises. Its main objective is the expansion of the system. It is characterized by large-scale farms, use of large amount of inputs and no direct use of land, with more access to global markets. The distinction between these categories is crucial since they show radically different contributions to the climate issue.

SSLF is the livestock system that competes least for human food, given its dependence primarily on grazing and scavenging. Pastoralism is practiced on 25% of the global land. Some communities practice mobile grazing, others are sedentary, although generally depending on communal grasslands. Ranchers who keep animals extensively on rangelands, are found in temperate zones where high-quality grassland and fodder production can support larger numbers of animals. These areas include parts of Europe, North America, South America, parts of Oceania and some parts of the humid Tropics. In this case animals are almost exclusively kept for income, and the land tends to be their property. Another subgroup of SSLF, largely spread among peri-urban farms, is backyard pig and poultry production, where livestock is fed through crop residues and scavenging. This system is characterized by being very efficient in recycling residues. According to some estimation, scavenging poultry can provide a 600% return on a minimum investment. More than 90% of rural families in most developing countries keep one or more poultry species. Finally, mixed farming systems are those SSLF systems where cropping and livestock rearing are more closely linked together. Rain-fed mixed farming systems are found in temperate regions of Europe and Americas and sub-humid regions of tropical Africa and Latin America.

They are mostly characterized by individual ownership, often with more than one species of livestock. Irrigated mixed farming systems prevail in East and South Asia, mostly in areas with high population density. Most of small-scale mixed livestock keepers undertake other gainful activities to guarantee their livelihoods. As in the case of pastoralism, backyard pig and poultry production, small ranching, and small mixed farming, are similarly characterized by the high multifunctionality of livestock – draught power, manure, pest control, crop residues, etc. In total, SSLF and MSFS together produce 83% of beef meat, 99% of mutton, 45% of pork, 28% of poultry meat and 39% of eggs. Thus, their importance in terms of quantity is considerable, mostly in the case of ruminants.

Despite the importance of SSLF and MSLF, in the last few decades, a significant shift has been reported in livestock production, away from a local multi-purpose activity (SSLF and MSLF) more into market-oriented livestock production systems (LSLF) located close to urban centres. This shift is combined with a sharp increase in cereal-fed monogastric livestock species and a decrease in ruminants.

Pastoralism, with ruminants in grasslands, backyard pig and poultry production, with scavenging monogastrics, and small mixed livestock farming, with ruminants fed with crop residues, are efficient and sustainable methods of providing high-quality proteins with minimal environmental impacts, by relying on grasslands and residues. These small livestock keepers leave insignificant environmental footprints in terms of inputs.

SSLF, food security and CC

In terms of SSLF capacity in producing animal source foods for a growing population, the first question that needs to be raised is whether or not an increase in animal production is indeed required. In fact, some authors suggest that the present increase in animal source food production is supply-driven rather than demand-driven, triggered by a combination of supply increments, fostered by multilateral organizations in developing countries, and favoured by the externalization of environmental and social costs, a mix that in the end affects both product prices and consumer habits. In addition, such supply-driven increase in livestock production is causing health, environmental and social problems, consequently disempowering both producers and consumers at the same time. Accordingly, a growing number of authors claim the need to reduce the amount of meat consumed, particularly in rich countries. A redistribution of livestock consumption from food surplus to food deficit regions could produce human health and environmental benefits. Hence, in order to question properly the capacity of SSLF systems to feed the world, we should consider that the projected increase in production of animal source food may be based on wrong assumptions (i.e., to be solely demand-driven), and that it may not be desirable from a human health perspective, not from an ecosystem and social health one. However it is clear that the issue of food security needs to be integrated into a wider perspective where other social and environmental drivers and outcomes are addressed along with it.

Consequently, it seems no longer acceptable to address the world future demand for animal source food by the same approach that in the last two decades led to increased exploitation of land, fossil fuels, water, etc., and further acceleration in the shift away from SSLF towards LSLF. Additionally, greater expansion of LSLF could reduce the amount of human-edible food as food crops to feed livestock are increasingly tapped. The same applies to water, if one considers that LSLF requires almost five times more water to produce the same amount of edible animal source food, and that the proportion of people living in water-stressed regions is increasingly growing.

In order to guarantee animal source food security in the current situation of shortage of natural resources, population growth, and increasing climate variability, the livestock sector must shift its focus from increased production toward enhanced resilience. However, this is not contradictory with increasing, production when required, as long as resilience remains the primary focus. Accordingly, it seems that a major shift towards SSLF systems, and a reduction in meat consumption in rich countries, could represent a major contribution to counteract the current world food insecurity.

As observed in Turkana, Alaotra Lake region, Khar-o-Touran, and Huancavelica, SSLF communities are extremely efficient in producing animal source foods, thanks to their ability to take advantage of human-inedible forage and marginal lands, to produce high-quality and human-edible foods; to preserve socio-ecological balances that avoid depletion of natural resources and social arrangements; and to promote moderate meat consumption.

Differences between livestock farming categories

Relevant to the debate on livestock, CC and food security, the differences between the three livestock farming categories, as they move from SSLF and MSLF to LSLF, can be grouped into five clusters:

(I) Increased treatment of livestock farming as an industry.

Particularly LSLF, and to a less extent MSLF, imposes industrial production practices to livestock farming – mechanization, intensification, use of agrochemicals, monoculture, feedlots, etc. Among other things, this entails the concentration of production in LSLF operations to meet a large population of consumers living in the cities and buying from supermarkets. Consequently, this system is highly dependent on transport. The present global food system, based on LSLF, is characterized by a high dependence on fossil fuels, with devastating effects on GHG emissions. Livestock production, as a result of the shift from SSLF to LSLF, is being transformed from an energy-generating activity into an energy-consuming one.

LSLF has become heavily dependent on farmers' continuous investment in energy intensive machinery and fossil-fuel driven energy. This dependence is so high that in industrial agriculture the correlation between yield gains and input increases is perfect. As an example, grain-fed beef requires 35 calories for every calorie of beef produced. Thus, the livestock revolution expanding LSLF in developing countries can be perceived as a major climate threat. The gradual separation of livestock farming from grasslands, as we move from SSLF to MSLF and finally to LSLF, is in line with a decreasing role of ruminant livestock species, which often entails the degradation of carbon-rich grassland with a high potential for carbon sequestration, or their conversion into croplands (and correspondent GHG emissions).

(II) Increasing monofunctional role of livestock farming.

Livestock for small livestock keepers, and particularly pastoralists, represents more than just a source of food or of income. For SSLF communities, livestock provides fibres, social status, draught power, manure, recycling residues, cultural identity, financial security etc., all having importance in food security and maintenance of livelihoods. For instance, throughout the Horn of Africa, pastoralists define their wealth and poverty in terms of livestock ownership. Thus, it is not strange to picture the shift from traditional SSLF and MSLF towards LSLF as a process of substitution of multifunctional livestock production to commodity-specific livestock production. The highly multifunctional role that livestock plays in SSLF societies, as opposed to LSLF systems, is well reflected by the fact that approximately 80% of the value of livestock in low-input developing-country systems can be attributed to non-market roles, while only 20% is ascribable to direct production outputs; whereas, by contrast, over 90% of the value of livestock in high-input industrialized-country production systems is ascribable to the latter.

(III) Increasing separation between livestock and agriculture.

Every ton of additional humus in the soil relieves the atmosphere of the burden of 1.8 tons of CO_2. This points to the crucial necessity of integrating agriculture with livestock farming, and the major difficulty of landless industrial livestock production in mitigating GHG emissions. LSLF, by promoting a separation between agriculture and livestock, undermines the natural storage of CO_2 as organic matter in the soil. The animal food is cultivated away from where the animals are raised, over-exploiting soils that suffer from nutrients deficit, which must be compensated for with fertilizers, and these in turn are important contaminants, generating GHG emissions. As a matter of fact, a big share - often above 50% - of the energy use in farming is devoted to the production of synthetic fertilizers, in particular Nitrogen fertilizers and pesticides. Hence, the chemical fertilizers~~,~~ required by monocultures for animal feed production generate enormous quantities of NO_2.

At the same time, the nutrients produced by intensive livestock farms in the form of Nitrogen or Phosphorus become pollutants. It is estimated that the total amount of nutrients in livestock excreta is as large as the total amount of nutrients contained in all chemical fertilizer used annually. Furthermore, manure performs better than artificial fertilizers for soil structure and long-term fertility. In the last 50 years, the great use of chemical fertilizers and other unsustainable practices of industrial agriculture have triggered an average loss ranging between 30 and 60 tons of soil organic matter for every hectare of agricultural land. Some authors point that reverting soil fertility to pre-industrial levels would capture 30- 40% of current excess of CO_2 in the atmosphere.

Animals are inefficient nitrogen users. This is particularly true for ruminants. Nonetheless, when ruminants are fed with roughage - like grass or bran - and their excreta return to soils - as in SSLF and to less extent in MSLF - their nitrogen inefficiency has no remarkable negative impact in the way of GHG emissions. Likewise, manure deposits on fields and pastures do not produce significant amounts of methane, while factory farms and feedlots that manage manure in liquid form release 18 million tons of methane annually.

(IV) Decreasing capacity of valorizing marginal lands and products.

Another major difference between SSLF, MSLF and LSLF, is that while the latter and grain-fed MSLF compete directly with human beings for food; SSLF valorizes crop residues, human-inedible forage and marginal lands that could hardly be used for other purposes. It is clear that livestock keeping can contribute to further lowering GHG emissions by further using as feed roughage and nutrient rich residues from farms and households, and by reducing the amount of grain cultivated on high-input systems.

Livestock farming makes its most important contribution to food security when it is conducted in environments where crops cannot be grown easily, such as rangelands in case of pastoralism and ranching, and when livestock scavenge public land or are fed on crop residues, using feed sources that cannot directly be eaten by humans. In this way, SSLF makes notable contributions to the balance of energy and protein available for human consumption. LSLF, however, converts high-quality carbohydrates and proteins, which might otherwise be eaten directly by humans, into a smaller amount of higher-quality energy and proteins. In this latter case, livestock farming clearly contributes to increasing food insecurity and natural resources depletion. It is also clear that reducing the amount of human-edible food required to produce the livestock feed would be a valuable contribution to food security, as well as to CC mitigation

(V) Increasing reduction of diversity at all levels.

Biodiversity is a source of genetic diversity, which might be extremely useful to develop resilience in the livestock sector to the new stresses that can emerge in the future, by facilitating new adaptation strategies and production options. Linkages between biodiversity and livestock production systems are two-fold. Livestock-keeping communities promote and preserve biodiversity by maintaining marginal lands, i.e. important reserves of biodiversity, and by actively breeding a wide variety of livestock species and breeds, which are used in a great number of farming practices.

The promotion and preservation of biodiversity, both in a wild and domesticated setting, varies considerably between SSLF and MSLF, and LSLF. Biodiversity preservation is key to guarantee sustainability in SSLF systems and their adaptation to upcoming changes. Conversely, LSLF uses mostly three species - pigs, poultry, cattle - and very few breeds within these species - high-yield breeds fundamentally.

The breeds and lines selected for high-output production need standardized feed, intensive veterinary treatment and environmental control to prevent infections. These breeds have been selected for their high output and good feed-conversion ratios under high-external input conditions. Resistance to diseases and pests, heat and water stress, vitality, fertility and mothering abilities are largely neglected attributes. In addition, the high densities of animals with low immune systems found in LSLF easily translates into emergence of more diseases. This situation makes LSLF very vulnerable to climate variability, due to its extremely low capacity to adapt to changes. Conversely, SSLF systems breed and nurture 40 livestock species and almost 8,000 breeds. However, the expansion of LSFS together with the rejection of SSLF is favouring the disappearance of many local breeds, and thus limiting the capacity of the livestock sector to adapt to present and future climate variability.

Measuring GHG emissions

The interpretation of the notion of productivity is crucial to evaluate the amount of GHG emissions generated by different categories of livestock farming. In fact, the underlying notion of productivity calls for revision as it cannot any longer be the only criterion followed to measure GHG emissions, the amount of meat produced, the number of eggs laid by a hen yearly or the amount of milk produced daily. In fact this is linked to a narrow consideration of food security. It should be clarified that productivity is strictly related to the item being measured and the method of measurement applied, and in the CC debate, GHG emissions must relate to the climate impact of the whole product life cycle, including the feed footprint. The measurement most conventionally used to determine GHG emissions takes into account the volume of CO_2 emitted per mass of livestock product obtained, but there are other possible ways of measuring productivity.

Indeed, the use of different metrics favours different livestock types or systems. For example, as extensively-reared animals produce less edible output per unit of GHGs emitted than their intensively-reared counterparts, when the measurement applied correlates emissions with the quantity of livestock product obtained, LSLF is favoured. Instead, when a resource-sensitive measurement is applied, intensively reared animals show larger emissions per unit of resources used compared to pastoralism, ranching, backyard pig and poultry production, and small mixed farming. Thus, extensive grazing systems prove to be highly productive, if productivity is defined in terms of output of limited resources. Pastoral systems are found to be more productive per area unit due to the ability of pastoralists to move their herds opportunistically and take advantage of seasonally available pastures. Failures are also related to the value of the informal economy, the subsistence function of SSLF, the value of maintaining the ecosystem healthy and other land uses.

Livestock and mitigation strategies

The mitigation potential of the SSLF systems, as observed in Turkana, Alaotra Lake region, Khar-o-Touran, and Huancavelica, is enormous. It mainly consists of guaranteeing the maintenance of carbon-rich grasslands and soil fertility, utilization of close markets and little dependence on chemical inputs, and undertaking of carbon smart diets. In global terms, several strategies have been implemented in livestock farming with the objective of mitigating its GHG emissions: (i) mitigation through market mechanisms; (ii) mitigation through technological and managerial schemes; and (iii) mitigation through behavioural modifications. In general it can be stated that while SSLF tend to be related to strategies of mitigation through behavioural modifications, and MSLF to strategies of mitigation via technological and managerial schemes, LSLF is generally associated to mitigation strategies that use market mechanisms. Yet, each group of strategy has its own drawbacks.

(I) Mitigation through market mechanisms

Mitigation strategies based on market mechanism are not affecting SSLF communities positively, and are mostly thought to be implemented by LSLF operations. These communities have mainly access to informal and local markets, consequently are prevented from participating in low-carbon labelling schemes. SSLF communities are also excluded from GHG emission trading systems due to the high transaction costs that would have to be incurred. These mitigation strategies imply the privatization of carbon, allowing the distribution of the 'rights to emit', and rights trading. The underlying carbon-offsetting principle is fundamentally flawed since it hampers improvements in emissions' reduction.

(II) Mitigation through technological and managerial schemes

Although SSLF undertake quite a number of management practices concerning the high CC mitigation potential, such as moderate grazing, soil conservation, and use of local resources; most technological mitigation strategies being developed tend to be thought for LSLF operations, such as application of biochar, or technologies to reduce production of enteric CH_4 and N_2O through animal breeding or optimizing the balance between the content of carbohydrate and protein in the animal feed. The production of biogas from manure can also be operated by small livestock keepers. However, it entails the risk of favouring livestock corralling and intensifying the current lack of manure for soil conservation and GHG sequestration. Most of the technological mitigation strategies tend to suffer from too much narrow approach to the problem of GHG emissions by livestock farming. An excessive focus on GHGs sequestration offers a reductionist mitigation 'solutions', with no real impact and some distraction from the real challenge: reversing the fossil fuel dependence and changing the consumption patterns it induces, and restoring soil fertility.

(III) Mitigation through behavioural modification

Mitigation through the promotion of 'climate-smart diets' offers good opportunities for boosting the role of SSLF in CC mitigation, by favouring local consumption, organic production, and moderate meat consumption. However, research to establish how changes in behaviours can be achieved is still in its infancy compared to the abundance of works concerned with technological solutions to mitigate GHG emissions. This imbalance reflects the low priority given by policy makers to behavioural change as a strategy towards GHG mitigation.

Adaptation strategies of SSLF communities to climate variability

The main CC-related hazards affecting small-scale livestock farming systems, that call for adaptation strategies are: increased temperature, changes in seasonal rainfall patterns and more erratic rainfall, higher prevalence of weather extreme events and higher atmospheric concentrations of CO_2. Specifically, in Turkana, Alaotra Lake region, Khar-o-Touran, and Huancavelica, high prevalence of droughts with occasional flooding, and increasing calendar unpredictability, have been the CC-related hazards identified in all four cases.

The adaptation potential of SSLF systems to climate-related hazards, as observed in Turkana, Alaotra Lake region, Khar-o-Touran, and Huancavelica, is remarkable. SSLF consists in a class of livestock production systems developed to guarantee the livelihood of communities living in climate margins, namely mountains, cold regions, and drylands. Their knowledge, institutions and customary practices, highly adapted to the local conditions and developed throughout centuries of co-evolution with changing environments, can be of great value to adapt the whole livestock sector to the current situation of increased climate variability.

SSLF communities implement their own adaptation centred on four types of adaptations: **(i)** enhancing mobility, i.e. moving herds to areas with better grazing and water conditions and securing access to critical resources during difficult times; **(ii)** boosting social cooperation and reciprocity, i.e. adopting strategies such as food sharing, livestock loans, joint ventures, friendly collaboration, communal planning, communal ownership, splitting the herd among different family members, communal grazing, and labour exchange, thus strengthening the sense of belonging to a community and increasing the resilience of the community to future changes by fostering mutual support and exchange of knowledge and capacities; **(iii)** favouring diversification and multi-purpose strategies, as a precautionary strategy to reduce the risk of losses in front of the upcoming of possible unexpected changes; or **(iv)** preserving and promoting biodiversity, both on a wild and domesticated level, including shifting towards other types of livestock more adapted to new socio-ecological conditions, such as browsers –camels, goats - or short-cycle animals – poultry, pigs, dairy cows.

The cost-effectiveness of these autonomous adaptation strategies, and the fact that most of them are of an anticipatory and endogenous nature, show that much can be learned from the adaptation strategies that SSLF communities undertake. Other adaptation measures undertaken by these communities are planned and promoted by external institutions. These include **(v)** empowering community members by offering them services and training, such as schooling, health care, and pastoralist field schools; and finally **(vi)** offering to these communities schemes of sedentarization, food relief and improved market access, to try to improve their livelihoods. In this case they are both anticipatory and reactive. Other strategies can be autonomous or planned, depending on the contexts, such as **(vii)** adoption of fodder crops and pasture enclosures, which in some cases can also lead to livestock corralling, to guarantee more stable feeding conditions for the livestock.

Adaptation to climate variability is a never-ending process, because vulnerabilities and impacts are permanently evolving, which means that some forms of adaptation that prove appropriate now, may not prove so in the future. Furthermore, we might find that socio-institutional innovations, however less spectacular – and less expensive in monetary terms - may strengthen resilience further compared with other technical innovations. However, it is not less true that not all autonomous innovations end up enhancing communities' resilience. While SSLF autonomous innovations should not be idealised, top-down interventions should be always critically assessed.

Socio-economic drivers intensifying CC impacts on SSLF communities

As seen in Turkana, Alaotra Lake region, Khar-o-Touran, and Huancavelica, SSLF communities are highly effective in CC mitigation and adaptation, while guaranteeing animal source food security. However, as identified in all four cases, to guarantee SSLF endurance and to preserve its related benefits, it is urgent to deal with a set of socio-economic drivers that hinder the development and promotion of the above livestock farming categories: **(i)** demographic growth, **(ii)** neglect of SSLF knowledge, customary practices and institutions in policy-making, and **(iii)** increasing integration of SSLF societies within the market economy.

In our case studies, as well as in many other ssituations, we are withessing the gradual disruption of local traditional knowledge, abandonment of communal planning and institutions, increase in social differentiation, and overexploitation of the limited resources of rangelands. Rising tensions, both within the community and among communities, and growing levels of malnutrition, are being identified as urgent issues in Turkana, Alaotra Lake region, Khar-o-Touran, and Huancavelica. These drivers are critically damaging the considerable capacity of SSLF to enhance GHG sequestration, CC-related hazard adaptation, and animal source food security, which need to be specifically tackled.

Finally, the following set of recommendations has been drafted, to counteract these damaging trends in the specific case of the four case studies:

- In Turkana, action is urgently needed to stop the violence between neighbouring pastoral communities, and to direct humanitarian aid more towards pastoralists restocking and training and less towards food relief.
- In the Alaotra Lake, action is urgently needed to stop livestock raids, control grassland fires, and prevent further soil erosion and favour soil preservation measures.
- In Khar-o-Touran, action is urgently needed to stop the violence between pastoralists and settled farmers, and ensure more control of the natural resources for pastoralists.
- In Huancavelica, action is urgently needed to stop the violence between neighbouring pastoral communities, and favour grassland preservation measures to prevent degradation.

1. Introduction

Worldwide, livestock production is an activity that allows people to eat meat, milk-related products or eggs. Additionally, livestock has traditionally provided leather for making shoes or clothes, energy in the form of work to plough the soil or simply to carry people over long distances. In many regions, livestock is one of the essential components upon which the livelihood of a community depends and is also a necessary complement of the agricultural activity: animals eat plants in rangelands that would not otherwise be consumed or cultivated and produce organic fertilizers in the form of manure. They also are a key component in ensuring landscape preservation in many areas. Small-scale livestock farming (SSLF) is probably the best example of a long-term traditional balance between human beings, livestock and agriculture with the environment, a system in which each component is given a benefit. The complexity and variety is enormous: thousands of domestic species adapted to many different geo-climatic contexts. During the last century other livestock breeding and management practices have been developed, in which livestock farming was considered an industrial activity in a global economy of scale separated from agriculture. Each system has different characteristics, different stakeholders, different beneficiaries, different impacts on society and on the environment, and is affected by agricultural, by development or by environmental policies, including those on climate change (CC) adaptation and mitigation differently.

Climate change poses new challenges to agriculture, particularly in terms of land use and food supply. For years, CC has been out of the food policy agenda, both of policy-makers and social movements. However, the debate on climate change in Copenhagen at the 2009 United Nations Framework Convention on Climate Change and the publication of scientific data showing the importance of the agro-food system as net emitter of green house gases, have increased the interest in the interactions existing between climate change and the food security. Together with other factors, such as world demographic growth, peak oil, agro-fuel production, rising food market speculation and land grabing, climate change pushes agriculture and livestock farming towards a new era of major uncertainties and shocks (Almas et al., 2011). The instability of the global agro-food system is an undeniable fact and new solutions are urgently required.

Since the FAO Livestock's Long Shadow Report in 2006 (Steinfeld et al., 2006), there has been a fast increase in research regarding the importance of livestock for food security, the growth in livestock sector, and its impact on CC (HLPE, 2011; Development Fund /Utviklingsfondet, 2010; Bennett et al., 2006; Hancock, 2006).
Worldwide researchers investigate the role of livestock in CC, showing both the role of livestock in climate change and the impacts of climate change on livestock production, and study alternatives for mitigation and adaptation. But most of the proposals fail to considerate that different livestock systems require different policies and actions. For instance, they tend to present solutions based on new technologies to reduce emissions (mitigation) using top-down approaches, focusing primarily on industrialized productions systems. On the other hand, many studies revolve around SSLF alone, but almost none looks into its relation with CC, including mitigation and adaptation strategies. Only few attempts have been made to develop the issue of CC and livestock, that differentiate industrial large-scale livestock farming from SSLF (IUCN and WISP, 2010; Rivera-Ferre, 2010).

This report aims at filling this information gap. The main objective is to contextualize the role played by small scale livestock farming within the climate change debate, as well as its potential contribution to food security. The hypotheses of this study are: that small scale livestock farming can contribute to mitigation of climate change and as such needs to be taken into account in the policy debate; and that autonomous adaptation strategies of local communities, mostly based on local traditional knowledge, can be acknowledged as a reliable pool of adaptation measures to climate change, while at the same time they offer a sound contribute to global food security. The questions that this report aims to address can be summarized as follows: (i) how sustainable SSLF systems are and what is their contribution to climate change mitigation; (ii) how efficient SSLF are in producing animal source foods for the growing population and in addressing future food security challenges; (iii) how consistent 'traditional' options to mitigate livestock impact on climate change are with SSLF communities, and more particularly with pastoral livelihoods.
This report also illustrate how small-scale livestock farming, and particularly pastoralism, may play a role in providing the new solutions required. SSLF is crucial to food security for millions of people today and will be ever more crucial in the coming decades in a context of climate variability.

To address these issues the report first proposes a different categorization of livestock production systems, going beyond conventional categories. Our attempt is to introduce in the classification process not only the inputs utilized by different livestock farming systems, but to link them with each scale of production system, so as to add a food system dimension to the categories. Subsequently, the report critically takes stock of the current literature on livestock production and mitigation alternatives. Finally, based on a fieldwork carried out in four case studies, it presents the adaptation measures undertaken by small scale livestock farming communities in Turkana (Kenya), Alaotra Lake (Madagascar), Khar-o-Touran (Iran) and Huancavelica (Peru), as well as the main socio-economic drivers that magnify the CC's effects they encounter, which hinder their adaptation strategies. These adaptation measures are first assessed, both identifying the main obstacles they meet, and their potential maladaptation in each case. Our conclusions, together with some recommendations to policy-makers are proposed in a final section.

1.1 Contribution of the food system to greenhouse gas emissions

There are several assessments of the greenhouse gas (GHG) emission of individual food products. They generally find that meat and dairy products, and air freighted foods, tend to carry the highest GHG burden (European Commission, 2006). When land use change impacts are included, the GHG contribution from livestock increases further (FAO, 2006). In Sweden and the Netherlands, for instance, it is estimated that consumption of meat and dairy products contributes about 45–50% to the global warming potential of total food consumption (Pathak et al., 2011). In industrialized countries (Garnett, 2011), total emissions along the food chain are split at 50%, between pre-farm gate activities and the post-farm gate stages of processing, packaging, storage, distribution and food preparation. In impoverished countries there are not much data available, but a recent study in India (Pathak et al., 2010) estimates that only 13% of total emissions come from post-farm gate stages. This seems to occur mainly because most people in developing countries consume fresh food mostly produced locally, with much less transport and refrigeration requirements than in rich countries. This is confirmed by an ETC study (2009). To date, no full "cradle-to-plate" estimates of global food system greenhouse gas emissions are available (Garnett, 2008). However, the Intergovernmental Panel on Climate Change (IPCC, 2007b) estimates the direct contribution from agriculture at 10– 12%, without accounting for land conversion effects. If the latter is included, Bellarby et al. (2008) estimate agriculture's contribution in the region of 17–32% of anthropogenic emissions.

Estimates of full supply chain emissions are available for the European Union (EU)-25, which suggest that the food system contributes 31% to total emissions (Tukker et al., 2006). A large fraction of these emissions are attributable to the livestock sector (Steinfeld et al., 2006). As of 2000, the livestock sector is estimated to have contributed 14% of anthropogenic greenhouse gas emissions - 18% taking into account land use, land use change, and forestry (Steinfeld et al., 2006). Other authors suggest that this is anunderestimation and that the real value is 51% of total GHG emissions (Goodland and Anhang, 2009). In any case, these emissions make livestock a major target for mitigation options. The composition of GHG emissions in agriculture is very different from that of other industries, as might be observed in Fig. 1. Carbon emissions account for only about 9%, whereas nitrous oxide (N_2O), mainly from fertilizer use, and methane (CH_4) emissions from ruminant digestion, manure management and cultivation of rice in flooded conditions represent 46 and 45% respectively.

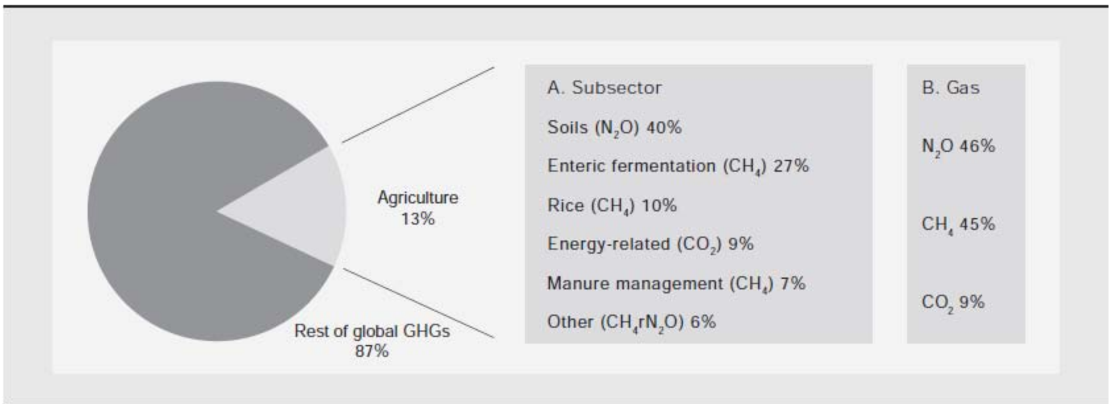

Figure 1. Greenhouse-gas-emission profile of agriculture.

Source: Kasterine and Venzetti (2010)

The livestock sector utilized 58% of directly used human-appropriated biomass in 2000 (Krausmann et al., 2008). Humans appropriate 24% of potential net primary productivity, with the food system consuming 12% (Haberl et al., 2007). Livestock production accounts for 70% of agricultural land and 30% of land globally, 26% of the world land is used for grazing and 33% of the agricultural area for feed crop production (Steinfeld et al., 2006). Additionally, intensive livestock production has indirect environmental impacts through the promotion of intensive agriculture for feed production. As regards the most important GHG emitted by the livestock activity, Kasterine and Venzetti (2010) state that methane emissions of livestock are principally a function of the industrialization of production, through enteric fermentation and manure lagoons. In line with this, researchers at the International Livestock Research Institute found that methane emissions of a typical African cow are normally offset by carbon sequestration in its pastures (Maarse, 2010). There is a crucial interplay between ruminant management and grasslands, which represent 45% of all land and a major stock for carbon (Paul et al., 2009).

> Based on the suggestion by Allison et al. (2009) that per capita GHG emissions must fall below one metric ton per year of CO2eq/year by 2050 to prevent a potentially dangerously destabilizing increase in mean surface temperatures above 2 °C – that is, 8.9 billion ton of CO2eq as a whole – Pelletier and Tyedmers (2010) compare the contributions of the global livestock sector in 2000 with the estimations of livestock in 2050 projected by the FAO (2006b). Thus, they estimate the direct livestock-related GHG emissions from meat, milk and egg production in relation with four different scenarios to illustrate the range of impacts associated with dietary choice at a global scale:
>
> a) **Situation at present**, in 2000: the livestock sector alone occupies 52% of humanity's suggested safe operating space for anthropogenic GHG emissions, leaving the remaining 48% for everything else.
> b) **FAO projection for 2050**: livestock emissions account for 72% of the total recommended.
> c) **Chicken substitution**: all livestock increases above the year 2000 level required to meet the demands of the extra 2050 population will come from chicken. Under this scenario, livestock consumes 63% of the world recommended anthropogenic GHG emissions.
> d) **Dietary protein needs are satisfied completely from livestock sources**: Dietary protein needs, as recommended by the USDA Food Pyramid, are satisfied entirely by livestock products completely from livestock sources at projected production ratios. Under this scenario, livestock consumes 92% of the world recommended anthropogenic GHG emissions.
> e) **Dietary protein needs are satisfied completely from legume (soybean) sources**: Dietary protein needs, as recommended by the USDA Food Pyramid, are satisfied completely from legume (soybens) sources. Under this scenario, livestock consumes 1% of the world recommended anthropogenic GHG emissions.

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1.2 Categories of livestock farming

However, there are multiple ways in which livestock farming can be conducted. As a result, we propose to distinguish between three main groups or categories of livestock farming: small-scale livestock farming (SSLF), medium-scale livestock farming (MSLF) and large-scale livestock farming (LSLF). Classification is made according to differences in farm size; utilization of external inputs – fertilizers, pesticides, oil, etc.; the particular utilization they undertake of the land – grazing, feed lot with arable land, and feed lot with no land; and the type of market to which they have more access to and tend to serve (Figure 3). These three livestock systems show fundamentally different approaches to livestock production, and the role this should play in society. While small scale livestock farming locates livestock raising in a socio ecological context, and search for stability; medium-scale livestock farming (MSLF) aims at optimizing the balance between inputs and outputs, but only at the animal or farm scale, trying to reach for the highest level possible in productivity; and large-scale livestock farming (LSLF) considers only the monetary dimension of livestock production business and by reaching economies of scale attempts at expanding the production (see Fig. 2 and Fig. 3). This is a crucial distinction since, as we will try to show later, the different livestock farming systems have radically distinct contributions to the climate issue. Steinfeld et al. (2006) classified livestock production as low input, medium input and high input. We believe that this classification is too narrow to address the problems of food security with a food system approach. For that reason we aim at integrating other elements within the description of the different types of livestock farming, such as market access.

Category	SMALL-SCALE LIVESTOCK FARMING	MEDIU-SCALE LIVESTOCK FARMING	LARGE-SCALE LIVESTOCK FARMING
Characteristics	Small-scale farm Low-input farm Predominantly grazing	Medium-scale farm Medium-input farm Predominantly arable land	Large-scale farm High-input farm Landless
Market access	Access to informal and local markets	Access to local, regional, global markets	Access to global markets
Rationality	Holistic approach in a socio-ecological context	Reductionist approach, centered on animal or farm conversion	Approach of economy of scale and chrematistics
Aim	Resilience	Productivity	Expansion

Figure 2. Main categories of livestock farming, their rationality and nature.

As may be observed in Table 1, SSLF is the livestock farming system that competes least for human food, given that it depends primarily on grazing and scavenging. It produces about 12% of the world's milk and 9% of its meat. MSLF is the livestock farming system in which animals eat grass and crop residues, as well as concentrates, producing 88% of the world's milk and 6% of the meat. The most intensive industrial livestock systems – LSLF – where the animals themselves occupy little land are kept in controlled environments and can be housed almost anywhere, produce 45% of the world's meat – mainly from poultry and pigs - and 61% of the world's eggs (FAO, 2009).

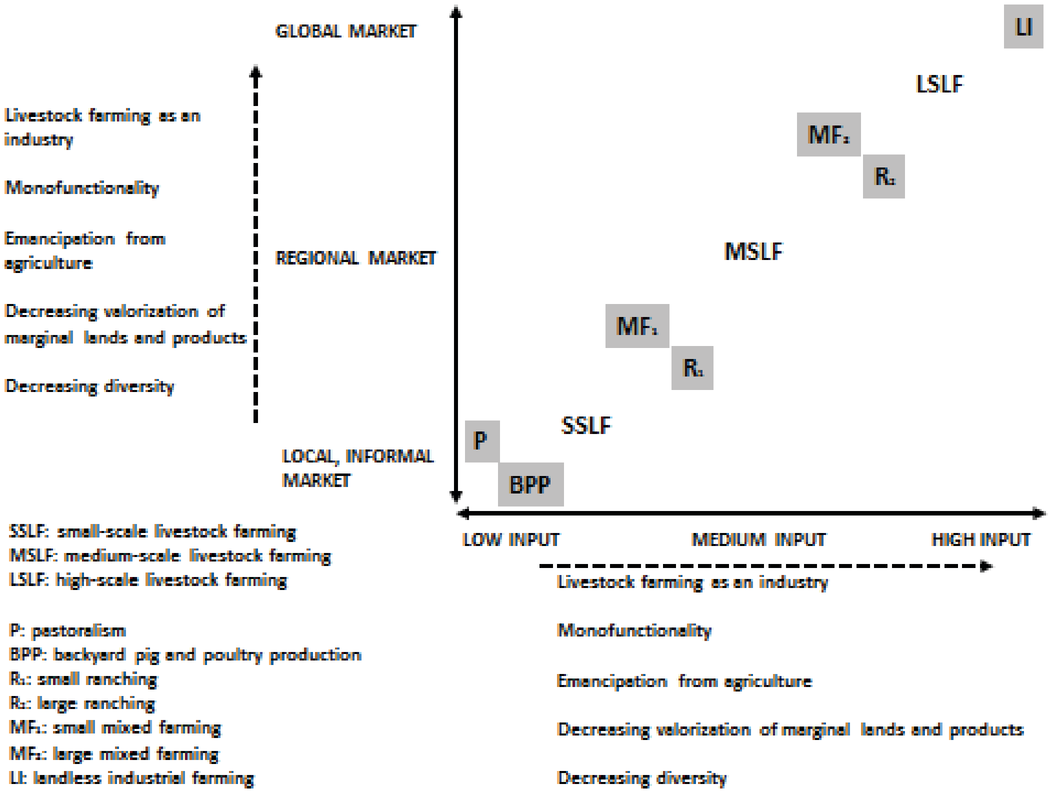


Figure 3. Main characteristics and transition of the different livestock farming categories.

Currently there are 120 million people depending on livestock (Raas, 2006, based on data from 2002), both pastoralists (SSLF) and ranchers (both SSLF-MSLF), that is, those whose livestock farming depends on grazing land. According to Sere and Steinfeld (1996) SSLF are those livestock systems in which more than 90% of dry matter fed to animals comes from rangelands, pastures, annual forages and purchased feeds, and less than 10% of the total value of production comes from non-livestock farming activities. Also, annual stocking rates are less than 10 livestock units per hectare of agricultural land. The number is a little bit higher for the ETC-group (2009) with about 190 million of pastoralists in the world. Pastoralism is an activity practiced on 25% of the global land (United Nations, 2010). Some communities practice mobile grazing, moving animals over extensive communal pasturelands; others are sedentary, although generally also depending on communal grasslands. Ranchers who keep animals extensively on the rangelands are another example of livestock-dependent people. They are found in temperate zones where high-quality grassland and fodder production can support larger numbers of animals. These areas include parts of Europe, North America, South America, parts of Oceania and some parts of the humid tropics. However, in this case animals are almost exclusively kept for income, and the land tends to be of their own. Although fewer in number than pastoralists, their contribution is relevant, mainly in Western countries, but not only. Rainfed grazing systems provide around 19.2 million tonnes of ruminant meat or 19% of world production (Steinfeld et al., 2006). According to the FAO report (2009b), they contribute about 17% of global beef and veal supply, and 17% of the sheep and goat meat supply. As in the case of pastoralism, intensive grass-fed meat production can contribute to cooling the planet through improved management practices of grassland, resulting in less CH_4 emissions and carbon sequestration. To achieve this goal, grassland management must not depend on chemical fertilizer (as can be the case in some MSLF). It is also important to consider their social implications. For instance, land ownership in these systems is a critical issue in the promotion of fairer systems (Rivera-Ferre, 2010).

Another subgroup of SSLF is backyard pig and poultry production (BPP). Here livestock is fed through crop residues and scavenging. This is a low-input, low-output system that provides the family with 'something for almost nothing'. According to Otte (2006) scavenging poultry can provide a 600% return on a small investment. This system is characterized by high waste recycling efficiency. This livestock system is largely disseminated among peri-urban farms. Scavenging pigs in Asia and Africa live on household waste, acting as garbage disposal units, and are housed at night in a rough shelter or kept in or under the family dwelling (ADB, 2010). These SSL farms tend to be resource-constrained. This is particularly acute as regards their lack of land. As in the case of pastoralism, BPP systems are similarly characterized by a highly multifunctional role played by livestock – draught power, manure, pest control, crop residues, etc. For example, herded ducks in the Mekong Delta and China travel from field to field eating snails, insects and discarded grain, thus providing pest control for rice crops (Yu et al., 2008). They are also the ones mostly practiced by women in developing countries (Gu.ye, 2005). More than 90% of rural families in most developing countries keep one or more poultry species – e.g. Chickens, ducks, guinea fowls, geese, pigeons, etc.. Regarding pigs, FAO (200) estimates that pigs in mixed systems account for about 35% of global production (FAO, 2009). Numbers from Steinfeld et al. (2006) would suggest that SSLF and MSLF produces 45% of total pork meat produced worldwide.

Table 1. Global livestock production average by livestock production systems, from 2001 to 2003.

	LIVESTOCK PRODUCTION SYSTEM			
	GRAZING	MIXED FARMING*	LANDLESS	TOTAL
		(Million head)		
POPULATION				
Cattle and buffaloes	406 (27%)	1,091 (71%)	29 (2%)	1,526
Sheep and goats	590 (33%)	1,178 (66%)	9 (1%)	1,777

PRODUCTION		(Million tons)		
Beef	14.6 (13%)	42.2 (70%)	3.9 (7%)	60.7
Mutton	3.8 (32%)	8.0 (67%)	0.1 (1%)	11.9
Pork	0.8 (1%)	41.6 (44%)	52.8 (55%)	95.2
Poultry meat	1.2 (1%)	19.7 (27%)	52.8 (72%)	73.7
Milk	71.5 (12%)	522.9 (88%)	-	594.4
Eggs	0.5 (ns)	22.7 (39%)	35.7 (61%)	58.9

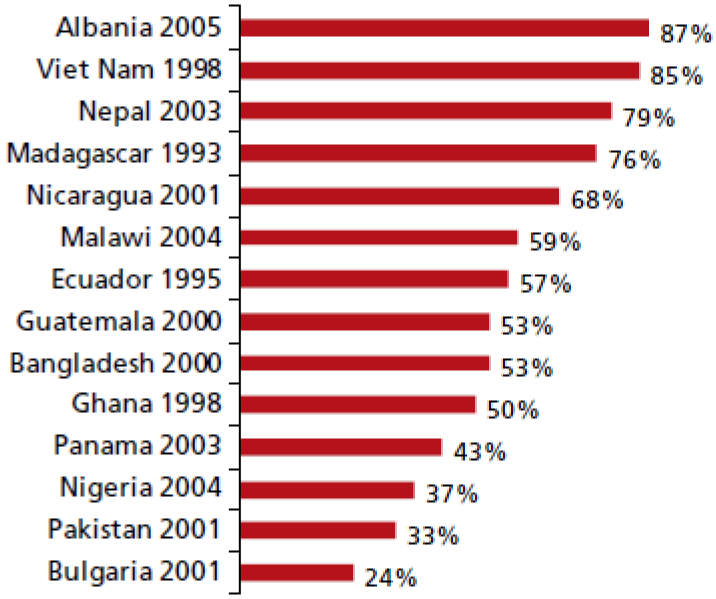
Source: adapted from Steinfeld et al. (2006)
Note: Mixed farming includes both rainfed and irrigated mixed farming.

In mixed farming systems (SSLF-MSLF), cropping and livestock rearing are linked activities. Sere and Steinfeld (1996) define mixed farming systems as those systems in which more than 10% of the dry matter fed to animals comes from crop by-products or stubble or where more than 10% of the total value of production comes from non-livestock farming activities. Mixed systems produce close to 50% of the world's cereals (FAO, 2009b). Rain-fed mixed farming systems are found in temperate regions of Europe and the Americas and sub-humid regions of tropical Africa and Latin America. They are mostly characterized by individual ownership, often with more than one species of livestock, and produce about 48% of global beef (FAO, 2009b) and 33% of mutton (Steinfeld et al., 2010). Irrigated mixed farming systems prevail in East and South Asia, mostly in areas with high population density. They provide about 30% of the world's pork and mutton and 20% of its beef (FAO, 2009b). On the global scale, mix-farming systems accounts for 90% of milk and 70% of ruminant meat output, 43% of pork and 25% of poultry meat (Steinfeld et al., 2010). Within the developing countries, they contribute to 45 and 39% of pig and poultry meat and eggs. It is not clear whether these numbers take into account backyard production systems (SSLF).

The prevalence of mixed farming varies by country and region (see Table 2). Ly et al. (2010) reported that in 2004, 83% of the cattle in West Africa and 75% of the small ruminants were kept in mixed crop-livestock systems, with traction being an important reason for keeping cattle. Most of small-scale mixed livestock farmers undertake other gainful activities to guarantee their livelihoods (FAO, 2009).The provision of food to Growing cities could be an important market for to provide livestock products from small-scale mixed livestock farms, but here they face strong competition from LSLF. This situation is captured by As a result, FAO (2009), that states that peri-urban small-scale farmers tend to be successful at supplying urban populations in the early stages of demand growth, but less so when food safety and land use regulations become stricter.

Pastoralism, with ruminants in grasslands, backyard pig and poultry production, with scavenging monogastrics, and small mixed livestock farming, with ruminants fed with crop residues, are efficient and sustainable methods of providing high-quality protein with minimal environmental impacts (Tilman et al., 2002), through by means of vavalorisation of grasslands and residues. Similarly, due to the very little inputs required, small livestock keepers leave an insignificant environmental footprint, too.

Table 2. Rural households in selected countries engaged in small mixed farming



Source: FAO, 2009

Despite the importance of SSLF and MSLF, Steinfeld (2003) emphasizes that, in the last few years, there has been a remarkable shift in livestock production, from a local multipurpose activity – SSLF and MSLF - into market-oriented livestock production systems – LSLF in this report, referred in Steinfeld as high-input livestock farming- with an increasing number of large-scale, industrial productions, which are located close to urban centres. These systems are characterized by Sere and Steinfeld (1996) as having on average stocking rates greater than 10 livestock units per hectare of agricultural land and <10% of the dry matter fed to livestock is produced on the farm. This shift goes with an increasing importance of cereal-fed monogastric livestock species, to the detriment of ruminants. Almost non existent 40 years ago, LSLF today t 40 years ago, grows at twice the annual rate of the more traditional mixed farming systems (4.3% against 2.2%), and at more than six times the annual growth rate of production based on grazing (0.7%) (FAO, 1996). Intensive landless systems of LSLF produce about 72% of the world's poultry meat and 55% of the pork (Steinfeld et al. 2010). One major problem of LSLF is the indirect environmental impact produced by the promotion of intensive agriculture for feed production. About 48% of shipped fertilizers are used to increase animal feed (Steinfeld et al., 2010).

1.3 Potential contribution of SSLF to food security in a food system approach

Presently, the number of undernourished people is among the highest in human history (FAO, 2010): 925 million people suffering from hunger. When dealing with this issue the first solution that people and many institutions tend to propose is to produce more food. In this respect, FAO (2009b) points that: *"The 925 million undernourished people are not undernourished because the global food supply is deficient, but because they cannot afford to buy food or they live in places or societies where it is hard to obtain (..). Reducing the grain fed to livestock would not ensure that these people could access food. Neither would it automatically result in more plant protein being grown, as it might* *reduce the prices for those commodities to a level where it would be less attractive to grow them, although the higher number of people to be fed and increasing resource pressure may change this in future"*. To complement this data, it is also important to highlight that more than 80% of the people that suffer from hunger live in rural areas: some 50% of the world's hungry are smallholder farmers who depend mainly or partly on agriculture for their livelihoods, but lack sufficient access to productive resources such as land, water and seeds. Another 20% of those suffering from hunger are landless families who survive as tenant farmers or poorly paid agricultural labourers and often have to migrate from one insecure, informal job to another. Another 10% of the world's hungry live in rural communities from traditional fishing, hunting and herding activities (UN, 2010). Thus, the issue of food security is a complex issue. Food security consists of four elements: availability (production, distribution and exchange), access (affordability, allocation, and preference), stability and utilization (nutritional value, social value, food safety). Production is probably the issue most researched in the literature when in fact it is only one constituent of food availability. Thus, the problem of food security needs to be addressed through a food system approach. Eriksen (2008) proposes a conceptualization of food systems to address global environmental change that includes the socioeconomic and environmental feedbacks of food system activities (producing, processing, packaging, distributing, retailing and consuming food) and outcomes (food security: access, availability, utilization; social welfare and environmental capital) into global environmental change and socioeconomic drivers. Thus, when addressing the problem of food security and livestock, many elements need to be considered. It is not only about producing more meat, but also about the interaction of livestock systems with the environmental (ecosystem services, ecosystem flows, access to natural capital) and social (employment, wealth, human capital, income, social and political capital) contexts, including institutional and governance issues. Considering UN projections, it is estimated that in 2050 there will be 9 billion people to feed, 30% more than in 2010 (UN Population Division, 2009). In addition, much of the new population will live in cities (UNFPA, 2010). The expanded population is expected to consume almost twice as much livestock products as nowadays and thus, FAO (2006b; see Table 3) assumes that the demand for livestock products will grow during the next 40 years. Obviously meeting this demand will be increasingly challenging. For instance, it is clear that doubling supply would place an extremely heavy burden on natural resources.

Table 3. Projected total consumption of meat and dairy products

	2010	2020	2030	2050	2050/2010
	(million tonnes)				
WORLD					
All meat	268.7	319.3	380.8	463.8	173%
Bovine meat	67.3	77.3	88.9	106.3	158%
Ovine meat	13.2	15.7	18.5	23.5	178%
Pig meat	102.3	115.3	129.9	140.7	137%
Poultry meat	85.9	111.0	143.5	193.3	225%
Dairy not butter	657.3	755.4	868.1	1 038.4	158%
DEVELOPING COUNTRIES					
All meat	158.3	200.8	256.1	330.4	209%
Bovine meat	35.1	43.6	54.2	70.2	200%
Ovine meat	10.1	12.5	15.6	20.6	204%
Pig meat	62.8	74.3	88.0	99.2	158%
Poultry meat	50.4	70.4	98.3	140.4	279%
Dairy not butter	296.2	379.2	485.3	640.9	216%

	2010	2020	2030	2050
Human population billions	6.83	7.54	8.13	8.91
	(Consumption million tonnes per billion people)			
Bovine meat	9.85	10.25	10.93	11.93
Ovine meat	1.94	2.08	2.28	2.64
Pig meat	14.98	15.29	15.98	15.79
Poultry meat	12.58	14.72	17.65	21.69
Dairy	96.24	100.19	106.77	116.55

Source: FAO, 2006b

In terms of production, it seems that the livestock sector is making an effort to meet the projected numbers and consequently global livestock production is quickly increasing. From 1967 to 2007 the production of pig meat has increased by 152%, 93% in the case of beef and buffalo meat, 183% in eggs, 92% in milk, 369% in poultry, and finally 105% in sheep and goat meat (see Table 4). This trend is also reflected in the trade in livestock products that has also grown enormously during this period (Table 5), by a factor of 30 for poultry meat, a factor of more than 7 for pig meat and a factor of 5 for milk. Pigs and poultry, especially those kept in intensive, peri-urban production systems, are mostly responsible for a per capita growth of livestock source foods. Three of the largest emerging economies – China, Brazil and India – have fast-growing poultry industries (FAO, 2009d). However, the growth in livestock production that took place during the livestock revolution – between the beginning of the 1970s and late 1990s in developing countries - was largely a result of an increase in the number of animals. At present, demand continues to increase despite economic shocks, but supply conditions seem to have changed. The pressures on natural resources may force the price of livestock source foods to rise (FAO, 2009). It is hard to imagine meeting 2050-projected demand (see Table 3) by raising twice as many poultry, 78% more small ruminants, 58% more cattle and 37% more pigs, without further damaging natural resources.

Table 4. Changes in global livestock production from 1967 to 2007.

ITEM	PRODUCTION *(million tonnes)*			PRODUCTION PER PERSON *(kg)*		
	1967	2007	2007/1967	1967	2007	2007/1967
Pig meat	33.86	99.53	294%	9.79	14.92	152%
Beef and buffalo meat	36.50	65.61	180%	10.55	9.84	93%
Eggs, primary	18.16	64.03	353%	5.25	9.60	183%
Milk, total	381.81	680.66	178%	110.34	102.04	92%
Poultry meat	12.39	88.02	711%	3.58	13.20	369%
Sheep and goat meat	6.49	13.11	202%	1.88	1.97	105%

Source: FAOSTAT (FAO, 2009d)

The shift from extensive grazing (SSLF) towards intensive livestock farming systems (LSLF) through further utilization of land, fossil fuel, water, etc., which has characterized the rise in livestock production in the last decades, seems no longer feasible. In this sense, proposals for more intensifive and market-based livestock farming, aiming at fulfilling the increasing consumption of meat (Steinfeld et al., 2010), can be questioned. Future livestock production requires reducing the amount of natural resources' depletion. While for SSLF systems the challenge is mainly overcoming remoteness from consumers and increased access difficulties to pastureland; and for MSLF systems the barriers posed by food safety and quality demands, as well as land scarcity; for LSLF the challenge lies in the unsustainability of the production system, both from the environmental (e.g., contamination of water and soil) and social (e.g. Concentration, exclusion) point of view, and its high dependence on fossil fuels in a context of lower and lower availability (and higher prices of energy) and increasing needs to reduce emissions.

Today the livestock sector must respond to the challenge of food security in a current situation of lack of natural resources and increased global population by shifting its focus from increased productivity or production towards increased resilience, more in line with the above mentioned food system approach. Building greater resilience into the global food system is crucial in a changing environment. This is not in contradiction to increasing productivity for those farming systems that might need it, as long as resilience is still their primary focus. The great capacity of SSLF systems to convert human-inedible forage and residues into human-edible protein seems crucial to enhance global food security, i.e. To make a more efficient use of available natural resources without competing with humans for food. Small-scale livestock farming systems (P, BPP, MF1, R1 from Figure 3) cover most of the areas of the world that are marginal for crop Production. These systems are characterized by ruminants - e.g. Cattle, sheep, goats, camels - grazing mainly grass and other herbaceous plants, often on communal or open-access areas; and by scavenging monogastrics – e.g. Poultry and pigs – taking profit of materials which are not used by humans. Particularly pastoralism, that is, raising of livestock in extensive grazing systems using mobility as the crucial management practice, consists in a livestock production system that is brilliant in Benefitting from marginal environments, characterised by climatic variability and low to variable biomass (WISP, 2007). On the other hand, however, it is estimated that further expansion of the industrial food production to meet the current and projected future demand could cause enormous environmental problems (Development Fund /Utviklingsfondet, 2011).

One major constraint for the expansion of livestock systems is the fact that the area available for livestock raising will hardly expand and their current access is already highly threatened (e.g., by industrial crop products like soya or biofuels). Additionally, greater expansion of the LSLF system could reduce the amount of human-edible food since it is using food crops to feed livestock. Currently, about one-third of the world's cropland is being used to produce animal feed and about half of the global cereal production ends up as animal feed (Steinfeld et al., 2006) for industrial livestock operation. More than 90% of global soybean production is for feed. Furthermore, it is estimated that large-scale industrial agriculture produces only around 30% of the total food consumed globally, while small-scale operations produce at least 70% (ETC-group, 2009). Thus, it seems that while more attention is paid into large-scale systems, the potential of small and medium-scale systems is far higher than the former, and this can be extrapolated to livestock systems too.

Table 5. Changes in Global trade of livestock products from 1967 to 2007.

ITEM	EXPORT (million tonnes)		
	1967	2007	2007/1967
Pig meat	1.48	11.13	750%
Beef and buffalo meat	2.41	9.46	392%
Eggs, primary	0.33	1.44	442%
Milk, total	18.84	93.19	495%
Poultry meat	0.39	12.66	3 206%
Sheep and goat meat	0.58	1.04	180%

Source: FAOSTAT. FAO (2009d)

Water availability should also be seriously addressed , since the proportion of people living in water-stressed regions is expected to rise to 64% by 2025 in comparison with 38% in 2002 (Rosegrant et al., 2002). The livestock sector is a major user of fresh water. It is currently estimated that it uses 20% of green water flow (Deutsch et al., 2010). It is estimated that 1 kg of edible beef requires 12,000 litres of water in grazing systems, while up to 53,200 litres in intensive systems (Steinfeld et al., 2010). The same point is also stressed by FAO (2009) when claiming that 'landless' livestock systems, namely those that are housed and take up little physical space – LSLF - are major users of water through their feed (FAO, 2009). Thus, increasing efficiency in the use that production systems make of natural resources while increasing resilience is one major objective in a context of global climate change. The UN Special Rapporteur on the Right to Food, Olivier De Schutter (2010), claims that "to feed 9 billion people in 2050, we urgently need to adopt the most efficient farming techniques available", and adds that "today's scientific evidence demonstrates that agro-ecological methods outperform the use of chemical fertilizers in boosting food production where the hungry live -- especially in unfavourable Environments". In the case of livestock systems, this would give a prominent role to pastoralists to the detriment of LSLF systems.

As previously stated, food security is not only about production, as other aspects need to be addresses too. In the case of livestock one major issue is the consumption of meat. Projections are made based on current levels of meat consumption and trends in demand, assuming it is a demand-driven process. However, those assumptions can be questioned, and consequently food security in relation to livestock will suffer from important implications. Rivera-Ferre (2009) suggests that the world increased demand for animal food products is a supply-driven process, caused by a combination of supply increments, boosted by multilateral organizations in developing countries, and favored by externalization of environmental and social costs, which in the end affects both product prices and consumer habits. Rivera-Ferre (2009) claims that this supply-driven increase in livestock consumption causes health, environmental and social problems, and it finally ends up disempowering both producers and consumers. In this way, contamination of freshwater resources or concentration of farming activities, which is typical of LSFS, are not included in the final price. Furthermore, the lack of support to other livestock systems limits the freedom of choice of consumers. Other authors, McMichael et al. (2007), suggest that the average global consumption of meat could be cut down to approximately 90g a day, compared with the current 100g, and that no more than 50g should come from red meat from ruminant. Consequently, one of the major arguments used against SSLF systems, namely their capacity to feed the world, can be discussed. Firstly, the projected demands can be based on wrong assumptions; secondly, these numbers are not desirable from a human or an ecosystem health perspective, not from a ecosystem health perspective; third, we need to integrate the food security issue into a wider framework which addresses not only the food system as a whole, but also integrates interactions among food security and other social and environmental drivers and outcomes. In this way, it seems clear that a major shift towards SSLF and MSLF systems, and a reduction in meat consumption in rich countries, could make a major contribution to deal with the current situation of world high food insecurity while stopping depletion of natural resources.

One example of the above arguments is the relation between SSLF systems and soil carbon sequestration: a relevant one, considering that soils represent the earth's largest carbon sink that can be managed. Today it is acknowledged that there is nearly as much carbon in the organic compounds contained in the top 30 cm of soil as there is in the entire atmosphere (Foresight, 2011). Therefore an appropriate soil management policy might help CC mitigation, and enhance food security associated to livestock systems. Grasslands cover approximately 26% of the emerged lands (FAO, 2005; WRI, 2000). The vegetation of these ecosystems is dominated by herbaceous species, with less than 10% of tree cover (Jones and Donnelly 2004). They are estimated to store up to 30% of the world's soil carbon, in addition to the amount of aboveground carbon stored in trees, bushes, shrubs and grasses (White et al., 2000; Grace et al., 2006). For that reason, conversion of rangelands to cropland is a major cause of emissions, resulting in 95% loss of above-ground carbon and up to 60% loss of belowground (Reid et al., 2009). As livestock products are the main outputs of grazing lands, it is clear that there is a huge potential of carbon sequestration in soils, that may be exploited through adequate livestock management practices. This could make it possible to obtain livestock products for human consumption, without competing. While ensuring consumption of livestock products which does not compete for human-edible food sources.

Furthermore, up to 71% of the world's grasslands were reported to be degraded in 1991 (Dregne et al., 1991). This implies that they are far from saturated in carbon and, thus, still have a significant capacity to store more carbon (Farage et al., 2003). Restoration and proper management of the damaged world rangelands suggest another way to exploit the potential contribution of adequate livestock management practices to address GHG. The potential for carbon sequestration through soil erosion control and soil restoration has been estimated at 12–18 billion tonnes of carbon over a 50-year period, resulting in a 5 to 15% offset of global emissions (Lal, 2004). Consequently, with proper rangeland managements the livestock sector could achieve a 1-2% increase in soil-carbon levels on existing agricultural, grazing and desert lands over the next two decades. According to GRAIN (2009), a 1-2% of organic matter in the top 30 cm increase could take 30% of the current excess of CO_2 in the atmosphere.

The technical mitigation potential of grazing systems' carbon sequestration is considered significantly higher than the reductions of methane emissions from enteric fermentation or manure management (FAO, 2009d). Improved livestock management practices could include promotion of moderate levels of grazing so as to favour carbon immobilization in roots rather than in above-ground plants, or the cultivation of deep-rooted plant species as cover crops in agricultural land. Furthermore, the IPCC (2007) has reported that pasture quality improvement can be important in reducing methane as this results in improved animal productivity and reduced proportion of energy lost in form of methane. It is clear that if at stake is rangeland preservation, pastoralist communities are the best candidate, as they preserved most of existing rangelands throughout the centuries.

In economic terms it is also important to highlight the contribution of livestock to the household economics and national economy and thus, to food security (availability and access) Livestock production accounts for 40% of the value of world agricultural output (Steinfeld et al., 2006). In some countries its contribution is particularly important. For instance, in Mongolia livestock production is reported to account for almost 90% of agricultural gross domestic product (GDP) and almost 30% of total GDP (Pilling et al., 2008). However, raw economic figures do not capture the full significance of livestock production to economies and livelihoods around the world, mostly if we refer to SSLF. This is the case of pastoralism, where some market (e.g. Manure, tourism) and nonmarket (environmental and social services) functions are not factored in the contribution pastoralism makes to household and national economies (WISP, 2006). Furthermore, the alternative activities that could be performed in the grasslands where pastoralists live are not evaluated to compare different economic returns of different activities in the same location. Yet, if only direct market values are considered, the contribution is highly relevant: 8.5% in Uganda, 9% in Ethiopia, 10% in Mali and 20% in Kyrgyzstan (WISP, 2008).

The genetic diversity of SSLF also needs to be factored in when addressing the contribution of these farming systems to food security. Animal genetic diversity plays an insurance role in the direction of reducing vulnerabilities to climate change, and thus, ensuring food. FAO-UNEP (2000) stated that domestic animal diversity is critical for food security. However, the loss of domestic animal breeds is cause for concern. In Europe, half of all domestic animals breeds that existed at the turn of the XX century have become extinct, and 43% of the remaining breeds are endangered (FAO-UNEP, 2000). Globally 20% of breeds are classified as endangered and critical (FAO, 2007). Industrialization of animal production and marginalization of traditional production systems are considered major threats to animal diversity (FAO, 2007; Pilling et al., 2008)

To sum up, the major arguments to support the capacity of SSLF not only of cooling the planet, but also of enhancing world food security are summarised hereafter:
(a) the capacity of converting low-quality food into high-protein food;
(b) the utilization of marginal lands, which could hardly be exploited enhanced by other activities;
(c) a low degree of natural resources' depletion;
(d) a reduced level of meat consumption;
(e) an increased capacity to preserve carbon-rich grasslands;
(f) the preservation and promotion of both, wild and domesticated biodiversity, which drawing on local and traditional knowledge proves fundamental to develop resilience to future changes.

1.4 Differences among livestock farming categories

The fundamental differences between the existing categories of livestock farming systems can be summarized in five groups (see Fig. 3): (a) increased treatment of livestock farming as an industry, from SSLF to MSLF and LSLF; (b) increasing mono-functional role of livestock farming from SSLF to MSLF and LSLF; (c) increased separation between agriculture and livestock farming from SSLF and MSLF to LSLF; (d) decreased valorisation capacity of marginal lands and products from the SSLF to MSLF and LSLF; and finally (e) increased reduction of diversity at all levels from SSLF to MSLF and LSLF.

1.4.1 Livestock farming as an industry

The trend of increasing consumption of animal products in impoverished countries has been referred to as the 'livestock revolution'. As previously stated, there is no consensus on whether this increase is demand-driven (Delgado, 1999) or supply-driven (Rivera-Ferre, 2009), although it is clear that in the last decades massive subsidies by international organizations and favourable regulations have supported the growth of industrial livestock production all over the world, and particularly in impoverished countries. This new demand is being mainly satisfied through the production of pig and poultry meat, by LSLF to urban consumers and by MSLF to peri-urban consumer. From 1970 to now, worldwide meat production has suffered an annual growth of 2.8% with poultry and pig production growing at a level twice that of ruminants (Rivera-Ferre, 2010). GHG emissions are predicted to rise between 35–60% by 2030 in response to population growth and changing diets in developing countries, in particular towards greater consumption of ruminant meats and dairy products, as well as the further spread of industrial and factory farming in rich and impoverished countries (IPCC, 2007). Industrial livestock production, which was almost non-existent 40 years ago, grew at an annual rate six times higher that of livestock production based on grazing – 4.3% and 0.7% respectively (FAO, 1996).
The process of industrialization has been particularly remarkable for pig, poultry and egg production, where about 50–60% of the world production is conducted under landless, factory conditions (FAO, 2009).

Many problems associated to factory farms like water, soil and air pollution, and severely compromised animal health and welfare, have largely expanded along the intensification process. As shown in Table 6, the impact on environment varies depending on the production systems and the species grown. Intensive farming systems (LSLF) have the highest environmental impact - and energy use. LSLF, and to a less extent MSLF, impose industrial forms of production to livestock farming – dependence on fossil fuels, mechanization, intensification, use of agrochemicals, monoculture, feedlots, etc. Among other things, this leads to production concentration to meet a largely concentrated bulk of urban consumers buying in supermarkets. Regarding species, it is accepted that poultry has the lowest environmental impact – due to the greater feed conversion efficiencies of mono-gastric (Henderson et al., 2011); while cattle production has the highest.

The 2009 FAO State of World Agriculture Report shows that in placing together these two factors - production systems and species - mono-gastric traditional production is, generally , the less pollutant system, while mono-gastric industrial systems are the most pollutants. In terms of GHG emissions, still mono-gastric traditional systems have the lowest emissions levels, while intensive ruminant production has the highest (FAO, 2009b). Maarse (2010) pointed out that the vast majority of GHG emissions come from wealthy countries practicing factory farming, and that the aggregate of all African ruminants, for example, account for only 3% of the global methane emissions from livestock.

Table 6. Comparing the impacts of grazing and intensive (confined/industrialized) grain-fed livestock systems on water use, grain requirement, and methane production.

Water	Measure of water use	Grazing	Intensive
		Liters day^{-1} per animal at 15°C	
Cattle	Drinking water: all	22	103
	Service water: beef	5	11
	Service water: dairy	5	22
Pigs (lactating adult)	Drinking water	17	17
	Service water	25	125
Sheep (lactating adult)	Drinking water	9	9
	Service water	5	5
Chicken (broiler and layer)	Drinking water	1.3–1.8	1.3–1.8
	Service water	0.09–0.15	0.09–0.15
Feed required to produce 1 kg of meat		kg of cereal per animal	
Cattle		–	8
Pigs		–	4
Chicken (broiler)		–	1
Methane emissions from cattle		kg of CH_4 per animal $year^{-1}$	
Cattle: dairy (U.S., Europe)		–	117–128
Cattle: beef, dairy (U.S., Europe)		53–60	–
Cattle: dairy (Africa, India)		–	45–58
Cattle: grazing (Africa, India)		27–31	–

Source: Godfray et al. (2010).

Note: The table does not include other impacts of differing livestock management systems such as (i) nutrient run-off and pollution to surface and groundwater, (ii) protozoan and bacterial contamination of water and food, (iii) antibiotic residues in water and food, (iv) heavy metal from feed in soils and water, (v) odour nuisance from wastes, (vi) inputs used for feed production and lost to the environment, (vii) livestock-related land-use change.

For thousands of years, agriculture produced food and fodder by relying only on renewable resources. The new industrial farming has replaced environment-friendly technologies in use for millennia, by fossil fuel energy-intensive technology (Development Fund /Utviklingsfondet, 2011). In terms of transport, all inputs, products and even labourers must be carried away from where their costs are cheaper. Locally available feed like grass and other roughage, as well as nutrient-rich waste from farms and households have been replaced by manufactured feed, produced and carried over long distances. The dependence on transport is so remarkable that often the road system and state-of-the-art refrigeration techniques are at the heart of the progress in industrialization. Thus, the present livestock system, based on LSLF, is characterized by a high dependence on fossil fuels, with particularly devastating effects on GHG emissions. This dependence is so high that, as highlighted by Tillmand et al. (2002), in industrial farming yield gains correlate perfectly with input increases. As a result of the large amounts of food and input transportation, the intensive monoculture production of feedstuff, land and forest degradation, and the use of chemical inputs, LSLF has become heavily dependent on farmers' continuing investments in energy-intensive machinery and fossil-fuel-based inputs, transforming livestock production from an activity in which energy is generated, into one in which energy is consumed namely a net contributor to climate change (Pimentel, 1997). Grain-fed beef requires 35 calories for every calorie of beef produced –the very opposite of what had been the main reason for developing agriculture (Development Fund /Utviklingsfondet, 2011). Thus, the livestock revolution, in that it led to the expansion of factory farming in impoverished countries, can be perceived as a major climate threat.

Furthermore, industrial livestock production under landless conditions (LSLF) requires a huge amount of cropland being devoted to concentrated feed production that also contributes to GHG emissions. The carbon emissions from feed grain production include: 41 million tons from fossil fuel used to produce fertilizers; 90 million tons from on-farm fossil fuel use; and 10-50 million tons from processing, mainly related to factory farms (Steinfeld et al., 2006). The related mono-cropping of feedstuff also generates enormous amounts of nitrous oxide emissions. The gradual separation of livestock farming from grasslands, as we move from SSLF to LSLF, is in line with a decreased importance of ruminant livestock species in favour of cereal-feed mono-gastric livestock species. This often entails the degradation of grasslands, or the conversion of grasslands into croplands. As previously mentioned, grasslands are among the planet's ecosystems with the largest CO_2 sequestration capacity. While forests expand their volume by only about 10% per year, savannahs can reproduce 150% of their volume (Paul et al., 2009). For instance, Maitima (2008) warns that the conversion of large areas of pasture lands into croplands in east Africa will be a major regional contributor to global warming. In addition, further emissions will be produced as a result of deforestation and destruction of other ecosystems. Deforestation has been largely driven by intensified cattle and animal feed. With regard to deforestation, of note is the damaging effect of the slush-and-burn agriculture, particularly in tropical regions. This is not an industrial activity (LSLF), but a traditional practice (SSLF-MSLF) that in many cases is now over-practiced because of population growth and degradation of pasturelands.

1.4.2 Multifunctionality vs. monofunctionality

Countless communities have been grazing livestock on extensive regimes in the course of history. Today 70% of the world's poorest communities raise livestock. For them, livestock is not only a source of food, but also a source of fibres , fertilizers, social status, draught power, manure, recycling wastes, cultural identity and lending etc. Even in industrialized countries, grassland plays an important role in agriculture, nutrition and society (Paul et al., 2009). Livestock for small livestock keepers, and particularly pastoralists, represents more than just an economic asset, but also social, cultural and spiritual values, as it plays a decisive role in social identity. For instance, throughout the Horn of Africa, pastoralists define their wealth and

poverty in terms of the amount of livestock they own (Aklilu and Catley, 2009). Thus, it is not surprising that the shift from traditional SSLF and MSLF systems towards industrial production systems (LSLF), can be pictured as a replacement process of multifunctional farming systems. In this process, livestock raising turns from a multifunctional into a commodity- specific activity. Unlike SSLF and MSLF systems, livestock production is no longer part of an integrated system based on local resources, with non-food outputs being employed as inputs in the system (FAO, 2009).

For small livestock keepers, livestock plays an additional function of buffer against shocks, and therefore contributes to enhancing the resilience of their livelihoods. The fact that livestock grows and reproduces makes it an expanding asset base for their owners. Thus, herd accumulation is a common practice even among agropastoralists, although livestock for them represents a minor income source in normal times (Ashley and Sandford, 2008). A 2003 study in Uganda revealed that livestock ownership in Kampala increased during times of social upheaval (Ashley and Sandford, 2008). This strategy has also been reported as an adaptation strategy followed by pastoralists in Huancavelica (see section 7.4). Moreover the role played by livestock is used by livestock keepers to allocate part of their resources to relatively risky but high-return enterprises promoted by financial institutions (FAO, 2009). For example, in Kenya, Imai (2003) found that having a higher value of livestock assets enables households to invest more in high risk activities such as coffee and tea plantations. In addition, livestock is also used by small livestock keepers to strengthen social relationships by helping the family through livestock loans. Small livestock keepers can lend or give animals to relatives, knowing that this gives them higher social status and puts them in a stronger position to ask for help in the face of a disaster. Because of their portability, livestock have a special role to play when people are physically displaced by conflicts or natural disasters. A family can move animals, but must leave buildings and crops behind (FAO, 2009). These two functions have also been identified as adaptation strategies to cope with climate variability by pastoralists in Turkana (section 7.1).

This highly multifunctional role that livestock plays in SSLF societies, as opposed to what happens in LSLF systems, is well reflected on the fact that approximately 80% of the value of livestock in low-input developing-country systems can be attributed to nonmarket roles, while only 20% is attributable to direct production outputs; whereas, by contrast, over 90% of the value of livestock in high-input industrialized-country production systems is attributable to the latter (FAO, 2007).

1.4.3 Emancipation from agriculture

Every ton of additional humus in the soil relieves the atmosphere of 1.8 tons of CO_2 (Hoffmann, 2011). This illustrates the urgent need for integrating agriculture into livestock farming, and the particularly controversial role of landless industrialized livestock production in terms of GHG emissions. However, in the last 50 years, the extensive use of chemical fertilizers and other unsustainable practices of industrial agriculture have triggered an average loss of between 30 and 60 tons of soil organic matter for every hectare of agricultural land (GRAIN, 2009). In line with this, GRAIN (2009) claims that restoring soil fertility to pre-industrial levels would capture 30-40% of current excess of CO_2 in the atmosphere. Thus LSLF, by promoting a separation from agricultural activity, destroys natural processes in the soil that lead to the storage of CO_2 as organic matter, and replaces them by chemical processes based on fertilizers. Due to the high dependence on chemical fertilizers (through agricultural production of monocultures for feed crops) intensive livestock farming generates important quantities of NO_2. A big share - often above 50% - of the energy used in farming is required for the production of synthetic fertilizers, in particular nitrogen fertilizers and pesticides (Hoffman, 2011). For instance, in Europe, 40% of the energy consumed on farm is due to the production of nitrogen fertilizers (GRAIN, 2009).

Animals are inefficient nitrogen users, and this is particularly true for ruminants. Nonetheless, when these animals feed on roughage, like grass or bran, and their excreta return to soils, as in the case in SSLF and some MSLF, their nitrogen inefficiency has no remarkable negative impact in terms of GHG emissions (Steinfeld et al., 2006). Likewise, it should be said that, from an emission perspective, the manure deposited on fields and pastures does not produce significant amounts of methane, while factory farms and feedlots that manage manure in liquid form release 18 million tons of methane annually (Steinfeld et al., 2006).

Given the disconnection between agriculture and livestock activities, agriculture aiming to to feed crops are cultivated the animals is conducted far away from where animals are kept, while the nutrients they produce in the form of nitrogen or phosphorus become pollutants. At the same time, agricultural systems suffer from nutrients deficit, which must be compensated for with inorganic fertilizers, whose production and use imply ich produce GHG emissions and dangerous contaminants. Menzi et al. (2009) estimated that the total amount of nutrients in livestock excreta is as large as the total amount of nutrients contained in all chemical fertilizers used annually. Furthermore, manure performs better than artificial fertilizers in terms of soil structure and long-term fertility. Its greatest value is well known by small-scale farmers, being a common practice between small agricultural farmers and livestock keepers to exchange grain for manure (Hoffman et al., 2004). Thus, while manure is a priceless asset for small-scale livestock keepers, it turns into a serious problem for landless large-scale intensive livestock production systems (LSLF), with no land to apply it, particularly in most industrialized countries, where some environmental acts restrict the amount of manure that can be applied.

Another effect of the independence of livestock activities from agriculture is related to the use of working animals. A recent study by Starkey (2010) indicates that the number of working animals in the world has decreased from 300–400 million in the 1980s to 200– 250 million today. It also highlights that the number of working animals is increasing in Africa, although significant decreases are taking place in other parts of the world. This finding, however, does not match with our observations in the case of Alaotra Lake, where zebus to work the paddies are being increasingly substituted by rotavators. In Western Europe and in the USA the use of animal draft power has almost disappeared, due to the large expansion of LSLF and MSLF systems which require no draught power and only little mechanization. Starkey (2010) also claims that while tractors seldom increase yields per hectare the replacement of animals with tractors does increase soil compaction and reduce manure availability for fertilization, household fuel, construction, as well as biogas production. Other synergies emerge out of the integration between livestock and agriculture systems, apart from manure and draught power, such as pest control or usage of crop residues. For example, herded ducks in the Mekong Delta and China travel from field to field eating snails, insects and discarded grain, thus providing pest control for rice crops (Yu et al., 2008).

According to International Soil Reference and Information Centre (ISRIC, in Development Fund /Utviklingsfondet, 2011), 46.4% of soils is experiencing an important decrease in productivity, and another 15.1% of soils can no longer be used for farming, while about 9.3 million ha of soil (0.5%) is irreparably damaged. In Africa, 128 million ha – 26% of its degraded soils – are classified as strongly or extremely degraded, while another 5 million Ha are irreclaimable. Overgrazing is the main cause of soil degradation in Africa (WHO and UNEP, 2010) accounting for 49% of the area, followed by agricultural activities (24%), deforestation (14%) and over-exploitation of vegetative cover (13%). Hence, as claimed by FAO (2009), interactions between livestock and crops, that tend to be lost when livestock systems are intensified, may need to be revisited. A tighter crop-livestock integration should be explored and promoted to reduce GHG emissions.

1.4.4 Valorization of marginal lands and products

Another major difference between SSLF, MSLF and LSLF, is that while the latter and grain-fed MSLF compete directly with human being for food, SSLF valorizes waste products and marginal lands that could hardly be devoted to other purposes. It is evident that livestock keeping can contribute, as it is the case of SSLF, to lower CO_2 emissions by using, as feed, roughage and nutrient rich waste from farms and households[1], and by reducing the amount of grain grown on high inputs.

Marginal lands and feedstuff can be efficiently used by livestock. However, in order for “marginal lands” to be used by SSLF communities, policy makers need to take into account the subtle and complex relationship existing between those marginal lands and the people using them. Marginal lands are often managed under a property regime of communal land where access to pastures, water and other resources is negotiated and depends on traditional arrangements. It should also be noted that SSLF, and in particular pastoralism, due to its periodical grazing pattern, uses land that would otherwise be left unproductive, and much of the grassland that is used to feed these animals could not be converted into arable land without producing major environmental side-effects (Godfray et al., 2010). As previously stated, grasslands cover 70% of the global agricultural land and their seasonal use by livestock contributes to grassland conservation as well as to their carbon sink function.

Thus, livestock farming contributes to food security in a decisive manner when it is conducted in an environment where crops cannot be grown easily, such as rangelands

[1] This practice is here assessed from an environmental perspective. From the animal production point of view, it is clear that in some places this practice might needs to be evaluated to increase the quality of the food offered to the animals.

– in case of pastoralism and ranching (SSLF and MSLF) - or when they the animals scavenge on public land, use feed sources that cannot directly be eaten by humans, or supply manure and traction for crop production – as in the case of SSLF and MSLF (FAO, 2011). In these cases, livestock farming contributes to balancing the amount of energy and protein available for human consumption in a formidable way. On the contrary, when livestock is raised in intensive systems – LSLF - they convert a given amount of high-quality carbohydrates and protein, which might otherwise be eaten directly by humans, to produce a smaller quantity of higher-quality energy and protein. In the latter case, livestock farming clearly is increasing households' vulnerability and depleting natural resources. This is well reflected in Table 7 which shows that those countries with a livestock farming sector closer to LSLF display an output/input ratio below or near one. This means that the livestock sector in the above countries consume more human-edible protein than it provides. Whereas those countries with a predominance of extensive ruminants in their farming sector show remarkably higher ratios, suggesting that they add give a positive contribution to overall supply of protein.

Table 7. Humand-edible protein balance in the livestock production of a set of countries.

	EDIBLE PROTEIN OUTPUT/INPUT		EDIBLE PROTEIN OUTPUT–INPUT TONNES	
	AV. 1995–1997	AV. 2005–2007	AV. 1995–1997	AV. 2005–2007
Saudi Arabia	0.15	0.19	-533 731	-659 588
USA	0.48	0.53	-7 846 859	-7 650 830
Germany	0.66	0.62	-921 449	-1 183 290
China	0.75	0.95	-2 822 998	-665 276
Netherlands	1.66	1.02	322 804	18 070
Brazil	0.79	1.17	-622 177	550 402
Nepal	2.25	1.88	37 370	40 803
India	3.60	4.30	2 249 741	3 379 440
Sudan	18.22	8.75	235 868	340 895
New Zealand	8.04	10.06	460 366	638 015
Mongolia	14.72	14.60	42 987	35 858
Ethiopia	16.02	16.95	99 909	141 395
Kenya	18.08	21.16	124 513	202 803

Source: FAO (2009)

Note: Edible protein output estimated from indigenous meat, milk and eggs. "Indigenous" meat production = production from slaughtered animals plus the meat equivalent of live animal exports minus the meat equivalent of live animal imports. Edible protein input estimated from available feed (domestically produced and imported) and primary crops that are edible by humans (excluding canary seed and vetches).

It is clear that reducing the amount of human-edible food required to produce the livestock feed would be a valuable contribution to food security, as well as to CC mitigation. However, Steinfeld et al. (2006) estimate that 77 million tonnes of plant protein are consumed annually to produce 58 million tonnes of livestock protein. Two main strategies are available to achieve this goal, namely: (a) producing a larger quantity of food through grazing livestock systems, and (b) stimulate, and where needed improve, those livestock farming systems that recycle waste products.

1.4.5 Diversity

Biodiversity is largely acknowledged as a fundamental resource for adaptation strategies in a changing environment. In many cases in the past, the genetic pool of peasant and wild plant and animal species proved to be essential for the survival of intensive crop and livestock production systems. The same is true also for those systems relying Indigenous and traditional knowledge, usually more linked to SSLF. The interrelation between biodiversity and livestock production systems is two-fold.
Firstly, SSLF often relies on the use and maintenance of marginal lands. Marginal lands are important reserves of biodiversity, which is considered a source of genetic diversity, preserving resources that might be extremely useful to develop resilience to future new stresses. Secondly, SSLF depends on and contributes to the preservation of a wide spectrum of livestock species and breeds used in different farming systems. It should be noted that genetic diversity defines not only animal breeds' production and functional traits, but also the capacity to adapt to different environments, including food and water availability, climate, pests and diseases (FAO, 2007), and the knowledge associated with each species. Despite local breeds – mainly in SSLF and MSLF - contribute to the livelihoods of 70% of the world's poor, they are not usually utilized in LSLF.

Intensive systems use mostly high-yielding breeds, in particular three species -pigs, poultry, cattle- and very few breeds within these species. Resistance to diseases and pests, heat and water stress, vitality, fertility and mothering abilities are largely dismissed attributes. These breeds and lines have been intensively reared for high output and good feed conversion ratios, under high external input conditions (Pilling and Hoffmann, 2011). Such breeds increasingly dominate global livestock production. They need standardized feeds, intensive veterinary treatment and a controlled environment to prevent infections.

High livestock densities lead to a depressed immune response, and high throughput provides a continually renewed supply of susceptible animals (Wallace, 2009). The condition of crowded farms, with animals with low immune systems found in LSLF easily ends up in the emergence of an increased number of diseases. Genetic monoculture removes all immune firebreaks that could slow down the transmission of diseases. Hence these systems are more vulnerable to the infectious agents, that spread more quickly through their populations (FAO, 2009).

This situation makes LSLF very vulnerable to climate variability, due to its extremely low capacity to adapt to changes that such a low genetic variability provides. On the contrary, while the genetic diversity in most industrial cattle and pig breeding lines is dangerously low, SSLF systems breed and nurture 40 livestock species and almost 8,000 breeds (ETC-group, 2009). According to Hoffmann (2007), 89% of the existing 6536 breeds recorded are local, and 93% are local or regional, that is, being involved in SSLF or MSLF. However, the expansion of LSFS together with the rejection of SSLF has favoured the disappearance of many local breeds. It is estimated that from a total of 7,616 livestock breeds known, around 20% are reported as at risk, and 62 of them have become extinct in the last six years (FAO, 2007). In general, the availability of larger number of varieties and species makes SSLF and MSLF more able to adapt to changing future conditions than homogenous LSLF (Borron, 2006; Altieri and

Koohafkan, 2008). Furthermore, SSLF breeds are selected to retain many genetic traits, such as fertility, vitality, and resistance to diseases and drought that no longer exist in animals kept in industrial systems. For instance, pastoralists focus on building resilience within, the system, rather than high levels of production (FAO, 2003; Mamo, 2007; Barrow et al., 2007). Here, diversity conservation and promotion plays a key-role. This trait is likely to be of increasing value in the face of climate change (Rivera-Ferre, 2010). As highlighted by Gliessman (1998) and Altieri (1994), diversity reduces risk for farmers, especially in marginal areas with more unpredictable environmental conditions. If one crop or livestock fails to perform well, other productions can compensate for LSLF also undermines diversity indirectly, through the promotion of industrial agricultural and monoculture for the production of feedstuffs. Over the years industrial agriculture has fostered the substitution of traditional crop varieties with high-yielding, uniform commercial varieties, thus leading to a dramatic loss in plant genetic diversity and, at the same time, in genetic options for coping with and for adapting to changing environments. Peasants have domesticated at least 5,000 plant species, but it is estimated that the industrial food chain uses only 3% of them (Small and Catling, 2008), and 60% of our energy requirements is being supplied only by 3 crops (maize, rice and wheat). Globally, over 4,000 assessed plant and animal species are threatened by agricultural intensification (IUCN, 2008). Deforestation is also one of the principal impacts caused by the expansion of industrial agriculture devoted to feedstuff production, being responsible for about 17% of GHG emissions (IPCC, 2007) but also for biodiversity loss. In the humid tropics, expansion of the different forms of agriculture and animal husbandry is responsible for nearly 85% of world deforestation (Lanly, 2004).

2. Measuring GHG emissions

In order to evaluate the amount of GHG emissions generated by different categories of livestock farming, a correct understanding of the notion of productivity is crucial. In fact, the deep meaning of productivity needs to be reviewed as new challenges, such as climate change and future low energy scenarios come to light. Measuring the amount of meat, eggs or milk produced daily, monthly or yearly can no longer be the only criterion available to evaluate farming systems' productivity. This approach is indeed linked to a narrow consideration of food security, in which only one part of the food availability component is considered, leaving aside other elements such as food access or food utilisation.

It should be clarified that productivity is relative to what is to be measured and how it is going to be measured. As claimed by Paul et al. (2009), the greenhouse gas emissions must relate to the climate impact of the whole product life cycle, including the feed footprint. Also, other environmental and social costs and benefits need to be included, since SSLF and MSLF - to some extent - fulfil these additional functions as well. For instance, productivity from extensive grazing systems (SSLF, MSLF) is low in terms of output per animal and per labour unit, but high in terms of output from limited resources. For instance, pastoral systems are found to be more productive per unit area due to the ability of pastoralists to move their herds opportunistically and take advantage of seasonally available pastures (Sandford, 1983) and to be more economically feasible than either sedentary or ranching systems (Niamir-Fuller, 1999). In fact, pastoralism does not represent its true value (Nassef et al., 2009). Omissions are related to the value of the informal economy and the subsistence function of SSLF, and the value of maintaining the health of ecosystems and other land uses (Rivera-Ferre, 2010). SSLF systems are well adapted to their environments and are very efficient in using the pastures available, and as claimed by FAO (2009), the survival of animals is as much a yardstick of efficiency as production per animal. Also when assessing the productivity of SSLF systems, it should be noted that their location has always been determined in relation to agriculture, with livestock taking the land that is too wet, dry, mountainous, distant or stony for cultivation. Another shortcoming of the 'per product' approach is that it does not incorporate an effort to globally reduce the emissions of the sector - in absolute quantity – by either rationalizing our diet or better managing stocks to avoid sparing. It is thus fundamental to identify alternative ways in which productivity might be measured.

Productivity is a measure of the efficiency of production. It is quantitatively determined by the ratio of output to input and it can also be measured in terms of time: the less time required to obtain a product, the more efficient. In livestock systems productivity is conventionally measured as the amount of animal products (kg meat, liters of milk, number of eggs) produced in a limited period of time (day, lactation) or per animal (carcasses), finally linked to the amount of money producers will obtain from the production system. Other disciplines (Ecological Economics) propose to measure productivity in different forms to include environmental perspectives, such as the amount of energy obtained per unit of energy introduced to the system, or the amount of territory required to obtain one given product.

Resilience: the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.

Vulnerability: the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007).

The measurement most conventionally used to determine GHG emissions relates to the volume of CO_2 emitted per mass of livestock product obtained. However, other possible ways of measuring productivity exist. Table 8 lists an overview of the different ways of measuring productivity and evaluating GHG emissions. This table also suggests how the different metrics used favour different livestock systems. Thus, given that extensively reared animals produce less edible output per unit of GHGs emitted than their intensively-reared counterparts, when the measurement employed relates emissions with the quantity of livestock product obtained, intensive productions are favoured (Garnett, 2011), that is, LSLF in this report. However, when land and other resources, such as water or fossil fuels, are considered, intensively-reared animals show larger emissions per unit of resources used than MSLF and specifically SSLF systems. This latter view sees a greater role for grazing animals, pastoralism and ranching, combined with the feeding of pigs and poultry on by-products – BPP - and small mixed farming – MF1. Livestock here is viewed as a positive asset rather than just a problem to be fixed. It is obvious that a holistic focus on yield per GHGs must be adopted, namely a resource-sensitive approach. Some resource-efficient strategies include, from a food security perspective, options such as using grains more efficiently to feed humans rather than animals. Another example is that conducted by grazing systems, where livestock is grazed in rotation with crops, while adding to the systems dung, draught power, etc. Often these mixed farming systems take place on marginal land of poor quality, which could not support crop production. In these cases, both ruminants and mono-gastric also tend to be fed with crop residues or food waste from humans, and thus, resources are more efficiently used. That is, new edible livestock products are generated from inedible waste and 'unproductive lands'. In the absence of this strategy, an equivalent amount of food should be obtained from elsewhere with an inevitable cost in the form of GHG emissions. All this should also be reflected upon when measuring the cost in GHG emissions of any given livestock farming system. Moreover, if well managed, grazing livestock on grasslands generate multiple additional benefits, such as maintenance of ecosystem services, carbon sequestration and biodiversity conservation (Allard et al., 2007; Leibig et al., 2010). For these reasons, although it is often stated that if reared in the same conditions, pigs and poultry – mono-gastric livestock – produce fewer emissions than ruminants, since their feed conversion efficiency is greater and methane is less of an issue (FAO, 2009), the benefits of grazing that ruminants generate should also be considered, particularly in extensive operations.

Table 8. Different metrics for assessing GHG emissions and productivity.

	Comments
Quantity based	
kg CO_2 eq/kg product	Mainstream metric – favours intensive monogastric production
kg CO_2 eq/kg protein, iron, calcium, fatty acid profile and so forth	Depends on nutrient: iron and calcium metric may favour ruminants; grass-fed ruminants may have better Omega 3–6 ratios than cereal fed animals (Aurousseau et al., 2004; Demirel et al., 2006); protein as metric will favour intensive monogastrics
kg CO_2 eq/kg food and non-food goods provided (leather, wool, feathers, dung, traction)	Variable; on balance likely to favour ruminants
Area based	
kg CO_2 eq per area of land	Emissions lower for extensive systems and for monogastrics
kg CO_2 eq per area of prime arable land required	Emissions lower for extensive systems, both ruminant and monogastric
Resources based	
kg CO_2 eq/kg of fossil fuel based inputs	Emissions lower for extensive systems, both ruminant and monogastric
kg CO_2 eq avoided through use of byproducts or poor quality land to rear livestock; this approach quantifies the GHG and land opportunity cost of needing to obtain an equivalent quantity of nutrition from elsewhere	Favours extensive systems and particularly landless household pig and poultry reliant on scraps
kg edible output per given quantity of ecosystem services provided on farmed land	Favours extensive ruminant systems
kg edible output per given area of land 'spared' for conservation or biomass production	Favours intensive systems, especially monogastrics

Source: Garnett (2011).

One interesting discussion is that of methane (CH_4), which as previously stated, accounts for 45% of total GHG, and 30% of total livestock emissions. The half-life of methane in the atmosphere is only around 7–8 years, unlike CO_2 and N_2O lasting more than 100 years. Thus, cutting methane would have a rapid impact on slowing climate change (Paul et al., 2009). In view of the high global warming potential of CH_4 in the first years of its atmospheric life, it is often argued that this and other short-lived gases should be a priority target (Moore and MacCracken, 2009). Garnett (2011) suggests that the different positions to the question of productivity are also reflected in the existing divergent attitudes regarding the characterization of CH_4 emissions. For those prioritizing methane emissions' reduction, it is vital to address ruminant emissions - as well as the ones from rice cultivation.

They argue in favour of a search for technologies that reduce CH_4 emissions, such as inhibiting CH_4 vaccines and feed supplements, and claim for a shift in consumption from ruminant to mono-gastric products (Weber and Matthews, 2007), or even advocate vegetarianism (Goodland and Anhang, 2009). An alternative view is the one that claims that a focus on 'quick wins', such as methane abatement, distracts from the imperative to tackle fossil fuels' dependency (Fairlie, 2010). Current levels of atmospheric methane are certainly an issue, but they have become so as a consequence of modern societies' dependence on fossil fuels , among which we include industrial livestock farming. An undue emphasis on methane justifies further development of the highly intensive rearing systems. To hold a clearer view on all this, it may be helpful to consider the abatement of GHGs emission as an outcome of good agricultural management rather than a prime goal.

3. Livestock and mitigation strategies

Mitigation describes measures that deal with the causes of climate change, while adaptation describes measures that deal with the effects of climate change. Thus, the IPCC (2001) defines mitigation as “an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases”, and adaptation as “the adjustment in natural or human systems to new or changing environments” in order to moderate harms or exploit beneficial opportunities. In addition, we consider ‘maladaptation’. That is, “actions taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups” (Barnett and O’Neil, 2010). At least five distinct pathways may be distinguished through which maladaptation arises. These are actions that are relative to alternatives:

- increase emissions of greenhouse gases,
- disproportionately put the burden on the most vulnerable,
- have high opportunity costs,
- reduce incentives to adapt,
- and set up paths that limit the choices available to future generations.

As we will see, and has been highlighted by Rundgren (2011), the areas in which livestock farming and CC interact are fundamentally the followings: farming emits GHGs; changes in farming practices have large potential for GHGs sequestration; changes in land use provoked by farming, have great impact on GHG emissions; and finally farming can produce energy and materials that can replace fossil fuels.

Adaptation: *adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or uses beneficial opportunities (IPCC, 2007).*
Proactive adaptation: *Adaptation that takes place before impacts of climate change are observed (IPCC, 2007).*
Reactive adaptation: *Reactive adaptation occurs after the initial impacts of climate change (IPCC, 2007).*
Autonomous adaptation: *Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems (IPCC, 2007).*
Planned adaptation: *Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state (IPCC, 2007).*
Mitigation: *An anthropogenic intervention to reduce the anthropogenic forcing of the climate system. It includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks (IPCC, 2007).*

As will be repeatedly mentioned in the following sections, great caution is needed in adopting mitigation strategies for GHG emissions reductions. Policy makers, as well as ordinary people, should bear in mind that solutions to climate change are not necessarily technical. Many of them are social and cultural. As highlighted by Paul et al. (2009), the need is urgent to shift our focus away from technological 'futures'

promises to the readily available knowledge, experience and resourcefulness of local communities, and in the case of livestock, pastoralists.
Several strategies have been implemented in livestock farming with the objective of mitigating produced GHG emissions. The mitigation strategies have been clustered according to the nature of the changes each of them generates. Obviously, special attention is placed upon strategies that are particularly relevant for SSLF systems. We depict the main characteristics of each of them below (see Fig. 4):

- Mitigation through market mechanisms
  - i/ GHG emission trading systems
  - ii/ Product carbon footprint labelling
- Mitigation through technological and managerial schemes
  - i/ Enhancing carbon removal and sequestration
  - ii/ Optimizing nutrient use
  - iii/ Improving productivity
  - iv/ Enhancing energy efficiency and use of alternative fuels
- Mitigation through behavioural modification
  - i/ Reduction in meat consumption
  - ii/ Favouring consumption of organic/local food

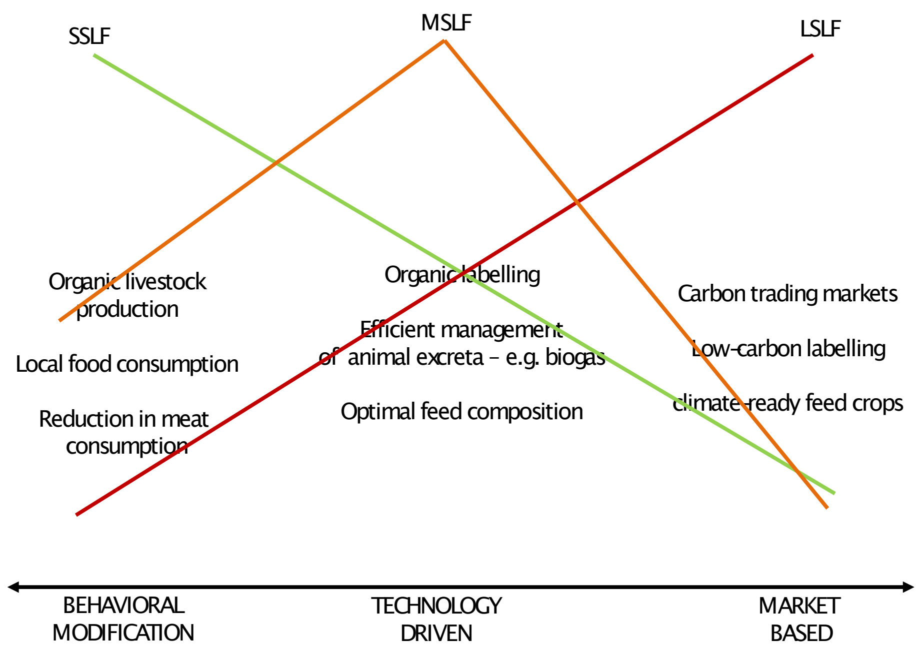


Figure 4. General trends in the participation of the main categories of livestock farming in the mitigation strategies.

3.1 Mitigation through market mechanism

One of the most advanced mechanism for CC mitigation is the one set up to develop market access tools and methodologies that take stock of GHG emissions from agricultural activities. There are two main sets of mitigation strategies being implemented: GHG emission trading systems and product carbon footprint labelling.

3.1.1 Greenhouse gases emission trading system

There are several market-based tools and measures through which agriculture can participate in GHG offset markets (see Table 9). These are different mechanisms that aim at internalizing the apparent cost that GHG emissions (for more information see Kasterine and Vanzetti, 2010).

The future of CO_2 emission trading market bodes well and global CO_2 markets are expanding rapidly. In the past two years the global carbon market has tripled reaching US$ 30 billions at the end of 2006 (World Bank, 2007). In 2008, 4.9 billion tons of carbon dioxide equivalent emission reductions were traded on the global carbon market. This implied an increase in carbon trading of 83% in one year (Paul et al., 2009).

Table 9. Examples of GHG emission markets.

Type of Market	Name
Regulatory (International)	Kyoto Protocol (Joint Implementation, Clean Development Mechanism, and International Emissions Trading)
Regulatory (EU)	European Union Emissions Trading Scheme
Regulatory (Australia)	New South Wales Greenhouse Gas Abatement Scheme
Regulatory (US)	Regional Greenhouse Gas Initiative (New England)
Voluntary	Chicago Climate Exchange (national/linked to EU)

One of the most used strategies in agriculture relate to the Clean Development Mechanisms (CDM), proposed in the Kyoto Protocol. CDM allows industrialized countries to invest in emission reduction schemes wherever it is cheapest. However, it is always difficult to judge whether or not projects really generate additional savings in GHG emissions. Thus, at present agribusiness and plantation companies are benefitting from about 10% of CDM credits, including livestock manure management (biogas from swine manure, etc.), heat generation from palm oil and using agricultural residues from biomass. Carbon trading has created windfall profits for fossil fuel and power companies and other industries responsible for high levels of GHG emissions (Paul et al., 2009). The principle of carbon-offsetting, underlying all GHG emission trading systems, is fundamentally flawed since any offset mechanism can lead to further emissions elsewhere[2]. Despite the great majority of proposals for a post-2012 climate change agreement point to a significant increase in carbon trading, the growing carbon markets have failed to produce overall CO_2 emission reductions in industrialized countries. Now, as negotiations for a new climate treaty to replace the 1997 Kyoto Protocol are in progress, it is expected that strong call will be made for a major role of carbon markets on the agricultural sector including payments for environmental services – particularly in soil sequestration.

[2] However, there exists an upper limit of emissions allowed to be reduced through CDM for the regulatory market – the rest having to be domestic reductions through technological improvement.

Carbon trading, under the Kyoto Protocol and other international schemes, is often presented as a solution for global warming. However it has also raised major criticisms among civil society organizations. Via Campesina (2007) argues that “after the privatization of land, water and seeds, it entails the privatization of air, that is, the privatization of carbon”. Consequently, it allows the distribution of the ‘rights to pollute’ and the trading of these rights. It is suggested that this strategy encourages industrialized countries to finance cheap carbon dumps, such as large-scale plantations in the South as a way to avoid reducing their own emissions. Large plantations or natural conservation areas are therefore being created in Asia and Latin America pushing communities out of their land and reducing their right to access their own forests, fields and rivers (Via Campesina, 2007). Although it is often claimed that these trading mechanism promote sustainable rural development in impoverished countries, this can be discussed. Most fundamentally, carbon trading markets in agriculture do not address the fundamental inconsistency of relying on a model of perpetual economic growth on a finite planet, often raised by ecological economists (Martinez Alier and Roca Jusmet, 2000). They hamper improvements in emissions’ reduction, and thus they contribute to accelerate the destruction of ecosystems that are crucial to stabilize climate, produce food and leave an habitable planet to future generations (Paul et al., 2009). The regulated carbon markets have not demonstrated until now that they can be favourable to small farmers and achieve the ‘development’ aim they claim for. The emissions trading systems can also prove unfavourable for small farmers since they tend to give priority to large projects involving high transaction costs.

3.1.2 Carbon footprint labeling

Another market mechanism used to mitigate CC is the development of agricultural product standards and labelling related to GHG mitigation benefits. That is the development of product carbon footprint standards - e.g. Carbon Reduction Label in United Kingdom; ClimaTop label in Switzerland; or the Carbon Label in France. Also, product carbon footprint standards are being increasingly integrated into existing labels on sustainable management of food - e.g. the Swedish Seal for food quality or the Swedish label KRAV for organic food. The carbon footprint labelling is mainly used for exported food from impoverished countries. As Hoffmann (2011) states, based on the lessons learned from the development of marketing channels for the organic and sustainable agricultural products, small peasants could benefit from such approach.

However, this will fundamentally depend on measurement and granting methodologies employed. Besides the issue of calculating the emissions and the availability of the required data – what is likely to be difficult, especially in the least developed countries – Brenton et al. (2010) suggest that there are not only technical issues surrounding the calculation of emissions from land use change, but fairness issues should be considered also It should be reminded that most rich countries do not need to include this source of emissions, since they have substantially modified their ecosystems - e.g. clearing their forests - decades or centuries ago.

3.2 Mitigation through technological and managerial schemes

In general, the application of technological and managerial strategies to mitigate GHG emissions is probably the strategy most commonly implemented by policy-makers. The literature here is abundant. We summarize the strategies most commonly implemented.

3.2.1 Enhancing carbon removal and carbon sequestration

Although aboveground carbon sequestration has been traditionally prioritized, via reforestation and afforestation - by stopping land clearing and deforestation for plantations, GRAIN (2009) claims that a total of 15-18% of total GHG emissions could be reduced -, the soil might represent even a larger carbon sink (Smith et al., 2007). In fact, it is the largest carbon sink that we could manage. It is estimated that there is almost as much carbon in the top 30cm of the soil as there is in the entire atmosphere (Foreshight, 2011) and thus, it is obvious that adequate management of the soil will strongly help in CC mitigation. Grasslands are estimated to store up to 30% of the world's soil carbon (White et al., 2000; Grace et al., 2006), despite up to 71% of the world grasslands were degraded in 1991 (Dregne et al., 1991). Conversion into croplands is a major cause of GHG emissions, since it implies 95% of loss in aboveground carbon and up to 60% of loss in below ground (Reid et al., 2009). Therefore, there is much room to mitigate GHG emission through rangeland management. The mitigation capacity through soil erosion control and soil restoration has been estimated from 5 to 15% of global emissions by Lal (2004), and that could take 30% of the current excess CO_2 in the atmosphere by GRAIN (2009). The technical capacity of favouring the carbon sequestration in grazing land is considered remarkably higher than other possible interventions in methane emissions from enteric fermentation or manure management (FAO, 2009d). This could be implemented through the stimulation of moderate grazing – as pastoralist do - or the cultivation of deep-rooted plant species as cover crops. Also the IPCC (2007) points at improving the quality of the pasture so as to improve livestock productivity, what at the same time reduces the proportion of methane lost.

Provided that carbon stocks in soils are highly correlated with productivity gains, soil conservation is a relatively affordable form of mitigation, for which many technical options are readily available (see FAO, 2009c). However, there may exist some trade-offs that question some of the mechanism implemented. For instance, when cropland is converted into grassland, wetlands or woodland, for sequestration purposes, this may involve intensifying cultivation elsewhere to compensate for yield loses, with the implication that GHG emissions can be produced. Evidence shows that the conversion of huge areas of pasturelands into croplands in east Africa will be a major contributor to global warming in the region (Maitima, 2008). It also exists, as stated by Garnett (2011), the risk of 'sequestration swapping', when organic matter is applied to a particular parcel and this occurs at the expense of other lands that were previously receiving this application. This would mean that the net carbon gain is zero. It should also be noted that when equilibrium is reached, there will be no more carbon sequestration and agriculture will become a net GHG emitter.

One of the strategies most often referred to in terms of increased GHG sequestration in the soil is the shift from conventional tillage to no- or minimum-till agricultural systems[3]. However, there is still no conclusive proof as to no-till agriculture's capacity to capture carbon in soil. Paul et al. (2009) suggest that there is little understanding of how tillage controls soil respiration in relation to N_2O emissions and denitrification and new studies have cast doubt on the carbon sequestration claims (Yang et al., 2008). The drawback of no-till monocultures is quite obvious, i.e. it would produce harm rather than benefit. Other technological solutions proposed to capture carbon is 'biochar'. This could be used by large-scale industrial agriculture devoted to the production of feed for livestock. Biochar is fine-ground charcoal that it is applied into the soil. There is no consistent information about its fate in soils. Ash accounts for a proportion of fresh biochar that contains nutrients and minerals that can increase plant growth – as takes place in slash-and-burn farming. However, soils treated in this way are exhausted after one or two harvests, as nutrients and minerals are quickly depleted (Paul et al., 2009).

Most fundamentally, and similarly to what has been previously stated, an excessive focus on carbon sequestration and associated offsetting activities distract from the real challenge: namely reversing the fossil fuel dependence and changing related consumption patterns. To avoid further soil carbon losses is a requirement as urgent as the need for more carbon sequestration. It may be helpful, as Garnett (2011) observed to consider soil carbon sequestration as an outcome of good agricultural practices, rather than a prime goal. This would be the case, for instance, of the moderate grazing promoted by pastoralism (SSLF). Good pasture management that keeps land from being degraded is the most appropriate way to capture carbon, mitigate GHGs and also to avoid the high cost of soil restoration.

3.2.2 Optimizing nutrient use

We know that plants and animals are inefficient in terms of nitrogen uptake. Most of the nitrogen added to fields or fed to livestock is lost in the environment. There are regions where LSLF nitrogen losses in the environment dominate the nitrogen cycle. On average, only a third of the nutrients fed to animals are absorbed and livestock excreta contain more nutrients than the inorganic fertilizer used annually. By means of growing feed crops and managing manure, the livestock sector also emits nitrous oxides and methane (Steinfeld et al., 2010). Intensive livestock outputs (e.g. slurry) have significant impacts on nutrient flows all over the world, as well as on the supporting crop and cereal system. Globally, ruminant livestock produce about 80 million tons of CH4 annually, accounting for about 33% of anthropogenic emissions of CH_4 (Beauchemin et al., 2008). Several are the technical options being extensively studied to reduce production of enteric CH_4, particularly from ruminant production systems, namely: (a) animal manipulation, such as reducing the number of unproductive animals on a farm, can potentially improve profitability and reduce CH_4 emissions; (b) dietary manipulation of forage, improving forage quality, either through feeding forage with lower fibre and higher soluble carbohydrates (changing from C4 to

[3] No-tillage agriculture is often associated to the promotion of GMOs and chemicals as an alternative to tillage, which may expose small farmers to other associated environmental and social risks.

C3 grasses (Ulyatt et al. (2002) report higher methane emissions from animals fed on subtropical C4 grasses than from those fed on temperate C3 grasses), or even grazing on less-mature pastures; (c) increasing the presence of condensed tannins in the diet to reduce methane production; (d) offering dietary supplements to improve ruminant fibre digestion and productivity and reducing CH_4; (e) manipulating microbial populations in the rumen through chemical means by introducing competitive or predatory microbes; etc.

Ruminants excrete between 75% and 95% of the N ingested, with excess dietary N increasingly excreted in the urine, whereas dung N excretion remains relatively constant (Castillo et al., 2000; Eckard et al., 2007). Out of the dietary N consumed by ruminants, less than 30% is utilized for production, with more than 60% being lost from the grazing system (Whitehead, 1995). Thus, to reduce N_2O several techniques are used, such as: (a) intervention on the animals, through genetic manipulation or animal breeding to improve the N conversion efficiency within the rumen, or raise animals that urinate more frequently or walk while urinating, all leading to lower N concentrations or greater spread of urine; also (b) to reduce N excretion in the urine, by feeding animals with condensed tannins or through salt supplementation to increase water intake in ruminants, both reducing their urinary N concentration and inducing more frequent urination events, thus spreading urinary N more evenly across grazed pasture; and finally, (c) through interventions on the soils, by means of modifying the rate, timing, and placement of animal effluent applied to soils that affect potential N_2O emissions, or applying nitrification inhibitors (chemical compounds that inhibit the oxidation of NH_4 to NO_3) in soils and thus reduce N_2O emissions from NH_4 based fertilizers and from urine.

However, most of the mitigation options show a narrow view on the problem of GHG emissions caused by livestock farming , and offer reductionist ‘solutions’ to a complex problem. In addition, most of them are not viable due to lack of knowledge or because too costly in monetary terms to be implemented on farm. In facing the emission issue they only look at the farm and everything else is put in a black box from where no information is given to us. Therefore, there is no assurance that the strategies recommended to farmers on the basis of the above assessments will effectively result in a meaningful net reduction in GHG emissions, neither is there assurance that a reduction in emissions at one point of the production cycle does not trigger higher emissions at another point. Furthermore, these are strategies exclusively befitting highly-intensive animal production systems. Almost none of them are meaningful for SSLF.

Pelletier and Tyedmers (2010) highlight that mitigation objectives are unlikely to be met only through technological solutions. The need to optimize fertilizer inputs is widely accepted. Those committed to organic or low-external-input farming question the need for inorganic synthetic fertilizers per se (Garnett, 2011). Additionally, small farmers cannot afford buying inorganic fertilizers. Some also claim that mitigation is possible by shifting production resources, particularly concentrate feeds, from ruminant to mono-gastric enterprises, given their higher feed conversion efficiencies and lower emission intensities (Henderson et al., 2011). Once again, it seems more reasonable to conceive the optimal nutrient use as an outcome of good agricultural practices, rather than a goal per se. In this regard, small farmers are in line with this objective by incorporating nitrogen-fixing legumes into rotations and crop associations, and by integrating livestock into agriculture through traditional mixed farming systems.

3.2.3 Improving productivity

From a traditional productivity viewpoint , further intensification of the farming activity is one of the recommendations proposed by the UN Framework Convention on Climate Change to mitigate climate change (UNFCC, 2008). This option emphasizes the importance of increasing yields as a route to reduce GHG emissions . The objective is to minimize both land requirements and GHG emissions per unit of farming product generated (World Bank, 2009; Godfray et al., 2010). This strategy is based on the notion of 'sustainable intensification', which means improving yields without damaging ecosystems (Garnett, 2011). It includes measures such as crop and animal breeding, feed optimization and dietary additives, and pest and disease management. We have previously discussed the need to change the way in which productivity is measured and here we summarize the main debates around this proposal.

This productivity-oriented approach is promoted on the principle of 'land sparing', whereby intensive production takes place on the smallest possible area in order to maximize exploitation of available land for conservation or forestry. The idea is that raising the yield potential will reduce pressure on ecosystems. The real impact of this mitigation strategy should be carefully assessed. It also raises several environmental and ethical concerns. The effectiveness of land sparing strategies in a profit-driven global market has been criticized; some have argued that it is not effective in preserving biodiversity or in halting deforestation (DeFries et al., 2010; Vandermeer and Perfecto, 2006).

In crops, conventional breeding approaches aim at developing pest and disease resistance, better nutrient uptake and the partitioning of more energy into the grain rather than the stalk (Fedoroff et al., 2010; Tester, 2010). While such purposes may be commendable, there is controversy over the tendency to give too much priority to few key commercial crops to the detriment of those managed by small farmers or poor peasants , as this generates social, economic and ethical imbalances , marginalisation of the crops of farmers and isolated peasants; and overall reduction in farming diversity, that amounts to making the whole farming system more vulnerable to pests and diseases IAASTD, 2009). Moreover, a sole focus on edible outputs and feedstuff fails to consider the multiple usages that rural communities make of crops and livestock.

Similarly, as the livestock sector utilizes around 70% of the world's arable land and generates a large proportion of agriculture GHGs, there is a perception that attempts to increase livestock yields generate both environmental and commercial benefits. This includes the use of improved fodder varieties in the form of low quality grass; the crossing of traditional breeds with imported higher-yield breeds; efforts to optimize the balance of carbohydrate and protein content in feed by minimizing nitrogen and methane losses through diets, including high levels of concentrates (based on cereals and oilseeds, particularly soy) to the detriment of grasses and coarse agricultural by-products. When breeding strategies only focus on developing highly productive animals, less priority is given to other traits, such as their adaptability to less hospitable locations and climates, or their aptitude to use non-optimal feedstuffs. With CC likely to give rise to unpredictable increases, it seems appropriate to breed livestock that can cope with variable environments and feedstuffs (Hoffman, 2010), even if they grow more slowly. This is in line with the above mentioned focus on resilience. In addition, breeding and feeding strategies exclusively focused on developing higher yields can cause health problems, such as greater infertility and higher mortality rates, that in turn increase GHG emissions per unit of production (Garnsworthy, 2004). The justification of intensive production on grounds of carbon efficiency also raises serious environmental and animal welfare questions that cannot be ignored. A fundamental criticism of the productivity approach is that it does not consider the multiple functions of land use and livestock.

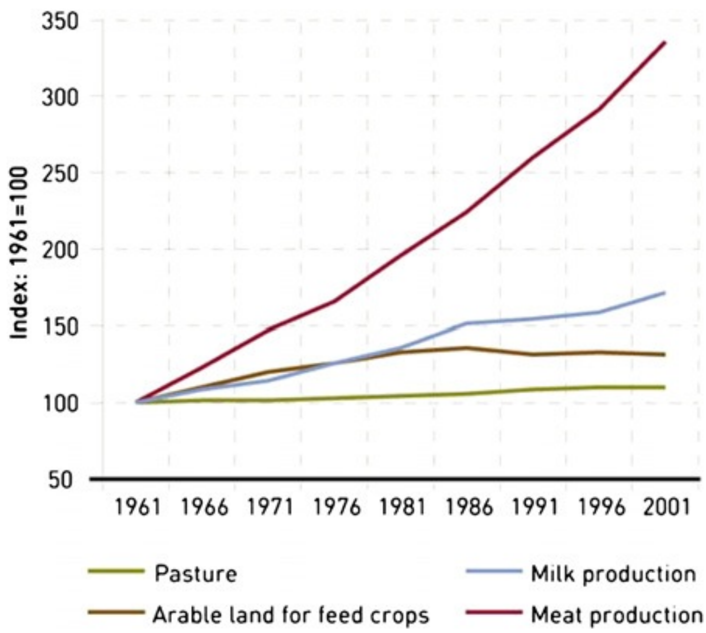


Figure 5. Land used by livestock between 1961 and 2001.

Source: (FAO, 2006).

In sum, this approach proposes further intensification through industrial livestock farming as part of the solution to the problems of climate change to which LSLF has already contributed through its dependency on fossil fuel, synthetic fertilizers and industrial agriculture feedstuffs[4]. Faster growth and the reduction of the amount of feed required to produce meat, eggs or milk, have been achieved over the past decades. In so doing , proponents of the productivity-oriented strategy claim that it is possible to save the climate. But this will only be possible by further externalizing environmental and social costs of feed production, and by ignoring massive animal welfare problems. Thus, climate change would not be mitigated but exacerbated. Two more remarks should be added: firstly, the objective should be to reduce GHG emissions globally; and secondly, the notion of productivity should be reconsidered so as to include all the inputs directly or indirectly used to produce all sorts of outputs. The argument that the livestock sector has to increase to provide safe, cheap and abundant meat in order to meet the demand of an ever-growing market, while at the same time mitigating GHG emissions, can only be justified when direct and indirect services provided by ecosystems and human beings are not measured (Rivera-Ferre, 2009).

[4] To further reduce GHG emissions of industrial monoculture agricultural production, it is proposed to produce agro-fuels and biochar on a massive scale to develop a bio-economy in which fuels and industrial materials are produced from biomass instead of from fossil oil.

3.2.4 Enhancing energy efficiency and the use of alternative fuels

a) Biogas from manure

Managing and enhancing the outputs that livestock farming generates, fundamentally manure, is another interesting mitigation strategy. This amounts to suggesting as the UNFCC among others is doing , that industrial livestock farming can contribute to climate change mitigation (Paul et al., 2009). Manure from pig and dairy enterprises contributes to greenhouse gas emissions through the handling and storage of slurry (Henderson et al., 2011), but this can be processed through biogas units. Manure from grazing livestock creates N_2O emissions when it is broken down by microbes (Steinfeld et al., 2006).

It is possible to recycle livestock waste through large-scale anaerobic digesters that turn solid food waste into biogas, or large-scale composters to turn food waste into compost that can then be used as farm fertilizer (Harvey, 2010). However, according to estimations from Th.y et al. (2009), only 1% of global manure is at present being recycled as biogas. This seems to offer a good opportunity for a win-win strategy, particularly for LSLF systems, which will mitigate GHGs while at the same time reducing the associated costs of waste disposal. An example of this strategy can be found in China, where a national plan for biogas promotion is being enforced (Junfeng, 2007), calling for 4,700 large-scale biogas projects on livestock farms, thereby increasing biogas-using households by a further 31 million – to a total of 50 million or 35% of total rural households. It is mainly centred on peri-urban areas. The total amount of livestock and poultry wastes generated in the country reached 2,485 billion tonnes in 1995, about 3.9 times the total industrial solid wastes (Kangmin and Ho, 2006). It is estimated that 10 million Ha of farmland in China are seriously polluted by organic wastewater and solid wastes.

This strategy raises one main concern: since manure collection is more readily achievable in confined rearing systems, a strong focus on linking anaerobic digestion to farming may add weight to arguments for the development of LSLF. Among others, animal welfarists criticize this strategy (Garnett, 2011).

b) Fuel from crops and forestry

Another energy-efficiency based mitigation strategy that has been promoted is the production of fuels from crops and forestry. However, this strategy is controversial due to social opposition claiming its potential contribution to the 2007-2008 food crisis, and new scientific evidence showing inefficiency in terms of GHG emissions and land use (Cassman, 2007; Runge and Senauer, 2007). Agrofuel production will increase intensive monoculture plantations of oil palm, corn or sugarcane and will contribute to deforestation, biodiversity destruction and grassland expropriation from small livestock keepers. Thus, we may find that industrial bio-fuel production could actually increase global warming instead of reducing it. In terms of forest, major concerns refer to the argument of conceiving tree plantations as "green desserts". The counterargument of their opponents claims that these plantations should not be considered as forests as they do not support life, in fact they promote the expulsion of indigenous people from their lands and are viewed as a threat to biodiversity
(see *http://www.carbontradewatch.org/issues/monoculture.html*)

Agrofuels and biomass enhancement raise the question that food production might be displaced. The Development Fund /Utviklingsfondet (2011) claims that it is impossible to produce agrofuels in quantities that could conceivably replace fossil fuels or even replace substantial parts of the oil which is being consumed. Indeed, to replace only the gasoline and diesel used for transport it would require more agricultural land than it is available on the entire planet. The counter-argument of the defenders of this strategy claims that the existence of considerable extents of marginal, under-used, abandoned land, would not compete with food production, and could be an opportunity for producing agrofuels, thus creating a win-win situation (Paul et al., 2009). However, others warn that much of this so-called ‘marginal land’ is usually collective land used by local communities, such as pastoralists, as a source of water, food, feed medicines, timber, firewood, etc. Despite harsh environmental conditions of these ‘marginal lands’, many communities rely on them for their survival, particularly in difficult times. The dispossession of these ‘marginal lands’ would make local communities much more vulnerable to climate change. In this case, local communities, i.e. indigenous peoples and small-scale farmers, would be in danger of being expropriated with the ironical excuse of mitigating GHG emissions.

3.3 Mitigation through behavioral modification

The mitigation of GHG emissions through behavioural modification is probably the least employed and least investigated group of mitigation strategies. The fundamental purpose of the behavioural modification is to foster ever-growing ‘climate-smart diets’. According to the literature review, it is mainly focused on: reducing the amount of meat consumed and consuming organically-produced food.

3.3.1 Substitution of animal food products for crops

The current global average meat consumption, excluding dairy products, is 100 gram per person per day (g/d), and 36.5 kg per year (McMichael et al., 2007). On average, industrialized countries consume 224 g/d, while impoverished countries consume 47 g/d. It is estimated that between 1997/1999 and 2030, meat consumption in impoverished countries will increase to 101 g/d (Steinfeld, 2004) and that global production and consumption of meat will rise from 233 million tonnes in 2000 to 300 million tonnes in 2020 (Speedy, 2003). McMichael et al. (2007) recommend a meat consumption of maximum 90 g/d. According to the WHO (2010), there are one billion obese persons in the world, a figure as big as the amount of undernourished persons (Paul et al., 2009). Obesity is an issue that must be addressed for a number of reasons, including climate change (Rayner et al., 2008).

Likewise, international environmental observers (World Bank, 2009; UNEP, 2010) have drawn attention to the environmental impacts of the high levels of meat consumption. On average, 25 kcal fossil energy is used per kcal of meat produced, compared with 2.2 kcal for plant-based products (Pimentel and Pimentel, 2003).

A growing body of literature suggests that if we are to achieve substantial reductions in GHG emissions in the agricultural domain, we must address not only how we produce our food, but also what is eaten. In particular, a number of environmental studies have focused on the need to reduce consumption of meat and dairy foods (Gerbens-Leenes and Nonhebel, 2002; Weber and Matthews, 2007; Stehfest et al., 2009; Garnett, 2009; Godfray et al., 2010; Stehfest et al., 2009).

However, a low-meat global scenario raises several concerns. In theory, a diet with moderate, or even no animal source foods can be healthful, if well planned. In developed and rapidly industrializing countries a reduction in consumption of animal source foods can lead to health benefits. On the other hand, in impoverished countries, where access to varied food types is limited, and where there are serious problems of mal- and under-nutrition, animal source foods can make a critical difference to the nutritional adequacy of the family diet (Neumann et al., 2002). It is also important to consider that 70% of the world's 'extreme poor' rely on animal rearing for their livelihoods (FAO, 2009). Hence a context-specific approach to meat and dairy consumption is required, one that situates livestock farming within a policy framework that integrates agricultural, environmental and nutritional goals.

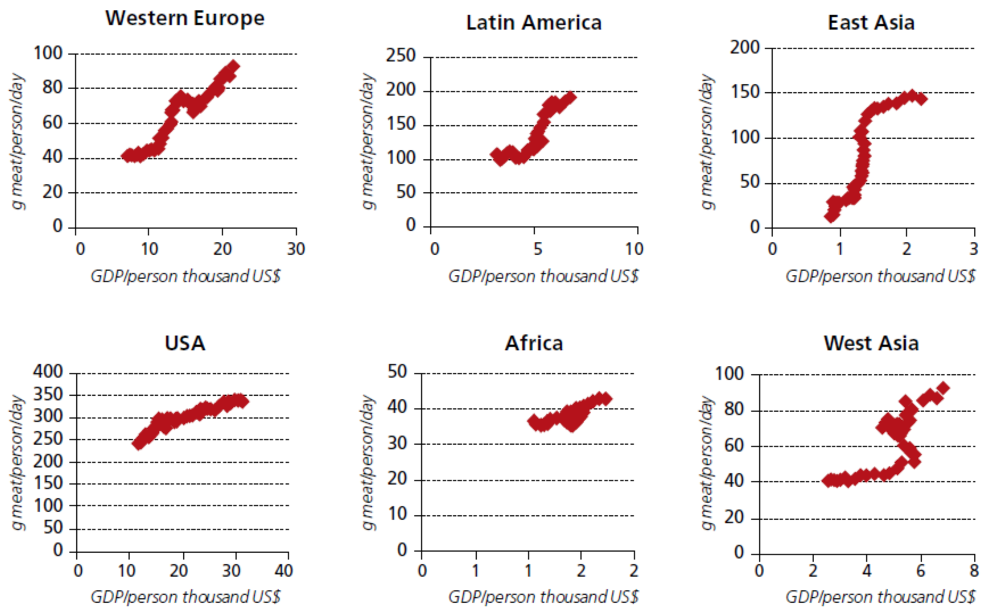


Figure 6. Relationship between GDP per person and meat consumption per person per day.

Source: http://www.ggdc.net/maddison/ and http://faostat.fao.org/site/291/default.aspx. Based on annual data from 1967 to 2007 (FAO, 2009).

Accordingly, some authors (McMichael et al., 2007; Rivera-Ferre, 2009) have suggested that a relevant mitigation strategy would be to find a balance in the consumption/production ratio among regions in the world, consequently meat consumption should decrease in industrialized countries and increase in developing countries. A redistribution of livestock consumption from food surplus to food deficit regions would have coupled health and environmental benefits (Stehfest et al., 2009; McMichael et al., 2007). Stehfest et al. (2009) found that a global food transition to less meat – a fall from the current 245 g/d in industrialized countries to 102 g/d– would have a dramatic effect on land use, freeing up pasture and cropland for carbon sequestration uses and substantially reducing nitrous oxide and methane emissions.

Some other shifts in food consumption for rich countries found in the literature (Edwards and Roberts, 2009; Garnett, 2008), to mitigate GHG include: reducing food consumption in overweight populations; cutting food waste and manage unavoidable food residues properly (33% of global food production is wasted between production and plate according to Stuart, 2009); consuming seasonal and field-grown vegetables, to reduce transport and cold storage-relate GHG emissions; and reduced consumption of ‘unnecessary’ foods, such as tea, coffee and chocolate.

Evidences on what a sustainable diet might look like are growing and research is also starting to uncover the drivers of consumption. However, research into how changes in behaviour can be achieved is still at its infancy compared to the profusion of works tackling technological solutions for GHG mitigation. This imbalance, as remarked by Garnett (2011), reflects the low priority that policy makers place on behavioural change as an approach to GHG mitigation, which at the same time shows how widely pervasive is the reluctance to question the inevitability and desirability of today’s growth consumptionand development model.

Table 10. Average daily consumption per person of livestock protein compared to safe level *

		G/DAY				% OF RECOMMENDED "SAFE"[1] CONSUMPTION FROM LIVESTOCK
AREA	YEAR	MEAT	DAIRY (NOT BUTTER)	EGGS	TOTAL	
Africa	1995	5.3	3.1	0.6	9	
	2005	5.9	3.4	0.6	9.9	17
Americas	1995	26.1	14.3	2.7	43.1	
	2005	28.1	14.1	3.1	45.3	78
Asia	1995	7.5	3.8	2.2	13.5	
	2005	9.2	4.7	2.7	16.6	29
Europe	1995	24.1	17.9	3.6	45.6	
	2005	24.7	19.2	3.8	47.7	82
Oceania	1995	24.9	18	1.9	44.8	
	2005	39.3	15.8	1.7	56.8	98
Least developed countries	1995	3.3	2.2	0.2	5.7	
	2005	4.1	2.7	0.3	7.1	12

Source: FAOSTAT for consumption figures.

*Recommended “safe” consumption is 58 g per person per day, estimated as the minimum average plus 2x standard deviation (WHO, FAO, UNU, 2007).

In addition, it would be interesting, as suggested by Garnett (2011), to investigate not only possible behavioural modifications in the rich world, but also how impoverished countries can be supported in developing nutritious dietary patterns that avoid theenvironmental and health problems associated with Western modes. For instance, meat consumption in the USA is about 120 kg per year per person, world average is 43 kg, and in India, it is 5 kg. A lot of the meat production in the USA is dependent on grain which is fed to the animals. Thus, USA grain consumption is 800 kg per person per year, while in India, it is 200 kg. This means that current grain production provides enough for 2.5 billion people with a USA diet, but 10 billion people with an Indian diet (FAOSTAT, November 2008; in Development Fund /Utviklingsfondet, 2011). Fig. 6 shows the close relationship between GDP per person and meat consumption per person in six regions, using annual data over a 40-year period. In addition to regional differences (see Table 10 for comparison), there are differences between urban and rural consumption. In both poor and emerging economies, urban dwellers tend to buy more livestock products through formal channels, particularly higher value processed products (FAO, 2009).

Another possible mitigation strategy would be a shift in production away from ruminants (McAlpine et al., 2009) towards lower impact mono-gastric species, such as poultry (Sustainable Development Commission, 2009; McMichael et al., 2007). As a consequence of the specificities of their digestive systems, cattle, sheep and goats emit higher levels of methane. A shift in production of mono-gastric species has the potential, according to Steinfeld and Gerber (2010) to reduce GHG emissions per unit of product. Finally, although addressing the excessive levels of consumption will help to mitigate GHG emissions and other environmental impacts related with meat production, distribution and consumption; there is a vast mitigation potential on the production side. Addressing environmental impacts of livestock on the production side may also carry important benefits for socially and economically disadvantaged livestock producers in developing countries (Steinfeld and Gerber, 2010; Rivera-Ferre, 2009).

3.3.2 Favouring consumption of organic and local

Organic livestock production, as all low-external-input livestock farming systems, is an attempt to close nutrient loops, build soil fertility and enhance on-farm biodiversity. In contrast with the ‘land-sparing’ approach discussed above, which focuses on freeing as much land as possible for wilderness and other uses, organic production seeks to integrate the natural world into the human-made farmed environment. Some studies argue that organic and low-input systems can be an effective route to mitigation (Niggli et al., 2009). Hoffmann (2011) emphasizes the high mitigation potential of conversion to organic farming, highlighting reductions in industrial nitrogen-fertilizer use, enhance soil sequestration of carbon. Indeed, excessive use of fertilizers by intensive farming systems results in a long-term reduction of productivity. A comparative analysis of energy inputs on long-term trials at the Rodale Institute found that organic farming systems used 63% of the energy required by conventional farms, largely because of saving the energy input that would have been required for synthetic nitrogen fertilizer (Pimentel et al, 2005). Organic agriculture, on the contrary, has a higher capacity to increase the productivity through management measures (De Shutter, 2010; Shiva and Panday, 2006). In addition, organic systems also tend to be more resilient than industrial in terms of withstanding environmental shocks and stresses including droughts and flooding (Development Fund /Utviklingsfondet, 2011).

Despite the high potential for GHG mitigation held by organic production and consumption, when this is based on a mere input substitution, from synthetic to biological inputs, there is no fundamental difference between industrial and organic modes of agricultural production and consumption (Rosset and Altieri, 1997). In this case, it does not matter where biological inputs come from or if these have a higher cost than their synthetic counterparts. When organic agriculture and livestock farming is based on the input-substitution model, it shares with industrial agriculture its main objective: increasing yields and profits. This means, for instance, that the feedstuffs of organic livestock can be obtained from large monocultures or that their products might be travelling huge distances to reach consumers, often in large supermarkets, etc. For instance, the food we have in our plate has travelled on average 6,400 km, while in the case of sustainable small-scale production, there is practically no use of fossil fuel when the food is processed and consumed locally (Development Fund /Utviklingsfondet, 2011).

Thus, organic farming by merely inputs substitution dismisses any other social function that the livestock farming activity might play. A food system approach, which includes not only the production system, but also distribution, production of waste, etc., is required to achieve this objective. Food processing, packaging and transport contribute to 10-12% of total greenhouse gas emissions (GRAIN, 2009). This negative impact can be avoided with a different production model and localized food systems. Small-scale farmers, pastoralists and poor consumers, as a consequence of being located in remote areas, tend to do the majority of their trading through informal markets and often close to home. These factors encourage producers to consume at home and sell milk, meat and eggs in local marketplaces (FAO, 2009). ETC (2009) found that 85% of the world's food is grown and consumed – if not within the "100 mile diet" – within national borders and/or the same eco-regional zone. Most of this food is grown from peasants without the industrial chain's synthetic fertilizers.

3.4 CC Mitigation and SSLF

Agriculture is the economic sector with the highest potential to transcend from being a problem to becoming an essential part of the solution to CC, provided there is a more holistic vision of food security, food safety, and mitigation and adaptation practices. For this, as mentioned in the IAASTD report (2009), there is the need for "a rapid and significant shift from industrial monocultures and factory farming towards mosaics of sustainable production systems that are based on the integration of location-specific organic resource inputs; natural biological processes to enhance soil fertility; improved water-use efficiency; increased crop and livestock diversity that is well adapted to local conditions and integrated livestock and crop farming systems". In addition, as remarked by Hoffmann (2011), most of these sustainable production systems have demonstrated that they provide synergies between productivity, livelihood maintenance potential and environmental sustainability.

SSLF has proved along history, and all over the world, that it is capable of fulfilling the requirements mentioned by the IAASTD report, so as to help mitigating and adapting to climate change in a sustainable manner. For instance, pastoral systems have shown their resilience through enabling small-scale livestock farming families to cope with more or less unpredictable environments. To make livestock raising GHG-efficient and climate-resilient, landscapes and livestock farming systems need to be adapted to actively absorb and store carbon in soils and vegetation; reduce emissions of methane from livestock and burning; and decrease nitrous oxide emissions from fertilizers, on the one hand, and enhance the resilience of production systems and ecosystem services to climate, on the other. All this is accomplished by SSLF, and more specifically by pastoralist communities, whereas they keep proud of themselves and can be ruled by their own institutions on the basis of customary practices, as well as decide according to own their local and traditional knowledge.

Furthermore, SSLF is considered a multifunctional activity. Not only does it produce foodstuffs, but guarantee many more functions related to issues such as fibres, social status, manure, draught, savings, and can effectively recycle wastes into soil restoration. Also we could add preserving biodiversity, soils, and water sources in tune with the local ecology and with full capacity to capture GHG; as well as guaranteeing additional cultural, landscape and livelihood values for local communities. Consequently, the high climate-mitigation potential of SSLF does not come alone, but with additional advantages in all domains. This concerns both social benefits (a better preservation of the autonomy through low dependence on the outside; food security benefits, with more stable yields under extreme weather events); environmental benefits (better water and soil management, preservation of biodiversity, lack of pollution from agro-chemicals); and cultural benefits (strengthening of local knowledge and skills as well as communal relations and institutions).

4. Climate change adaptation and SSLF

4.1 Climate-Change related hazards to SSLF

As remarked by Morton (2007), the impact of climate change on SSLF systems will be difficult to model or predict because of (i) the lack of standardized definitions of these farming systems, and therefore of standard data above the national level; (ii) intrinsic characteristics of these systems, particularly their complexity, their location-specificity, and their integration of agricultural and non-agricultural livelihood strategies; and (iii) their vulnerability to a range of climate-related and other stressors. However, scientific consensus suggests that climate change will bring more intense and more frequent extreme events (IPCC, 2007; see fig. 7).

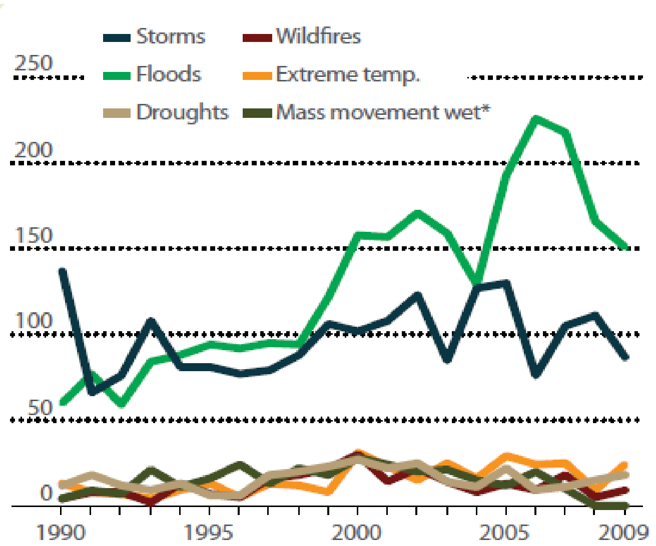


Figure 7. The rising number of extreme climate-related events.

Source: CRED (2011) in Hellmuth et al. (2011)

More precisely, the followings are the main climate change-related hazards that may affect small-scale livestock farming systems:

a) a) Higher temperatures affect plant, animal and farmers' health, enhance pests and reduce water supply, increasing the risk of growing aridity and land degradation (Paul, 2009; Hoffmann 2011). Moreover, plants and animal species are disappearing at an unprecedented pace. Certain animal and human diseases are likely to expand their range as a result of climate change, especially when they or their vectors - insects, mites and ticks - depend on warm annual temperatures and humidity. In addition, the IPCC (2011) shows high confidence that changes in heat waves, glacial retreat and/or permafrost degradation will affect high mountain phenomena such as slope instabilities, movements of mass, and glacial lake outburst floods.
b) Changes in seasonal rainfall patterns and more erratic rainfall enhance water scarcity and consequently, drought stress for crops, pastures and water supplies, but also floods. They also affect predictability, necessary for farmers' planning (Paul, 2009). Livestock farmers have to adjust to these changes by adapting their

usual production systems to an unpredictable situation. Pastures and water points are bound to become increasingly scarce, scattered and changeable. Longer and more frequent droughts are likely to result in a significant rise in destitution among pastoral groups. This is because successive years of extreme drought decimate herds and prevent their reconstitution (Hesse and Cotula, 2006). The IPCC (2011) points that it is likely that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe. It also shows medium confidence that droughts will intensify in the 21st century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration.

c) The enhanced frequency of weather extremes may significantly influence both crop and livestock production. It may also considerably impact on or destroy farmland, grazing land and physical infrastructure for agriculture and livestock (IPCC, 2007; Hellmuth et al., 2011). Average tropical cyclone maximum wind speed is likely to increase, although increases may not occur in all ocean basins. The IPCC (2011) points that it is likely that the global frequency of tropical cyclones will either decrease or remain essentially unchanged.

d) Higher atmospheric concentrations of CO_2 may, for a limited period of time, lead to 'natural' carbon fertilization and thus a stimulus to crop productivity (Hoffmann, 2011).

A growing body of evidences points to the direct effects of climate on economic and human development, particularly in low-income countries (UNDP, 2008; Mutter, 2010). Also Hoffmann (2011) points out that generally the impacts of climate change on livestock farming tend to be more severe in those regions with higher temperatures and lower levels of development, particularly in marginal lands. Particularly, in the four regions that have been studied in this report, as will be further developed in section 7, higher prevalence of droughts with occasional flooding, and increasing calendar unpredictability, have been the CC-related hazards identified in all four cases.

4.2 Adaptation strategies of SSLF communities to climate variability

SSLF, and particularly pastoralism, is highly dependent on a "subtle" and constantly evolving balance between pastures, livestock and peoples. If pastoralist herd too many animals, there may be a lack of pasture, and that poses a danger of overgrazing if livestock mobility is constrained. If the number of animals is too low, the subsistence of the family may be in danger. If the family is too small, livestock may be inadequately managed. If the quality and quantity of pastures is reduced, small livestock keeping families may find it increasingly difficult to maintain their livestock and face livelihood uncertainties. Small livestock keepers use a range of adaptation strategies to maintain that balance. Table 11 shows the fundamental adaptation strategies that the SSLF communities of Turkana, Alaotra Lake, Khar-o-Touran and Huancavelica, undertake to cope with climate variability. As we can see, central among them is mobility, which implies moving herds to areas with better grazing and water conditions and securing access to critical resources during difficult times. Not only are herds moved, but households and crops may be relocated too.

Another group of adaptation strategies being extensively used by small livestock keepers are those enhancing social collaboration and reciprocity. This is the case of adaptation strategies as: food sharing, livestock loans, joint ventures, friendly collaboration, communal planning, communal ownership, splitting the herd among different members of the family, communal grazing, labour exchange, etc. Strengthening the sense of community is crucial to avoid climate-related vulnerabilities, especially for pastoralist communities, offering a network of social relationships and exchange practices, which increase enormously the resilience capacity of the community through mutual support and exchange of knowledge and capacities. Diversification and multiple farming activity is another strategy often followed by the SSLF communities to deal with climate variability. Thus, adaptation strategies such as livestock diversification, crop diversification, economic diversification, multi-purpose crops, multi-purpose livestock, shift towards agro-pastoralism, etc., are very often used, as may be observed in Table 11. Also, and related to the previous group, promotion and preservation of biodiversity, both wild and domesticated, through breed and crop selection, livestock diversification or application of traditional knowledge, is a fundamental group of adaptation strategies to foster adaptation capacity to future changes.

Highly related to the latter group are those adaptation strategies consisting in changing the types of livestock raised. In line with this, two are the main trends identified: (a) a shift from grazers, fundamentally cattle and sheep, to browsers, mainly camels and goats; and (b) a shift towards raising short-cycle animals, mainly poultry, pigs, and dairy cows, as these livestock types provide daily revenues and food security, and also entail minor risk of losing revenues, since they require less time and less feed to be raised. Another group of adaptation strategies being implemented to guarantee more stable feeding conditions for the livestock is the adoption of fodder crops and pasture enclosures. This in some instances also implies livestock corralling, and the adoption of improved breeds. Also food relief, sedentarization policies and improve market access are another group of adaptation strategies being often offered to SSLF communities by governments and internationals institutions and NGOs to try to improve the quality of life of their members, particularly in the face of climate disasters

Table 11. Fundamental adaptation (A) strategies implemented by the SSLF communities of Turkana in Kenya (T), Alaotra Lake in Madagascar (AL), Khar-o-Touran in Iran (K), and Huancavelica in Peru (H), to face drought and extreme heat, occasional cyclones and floods, and changes in calendar.

Biophysical Impacts	Socio-economic Effects	Adaptation Strategies	Type of A*	T	AL	K	H	Potential maladaptations
Soil erosion and desertification	Pasture shortage, deforestation, changes in vegetation, lack of water, and increased conflicts over scarce resources	Herd mobility	A-AN	X	X	X	X	❖ There is a risk of loss of autonomy and an increasing need to get involved in income-generating activities in these strategies increasing market dependence, such as growing mechanization, adoption of cash loans, and early selling.
		Nomadism	A-AN	X		X	X	
		Herd composition	A/P-AN/R	X	X	X	X	
		Destocking/restocking	P-AN	X			X	
		Herd reduction	A-R	X	X	X	X	❖Increasing GHG emissions with adaptations strategies favouring mechanization and buying fuel.
		Early selling	P-R	X				
		Traditional knowledge	A-AN	X	X	X	X	
		Livestock corridors	A/P-AN	X		X	X	
		Splitting the herd	A-AN	X			X	❖Adaptation strategies based on mono-functional notions of livestock (income generation) should be carefully examined since they undermine the fundamental rationale behind SSLF, which is the multifunctional role of livestock. For the preservation of SSLF such rationale must be respected.
		Livestock diversification	A-AN		X		X	
		Livestock corralling	P-AN/R		X	X	X	
		Women in livestock raising	A/AN		X		X	
		Herding with guns	A-R	X				
		Sell livestock to buy forage	A-R			X		
		Communal planning	A-AN	X	X	X	X	❖ Risk of mounting violence in herding with guns.
		Communal grazing	A-AN	X	X	X	X	
		Communal ownership	A-AN	X		X	X	

		Land resting	A/P-AN	X	X	X	X	
		Hay-, fodder-making	P-R	X	X		X	❖ Risk of fodder shortage in livestock corralling. Also there exists here a risk of degradation of the capacity of grasslands to capture carbon.
		Pasture enclosures	A-R	X		X	X	
		Crop residues	A/P-AN		X	X		
		Multi-purpose crops	A-AN			X		
		Grassland fires	A-AN		X		X	❖ Risk of traditional knowledge and livelihood degradation in the case of pastoralist field schools if these do not consider appropriately the local socio-ecological conditions.
		Agricultural diversification	A-AN		X			
		Conservation agriculture	P-AN		X			
		Stop agriculture	A-R	X	X	X		
		Pasture irrigation schemes	A/P-AN				X	❖ Risk of grassland degradation, and consequently of hampering grasslands' carbon sequestration potential, with the strategy of using grassland fires to enlarge pasturelands.
		Cultivation in terraces	A-AN				X	
		Water infrastructures	P-AN/R	X	X	X	X	
		Mechanization	A-R		X			
		Tree nurseries	A/P-AN/R	X	X			❖ Risk of increasing dependence on outside technologies and skills that the community cannot control. This is the case in the construction of water infrastructures, as well as plans for manure-into-biogas installations.
		Peace keeping	A/P-AN	X				
		Pastoralist Field School	P-AN/R	X				
		Manure into biogas	P-AN		X			
		Buying fuel	A-R			X		❖ Increasing the role of women in livestock raising, if not accompanied by specific gender-related measures, it can increase work-load for women.
		Manure as household fuel	A-AN				X	
		Cash loans	P-R			X		

Decreased livestock and crop productivity, lack of game, and wild vegetation disappearance	Rising food insecurity and malnutrition, reduced dependence on traditional diet, and outmigration	Herd mobility	A-AN			X		❖Strategies entailing education and training of SSLF community members should guarantee that training ensures the fulfillment of their expectations. Also there exists the risk of sedentarization by imposing sedentary education systems. This would make appropriate managements of grasslands and livestock more difficult, leading to diminished capacity of grasslands to capture carbon, and reducing resilience of SSLF communities, putting their livelihood at risk. Education schemes should value SSLF livelihoods, particularly in children education.
		Livestock corralling	P-AN/R		X		X	
		Keep herd size	A-AN				X	
		Improved breeds	A/P-R		X	X	X	
		Early selling	P-R	X	X			
		Avoiding infected herds/plots	A-AN	X	X	X	X	
		Women in livestock raising	A/AN				X	
		Shift to agropastoralism	A/P-AN	X	X	X	X	
		Traditional knowledge	A-AN	X	X	X	X	
		Joint ventures	A-AN			X		❖ Relief food campaigns should also be cautiously implemented, since they often save pastoralists' lives but fail to save pastoralists' livelihoods, and consequently fail to save also the carbon-rich grasslands. They also fail to facilitate the right to food since they are rarely culturally correct.
		Multi-purpose crops	A-AN			X		
		Plot dissemination	A-AN				X	
		Seed selection	A/P-AN/R		X		X	
		Crop rotation	A/P-AN		X		X	
		Intercropping	A/P-AN		X		X	
		Susceptible crops higher	A-AN				X	❖ Breed and seed selection have the risk of adopting breeds and seeds that are not well adapted to the local conditions, or are less multifunctional and consequently less suitable for SSLF.
		Access to irrigation	A/P-AN/R	X	X	X	X	
		Clan support	A-AN	X	X	X	X	
		Livelihood diversification	A/P-AN/R					
		Food sharing	A-AN	X	X			
		Traditional diet preserving food	A-AN	X	X	X	X	❖ Risk of favouring grassland and livestock

		Women entrepreneurship	A/P-AN	X	X			mismanagement in livelihood diversification.
		Labour exchange and barter	A-AN				X	❖ Moving susceptible crops to higher latitudes may put at risk the carbon-rich grasslands, increasing GHG emissions.
		Manufactured products/handicraft	A-AN		X	X	X	
		Decreased household size	A-AN/R			X		
		Cash loans	P-R		X			
		Children education	P-AN	X			X	
		Mobile schooling	P-AN	X				
		Mobile health care services	P-AN	X				
		Relief food	P-R	X				
		Migration	A-R	X		X	X	
Increase in livestock diseases and mortality	Changes in frequency of livestock disease	Splitting herd	A-AN	X	X		X	❖ Risk of fodder shortage in livestock corralling. Also there exists here a risk of degradation of the capacity of grasslands to sequester carbon.
		Livestock corralling	P-AN/R		X		X	
		Livestock loans	A-AN	X				
		Feed supplement	A/P-AN/R				X	
		Immune animals survive	A-AN		X			
		Local and mixed breeds	A-AN		X			
		Restocking	P-AN	X				
		Expanding animal health care	P-AN/R		X			

*Being A: Autonomous; P: Planned; AN: Anticipatory; and R: Reactive.

Finally, the eighth adaptation strategy group, adopted by SSLF communities through the past centuries, has been very efficient for living in marginal climate, and nowadays it allows to face an increasing climate variability. Furthermore, these strategies are supporting and empowering SSLF communities, as can be seen, for instance, in some experience of pastoralist field schools, mobile health care services and mobile schooling schemes. Indeed, the adaptation strategies based on supporting the local community should be carefully assessed, for instance, to check if they are really empowering the community. In terms of schooling, while in some instances it clearly strengthens the community by training young members in skills needed by the community. In other instances, schooling only implies a process of normalization and drifting apart young people from the rest of the members of the community. In those cases the SSLF community is flooded with too many external elements, threatening the traditional livestock herding system. This would be a case of maladaptation, since it would make the community much more vulnerable to climate variability. In general, all the above mentioned adaptations , depending on the way they are implemented, may end up strengthening or weakening SSLF community. In order to avoid the emergence of maladaptations, it is important to take into account the social, cultural, economic and geographical context within which these strategies of adaptation are being applied and to assess what unintended effects might arise (see Table 11).

4.2.1 Type of adaptation strategies implemented by SSLF communities

There are several ways in which the adaptation strategies conducted by SSLF communities can be grouped. Following IPCC (2001) approach we provide a distinction between planned and autonomous strategies, as well as between strategies focused on impacts – reactive adaptation strategies – and on vulnerability – anticipatory adaptation strategies. Planned adaptation is the result of deliberate decision, based on the awareness that conditions have changed or are expected to change, and that some form of action is required to maintain a desired state. Such adaptation would progress based on a top-down approach, through regulations, standards, and investment schemes. Governments and some NGOs tend to promote such kind of adaptation strategies. Autonomous adaptation refers to those actions that are taken by individual members or communities based on their perceptions on climate risk. Such autonomous actions are considered as following a bottom-up approach. Depending on the timing, goal and motive of its implementation, adaptation strategies can be either reactive or anticipatory. Reactive adaptation occurs after the initial impacts of climate change become evident. That is, it constitutes the reaction to the effects of a given impact so as to recover from it. However, anticipatory adaptation strategies are being implemented before the impact occurs. Thus, while the main focus in reactive adaptation strategies is placed on the impact, on recovering from it, in anticipatory adaptation strategies the focus is placed on reducing vulnerability by enhancing resilience. See Fig. 8 and Fig. 9, and also Table 11, for classifications of the adaptation strategies that the communities of Turkana, Alaotra Lake, Khar-o-Touran and Huancavelica are conducting, in these particular cases to cope with drought and occasional flooding events.

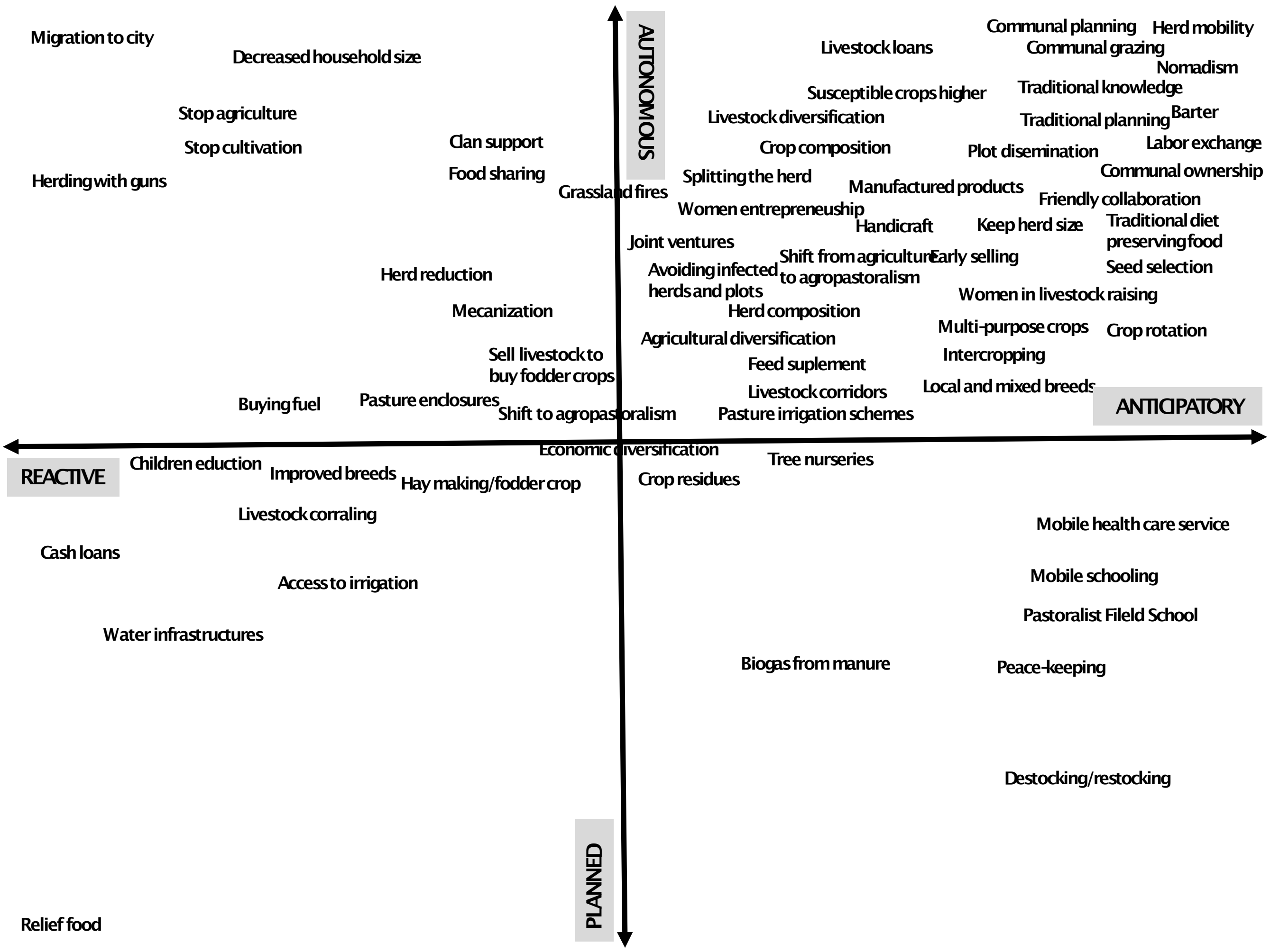


Figure 8. Classification of the main adaptation strategies being adopted by the pastoralist communities of Turkana, Alaotra Lake, Khar-o-Touran and Huancavelica.

As may be observed in the Figures 8 and 9, as well as in Table 11, those adaptation strategies being centred on boosting mobility, biodiversity, and also those enhancing social collaboration and reciprocity, tend to be of a n anticipatory and autonomous nature. Whereas strategies centred on offering to SSLF communities schemes of sedentarization, food relief, or market access, are planned as reactive adaptations strategies. Those strategies of adaptation based on empowering the SSLF communities are usually planned and anticipatory. Finally, in case of strategies aimed at fostering diversification, multi-activity and multi-purpose livestock and crops, their nature is more complex. They may be either planned or autonomous, and either anticipatory or reactive. In any case, it should be kept in mind that adaptation to climate variability is a never-ending process. Since vulnerabilities and impacts are permanently evolving, this entails that some forms of adaptation that may be appropriate now, may not be so in the future. Also it should be borne in mind that socio-institutional innovations, however less spectacular – and less expensive – may strengthen resilience further compared to other technical innovations. However, it is not less true that not all autonomous innovations end up enhancing community's resilience. While autonomous innovations by SSLF should not be romanticized, top-down interventions should always be critically assessed.

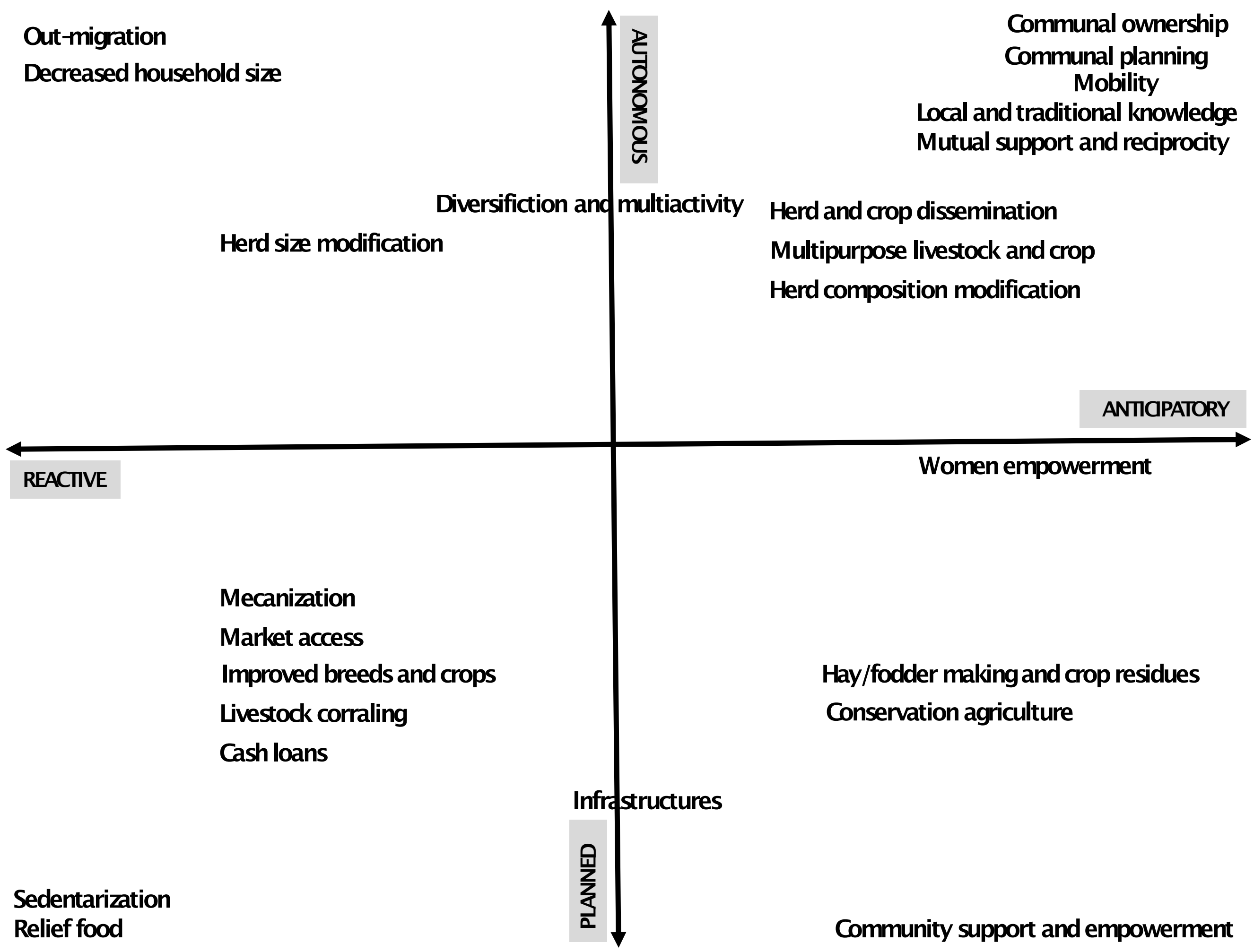


Figure 9. Main groups of adaptation strategies being implemented by the Turkana, Alaotra Lake, Khar-o-Touran and Huancavelica pastoralists' communities.

5. Socio-economic drivers intensifying CC's impacts on SSLF communities

Beyond climate variability, there exist other socio-economic drivers that exacerbate the damaging effects of climate change impacts. They do so by making traditional SSLF adaptation strategies more difficult to implement, undermining their ability to make a living in marginal climate conditions, and to cope with the increased climate variability. Table 12 presents a short list of the main drivers identified in the four case studies conducted in this research – Turkana, Alaotra Lake, Khar-o-Touran and Huancavelica. An interesting finding to be highlighted is that, despite communities belong to countries which are far away from each other – as they belong to three different continents – they display similar socio-economic drivers. This shows that all types of existing SSLF activities stem from a common root, namely, traditional knowledge highly adjusted to the local environment, in the case of pastoralism, communal planning and ownership of natural resources, livestock raising and mobility, and vulnerability to common drivers. In three cases out of four, the drivers investigated in this section are more focused on pastoralism.

The existence of these drivers and their highly damaging effects on livestock keepers, more particularly pastoralists' livelihoods, show that SSLF, despite being a long-standing practice very well adapted to cope with climate variability, has a limited resilience capacity. This capacity is particularly hindered by three main socio-economic processes: firstly (a) demographic growth, showing the limited carrying capacity of grasslands, and the rising competition for the use of them; secondly (b) the systematic political negligence of SSLF institutions, knowledge, and customary practices; and finally (c) the increasing integration of small livestock keepers within the market economy, leading to a drastic shift in their value system.

Table 12. Fundamental drivers observed in the SSLF communities of Turkana (Kenya), Alaotra Lake (Madagascar), Khar-o-Touran (Iran), and Huancavelica (Peru), which intensify the impacts of climate variability.

DRIVERS	TURKANA (KENYA)	ALAOTRA LAKE (MADAGASCAR)	KHAR-O-TOURAN (IRAN)	HUANCAVELICA (PERU)
Rising population and competition for the use of rangelands	X	X	X	X
Top-down planning and negligence of traditional institutions and customary practices	X	X	X	X
Increasing integration within the market economy	X	X	X	X

Demographic growth is a shared characteristic in all four cases, being a consequence of either natural growth or the arrival of immigrants. The latter is particularly remarkable in the Alaotra Lake region. The area surrounding Khar-o-Touran, the Semnan province, has witnessed a rise of almost 20% over a 10-year period, from 1996 to 2005. The population of Alaotra Lake has tripled since 1960. The population of Turkana has also tripled during the last 40 years. A similar trend is undergoing in Huancavelica. This trend is highly damaging, since it intensifies one of the most important effects of climate variability, that is, the reduction in the amount of grazing land and of water resources available – as observed in the four case studies where the main CC hazards were drought and occasional flooding events , leading to overgrazing and water scarcity.

The rise in population is also closely related to the other process with pernicious effects on the resilience capacity of SSLF communities, that is, the degradation of their knowledge and institutions. When a strong influx of immigrants takes place, those immigrants tend to bring along their own knowledge and traditional practices that may not be well adapted to the particular local environment they are moving in. This could be one of the causes behind the massive clearing of the rainforest area around of the Alaotra Lake carried out for agricultural, livestock and charcoal-burning purposes. As to pastoralism, its limited potential in a context of population growth tends to give rise to alternative uses of rangelands. Particularly widespread is the competition between pastoralists and settled farmers. This has been reported in all the four cases. However pastoralism does not compete with agriculture only, as other activities such as mining, road infrastructures, natural reserves management, oil refineries, etc. are involved in the process. Not only do these activities reduce the amount of available grazing land available, but they also disrupt their migratory routes, an effect that is highly damaging when these communities have to adapt to climate variability. In some cases, such as with the oil refineries in Khar-o-Touran or the mining fields in Huancavelica, the alternative options of rangeland are polluting the resources pastoralists' livelihoods depend upon – water sources and pastures.

The struggle that small-scale livestock keepers wage against alternative economic activities in the battlefield of rangelands are often closely related to land expropriation practices. Due to remoteness, SSLF communities tend to be marginalized by policy-makers, who associate them with backwardness and poverty, and also blame them for being one major cause of rangeland degradation. In all four case studies, extensive practices of rangeland expropriation took the land away from the pastoralist communities into the hands of non-nomadic, non-pastoralists people. The 1969 agrarian reform in Peru, the 1962 law of 'Nationalization of Natural Resources' in Iran, the lack of property security in Madagascar since the end of colonial times, are some of the most significant attempts ever made to undermine rangeland communal ownership. Many other attempts aiming at expanding paved roads, factory installations and irrigation plants, among other things, have followed suit. There are countless examples.

Another form of land expropriation, which is gaining increasingly ground and is obviously affecting SSLF, is the rapid and abundant leasing and purchasing of land in developing countries, especially Africa, by multinational companies and foreign governments. This land grabbing was boosted by the food and financial crises of 2007–2008. It results from the lack of confidence of governments and other large investors in the global market as a source of supply food. A recent report of the UN Committee on World Food Security (HLPE, 2011) estimates between 50 to 245 million ha of land being sold or leased out in such big land deals in recent years. As a result of land grabbing, peasants and pastoralists are forced off the land they have used for generations, which results in increased poverty.

Marginal importance is given to small-scale livestock keepers, and particularly to pastoralist communities, within the urban-oriented policy measures to manage the rangelands. Top-down planning, negligence of SSLF institutions and disregard for their customary practices are dramatically common. The traditional committees of elders that in the past used to lead the communal planning of rangeland and water resources are being increasingly displaced by other policy figures – as is the case in Turkana by the imposition of the chief of the community by the Kenyan Government – or simply disregarded. This kind of top-down decision-making process make that governments and development agencies ignore the benefits of the rangeland management that SSLF communities undertake, by failing to understand the complexities of their livelihoods; furthermore, they turn well-intentioned policy measures into damaging interventions. The latter could be the case of food aid – particularly recurrent in Turkana. While in many occasions they save SSL farmers' lives, they often fail to save small livestock keepers' livelihoods, also failing to preserve carbon-rich rangeland. Inappropriate irrigation schemes in Huancavelica and maladapted planting practices in Khar-o-Touran, are other examples of the mismanagement of resources that the implementation of top-down policy measures often entails. Many national policies fail to promote livestock production or consumption in a way that is favourable to SSLF but aim at favouring wealthier producers, focusing on livestock and technical issues rather than on people and poverty reduction (Ahuja et al., 2009). This is probably due to a lack of knowledge by policy-makers, who ignore that pastoralism is practiced in 25% of the global land area, and is providing 10% of the world's meat production (United Nations, 2010).

In addition, as highlighted by FAO (2009), poorly-planned attempts to reduce public spending through privatization of veterinary services have resulted in under-funded state veterinary and livestock extension systems and a private sector unable to fill the gap, leaving small-scale livestock farmers highly vulnerable to losses from epidemic and endemic diseases. The fragility of the livelihoods of small-scale livestock farmers and pastoralists in countries such as Ethiopia, Senegal and Bolivia demonstrates the damage that such unsupportive policies can do to SSLF (Gning, 2005; Fairfield, 2004; Jabbar, et al., 2008; Halderman, 2005; Ear, 2005).

To all this we should add the evident incapacity of modern institutions to adapt to mobile livelihoods, and the obsession of many governments to sedentarize small livestock keepers, particularly the nomadic pastoralist communities. In our field cases, massive interventions to sedentarize nomadic pastoralists have been identified in Peru, Kenya and Iran. The 1969 agrarian reform undertaken by the Peruvian Government had, among its main objectives, to force pastoralists to settle down. Also the same 1969 massive displacement of Turkana pastoralists led to fishing and irrigation schemes. In Khar-o-Touran several sedentarization policy measures have also been enforced. Although up to now they have produced only little success.

The loss of faith in their traditional institutions and practices, as well the rising external pressures, are calling for the integration of SSLF communities into the market economy – e.g., Kenyan commission of meat. As the income-generating approach is spreading, two of SSLF main pillars are deeply damaged, i.e. social cooperation and reciprocity, and the traditional multi-purpose approach to livestock. As a result, these communities become much more vulnerable to climate variability, since livestock keepers see themselves as facing CC under an increasingly individual and isolated condition. Injustice is largely reported within the communities . All this leads to conflicts not only among small livestock keepers of the same community, but also among communities, as shown by the growth of livestock raids in Turkana or the rising number of human-caused fires to pastures in Khar-o-Touran. In the meanwhile, small-scale livestock keepers see how forces they can neither control, nor identify, are pushing up climatic pressures. This could be the case of the soaring food prices. Worldwide prices of food in general, including livestock source foods, were about 40% lower in the mid-1990s and early-2000s than they are today and a little more stable (IMF, undated). Farmers can no longer rely on cheap feed. Prices have risen and, more importantly they are unpredictable (Von Braun, 2008; Walker, 2010). SSL farmers at the end of long market chains are particularly vulnerable as they have very little control over the market and remain vulnerable to competition from larger players. SSL farmers living in remote areas face high transactions costs to access consumers (Costales et al., 2005), as well as obstacles to entering formal markets due to requirements to meet quality food standards. In this regard, it should be stated, as highlighted by FAO (2009), that behind the efforts made by some players to link small-scale livestock keepers to formal markets, there is the assumption they will have more lucrative and stable livelihoods, and that this will provide an incentive for them to become more efficient and productive. In terms of climate change, it is important to strength that the focus should be placed on increasing the resilience of farming activities.

6. Methodology

First of all, it should be reminded that this report is part of a research study still under way. Although four case studies have been included in this report, more will be added in the subsequent years of the research, such as SSLF in Brazil and in the Spanish Pyrenees. Likewise, more information about the case studies already considered will be added in the years to come. It should also be stated that three of the four case studies were located in places where different member organizations of VSF Europa are presently working. Specifically, VSF Belgium is working in Turkana, AVSF in Alaotra Lake region, and SIVTRO-VSF Italia in Khar-o-Touran in collaboration with CENESTA. All these organizations guaranteed in each case fundamental logistic support in the realization of the fieldwork and supplied relevant information on each specific region. In the case of Huancavelica, logistic support and relevant information on the area were supplied by PROCASUD (*Programa de Mejora de Camélidos Sudamericanos*).

The research revolves around two pillars: (a) literature review; (b) case studies' assessment. Each of them requires differentiated methodological approaches. The literature review is compiled to provide an update on the interactions existing between SSLF and climate change. This is accomplished through database and bibliography reference. The prevailing body of knowledge on the role of SSLF with regard to CC mitigation is reported, as well as the implications of the increasing trend of climate variability in the maintenance of SSLF. Moreover, the crucial elements distinguishing the interactions between SSLF and CC from the interactions between the whole livestock sector and CC are identified.

The second component of this report is the most innovative contribution of the study. Here, four case studies consisting of four SSLF communities have been investigated, namely: the pastoralist community of Turkana in Kenya, the small mixed farmers of Alaotra Lake in Madagascar, the pastoralist community of Khar-o-Touran in Iran, and the pastoralist community of Huancavelica in Peru. The fundamental source of information used here included comprehensive interviews and questionnaires to members of these SSLF communities (see annexes 1-4). Comprehensive interviews were conducted initially in Turkana, in Alaotra Lake, and in Khar-o-Touran to SSL farmers (youths, elders, men and women), but also to regional politicians, professionals, technicians, NGO members working with SSLF communities, community leaders and emigrants. In this stage,. As in this phase of the study the purpose is to cover as many aspects of the complex network of interactions between SSLF communities and CC as possible, a more open-ended social methodology was employed. People were asked not only to comment on climate change issues, but also on other socio-economic issues affecting their livelihoods. In total, 25 interviews were conducted in Turkana, 18 in Alaotra Lake, and 6 in Khar-o-Touran, between October and November 2011. It should be stressed that not all the information gathered along the fieldwork in the four SSLF communities has been entirely processed yet, and will be presented in subsequent updating of the report.

The data gathered in the interviews, together with information originating from the literature review, was used to design a questionnaire used for structured interviews in all four places. This tool was more focused on climate change and was employed to obtain specific information on the type of climate changes being experienced by them, the biophysical impacts and the socio-economic effects caused by these changes, the adaptation strategies the SSLF communities implement to face the climate variability, and finally the main socio-economic drivers exacerbating CC's impacts that these communities encounter. Also, additional information is obtained by asking the members of the community about the magnitude of each particular effect identified, if these effects are negative or positive, and the capacity of SSLF communities to adapt to upcoming changes. Particularly about their adaptation strategies, people were asked if the given measures are implemented individually, by the whole community, by NGOs, or being promoted by the government. The domains of the communities' livelihoods taken into consideration are the followings: livestock, grazing resources, agriculture, water, ecosystem, socio-economic sphere, gender issues and traditional knowledge. The criterion followed to select interviewees consists in collecting as much diversity as possible of opinions existing within the community about the state of SSLF. Accordingly, our interviewees consisted in: a balanced representation of young and elder community members, men and women, community leaders and subordinate members, people with or without access to information from outside of the community, large and small SSL farmers, full-time and diversified SSL farmers, people with particular roles within the community etc. Structured interview is the methodology chosen at this stage of the study, instead of other social sciences methodologies, as it proves to be a very convenient methodology to obtain information from individuals based on their experiences on very specific issues and in a short period of time. The same questionnaire was used in all the SSLF communities considered. During this first year of the study a total of 47 questionnaires have been conducted, 32 in Alaotra Lake, and 15 in Huancavelica.

In the fieldwork, fundamentally through the interviews to SSL farmers, several difficulties were encountered that may be of interest for future research:

- Misunderstandings between the concepts of migration, transhumance and nomadism, interviewees attached a variety of meanings to the three concepts.
- It was often difficult to interview individuals alone. The rest of the community tended to gather around.
- It was important to plan the best time for our visit. That can be either early in the morning or late in the evening, so to avoid to meet always the same kind of persons.
- In general, special efforts were required to stimulate conversation when interviewing young people, since they tended to give short answers.
- In some areas, political instability made interviewing local farmers particularly complex.

7. Case studies

7.1 Pastoralism in Turkana (Kenya)

Dry and pastoral lands occupy more than 80% of Kenya, and are home to approximately 4 million pastoralists, who constitute more than 10% of Kenya's population (Kirbride and Grahn, 2008). Turkana is a semiarid region located in North-western Kenya (see Fig. 10 for the seasonal calendar, and Fig. 11 for location). The area of Turkana shelters a population of almost one million people, who designate themselves as Turkana and also speak the Turkana language. Pastoralism is the main source of livelihood for the Turkana. Pastoralism is so important in this culture that in their oral traditions they call themselves as 'the people of the grey bull' – obviously after the zebu. Despite the importance of cattle raising, the Turkana also raise goats, donkeys and camels. In recent years, development aid programs have attempted at introducing fishing among the Turkana Lake, with limited success. Eating fish is still a taboo in many Turkana communities. The Turkanas rely on several rivers, such as the Turkwel and Kerio rivers. When these rivers flood and water extends onto the river plains, these areas can be cultivated. But the condition of the crops in the region is poor, as a consequence of the fact that rainfall is not sufficient. As to drinking water and water for the livestock, open-pit wells are dug in the riverbanks – 37% of the households are fetching water from traditional hand-dug shallow wells (Ministry of State for the Development of Northern Kenya and other Arid Lands, 2011). Often families must travel several hours to reach them. It estimated that the average walking distance to and from water sources was 3.25 Km (Ministry of State for the Development of Northern Kenya and other Arid Lands, 2011).

The Turkana pastoralists use livestock not only as a source of milk, hide, blood and meat, but also as a form of mobile capital saving, which they use when required to go through difficult times and to pay dowries. The amount of livestock owned is an indicator of wealth in the community. In fact, it is not uncommon for Turkana men to lead lifestyles; always depending on the quantity of livestock a single man is capable of accumulating. The main function of zebus is to provide social status. Zebus are only eaten during celebrations. Goat is consumed more frequently, as well as game – particularly the *dik dik* small antelope. Gathering honey and wild fruits are also remarkable sources of food for the Turkana pastoralist.

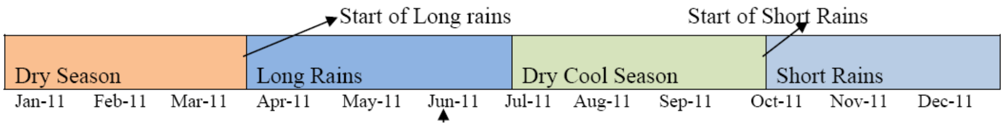


Figure 10. Tradition seasonal calendar in Turkana

Source: Ministry of State for the Development of Northern Kenya and other Arid Lands (2011)

The Turkanas place such a high value on cattle that they often raid other tribes to acquire more animals. This is a widespread practice among pastoralist communities, not only in Northern Kenya, but also in other regions of Africa, such as Madagascar. Thus, cattle raids are common between Turkana peoples and their neighbouring communities, particularly the Karamojas and Matheniko of Uganda, the Pokots and Marakwets of Southern Kenya. The Toposa of Sudan. Lately, cattle raids have become more frequent than in the past. It seems that the purpose of livestock raids has changed. Now it is being undertaken not so much for wedding reasons, but also to obtain cattle to be sold to the Kenyan export meat commission and get money. Unfortunately, these cattle raids are becoming more and more dangerous as small firearms are being increasingly used. All this causes not only livestock losses and violence, but also the underutilization of grazing resources and watering points. Thus McCabe (1990) estimated that up to one quarter of the territory of the Nginsonyoka, comprising Turkana's best highland grazing land, is rarely used due to lack of security. The Ministry of State for the Development of Northern Kenya and other Arid Lands (2011) claims that the conflicts between the Turkana and their neighbours is mounting, and the loss of humans lives and property thefts are recorded every year. Restrictions on mobility, due to insecurity in the border areas, trigger overgrazing in the secure areas, which in turn in the long term will entail grassland degradation.

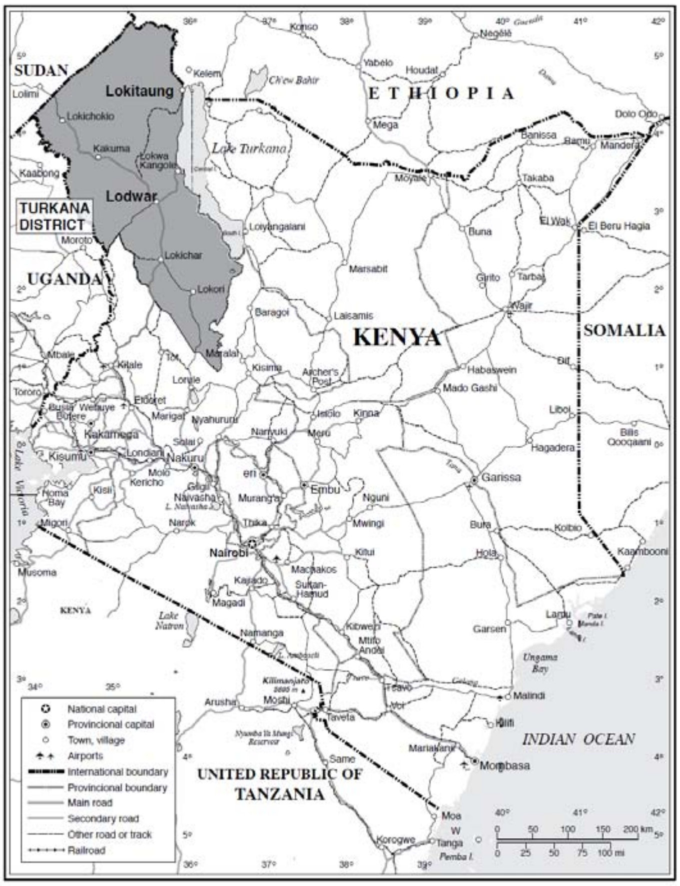


Figure 11. Map of Turkana

Source: Omolo (2010)

In order to adapt to weather uncertainty and derived ecological transformations in the semiarid region of Turkana, pastoralist communities have developed highly complex collective-based social arrangements, which include mobility – the average grazing distance between the main grazing areas and livestock concentration points is 5.9 Km (Ministry of State for the Development of Northern Kenya and other Arid Lands, 2011); herd splitting; livestock diversification to be able to use different pasture resources and at a different period of the year; a strong sense of belonging to the community; respect for the elders; livestock loans; practice of agriculture along the rivers; gathering of wild fruits and hunting of wild animals. All this has formed a network of social relationships, knowledge and pastoralists practices that allowed the Turkana people to develop their culture in the dry savannah of Northern Kenya. For millennia pastoralism has flourished in the dry lands of Turkana, because it is a rational, adaptable, tried and tested production system particularly suited to them. However, an increasing number of severe droughts and occasional floods, combined with additional socio-economic drivers that intensify the effects of climate variability, such as population growth, rising insecurity, and political negligence of pastoralists' livelihoods, are making more difficult for pastoralist communities to guarantee their livelihoods. All these factors are forcing most nomad Turkana pastoralists to adopt sedentary lifestyles (Aklilu and Wekesa 2002; Watson and Binbergen 2008). The result has been an increasing trend towards livelihood diversification and the rising presence on the rangeland of non-pastoralist activities, such as irrigated farming, wildlife reserve, human settlements, etc., which are being facilitated by government, multilateral institutions and some NGOs. Accordingly , preliminary findings (KVRT, 2009) reveal that a rapid change is taking place in the Turkana's nomadic lifestyles, from nomadism to semi-permanent settlements. This triggers growing food insecurity in the Turkana pastoralist communities, and also harms the carbon-rich grasslands they maintain. Thus, the percentage of children under five years at risk of malnutrition is dramatic and growing, 28.18% (Ministry of State for the Development of Northern Kenya and other Arid Lands, 2011). To face this situation, many pastoralist households migrate towards neighbouring villages, counties and countries. Also, the loss of livestock many Turkana pastoralists are going through, is combined with a rising social status for women, due to the fact that women are being increasingly engaged in income-generating livelihood diversification activities, such as charcoal burning. However, women are among the most vulnerable segments of the community in terms of insecurity and violence. This is because women are responsible for their children and cannot move in case of raids. In addition, women-headed households are particularly vulnerable since women have poor customary rights to land, water sources and livestock.

In conclusions, the last droughts would not have been such a tragedy, had communal capacity and institutions of pastoralist communities not been overwhelmed by a ten-fold rise in pastoral population over the last century; by the expropriation of grazing lands and resources to make room for infrastructures, natural parks, farms and towns; and by the marginalization of pastoralist communities in the policymaking agenda.

7.1.1 Socio-economic drivers intensifying CC's impacts

Climate change is only one of the multiple stressors SSLF communities are nowadays facing worldwide. The main socio-economic drivers that exacerbate the impacts of climate variability and/or hinder the implementation of adaptation strategies of Turkana pastoralist communities are briefly described below:

❖ Rising population and competition for the use of rangelands

Turkana is suffering a remarkable process of demographic growth, which triggers a harsh competition for the use of rangelands, as new people seek alternative usages of rangelands, particularly in areas close to water resources. This situation mainly applies to rain-fed agriculture, charcoal burning, oil extraction infrastructures, construction of road infrastructures, creation of national parks and the expansion of urbanization. All this leads to overgrazing, lack of water resources, and replacement of communal ownership by private access. The population of pastoralists in Kenya has tripled over the last 40 years. Turkana pastoralists use firewood for cooking. The arrival of new immigrants, together with the natural population increase, has led to a significant growth in firewood trade. This activity becomes even more rampant during periods of drought, as livestock raising becomes less accessible and pastoralists need to diversify their livelihoods. As population grows, arable farming tends to expand towards the best rangelands, and people and institutions with different creeds, beliefs and value systems compete for the use of the rangelands. As a result, the rapid population growth is exacerbating conflicts over land, which in turn poses additional restrictions to herds' mobility. Furthermore, relentlessly demographic pressures lead to an exponential increase in the amount of people having very limited access to any animal resource or to permanent water resources. All this results in a situation of dramatic vulnerability and highly dependence on humanitarian aid by the Turkana pastoralist communities, particularly when periods of drought intensify.

Land, particularly rangeland and water resources, is being expropriated from pastoralists' communities, and their sense of ownership, and particularly of communal ownership, is weakening. The slow but inexorable advance of family farms and the sprawl of urban areas are swallowing up vast areas of pastures, especially those with better access to water resources. This consequently is combined with a process of rangeland privatization. The parts of the rangelands more suitable for irrigated farming, and some crucial parts of it – e.g. dry season pasturelands – are being taken away from pastoralists. Cropping systems have encroached on extensive areas along Turkwel and Kerio rivers, and also along some seasonal rivers in the region (Watson and Binsbergen 2008). According to local communities, the encroached rangelands mainly include the best dry season grazing areas with easier access to water. All this is not only expropriating the rangelands from the pastoralists' communities, but it is also leading to rangeland fragmentation and herd mobility difficulties. The establishment of national parks, as well as the expansion of paved roads are also playing a role in further restricting herds' mobility. In addition to the reciprocal livestock raids described above, several surrounding communities compete for grazing resources. As a result, a large expanse of rangeland is being under-grazed due to insecurity reason, while other rangelands are over-grazed. Insecurity increases as demographic growth and drought intensify. Consequently, herding with guns has become common practice near border areas.

❖ Top-down planning and neglect of traditional institutions and customary practices

Pastoral communities are located away from the political centres where the main decision-making power is located. Consequently, pastoralists' needs and viewpoints appear less visible to policy-makers, hence pastoralists' political marginalization. Not only are their needs and values disregarded, but often they are utterly unknown. The pastoral communities of East Africa are characterized by minimal government investment in infrastructures and in basic services. Pastoralism in the mind of many politicians remains linked to backwardness and poverty – or to a primitive economy, as many of the Turkana people already mentioned to us – despite the fact that it takes advantage of conditions that are often unsuitable for any other economic activity – as we have extensively mentioned in the first section of this report. In addition, on several occasions pastoralists have been blamed for overexploiting the rangelands, causing their degradation. This latter point is also being proven wrong throughout the report, as we argue that the main cause of degradation in the rangelands is the degradation of pastoralists' way of living.

The problems underlying the pastoralists' livelihoods in Turkana cannot be dealt with by humanitarian interventions solely, as it is often the case. It is necessary to apply long-term development strategies that build on and strengthen, rather than undermine, local institutions and pastoralist livelihood strategies. This in turn calls on pastoralist communities to get urgently involved in designing and implementing interventions that might help them cope with droughts and other CC's hazards. As highlighted by the IIED and SOS Sahel International (2010), very often development agencies fail to grasp the complexities of pastoralists' livelihoods and promote policy measures that, however inspired by well-intentioned advice, may cause long-term damage to the communities, as in the case of the over-priced drought relief. Therefore in many cases, policies save pastoralists' lives but fail to save their livelihood. Thus, when the rain is back they are unable to return to mobile livestock farming and keep on depending on food aid, or they try to succeed in new farming practices, through agriculture, charcoal burning or, in extreme cases, leading violent lifestyles. When assessing the convenience of food aid, pastoralists often make the same claim "they should be providing us with money and restocking instead of food".

In Turkana, as in many other pastoral areas, modern institutions and policy measures are strongly promoting the settlement of pastoralist communities, as well as restricting their herds' mobility. Among others, this has been implemented through imposing state borders, compulsory immobile schooling, and agricultural practices to cope with food insecurity. These efforts to confine pastoral populations within restricted areas are a continuation of policy measures issued by colonial governments (Pavanello and Levine, 2011). In the Turkana region people are well aware of the massive interventions undertaken in 1969, when after severe drought several pastoralist communities from Northern Turkana were displaced and had to settle around a new irrigation scheme implemented to make their living out of agriculture, and around the Turkana Lake to make their living out of fishing. Another example of negligence of pastoralist institutions and customary practices is the current substitution of the committee of the elders by the chief of the community, who is nominated by the Kenyan Government, as a civil servant. This undermines the authority of the committee of elders and weakens the traditional pastoralist practices, such as communal grazing planning, and communal values. All in all, there seems to be a lack of will, but also a lack of capacity in modern institutions to adapt to pastoralist way of life, and particularly, to mobile livelihoods. A few examples might be found that try to deal with this issue, such as a few projects on mobile health care services and mobile schooling. The farming extension service of the Pastoralist Field School could also be an example, in case the expectation of the pastoralists are met. The same applies to the implementation of microfinance/loan services.

- **Increasing integration within the market economy**

The increased integration of pastoralists within the market economy – as one of the consequences of the urban expansion, the inflow of immigrants and urban people, the spread of communications infrastructures and media –is increasing their vulnerability. It fosters a shift from livestock – mainly zebus – as a mobile reserve of value to be used in difficult times or when required, to livestock as a systematic source of meat to be sold. While undermining the traditional notion of livestock as a source of status, it also does not guarantee that pastoralists receive appropriate prices for their products, but it is often the other way around. All this makes pastoralist communities increasingly vulnerable to external forces that they cannot control, such as the worldwide trend of soaring food prices.

7.1.2 Adaptation strategies

CC-related hazards in Turkana are described, together with the biophysical impacts and the socio-economic effects they entail. Adaptation strategies being implemented in each case are also described, and characterized according to the axes of autonomous/planned and anticipatory/reactive adaptation.

Table 13. Adaptation strategies in Turkana

BIOPHYSICAL IMPACT	SOCIO-ECONOMIC EFFECT	ADAPTATION STRATEGY	TYPE OF ADAPTATION*
HAZARD: Drought and extreme heat			
Desertification of the savannah	Pasture shortages.	Herd mobility.	A-AN
		Securing pastoralists rights to pasture through the establishment of livestock corridors.	A/P-AN
		Herding with guns to go to unsecure grazing areas.	A-R
		Facilitate access to under-utilized grazing areas, particularly to unsecure areas, which are dry season grazing regions, though peace-keeping initiatives.	A/P-AN
		Maintenance of the traditional communal planning of grazing led by the committee of the elders.	A-AN
		Clearing of trees to be used for livestock feeding during dry periods. This is the case of the acacia pods from acacia trees.	A-AN/R
		Hay making, collection and forage conservation, as well as pasture enclosures – mainly along the river bank –	P-AN/R

		to prepare for adverse conditions or drought periods when no pasture is available – particularly for weak animals, lactating cows and calves.	
		Modifying livestock diversity, composition and numbers. Adjusting herd composition towards fewer grazers – cattle and sheep – and more browsers – animals that consume shrubs, such as camels and goats.	A-AN
		Shifting towards kinds of livestock, such as shoats, which can be easily sold and provide daily revenues.	A-AN
		Reducing the number of livestock to minimize the effects of drought, and converting some of the livestock into fixed assets (e.g. selling animals to build/buy houses in town to rent or investing in other income generating activities like petty trade and small enterprises).	A-AN
		Destocking and restocking. Pastoralists build their herds when feed is plentiful – particularly breeding animals – and sell them during droughts to cover essential expenses. Breeding females are maintained so that the herd can be re-established when conditions improve and only sold in extreme emergencies.	A/P-R
		Splitting the herd to be managed by different members of the family at different areas to diversify risk of losses.	A-AN
		Encouraging community-based capacity building. Education and training programs to enhance pastoralists' skills and help them to improve resource management, such as the establishment of Pastoralist Field Schools. CAUTION here: bottom-up approaches ensuring participation and the fulfillment of pastoralists' expectations.	P-AN/R
		Land resting	A/P-AN
	Temporal migration of men in search of pasture, splitting of families and rising vulnerability for women, children and the elderly.	Further inclusion of women in the decision-making processes of the communities, e.g. many women as chiefs of community. Increasing social acceptance of woman entrepreneurship.	P-AN A-AN

	Increased conflicts over scarce resources among communities (e.g. livestock raids).	Peace-keeping initiatives have been conducted, although with minimal results. Inter-community reciprocal grazing agreements to stop raiding between them, so as to enlarge the grazing land available, e.g. Tukana and Pokot in Kenya, Turkana and Matheniko of Uganda, Turkana and Toposa of Sudan, etc.	A/P-AN
Deforesta-tion	Soil erosion	Tree nurseries to rehabilitate degraded land by planting trees.	P-AN/R
	Loss of trees used as a forage	Maintenance of the traditional communal planning of grazing led by the committee of elders.	A-AN
Changes in vegeta-tion.	Some herbs are used for livestock diseases – zebu mainly. Loss of local and traditional knowledge as these plants disappear or are more difficult to find.	Maintenance of the traditional communal planning of grazing led by the committee of elders. Tree nurseries to rehabilitate degraded land by planting trees.	A-AN P-AN/R
Less water availability both quantita-tive and qualitative for livestock and communi-ties.	Lack of water for the animals.	Herd mobility. Securing pastoralists rights to water through the establishment of livestock corridors. Modifying livestock diversity, composition and numbers. Adjusting herd composition towards more drought-tolerant species, such as camels and goats. Also shift to small animals, such as goats and sheep to save water. Shifting towards other types of livestock, such as goats, which can be easily sold and provide daily revenues or food, or camel, which are more resistant. Splitting the herd to be managed by different members of the family at different areas to diversify risk of losses. Reducing the amount of livestock. Maintenance, rehabilitation and construction of water infrastructure.	A-AN P-AN A-AN A-AN A-AN A-AN/R P-R

		Digging water pans. Maintenance of the traditional communal planning of grazing led by the committee of elders.	P-R A-AN
	Increase in livestock diseases due to high accumulation of animal in watering points.	Early selling of animals before the disease reaches the community. Quarantining of new animals, avoiding neighboring herds when a disease outbreak has occurred in the vicinity, avoiding wildlife, controlling ticks and tsetse flies, and the use of antibiotics, when available, are all risk management practices used by pastoralists. Maintenance, rehabilitation and construction of water infrastructure. Despite the important shift from herbal medicines to modern ones for treating diseases, where modern medicines are not accessible, pastoralists use herbs to treat specific diseases.	P-R A/P-AN/R P-R A-AN
	Increasing vulnerability of the communities – particularly women – that have to spend more time going for water.	Alternative energy sources – solar energy with solar cells, and wind power with windmill – to pump water from a borehole. An oil exploration company has provided two bore holes to one community. Separation of people's water and livestock water.	P-R P-R P-R
Decreasing presence of wild animals, particularly the ones that used to be hunted.	Increasing presence of wild predators (e.g. Hyenas, wild cats, Leopards and Foxes) around domestic animals and human beings due to extinction of wild animals they used to feed from.	Herding with guns.	A-R

	Reduced dependence on traditional diet (meat, blood, game, wild fruits...)	Involvement in income generation activities through diversifying the sources of livelihood towards other gainful activities. This could be done with microfinance/loan services (village community banks and asset based community development) that help pastoralists to maintain viability at times of adverse conditions through involvement in livelihood diversification activities. Shift from pastoralism to agropastoralism, with cash crops. Food sharing is done by the community when an individual lacks food and other has or has received from relief aids. Improving children's education so they can engage in different income generating activities and support their parents in the future. Caution: not sedentary education and also education that respects and values their livelihoods, such as mobile schooling. Some pastoralists still store wild fruits to endure droughts. Waiting for relief food campaigns.	A/P-AN/R A-AN A-AN A/P-AN A-AN P-R
Decreased productivity of the livestock (milk, meat, blood...) and of the fruit trees.	Rising food insecurity and malnutrition – mainly among children, pregnant women, the elderly and herders. This goes with reduced dependence on traditional diet (meat, blood, game, wild fruits...)	Early selling of weak and old animals while livestock prices are still good. Involvement in income generation activities through diversifying the sources of livelihood towards other gainful activities, such as small scale trading, wage labor, starting businesses, building houses, fishing, irrigation, firewood and charcoal burning, mining, honey making... also cattle raiding and illegal brew. This could be done with microfinance/loan services (village community banks and asset based community development) that help pastoralists to maintain viability in adverse times through involvement in livelihood diversification activities. Also the establishment of Pastoralist Field Schools may help pastoralists during this transformation. Shift from pastoralism to agropastoralism. During the rainy season behave as pastoralist, and during the dry season behave as agricultural farmers – particularly drought-tolerant plants – e.g. *Aloe vera* – or cash crops, when irrigation schemes are available.	P-R A/P-AN/R A-AN

		Food sharing is done by the community when an individual lacks food and another has or has received relief aid. Improving children's education so they can engage in different income generating activities and support their parents in the future. CAUTION: not sedentary education and also education that respects and values their livelihoods, such as mobile schooling. Some pastoralists still store wild fruits to endure droughts. Relief food campaigns.	A-AN A/P-AN A/AN P-R
Better conditions for human disease pathogens.	Increasing occurrence of human diseases, such as malaria.	Clan support – food sharing – to those suffering. Despite the important shift from herbal to modern medicines, when modern medicines are not accessible, pastoralists still use herbs to treat specific diseases. Mobile health care services	A-AN A/AN A/P-AN
Better conditions for livestock disease vectors, such as ticks, insects and mites.	Increase in livestock diseases and mortality.	Livestock loans among the members of the community. Early selling of animals before the disease reaches the community. Quarantining of new animals, avoiding neighboring herds when a disease outbreak has occurred in the vicinity, avoiding wildlife, controlling ticks and tsetse flies, and the use of antibiotics, when available, are all risk management practices used by pastoralists. Restocking for those who have lost livestock. This could be undertaken by NGOs – e.g. VSF-B – or by members of the community. Despite the important shift from herbal to modern medicines, when modern medicines are not accessible, pastoralists still use herbs to treat specific diseases. Mobile health care services	A-AN P-R A/P-AN/R A-AN/R A/AN A/P-AN
HAZARD: Occasional floods			
Damage to pastures	Pasture shortages.	Herd mobility. Securing pastoralists rights to pasture through the establishment of livestock corridors	A/AN A/P-AN

		Facilitate access to under-utilized grazing areas, particularly to unsecure areas, which are dry season grazing region, though peace-keeping initiatives. Maintenance of the traditional communal planning of grazing led by the committee of elders. Modifying livestock diversity, composition and numbers. Adjusting herd composition towards fewer grazers – cattle and sheep – and more browsers – animals that consume shrubs, such as camels and goats. Shifting towards other types of livestock, such as goats which can be easily sold and provide daily revenues. Reducing the number of livestock to face the lack of feedstuff, and converting some of the livestock into fixed assets (e.g. selling animals to build/buy houses in town to rent or investing in other income generating activities like petty trade and small enterprises). Destocking and restocking when feed will be plentiful again. Splitting the herd to be managed by different members of the family at different areas to diversify risk of losses. Encouraging community-based capacity building. Education and training programs to enhance pastoralists' skills and help them to improve resource management, such as the establishment of Pastoralist Field Schools. CAUTION here: bottom-up approaches ensuring participation and the fulfillment of pastoralists' expectations. Land resting	A/P-AN A/AN A-AN A-AN A-AN A/P-R A-AN P-AN/R A/P-AN
	Temporal migration of men in search of pasture, splitting of families and rising vulnerability for women, children and the elderly.	Further inclusion of women in the decision-making processes of the communities, e.g. as chief of the community Better social acceptance of woman entrepreneurship (shops, agriculture...).	P-AN A-AN

	Increased conflicts over scarce resources among communities (e.g. watering points).	Peace-keeping initiatives have been conducted, although with minimal results. Inter-community reciprocal grazing agreements to stop raiding between them, so as to enlarge the grazing land available, e.g. Tukana and Pokot in Kenya, Turkana and Matheniko of Uganda, Turkana and Toposa of Sudan, etc.	A/P-AN
Better conditions for human disease pathogens.	Increasing occurrence of human diseases, such as malaria.	Involvement in income generation activities through diversifying the sources of livelihood towards other gainful activities. This could be done with microfinance/loan services (village community banks and asset based community development) that help pastoralists to maintain viability in adverse times through involvement in livelihood diversification activities. Shift from pastoralism to agropastoralism, with cash crops. Mobile health care services	A/P-AN/R A-AN A/P-AN
Better conditions for livestock disease vectors, such as ticks, insects and mites.	Increase in livestock diseases and mortality.	Livestock loans among the members of the community. Early selling of animals before the disease reaches the community. Quarantining of new animals, avoiding neighboring herds when a disease outbreak has occurred in the vicinity, avoiding wildlife, controlling ticks and tsetse flies, and the use of antibiotics, when available, are all risk management practices used by pastoralists. Restocking for those who have lost livestock. This could be undertaken by NGOs – e.g. VSF-B – or by members of the community. Clan support – restocking and food sharing – for those who have lost livestock.	A-AN P-R A/P-AN/R A-AN/R
Deforesta-tion and land degradation	Soil erosion.	Maintenance of the traditional communal planning of grazing led by the committee of elders. Tree nurseries to rehabilitate degraded land by planting trees.	A-AN P-AN/R

7.2 Small mixed farming in Alaotra Lake (Madagascar)

The Alaotra Lake is the largest lake on the island of Madagascar. It is located 750 m.a.s.l. in the Ambatondrazaka area in Eastern Madagascar (see location in Fig. 12). The lake is surrounded by hills, which reach 1300 m.a.s.l. The surrounding area of the lake is mainly used for rice-cultivation. This region is considered as hosting the most productive land of the island (e.g. Wright and Rakotoarisoa, 2003). The cultivation of rice is associated with extensive livestock farming of zebu to be used to work in the paddies. Other crops are also cultivated, mainly for self-consumption, such as maize, manioc and taro; but also for selling, such as peanut and red pepper. Poultry is also another type of livestock widely raised in the region. However, rice is the crucial staple for Malagasy people, and Alaotra Lake region is the most important rice-growing area in the country (see Fig. 13 for the different land uses coexisting around the lake).

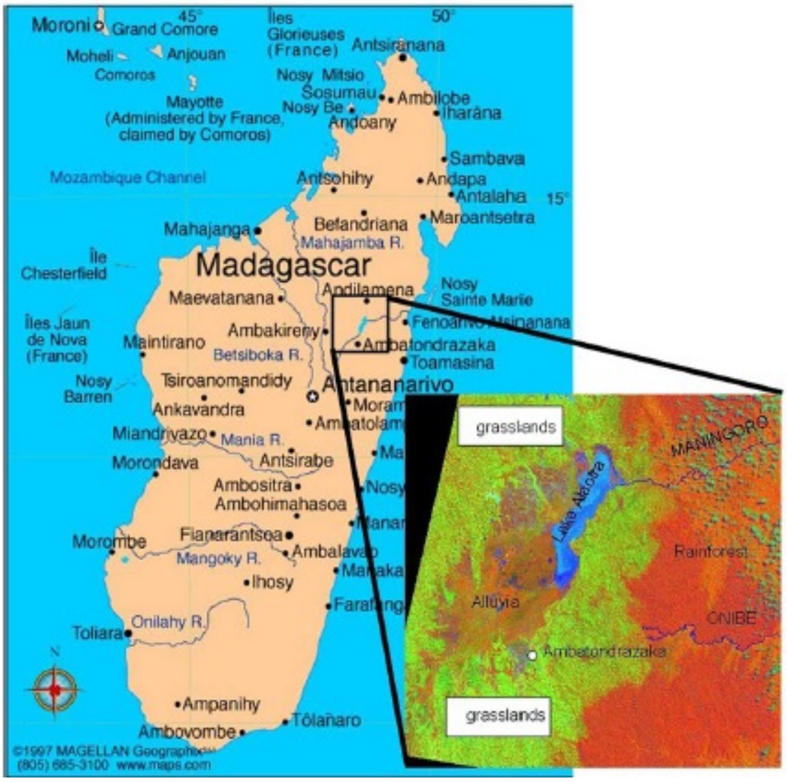


Figure 12. Map of Alaotra Lake.

Source: Bakoariniaina et al. (2006)

However, the lake has been dramatically reduced in recent years. Its size and shape have changed and the rice production has decreased. The lake is clogging: since 1960, a 60% reduction; since 1980, a 40% reduction; and since 2000, a 20% reduction. The dramatic clear cutting of the surrounding primary forests has caused catastrophic degradation of the hill slopes (*tanety* in local language) by gullies – lavakas. Hill slopes have been rapidly eroded, and the streams are now transporting muddy and silty waters, which when reach the valley – baiboho – cover and suffocate the paddies (Bakiariniaina et al., 2006). As a consequence rice production is going down, and the Alaotra Lake is being filled with sediment.

The existence of the rainforest in Eastern Madagascar is under serious threat, by the burning and clear cutting of the woods for charcoal burning, as well as for expanding cultivation, dwelling areas and pastureland (Dufils, 2003; Wright and Rakotoarisoa, 2003). Mutschler (2003) compiled that local people transformed marsh zones into rice cultivation and even tried to get some space for cultivation because some lands are no longer productive. The alternation of drier seasons with wetter seasons intensifies soil erosion given that land remains unprotected without the forest, and then rapid runoff occurs. Lavakas decorates hill slopes with red-coloured soil, and dry grasses and shrubs are the new vegetation types observed in state of the ancient rainforest (Bakoariniaina et al., 2006). However, it should be stated that the most dramatic disappearance of the rainforest in the area started during colonial times in the 1900s (Kull, 2002).

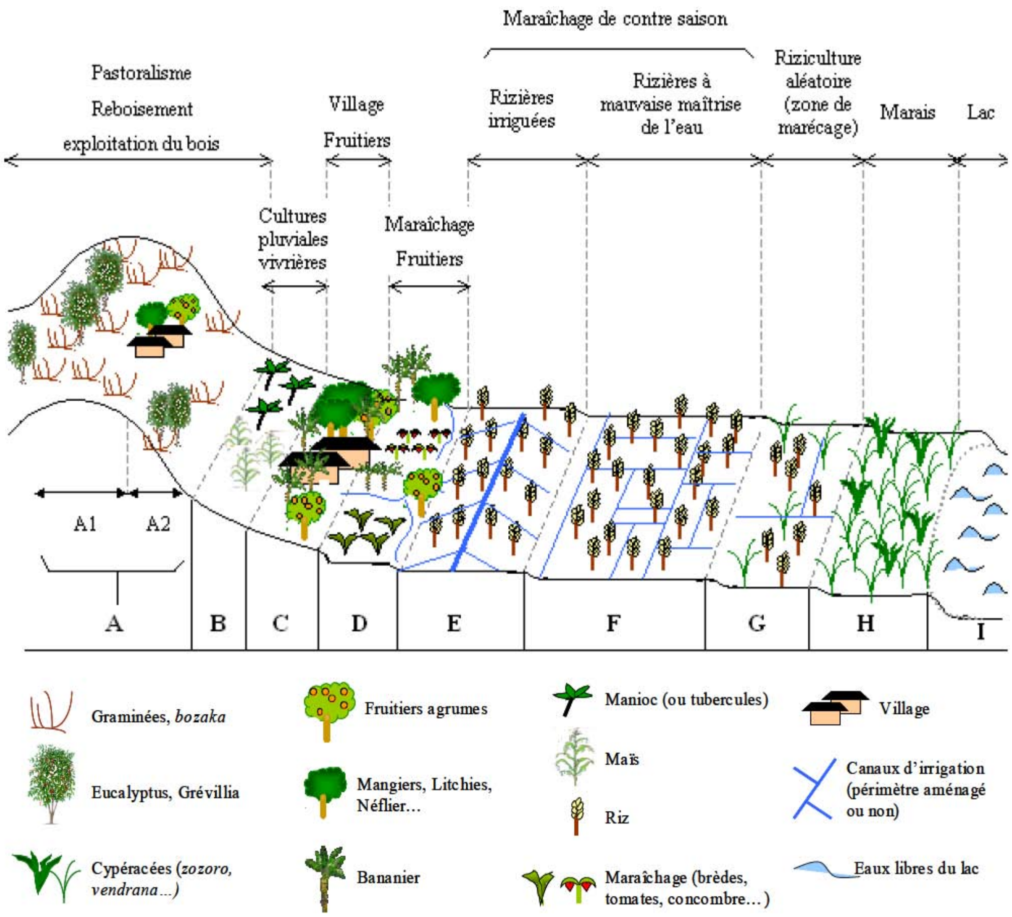


Figure 13. Land use in the Alaotra Lake region.

Source: Claire and Stéfanie (2007)

Rainforest disappearance, soil erosion, siltation of lowlands, and loss of soil fertility, all these processes are threatening the traditional small mixed farming activity in the region (MF1 in **Figure 3**), which used to consist in a combination of rice-cultivation and zebu raising, as well as fishing and fruit gathering and game. These processes are being intensified in the last years by an increasing arrival of immigrants – the population has tripled since 1960 – and the shortening of the rainy season and unpredictability of rains that makes increasingly difficult for the small mixed farmers to predict the most appropriate farming calendar. It is difficult to forecast when will be the best moment to undertake each farming practice. This goes in hand with rising food insecurity. Between

1930 and 2006 the average rainfall has diminished by 350mm. Small mixed farmers in the region try to adapt to this increased climate unpredictability through enhancing diversification, both livestock and crop diversification, but also livelihood diversification. A remarkable shift is taking place in the region towards raising short-cycle animals, mainly poultry and pigs – as well as dairy cows, given that these livestock types provide daily revenues and food security. Also there is less risk of losing revenue because these animals require less time and feed to be raised. Farmers also adapt to the decreased soil fertility by using livestock to obtain manure to fertilize their fields. It should be born in mind that around 35% of the *tanety* region has been abandoned as a result of soil fertility degradation. The traditional zebu raising is also being threatened by pasture shortage; increasing insecurity due to raids; and by the fact that the zebus in some occasions are being substituted by rotavators to work the paddies since they allow to undertake the agricultural practices quicker and thus adapt to the reduction of the rainy season.

7.2.1 Socio-economic drivers intensifying CC's impacts

The main socio-economic drivers that exacerbate the impacts of climate variability and/or hinder the adaptation strategies that the small mixed farming communities of Alaotra Lake region are briefly described as follows:

- **Rising population and competition for the use of rangelands**

A remarkable process of population growth is taking place in the region, mainly as a consequence of the arrival of immigrants, who arrive to the Alaotra Lake region attracted by the opportunities of livelihood the regions offers, such as fishing in the lake, rice cultivation, and exploitation of the tanety. Thus, the population has tripled since 1960. The enormous population pressure is leading the region towards increased competition among alternative uses of rangelands, particularly those close to water sources. SSL farmers have a lot of difficulties to find pastures for the zebus. There is a conflict between agriculture and livestock grazing in the tanety. Also the spread of tree plantation – mainly eucalyptus, with its origins in colonial times to fuel steam locomotive – in the tanety is playing a role, as well as the common practice of grassland fires to expand agriculture and grazing area for the dry season. In addition, livestock raids are becoming more and more frequent. This is particularly damaging for the zebu farming: firstly, because this is the most valuable animal; and secondly, because it is making increasingly risky to find grazing land for them. This is affecting the capital-saving role of the zebu. SSL farmers attribute the increasing number of livestock raids to the situation of political instability that Madagascar has been going through in the last years. All this leads to a situation of increased deforestation, overgrazing, water scarcity, replacement of communal ownership by private access, and increased violence.

- **Top-down planning and neglect of traditional institutions and customary practices**

Land, particularly rangeland and water resources, is being expropriated from SSLF communities. Their sense of ownership, communal ownership is weakening. There is strong land property insecurity in the region. This is a problem that the whole country is suffering since the end of colonial times. This insecurity has been particularly damaging to SSL farmers. There are tensions between pastoralists and settled farmers. Land tenure policies are not clearly defining the rights and delimitation of land users. This has allowed privatization of grazing land for agricultural purposes. SSL farmers perceive how their herd mobility is being restricted, what leads to overgrazing and land degradation. To cope with this, some of them shift towards keeping small animals, which can be sold quickly, or move towards agropastoralism reducing the size of the herd. This also goes with a notable negligence of SSLF institutions and customary practices. This is clearly shown in the Alaotra Lake region, for instance, by the recurrent conflicts between the central government and the traditional courts, called *dina*.

- Increasing integration within the market economy

The greater integration of SSLF communities into the market economy is making those communities more vulnerable since the production system is subject to changes that make the adoption of CC adaptation strategies more difficult. This process seems to be driven by immigration inflows, growing urbanization, and dissemination of communications infrastructures and media. It fosters a shift from livestock – mainly zebus – as a mobile reserve of value to be used in difficult times or when required, to livestock as a systematic source of meat or milk. Also this does not guarantee that SSL farmers receive appropriate revenue in exchange for their products, in fact it is the other way around. Furthermore, this makes pastoralists communities increasingly vulnerable to external forces that they cannot control, such as the worldwide trend of soaring food prices.

7.2.2 Adaptation strategies

The CC-related hazards in the Alaotra Lake region are described below, together with the biophysical impacts and the socio-economic effects they entail. Also the adaptation strategies being implemented in each case are described, and characterized according to the axes of autonomous/planned and anticipatory/reactive adaptation.

Table 14. Adaptation strategies in Alaotra lake area

BIOPHYSICAL IMPACT	SOCIO-ECONOMIC EFFECT	ADAPTATION STRATEGY	TYPE OF ADAPTATION*
HAZARD: Drought and extreme heat			
Shortening of The rainy season and unpredict-ability of rains.	Unpredictable farming calendar. It is difficult to forecast when will be the best time to undertake each farming practice. This	Shift towards raising short-cycle animals – mainly poultry and pigs - and dairy cows - it is not a short-cycle but is something similar given that it provides almost daily revenues and food stability. The interest in undertaking such kinds of livestock farming lies in the fact that they generate revenues and food in a very short period of time, which makes them very well adapted to changing conditions. Also they require lower capital investment, and if one dies it is not much damaging.	A/P-AN

	goes with rising food insecurity and a reduced dependence on traditional diet – e.g. from rice to manioc.	The zebus working in paddies are being substituted by cultivators, in order to conduct agricultural activities more quickly and adapt to the reduction of the rainy season. However, this may imply a lack of manure for crop cultivation, as well as increases the cost of production.	A-R
		Livestock diversification between small and large stock to guarantee food security, given that small animals reproduce faster – poultry, pigs, guinea pigs, apiculture, etc. - while large animals have greater value.	A-AN
		Agricultural diversification at the expense of rice cultivation to diminish the risk of losing all the harvest.	A-AN
		Shift from pastoralism to agropastoralism - in some cases with cash crops.	A-AN
		Shift from rice cultivation to other crops, less water-demanding, such as potato, tomato, horticulture, etc.	A-AN
		Shift to early-maturing rice varieties - not autochthonous.	A/P-AN/R
		Construction of new wells and watering points.	A-AN
		More active role of women in livestock production – particularly in small animals and dairy cows.	A-AN
		Food sharing to compensate those having lost livestock or crops.	A-AN
Loss of soil fertility.	Pasture shortages, both in quantity and quality -particularly harmful for the managing of zebus.	Herd mobility. Transhumance to mountain areas during dry seasons, to feed animals - zebus.	A-AN
		Animals can graze freely over all paddies when there is no rice.	A-AN
		Grazing land preservation for difficult times.	A-AN
		Some land lying fallow.	A-AN
		General decrease in the size of the herd, as a consequence of the lack of feedstuffs and the livestock raids – remarkably in zebu raising.	A-R
		Shift towards monogastric livestock – mainly, poultry and pigs – which do not depend on high-quality pasture and can be fed on household and crop wastes, as well as scavenging.	A/P-AN/R

		Shift form pastoralism to agropastoralism. Accumulation of the rice straw for animal feeding. This was not usual before. This is a way to compensate for the lack of pastures. Adoption of fodder crops to cope with the lack of natural pasture, both in quantity and quality. Application of conservation agriculture measures: - Adoption of crop rotation with leguminous plants to face the lack of soil fertility. - Adoption of cover crops (*Stylosanthes*, *Brachiaria*, vetch, rice straw, etc.) to enhance carbon fixation in the soil, semi-direct seeding of the rice, and crop rotation, to face the lack of soil fertility. Grassland fires to maintain grasslands. CAUTION the side effects of this practice are not clear. Land resting	A-AN A/P-AN P-AN A/P-AN A-AN A/P-AN
Decreased productivity of the livestock	Rising food insecurity - mainly among children, pregnant women, and the elderly. This goes with reduced dependence on traditional diet (meat, rice, game, fruits, fish...).	Improvements in animal housing, such as increase of litter in housing in cold season and putting in a roof to protect herd. Shift from grazing to livestock corralling to improve animal feed and health. Maintaining of local or mixed breed for their hardiness to climate, disease and more strength for field labor. Accumulation of the rice straw for animal feeding. This was not usual before. This is a way to compensate for the lack of pastures. Livestock diversification between small and large stock so as to guarantee food security, since small animals reproduce faster – poultry, pigs, guinea pigs, apiculture, etc. - while large animals have greater value. Also, the small livestock is often managed and/or owned by women. Livestock may also build social capital to help a family through a crisis. Smallholders and pastoralists will sometimes lend or give animals to relatives, knowing that this gives them social standing and puts them in a stronger position to ask for help in the face of a disaster.	P-AN/R P-AN/R A-AN A/P-AN A-AN A-AN

		Shift from pastoralism to agropastoralism - in some cases with cash crops. Livelihood diversification to other activities, such as making honey, fish farming, wage-earning activities, charcoal burning, eucalyptus plantation, cow manure collection and selling, etc. Remarkable role of women in the new activity. Yogurt making so as to get better price from the milk. More active role of women in livestock production – particularly in small animals and dairy cows. Increasing social acceptance of woman entrepreneurship. Food sharing to compensate those having lost livestock or crops.	A-AN A-AN A/P-AN A-AN A-AN A-AN
Decreasing production of the crops and fruit trees.	Rising food insecurity - mainly among children, pregnant women, and the elderly. This goes with reduced dependence on traditional diet (meat, rice, game, fruits, fish...)	Adoption of livestock for manure. Shift from agricultural farming to agropastoralism. Shift from grazing to livestock corralling to improve animal feed and health, and to accumulate manure – e.g. poultry, pig, guinea pig, zebu. Improvements in animal housing, such as putting in a roof to maintain the quality of manure. Composting the manure to obtain organic fertilizer of greater quality and quantity. Application of conservation agriculture measures: - Adoption of crop rotation with leguminous plants to face the lack of soil fertility. - Adoption of cover crops (*Stylosanthes*, *Brachiaria*, vetch, rice straw, etc.) to enhance carbon fixation in the soil, semi-direct seeding of the rice, and crop rotation, to face the lack of soil fertility. - Adoption of the semi-direct seeding of the rice to face the lack of soil fertility. - Superficial tillage. Livelihood diversification to other activities, such as making honey, fish farming, wage-earning activities, charcoal burning, eucalyptus plantation, cow manure collection and selling, etc. Remarkable role of women in the new activity.	A/P-AN P-AN/R P-AN/R P-AN A/P-AN A-AN

		Leaving the land fallow. Increasing social acceptance of woman entrepreneurship. Microfinance/loan services - rice growers association - that help pastoralists to modernize rice growing – buy and sell together. Food sharing with those having lost livestock or crops.	A-AN A-AN A/P-AN A-AN
Better conditions for some vectors of livestock diseases - e.g. ticks, insects, mites.	Expansion of livestock diseases, both geographically and temporally. Poultry and pig raising are the most vulnerable kinds of livestock.	Early selling of animals before the disease reaches the community. There is a kind of unwritten law that states that in this case neighbours have to buy parts of this meat. It is a form of solidarity. Quarantining of new animals, avoiding neighbouring herds when a disease outbreak has occurred in the vicinity, controlling ticks, and the use of antibiotics, when available. Splitting the herd, so as to diminish the risk of losing all animals. Often this is done with the participation of relatives – mainly conducted in zebus, poultry and pigs. Maintaining of local or mixed breed for their hardiness to climate, disease and more strength for field labor. Manual removal of ticks from the animals. Some herbs and traditional cures are used from time to time - fundamentally for the zebus. Shift from grazing to livestock corralling to improve animal feed and health. Expanding the animal health services by training pastoralist on emerging disease and guarantying a quick intervention. This is the case of the ACSA project ('Agents Communautaires de Santé Animal') being run by AVSF. Wait for the immune animals to survive and rebuild the herd when conditions improve based on these individuals. Use of vaccines.	A-AN A-AN A-AN A-AN A-AN A-AN P-AN/R P-AN A-AN P-AN

Deforestation.	Soil erosion, e.g. *lavakas*.	Tree nurseries to rehabilitate degraded land through reforestation, in the *tanety* – mainly eucalyptus, pine trees, *Grevillia*. Stop cultivation in the *tanety*. Implementation of projects of biogas production from cattle manure, to diminish the consumption of firewood and charcoal.	A/P-AN/R A-R P-AN
	Disappearance of wild fruit trees.	Tree nurseries to rehabilitate degraded land through reforestation, in the *tanety* – mainly eucalyptus, pine trees, *Grevillia*. Cultivation of fruit trees.	A/P-AN/R A-AN
	Disappearance of the majority of the animals, such as large mammals - lemurs, etc. - and birds that used to be hunted in the *tanety.*	Tree nurseries to rehabilitate degraded land through reforestation, in the *tanety* – mainly eucalyptus, pine trees, *Grevillia*.	A/P-AN/R
	Some herbs are used for livestock diseases – zebu mainly. Loss of local and traditional knowledge as these plants disappear or are more difficult to find.	Tree nurseries to rehabilitate degraded land through reforestation, in the *tanety* – mainly eucalyptus, pine trees, *Grevillia*.	A/P-AN/R
Fishing damages	Less fish captured, quantitatively and qualitatively, due to the lake clogging.	Undertaking of fish farming as a complementary activity. Tree nurseries to rehabilitate degraded land through reforestation, in the *tanety* – mainly eucalyptus, pine trees, *Grevillia*.	A-AN A/P-AN/R

HAZARD: Occasional cyclones and floods			
Damages to pastures	Pasture shortages	Herd mobility. Transhumance to mountain areas during dry seasons, to feed animals - zebus.	A-AN
		Animals can graze freely over all paddies when there is no rice.	A-AN
		General decrease in the size of the herd, as a consequence of the lack of feedstuffs and the livestock raids – remarkably in zebu raising.	A-R
		Shift towards monogastric livestock – mainly, poultry and pigs – which do not depend on high-quality pasture and can be fed on household and crop wastes, as well as scavenging.	A-AN
		Shift from pastoralism to agropastoralism – in some cases with cash crops.	A-AN
		Accumulation of the rice straw for animal feeding. This was not usual before. This is a way to compensate for the lack of pastures.	A/P-AN
		Adoption of fodder crops to cope with the lack of natural pasture, both in quantity and quality.	P-AN
		Application of conservation agriculture measures: - Adoption of crop rotation with leguminous plants to face the lack of soil fertility. - Adoption of cover crops (*Stylosanthes*, *Brachiaria*, vetch, rice straw, etc.) to enhance carbon fixation in the soil, semi-direct seeding of the rice, and crop rotation, to face the lack of soil fertility.	A/P-AN
		Grassland fires to maintain grasslands. CAUTION the side effects of this practice are not clear.	A-AN
		Land resting	A/P-AN
	Soil erosion.	Tree nurseries to rehabilitate degraded land through reforestation, in the *tanety* – mainly eucalyptus, pine trees, *Grevillia*.	A/P-AN/R
		Stop cultivation in the *tanety*.	A-R
		Implementation of projects of biogas production from cattle manure, to diminish the consumption of firewood and charcoal.	P-AN

Better conditions for some vectors of livestock diseases - e.g. ticks, insects, mites.	Increasing number of outbreaks of livestock epidemic diseases take place after floods. They are no new epidemics, but they emerge more recurrently.	Early selling of animals before the disease reaches the community. There is a kind of unwritten law that states that in this case neighbours have to buy parts of this meat. It is a form of solidarity.	A-AN
		Shift from grazing to livestock corralling to improve animal feed and health.	P-AN/R
		Quarantining of new animals, avoiding neighbouring herds when a disease outbreak has occurred in the vicinity, controlling ticks, and the use of antibiotics, when available.	A-AN
		Splitting the herd, so as to diminish the risk of losing all animals. Often this is done with the participation of relatives – mainly conducted in zebus, poultry and pigs.	A-AN
		Maintaining of local or mixed breed for their hardiness to climate, disease and more strength for field labor.	A-AN
		Manual removal of ticks from the animals.	A-AN
		Some herbs and traditional cures are used from time to time - fundamentally for the zebus.	A-AN
		Expanding the animal health services by training pastoralist on emerging disease and guarantying a quick intervention. This is the case of the ACSA project ('Agents Communautaires de Santé Animal') being run by AVSF	P-AN
		Wait for the immune animals to survive and rebuild the herd when conditions improve based on these individuals.	A-AN
		Use of vaccines.	P-AN
		Food sharing to compensate those having lost livestock or crops.	A-AN
Destruction of water infra-structures.	Increasing vulnerability of crops to rain unpredictability and floods.	Land abandonment and moving towards wage labour.	A-R
		Shift from rice growing to other less water-demanding crops, such as tomato, potato or horticulture.	A-AN

		Application of conservation agriculture measures: - Adoption of the semi-direct seeding of the rice to face the lack of soil fertility. - Adoption of crop rotation to face the lack of soil fertility.	A/P-AN
		Livelihood diversification to other activities, such as making honey, fish farming, wage-earning activities, charcoal burning, eucalyptus plantation, cow manure collection and selling, etc. Remarkable role of women in the new activity.	A-AN
		Maintenance, rehabilitation and construction of water infrastructure.	P-AN/R
		Food sharing to compensate those having lost livestock or crops.	A-AN

*Being A, Autonomous; P, Planned; AN, Anticipatory; and R, Reactive.

7.3 Pastoralism in Khar-o-Touran (Iran) [5]

Khar-o-Touran is the Abolhassani tribe territory. It is located in the Southeast of the Semnan province in Iran, in a desert region. The province of Semnan covers an area of 96,816 km. and limits with the Alborz mountain range and the Dasht-e Kavir desert (see Fig. 14). In 2005 the province had a population of 289,000 inhabitants. The province is divided into two parts: a mountainous region, and the plains at the foot of the mountains. Despite being a dry area, its ecological value is outstanding. The 'Man and Biosphere' program named Khar-o-Touran one of the nine Biosphere reserves in the world. For this obviously it is the local people that have to be credited for having preserved up to nowadays such environment.

The predominant activity conducted by the Abolhassani people is pastoralism. Sheep, goat and camel are the main types of livestock they raise. Most of them are nomads – about 70% according to CENESTA - who move with the herd between the winter and the summer seasons. The length of migrations may vary from 10 to 50 km. In 1980, 150,000 sheep and goats winter in this area from November to May, of which 25,000 belonged to the local settled population who remain in the area through summer (Spooner and Horne, 1980). Due to remoteness, the villages in the area show a lack of facilities, services and infrastructures. The management of rangelands is undertaken communally, and the committee of the elders of communities still plays a crucial role in deciding when, where and which kind of animals are led to each pasture. The same applies to water resources – *qanats*, springs and wells. In the surroundings of the villages, agriculture is also being conducted, mainly barley and wheat, as well as gardening and fruit tree cultivation, such as pomegranate.

[5] The authors would like to thank CENESTA, since they performed the interviews and have provided the majority of the information that has been used to write this section.

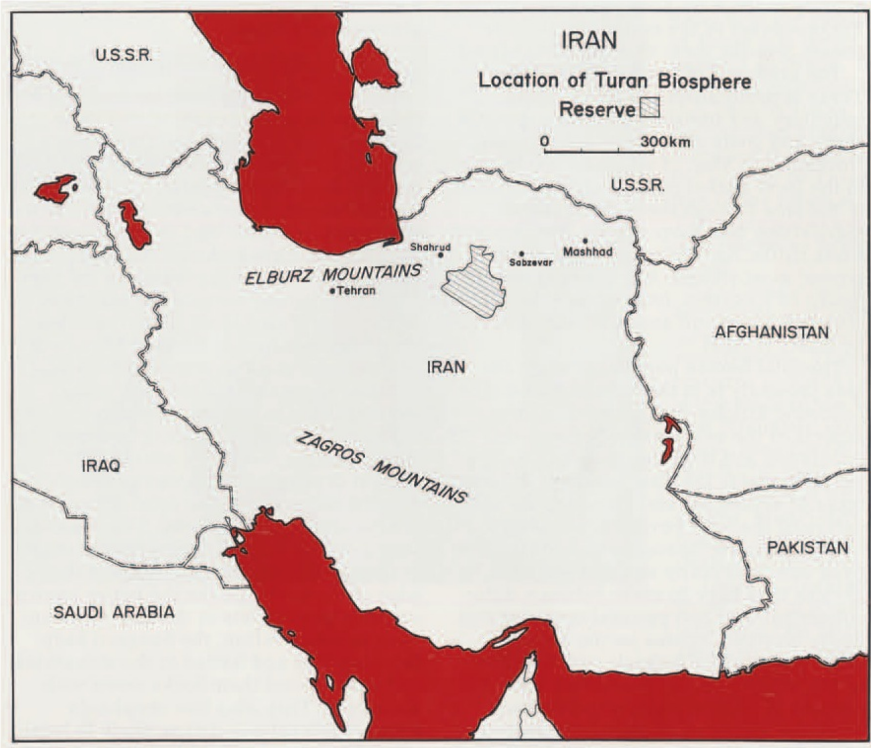


Figure 14. Map of Khar-o-Touran.

Source: Spooner and Horne (1980)

In recent years, the frequent and long drought periods experienced have caused some detrimental impacts on the Abolhassani pastoralist livelihoods – e.g. decreased livestock and agricultural productions, shortage of drinking and irrigation water, decreased pastures fodder, sand dunes' flowing and loss of vegetation cover in the rangeland. This is making pastoralists' livelihoods increasingly difficult. However, Abolhassani pastoralists are used to surmounting drought periods and have highly adapted traditional knowledge to cope with it. This knowledge might be found in their migratory methods, the way of varying herd composition, the adoption of multi-purpose crops. However, the dismissal of traditional practices and institutions, migrations to urban areas, and the marginalization of Abolhassani from decision-making centres have being weakening their resilience capacity. This is leading to overgrazing, land degradation, salinization of water resources. In a recent study conducted in the area (Abolhassani, 2011), the Abolhassani pastoralists highlighted the following factors as the main causes of rangeland degradation: 40% rainfall reduction; 56.1% land reform; 9.75% overgrazing; 4.74% changes in livestock breeds; and finally 2.44% conflicts among local people.

7.3.1 Socio-economic drivers intensifying CC's impacts

The main socio-economic drivers that exacerbate the impacts of climate variability and/or hinder the adaptation strategies implemented by pastoralist communities in Khar-o-Touran are briefly described below:

- **Rising population and competition for the use of rangelands**

The population of the Semnan province is growing, which leads to overgrazing, increasing lack of water and migration of pastoralist households to the city. While the population of the Semnan province in 1996 was of 501,000 inhabitants; in 2005 it reached 589,515 inhabitants. As a consequence, the pressure on land resources increased, and Abolhassani pastoralists have to compete for alternative uses of rangelands, which not only reduces the amount of pastures available for their herds, but also blocks their migratory routes. The main alternative uses of rangelands that are taking place in the area include: expansion of rain-fed farming in rangelands; establishment of natural reserves – e.g. the Khar-o-Touran biosphere reserve; setting up of industrial installations; construction of governmental military quarters; establishment of mining and oil-extracting installations; construction of roads and highways; and urban areas expansion. In addition, neighbouring communities occasionally set rangelands on fire to prevent nomadic tribes from using them. Moreover, pastoralists claim that the oil refineries' gases have devastating effects on the grass and shrubs of the surrounding rangelands. In addition, the Iranian Government is also expropriating the rangelands legally. In 1962 the law of 'Nationalization of Natural Resources' was issued in Iran. This law stated that the Iranian Government was the sole owner of the land in the country and thus, of the rangelands. Since then, pastoralists have to ask permission to the Government to graze in a given pasture. This not only has caused a loss of sense of ownership in communal rangelands, but has also led to the loss of traditional Abolhassani institutions and practices, entailing the transfer of the rangelands' ownership to non-nomadic, non-pastoralist individuals. Consequently, new activities have flourished in the rangelands making pastoralists' livelihood increasingly difficult to handle, as well as leading to overgrazing and water resources scarcity.

- ❖ Top-down planning and neglect of traditional institutions and customary practices

Top-down planning and negligence of pastoralist institutions and customary practices have been frequently witnessed in the region. This is the case of the implementation of certain national anti-desertification plans that ignore the benefits of local communities; authorizing agricultural activities in rangelands; lack of support to local organizations; unruly actions of the Government - Natural Resources Department - in planting maladapted saplings; and preventing camels from having access to the rangelands, considering them harmful to rangelands. Another example of the lack of will and capacity of governmental institutions to adapt to pastoralists' way of living is the pressures they receive to shorten the seasonal migration, that is, the time they spend to move the herds from the summering ground to the wintering one, and vice-versa. This practice used to take about a couple of months, while now it takes 20 or 25 days, or only 24h when trucks are used, which is leading to overgrazing and land degradation. This is also shown by the 1962 law of 'Nationalization of Natural Resources', which shows that authorities are quite reluctant to facilitate local pastoralists' involvement in rangelands and water resources management. Thus, the primacy of local and traditional knowledge, which the Abolhassani pastoralists have been nurturing over the centuries for communal rangeland planning, is being denied. On a few occasions, even some grazing permits have been denied. In line with this, several governmental sedentarization attempts of the Abolhassani pastoralists should be mentioned. For instance, in Namdan Dasht 800 Ha of pastures were expropriated to build houses for tribes to be settled down, although no one moved there. The government promoted the sedentarisation by providing the settled tribes with grants and housing loans.

However, such efforts have often failed, since the plans do not match pastoralists' needs. Only poor pastoralists, with no other options to make a living, welcomed such plans. It seems obvious that policy-makers ignore and deny the benefits of rangelands herding, that the Abolhassani pastoralists have been conducting for centuries, which intensifies CC-related degradation of rangelands, by enhancing overgrazing and conversion of rangelands into agricultural land. In general, Abolhassani nomadic pastoralists look at the restoration of their social organization as a solution to their problems, as well as regaining control over natural resource management and land ownership. Also the youth should be educated on new technologies on animal husbandry, veterinary medicine, conservation and revitalization of rangelands and forests. Customary laws and practices are still in place, particularly with respect to water and pasture management. Elders and traditional leaders are still respected although their role is weakening.

- **Introduction of the market economy**

As in the three other cases, the Abolhassani communities realise that their lives are more and more dependent on the market economy. Thus, practices such as the utilization of loans to buy fodder or hire gamekeepers or herders are nowadays usual practices in the region. This is also shown by the rising interests they show, for instance, for improving sheep and goat breeds, for which there are larger productions, despite the traditional breeds prove more adapted to the dry conditions of the regions. This makes pastoralists more vulnerable to the soaring world food prices. In addition, it does not guarantee that they will receive appropriate prices for their livestock products.

7.3.2 Adaptation strategies

CC-related hazards in the Khar-o-Touran region are described below , together with the biophysical impacts and the socio-economic effects they entail. Adaptation strategies being implemented in each case are also described below, and characterized according to the axes of autonomous/planned and anticipatory/reactive adaptation.

Table 15. Adaptation strategies in Khar-o-Touran

BIOPHYSICAL IMPACT	SOCIO-ECONOMIC EFFECT	ADAPTATION STRATEGY	TYPE OF ADAPTATION*
HAZARD: Drought			
Desertifi-cation	Pasture shortages	Nomadism. That is, household and herd seasonal movement between summering and wintering quarters.	A-AN
		Reducing the number of ewes and increase the number of goats, as goats take more benefit from desert pastures.	A-AN
		Customarily communal grazing decision system, based on the agreement between the elders of the tribe, to decide the quantity of livestock, the type of livestock, and the amount of time to be spent grazing in each pastureland.	A-AN

		To respect the width of about 700 to 800 m of pasture that herder whose pastures are in the migration paths of nomadic pastoralists should guarantee for the migrating flocks.	A-AN
		To get loans to buy fodder.	A/P-R
		'Boundless grazing' is a traditional implying that all pastoralists, regardless of pasture ownership and boundaries, can lead the herd to graze from April to mid-May - 45 days - wherever they want. This tradition provides several benefits for the overall management of the rangelands in the region – e.g. the distant or low water resources pastures are grazed in springs under favourable conditions, reduces conflicts between the tribes in this period, delays the grazing of the summering pastures allowing them to develop appropriately, etc.	A-AN
		Maintaining the traditional practices and calendar of the seasonal migration of the herd from the summering pastureland to the wintering pastureland.	A-AN
		Lengthening the migration path and grazing in more distant pastures, if necessary into other communities' territories.	A-AN/R
		Renting the farmlands residues of other communities.	A-AN/R
		Adoption of multipurpose crops and fruit trees – e.g. watermelons, cotton, pistachio, red pepper, sunflower, almond, pomegranate, etc. Used as cash crops, livestock fodder and self-consumption.	A-AN
		Selling a part of the herd to afford buying fodder for the remaining.	A-R
		Application of 'closed pastures' to allow appropriate grassland development before grazing. This implies hiring a gamekeeper to protect the pastures.	A-AN
		Promoting friendly collaboration with local communities.	A-AN
		Maintaining the tradition ruled by the elderly council of sending some pioneers to measure the plant coverage of the migratory routes to know it the grass is in good conditions before the tribe decides what route following to reach the wintering pasturelands.	A-AN
		Land resting	A-AN

	Increased conflicts with other land uses, as well as with livestock farmers from other communities.	Maintaining the traditional practices and calendar of the seasonal migration of the herd from the summering pastureland to the wintering pastureland.	A-AN
		Application of 'closed pastures' to allow appropriate grassland development before grazing. This implies hiring a gamekeeper to protect the pastures.	A-AN
		'Boundless grazing' is a traditional implying that all pastoralists, regardless of the pasture ownership and boundaries, can lead the herd to graze from April to mid-May - 45 days - wherever they want. This tradition provides several benefits for the overall management of the rangelands in the region – e.g. the distant or low water resources pastures are grazed in spring under favourable conditions, reduces conflicts between the tribes in this period, delays the grazing of the summering pastures allowing them to develop appropriately, etc.	A-AN
		Keeping the sense of rangeland communal ownership.	A-AN
		Promoting friendly collaboration with local communities.	A-AN
		Decrease the size of the household – amount of people.	A-AN/R
Decreased producti-vity of livestock (wool, meat, hide, milk…).	Rising food insecurity - mainly among children, pregnant women and the elderly. This goes with reduced dependence on traditional diet – meat, dairy products and native vegetables - in favor of manufactured foods.	Nomadism. That is, household and herd seasonal movement between summering and wintering quarters.	A-AN
		Migration of the household to the cities in search of new sources of livelihood.	A-R
		Reducing the number of livestock particularly sheep – ewes.	A-R
		Shifting towards Pakistani goat which produced more milk and meat than the native one.	A-AN/R
		Shifting from native sheep breed to more productive Afshari sheep breed.	A-AN/R
		Herd reduction.	A-R
		Camels range freely and are rounded up periodically to be sold for meat.	A-AN
		From pastoralism to agropastoralism with stall-fed sheep. Expansion of rain-fed farming in rangelands. Replacement of pasture by fodder crops. Shift from mobile systems to semi-mobile and even completely settled.	A-AN/R

		Selling a part of the herd to afford buying fodder for the remaining.	A-R
		Adoption of multipurpose crops and fruit trees – e.g. watermelons, cotton, pistachio, red pepper, sunflower, almond, pomegranate, etc. Used as cash crops, livestock fodder and self-consumption.	A-AN
		Because of the less numbers of livestock in each herd, they tend to joint 3 or 4 herds together to pay less for shepherd and keep some of the livestock in the stalls.	A-AN
		Maintaining the tradition ruled by the elderly council of sending some pioneers to measure the plant coverage of the migratory routes to know it the grass is in good conditions before the tribe decides what route following to reach the wintering pasturelands.	A-AN
		Livelihood diversification – e.g. mining, handicraft production – mainly conducted by women.	A-AN/R
		The traditional diet is full of many of products that different ways to preserve food for more difficult periods, mainly winter – e.g. as ghee, curd, etc.	A-AN
		When surpluses of crops exist, they may be bartered or sold to get clothes, sugar, medicines, fodder, staple, etc.	A-AN
		Decrease the size of the household – amount of people.	A-AN/R
Decreased produc-tivity of agriculture –e.g. barley, wheat, alfalfa.	Rising food insecurity - mainly among children, pregnant women and the elderly. This goes with reduced dependence on traditional diet – meat, dairy products and native vegetables - in favor of manufactured foods.	Shifting from gardening to fruit tree cultivation – e.g. pomegranate.	A-AN/R
		Migration of the household to the cities in search of new sources of livelihood.	A-R
		Livelihood diversification – e.g. mining, handicraft production – mainly conducted by women.	A-AN/R
		The traditional diet is full of many of products that different ways to preserve food for more difficult periods, mainly winter – e.g. as ghee, curd, etc.	A-AN
		Shift from agriculture of fodder and cash crops – e.g. barley, alfalfa, pistachio – to the cultivation of some few vegetables and fruit trees for self-consumption at the home garden and using the drinking water from the well.	A-AN/R

		When surpluses of crops exist, they may be bartered or sold to get clothes, sugar, medicines, fodder, staple, etc. Decrease the size of the household – amount of people.	A-AN A-AN/R
Deforesta-tion.	Soil erosion.	Stop wood cutting and buying fuel. Stop charcoal burning for selling purposes. Projects of sand dune stabilization thought artificial windbreaks made of dried tree branches. Nomadism. That is, household and herd seasonal movement between summering and wintering quarters.	A-R P-R P-AN A-AN
Changes in vegeta-tion.	Loss of local and traditional knowledge as native plants and trees disappear or are more difficult to find.	Buy 'modern' medicines in the city. Nomadism. That is, household and herd seasonal movement between summering and wintering quarters.	A-R A-AN
Less water availability for livestock and communities, both quantitative and qualitative salinization	Lack of water for animals and crops, due to reduction of water discharge of *qanats*, springs and wells.	Digging of new wells. Storage of rain water in cisterns Use of mobile tankers to provide water to those pastures with no water available. This must be paid. The pastoralist tradition of *Henar*, which implies watering the animals once every two days, generally from the end of fall to late winter – although the duration of the *Henar* varies depending on local conditions. This is a way to fight water shortage, saving labor for water extraction, as well as to promote animals' adaptation to lack of water. Nomadism. That is, household and herd seasonal movement between summering and wintering quarters. Respect of the traditional communal water resource management, e.g. distribute the access to the water of *qanats* among the neighbours in cycles of 12 days. Livestock transportation by vehicles due to lack of water in the migration routes.	A/P-AN/R A-AN A/P-AN/R A-AN A-AN A-AN A-R

		Shift from agriculture of fodder and cash crops – e.g. barley, alfalfa, pistachio – to the cultivation of some few vegetables and fruit trees for self-consumption at the home garden and using the drinking water from the well. Shift from agropastoralism to pastoralism, due to the lack of water to undertake agriculture. Decrease the size of the household – amount of people.	A-AN/R A-AN/R A-AN/R
Decreasing presence of wildlife – e.g. deer, Iranian zebra, partridges, antelopes.	Lack of game. This goes with reduced dependence on traditional diet (meat, rice, game, fruits, fish...).	When surpluses of crops exist, they may be bartered or sold to get clothes, sugar, medicines, fodder, staple, etc.	A-AN
Better conditions for livestock disease vectors, such as ticks, insects and mites.	Increase in livestock diseases and mortality – e.g. PPR, flaky fever.	Avoiding contaminated pastures and diminishing the contact with herds in passing. Utilization of local and traditional knowledge to livestock disease treatment and preventions – e.g. for 'popdardi', a lung disease, to avoid the spread of the disease to other animals, they cook the infected lung and grind it in a mortar with salt, to develop a tradition vaccination; for smallpox, they catch a porcupine, peel it and boil it in a pot, and then they feed each of the animals a gloss of this boiled mixture; for lip pimples, they give them vinegar and sour curd; for mange, they grind the tobacco, add some water and boil it and then rub on the infection part; for intestinal worms, they grind the roots of a plant (Ferula) and extract its water to give it to livestock; etc. Utilization of local and traditional knowledge to deal with ticks and other external parasites – e.g. burning the barns every year and construct them again. Utilization of 'modern' knowledge to deal with ticks and other external parasites – e.g. usage of pesticides and other spraying methods. Utilization of local and traditional knowledge to heal infected injuries of the livestock – e.g. boiling the children's urine in a pot and after getting darker and thick, rub it on the wound.	A-AN A-AN A-AN A/P-R A-AN

		To deal with the new diseases, such as the PPR, they turn to the veterinarian office to tell them what to do. Nomadism. That is, household and herd seasonal movement between summering and wintering quarters. From pastoralism to agropastoralism. Expansion of rain-fed farming in rangelands.	A/P-R A-AN A/P-AN/R
Better conditions for crop pests to develop.	Rising number of pests and weeds – e.g. cicada, *Sanak* (pest for cotton and pistachio), aphid, tripe, etc.	Shift from agriculture of fodder and cash crops – e.g. barley, alfalfa, pistachio – to the cultivation of some few vegetables and fruit trees for self-consumption at the home garden and using the drinking water from the well. Shift from agropastoralism to pastoralism, due to the lack of water to undertake agriculture.	A-AN/R A-AN/R
HAZARD: Increased seasonal variation in precipitation			
Increase in torrential rains during the wet season and a decrease to minimum flows during the dry season.	Soil erosion and loss of soil fertility.	Stop wood cutting and buying fuel. Stop charcoal burning for selling purposes. Nomadism. That is, household and herd seasonal movement between summering and wintering quarters.	A-R P-R A-AN
Pasture damages	Pasture shortages.	Nomadism. That is, household and herd seasonal movement between summering and wintering quarters. Lengthening the migration path and grazing in more distant pastures, if necessary into other communities' territories. Customarily communal grazing decision system, based on the agreement between the elders of the tribe, to decide the quantity of livestock, the type of livestock, and the amount of time to be spent grazing in each pastureland.	A-AN A-AN/R A-AN

		Reducing the number of ewes and increase the number of goats, as goats take more benefit from desert pastures. To respect the width of about 700 to 800 m of pasture that herder whose pastures are in the migration paths of nomadic pastoralists should guarantee for the migrating flocks. To get loans to buy fodder. 'Boundless grazing' is a traditional practice implying that all pastoralists, regardless of pasture ownership and boundaries, can lead the herd to graze from April to mid-May - 45 days - wherever they want. This tradition provides several benefits for the overall management of rangelands in the region – e.g. the distant or low water resources pastures are grazed in spring under favourable conditions, reduces conflicts between the tribes in this period, delays the grazing of the summering pastures allowing them to develop appropriately, etc. Application of 'closed pastures' to allow appropriate grassland development before grazing. This implies hiring a gamekeeper to protect the pastures. Adoption of multipurpose crops and fruit trees – e.g. watermelons, cotton, pistachio, red pepper, sunflower, almond, pomegranate, etc. Used as cash crops, livestock fodder and self-consumption. Promoting friendly collaboration with local communities. Selling a part of the herd to afford buying fodder for the remaining. Renting the farmlands residues of other communities. Maintaining the tradition ruled by the elderly council of sending some pioneers to measure the plant coverage of the migratory routes to know it the grass is in good conditions before the tribe decides what route following to reach the wintering pasturelands. From pastoralism to agropastoralism. Expansion of rain-fed farming in rangelands. Decrease the size of the household – amount of people.	A-AN A-AN A/P-R A-AN A-AN A-AN A-AN A-R A-AN/R A-AN A/P-AN/R A-AN/R A-AN

		Land resting	A-AN
Decreased produc-Tivity of livestock (wool, meat, hide, milk…).	Rising food insecurity - mainly among children, pregnant women and the elderly. This goes with reduced dependence on traditional diet in favor of manufactured foods.	Nomadism. That is, household and herd seasonal movement between summering and wintering quarters.	A-AN
		Migration of the household to the cities in search of new sources of livelihood.	A-R
		Reducing the number of livestock particularly sheep – ewes.	A-AN/R
		Shifting towards Pakistani goat which produced more milk and meat than the native one.	A-AN/R
		Shifting from native sheep breed to more productive Afshari sheep breed.	A-AN/R
		Herd reduction.	A-R
		Camels range freely and are rounded up periodically to be sold for meat.	A-AN
		From pastoralism to agropastoralism with stall-fed sheep. Expansion of rain-fed farming in rangelands. Replacement of pasture by fodder crops. Shift from mobile systems to semi-mobile and even completely settled.	A-AN/R
		Adoption of multipurpose crops and fruit trees – e.g. watermelons, cotton, pistachio, red pepper, sunflower, almond, pomegranate, etc. Used as cash crops, livestock fodder and self-consumption.	A-AN
		Sell a part of the herd to afford buying fodder for the remaining.	A-R
		Because of the less numbers of livestock in each herd, they tend to joint 3 or 4 herds together to pay less for shepherd and keep some of the livestock in the stalls.	A-AN
		Livelihood diversification – e.g. mining, handicraft production – mainly conducted by women.	A-AN/R
		The traditional diet is full of many of products and different ways to preserve food for more difficult periods, mainly winter – e.g. as ghee, curd, etc.	A-AN
		When surpluses of crops exist, they may be bartered or sold to get clothes, sugar, medicines, fodder, staple, etc.	A-AN

		Decrease the size of the household – amount of people.	A-AN/R
Crop damages	Rising food insecurity - mainly among children, pregnant women and the elderly. This goes with reduced dependence on traditional diet in favor of manufactured foods.	Migration of the household to the cities in search of new sources of livelihood. Livelihood diversification – e.g. mining, handicraft production – mainly conducted by women. The traditional diet is full of many of products and different ways to preserve food for more difficult periods, mainly winter – e.g. as ghee, curd, etc. Shifting from gardening to fruit tree cultivation – e.g. pomegranate. Shift from agriculture of fodder and cash crops – e.g. barley, alfalfa, pistachio – to the cultivation of some few vegetables and fruit trees for self-consumption at the home garden and using the drinking water from the well. When surpluses of crops exist, they may be bartered or sold to get clothes, sugar, medicines, fodder, staple, etc. Decrease the size of the household – amount of people.	A-R A-AN/R A-AN A-AN/R A-AN/R A-AN A-AN/R
Better conditions for livestock disease vectors, such as ticks, insects and mites.	Increase in livestock diseases and mortality – e.g. PPR, flaky fever.	Utilization of local and traditional knowledge to livestock disease treatment and preventions – e.g. for '*popdardi*', a lung disease, to avoid the spread of the disease to other animals, they cook the infected lung and grind it in a mortar with salt, to develop a tradition vaccination; for smallpox, they catch a porcupine, peel it and boil it in a pot, and then they feed each of the animals a gloss of this boiled mixture; for lip pimples, they give them vinegar and sour curd; for mange, they grind the tobacco, add some water and boil it and then rub on the infection part; for intestinal worms, they grind the roots of a plant (*Ferula*) and extract its water to give it to livestock; etc. Utilization of local and traditional knowledge to deal with ticks and other external parasites – e.g. burning the barns every year and construct them again. Utilization of 'modern' knowledge to deal with ticks and other external parasites – e.g. usage of pesticides and other spraying methods. Utilization of local and traditional knowledge to heal infected injuries of the livestock – e.g. boiling the children's urine in a pot and after getting darker and thick, rub it on the wound.	A-AN A-AN A/P-R A-AN

		To deal with the new diseases, such as the PPR, they turn to the veterinarian office to tell them what to do. Avoiding contaminated pastures and diminishing the contact with herds in passing. When surpluses of crops exist, they may be bartered or sold to get clothes, sugar, medicines, fodder, staple, etc. Nomadism. That is, household and herd seasonal movement between summering and wintering quarters.	A/P-R A-AN A-AN A-AN
Better conditions for crop pests to develop.	Rising number of pests and weeds – e.g. cicada, *Sanak* (pest for cotton and pistachio), aphid, tripe, etc.	Shift from agriculture of fodder and cash crops – e.g. barley, alfalfa, pistachio – to the cultivation of some few vegetables and fruit trees for self-consumption at the home garden and using the drinking water from the well. Shift from agropastoralism to pastoralism, due to the lack of water to undertake agriculture.	A-AN/R A-AN/R

*Being A, Autonomous; P, Planned; AN, Proactive; and R, Reactive.

7.4 Pastoralism in Huancavelica (Peru) [6]

The department of Huancavelica is located in South Central Peruvian Andes (see Fig. 15). Coclococha is a Quechua community placed in this department at 4.600 m.a.s.l. at 60 km from the capital city of Huancavelica. This section of the Peruvian highlands is part of the Central Andean "Puna", with tropical dry alpine vegetation – mainly grasslands with scattered forests and wetlands. This region, as the rest of the high Andes, is characterized by moderate precipitation, about 700 mm, which in addition often takes place as hailing. Rainfall is highly concentrated in a very short period of the year, between November and March. As in the rest of the Andean Quechua communities, pastoralism is the main economic activity of the people of Coclococha. In Peru, there are 170,000 households of pastoralists (Sociedad Peruana de Criadores de Alpacas y Llamas—SPAR 2005) living above 4,000 m.a.s.l.

The Coclococha inhabitants are devoted to livestock raising, fundamentally alpaca, and

[6] The authors would like to thank PROCASUD (Programa de Mejora de Camélidos Sudamericanos) from the Universidad Nacional de Huancavelica, whose contribution has been fundamental in developing the fieldwork in Huancavelica.

to a less extent llama and sheep, which they employ to produce fibre , hide, meat, milk, manure – used both as a fertilizer and as household fuel - and draught. The goods obtained are utilized for self-consumption, to barter or to be sold for cash. It should be highlighted that Peru shelters the largest population of South American Camelids. Livestock is the most important asset for Quechua pastoralists, while land and water resources are owned communally. The community owns these resources, and pastoralists – "comuneros" – are only using them. Pastoralists' livelihoods are organized between communal pastures, where the herds are led to graze, and a small number of privately-owned small pieces of land around the dwellings, which are devoted to the few crops that can be grown under the harsh local weather and orographic conditions.

These are fundamentally barley and "*chuño*" - dried bitter potato - cultivated for self-consumption. Household is the main unit of production and consumption. Social relationships and cultural constraints seem to prevent wealth accumulation – particularly, herd size – that would lead to social differentiation and overexploitation of limited resources (Browman 1974). A gender-based division of labour exists, since men are in charge of the alpacas and llamas, while women are responsible for the sheep (Postigo et al., 2008). Livestock management implies a herd mobility pattern, which takes into account the need to feed both the family and the flock, and on occasions, the need for goods from outside the community (Postigo et al., 2008). Livestock, as usual in pastoralist societies, is seen as providing social status as well as a way of keeping household savings. This is why traditionally meat production has only been undertaken from time to time, and for self-consumption fundamentally. However, as the living of pastoralists is increasingly influenced by market economy, this particular function of livestock is becoming increasingly important. The herding of llama, alpaca and sheep flocks is complemented with the annual capture and shearing of Vicuna - a wild Camelid – in the traditional celebration of Chaco.

Figure 15. Map of Huancavelica.

Source: Avilable at: http://archive.livinginperu.com/blogs/travel/185

The livelihood of Quechua pastoralists is very well adapted to the harsh weather and orographic conditions of mountain regions by means of a sound communal organization, which has been developed along centuries of co-evolution between rangelands, pastoralists and livestock. However, in the last decades, overgrazing of the Puna is crumbling this socio-ecological system. Particularly the rising of population, jointly with an increased presence of the market economy and a gradual dismissal of communal institutions, is leading towards a situation where traditional practices of rotational grazing and fallow periods has been increasingly substituted by continuous grazing, where pastures have no time to recover after grazing. This is being intensified by the rising drought. It seems that the fragile Andean Puna ecosystem – with very cold nights, days with high solar radiation, usual fires and long periods of drought - and the communal management conducted by Quechua pastoralists, are being threatened. In fact, the rural areas of the department of Huancavelica, where Coclococha is located, show high levels of children malnutrition, 52% among children below 5 years old (INEI, 1996). Urgent policy measures are required, based on the respect of pastoralist knowledge and institutions, to reverse the current damaging trends the inhabitants of Andean Puna are undergoing.

7.4.1 Socio-economic drivers intensifying CC's impacts

The main socio-economic drivers that exacerbate the impacts of climate variability and/or hinder the adaptation strategies that the pastoralist communities of Huancavelica are briefly described as follows:

- **Rising population and competition for the use of rangelands**

There is a high population pressure in the region, which leads to a situation of increased competition among alternative uses of the rangelands, particularly those close to water resources. This is the case of rain-fed and irrigated farming, natural reserves, mining, and the construction of roads and highways, which often imply the replacement of the communal ownership by private freehold. All this disrupts the herds' mobility, damage carbon-rich rangelands, and diminish the area of communal pasture available. In addition, in the case of mining, pastoralists claim that this activity is polluting both pastureland and waters sources. Another driver of land-use change is the pervasiveness of the potato blight epidemic. As farmers move their potato fields into higher altitudes to escape from the blight, they invade rangelands (de Haan and Juarez, 2010). All this intensifies the CC-related effects, such as overgrazing, increased water scarcity, replacement of the communal ownership to private access, and migration to the city.

Another process of rangeland expropriation from pastoralist communities is related to policy measures of land reform. Since the 1969 agrarian reform, there has been a persistent process of rangeland expropriation from pastoralists and a continuous weakening of the sense of communal pastoralist ownership of the land, that is, of pastures and water resources, whose property has been transferred to non-nomadic, non-pastoralist individuals. The exclusion of some pastures and water resources from the communal domain has been benefiting only a subset of the population, thus leading to the emergence of more social tensions.

- **Top-down planning and neglect of traditional institutions and customary practices**

Marginal importance is attached to mountain pastoralist communities within the urban-oriented policy measures issued by the Peruvian Government. Top-down planning and negligence of pastoralist institutions and their customary practices is something normal. Consequently there is in the region a lack of governmental support to rangeland management, and particularly to local organization. The central government tends to ignore the benefits of rangeland management conducted by pastoralists, particularly in terms of food security enhancement and the maintenance of carbon-rich grasslands. A clear example of the unwillingness of modern institutions to adapt to pastoralists' livelihoods is the implementation of the agrarian reform. The 1969 agrarian reform led to a crucial transformation in the whole Peru, and in particular in the Andean region (Eguren 2006). It aimed at abolishing feudal relationship through modernizing and mechanizing production, establishing wage labour, and forcing pastoralists to settle in communities (Kay 1988). However, since the 1990s, neo-liberal land policies have been counteracting the agrarian reform in Peru by promoting de-collectivization and individual land titling, leading to a new concentration of land, capital, and knowledge in agribusiness (Eguren 2006). These policy measures have diminished governmental participation in the region, and thus programs of agrarian extension and credit no longer exist (Postigo et al., 2008).

- ❖ **Increasing integration within the market economy**

The few policy measures and initiatives that are being enforced by the government favour a shift from extensive to intensive forms of livestock farming, and the establishment of agricultural activities in rangelands, often through the promotion of irrigation schemes. This favours an increased presence of money instead of barter and reciprocity, which used to be two crucial pillars in the traditional social organization of Andean pastoralist communities. This goes hand in hand with an enlargement of the inequity between hired herders and property-owning pastoralists, which fosters overgrazing, overexploitation of water resources, and increased social tensions within the community, as well as between communities. Also the growing role of the market economy in the pastoralist communities of Huancavelica makes them more vulnerable to the soaring food prices taking place globally, and to receive inappropriate prices for their products.

The Andean pastoralist communities make their livelihood out of a delicate balance between social, ecological and economic domains. This is a product of many centuries of co-evolution, of many centuries of trial and error, of many centuries of carefully designed institutional and knowledge arrangements, to deal with the inherent harsh and changing mountain conditions and make the best use of them.

The Andean pastoralists have used a myriad of practices to reduce and share the risks of living in a mountainous, harsh changing environment, such as access to multiple ecological zones at different altitudes; domestication of Camelids and hardy crops – quinoa and potato; farming practices – terracing, vertical and horizontal transhumant, and irrigation schemes. The above-mentioned barriers, jointly with the increased climate variability, are threatening this delicate balance and thus make pastoralists' communities more vulnerable to climate variability. All these factors are transforming the land tenure system and the cultural values of pastoralists, introducing rising tensions between the households and the community.

7.4.2 Adaptation strategies

CC-related hazards in the region of Huancavelica are described below, together with the biophysical impacts and the socio-economic effects they entail. Also the adaptation strategies being implemented in each case are described, and characterized according to the axes of autonomous/planned and anticipatory/reactive adaptation.

Table 16. Adaptation strategies in Huancavelica

BIOPHYSICAL IMPACT	SOCIO-ECONOMIC EFFECT	ADAPTATION STRATEGY	TYPE OF ADAPTATION*
HAZARD: Drought and extreme heat**			
Desertification of the *puna* grasslands. Increased seasonal variation in precipitation, as well as warmer temperatures during the day and colder at night.	Pasture shortage, both in quantity and quality, leading to overgrazing of the best grazing areas – particularly in the dry season in the *pajonal* and the *bofedal*.	Increasing herd mobility. Seasonal use of pastureland, as well as vertical and horizontal transhumance.	A-AN
		Modifying livestock diversity, composition and numbers. Adjusting herd composition towards more efficient grazers in the Andean highland conditions - alpaca.	A-AN
		Livestock diversification.	A-AN
		Maintenance of communal land ownership, particularly of the grazing land.	A-AN
		Maintenance of the traditional communal grazing management practices.	A-AN
		Irrigation furrows in the highlands for pasture conservation and to maintain wetlands, which are crucial grazing areas during the dry season.	A/P-AN
		Splitting the herd to be managed by different members of the family at different areas.	A-AN
		Grassland management with fire to maintain grassland fertility. CAUTION the side effects of this practice are not clear.	A-AN
		Destocking and restocking. Pastoralists build their herds when feed is plentiful – particularly breeding animals - and sell them during droughts to cover essential expenses.	P-R
		Pasture enclosures to feed the animals in difficult times.	P-AN/R
		Hay making and forage conservation to prepare for adverse conditions – particularly for weak and lactating animals. Normally these plots are irrigated.	A/P-AN/R
		Shift from grazing to livestock corralling to improve animal feed and health.	P-AN/R
		Undertaking of rotation grazing.	P-AN

		Reducing the number of livestock and converting some of the livestock into fixed assets - e.g. selling animals to build the houses, payment of school fees for children, buying medicines. Land resting	A-AN/R A-AN
	Increased conflicts over communal pastures among pastoralists, and among communities, as well as between pastoralists and natural reserves, agricultural activities, and paved road.	Securing pastoralists rights to pasture through the establishment of livestock corridors. Maintenance of communal land ownership, particularly of the grazing land and water resources. Traditional system of punishments and fines to those grazing outside designated lands, both with members of the community and with members of other communities – higher punishments. Maintenance of the communal work – *minka* – to help build infrastructures that benefit the community.	A/P-AN A-AN A-AN A-AN
Decreased productivity of the livestock (wool, meat, hide, milk…).	Rising food insecurity - mainly among children, pregnant women and the elderly. This goes with reduced dependence on traditional diet in favor of manufactured foods. Also with a lack of workforce.	Supply of feed supplement – mainly oat fodder. Shift from grazing to livestock corralling to improve animal feed and health. Livestock diversification. Barter animal products – meat, wool, etc. - for other staples, such as sugar, rice, potatoes, salt, batteries, tuna, matches and maize. Getting extra income through wool and wool handicraft sale – e.g. ponchos, socks, and hats - to be sold in local or regional market. Diversifying the economic uses of alpacas, e.g. hide and meat production, instead of only wool production. Reduction of slaughter rates to offset the losses – particularly in breeding females. Livestock serve as a mobile secure food and capital base. Construction of slaughterhouse, with apparently cleaner and safer operation - to sell meat to the regional market and the city. Shift to cattle raising to increase food availability – mainly dairy cattle. Shift from pastoralism to agropastoralism.	A/P-AN/R P-AN/R A-AN A-AN A-AN P-AN/R A-AN P-AN/R P-AN/R A-AN

		Livelihood diversification – e.g. mining, horticulture, construction, small scale livestock trading, running store, hired herder in other farms. Migration of the whole – mainly permanent, but also periodical - to urban areas in search of new income sources. Adoption of improved alpaca breeds. Supporting children's education so they can engage in different income generating activities and support their parents in the future. Further inclusion of women in the decision-making processes of the communities. More active role of women in livestock production – particularly in small animals, such as sheep. Maintenance of the communal work – *minka* – to help build infrastructures that benefit the community. Labor exchange between households.	A-AN A-R P-AN/R A/P-AN A/P-AN A-AN A-AN A-AN
	Lack of draft animals, mainly llamas.	More active role of women in livestock production – particularly in small animals and dairy animals. Maintenance of the communal work – *minka* – to help build infrastructures that benefit the community. Labor exchange between households.	A-AN A-AN A-AN
Decreasing crop production, and shifts in elevations where crops can be grown.	Rising food insecurity - mainly among children, pregnant women and the elderly. This goes with reduced dependence on traditional diet in favor of manufactured foods. Also with a lack of workforce.	Disseminate as much as possible the plots cultivated in terms of altitude, sun exposure and soil fertility to diversify the risk of crop failures. The *allapakuy* tradition means that farmers who experience crop failure can offer their labor in exchange for food to other members of the community. Seed selection. Utilization of drought-tolerant species and varieties. Application of crop rotation and fallow practices. Intercropping. Access to irrigation for buffering droughts.	A-AN A-AN A-AN A-AN A-AN A-AN

		Seed exchange to promote diversity of varieties.	A-AN
		Livelihood diversification – e.g. mining, horticulture, construction, small scale livestock trading, running store, hired herder in other farms.	A-AN
		Migration of the whole – mainly permanent, but also periodical - to urban areas in search of new income sources.	A-R
		Further inclusion of women in the decision-making processes of the communities.	A/P-AN
		Supporting children's education so they can engage in different income generating activities and support their parents in the future.	A/P-AN
Better conditions for livestock disease vectors, such as ticks, insects and mites.	Increase in livestock diseases – e.g. pneumonia, mange - and mortality.	Shift from grazing to livestock corralling to improve animal feed and health.	P-AN/R
		Traditional disease-control systems are used when veterinary care is unavailable or too expensive.	A-AN
		Splitting the herd to be managed by different members of the family at different areas.	A-AN
		Supply of feed supplement – mainly oat fodder.	A/P-AN/R
		Livestock diversification.	A-AN
		Pasture enclosures to feed the animals in difficult times.	P-AN/R
		Hay making and forage conservation to prepare for adverse conditions – particularly for weak and lactating animals. Normally these plots are irrigated.	A/P-AN/R
Better conditions for crop pests to develop.	Rising number of pests' appearance.	Seed selection.	A-AN
		Intercropping.	A-AN
		Planting most susceptible cultivars at higher altitudes. Mainly, to escape from potato blight.	A-AN
		Disseminate as much as possible the plots cultivated in terms of altitude, sun exposure and soil fertility to diversify the risk of crop failures.	A-AN
		The *allapakuy* tradition means that farmers who	A-AN

		experience crop failure can offer their labor in exchange for food to other members of the community.	
		Application of crop rotation and fallow practices.	A-AN
		Seed exchange to promote diversity of varieties.	A-AN
		Improved varieties.	P-AN/R
Less water availability, both quantitative and qualitative, for livestock and communities.	Increasingly difficult access to water for domestic consumption.	Separation of people's water and livestock water.	A/P-AN
		Alternative energy sources - solar energy with solar cells, and wind power with windmill - to pump water.	A/P-AN
	Lack of water for the livestock.	Securing pastoralists rights to water through the establishment of livestock corridors.	A/P-AN
		Maintenance of communal land ownership, particularly of the water resources.	A-AN
		Traditional system of punishments and fines to those grazing outside designated lands, both with members of the community and with members of other communities – higher punishments.	A-AN
		Destocking and restocking. Pastoralists build their herds when feed is plentiful – particularly breeding animals - and sell them during droughts to cover essential expenses.	P-R
		Construction of watering points that avoid livestock to drink water polluted by their own feces.	A/P-AN
		Maintenance of the communal work – *minka* – to help build infrastructures that benefit the community.	A-AN
		Building irrigation furrows in the highlands to preserve wetlands, which are crucial grazing areas during the dry season.	A-AN
		Reducing the number of livestock and converting some of the livestock into fixed assets - e.g. selling animals to build the houses, payment of school fees for children, buying medicines.	A-AN/R
	Increased conflicts between pastoralism and other land uses	Securing pastoralists rights to water through the establishment of livestock corridors.	A/P-AN
		Maintenance of communal land ownership, particularly of the water resources.	A-AN

	– agriculture, mining, etc. - where water is more available.	Traditional system of punishments and fines to those grazing outside designated lands, both with members of the community and with members of other communities – higher punishments.	A-AN
Deforestation – e.g. *Polylepis* forests less and less common.	Soil erosion	Utilization of livestock manure as a household fuel, to reduce firewood collection. Construction of irrigation furrows to increase infiltration of runoff and controlling erosion, while favoring grassland development. Cultivation in terraces. Maintenance of the communal work – *minka* – to help build infrastructures that benefit the community. Application of some traditional cultural practices of minimum tillage, such as the *chiwa* and *chacmeo* – e.g. for native potatoes cultivation.	A-AN P-R A-AN A-AN A-AN
Rising uncertainty on wild berries production or even disappearance.	Rising food insecurity - mainly among children, pregnant women and the elderly. This goes with reduced dependence on traditional diet in favor of manufactured foods. Also with a loss of local and traditional knowledge.	Shift from pastoralism to agropastoralism. Barter animal products – meat, wool, etc. - for other staples, such as sugar, rice, potatoes, salt, batteries, tuna, matches and maize. Getting extra income through wool and wool handicraft sale – e.g. ponchos, socks, and hats - to be sold in local or regional market. Supporting children's education so they can engage in different income generating activities and support their parents in the future. Livelihood diversification – e.g. mining, horticulture, construction, small scale livestock trading, running store, hired herder in other farms. Migration, both permanent and periodical, of the whole family to urban areas in search of a new income sources. Further inclusion of women in the decision-making processes of the communities.	A-AN A-AN A-AN A/P-AN A-AN A-R A/P-AN
Changes in vegetation.	Some herbs are used for livestock diseases. Loss of local and	Traditional disease-control systems are used when veterinary care is unavailable or too expensive.	A-AN

	traditional knowledge as these plants disappear or are more difficult to find.		
Decreasing presence of birds - particularly those that used to be hunted.	Reduced dependence on traditional diet in favor of manufactured foods.	Barter animal products – meat, wool, etc. - for other staples, such as sugar, rice, potatoes, salt, batteries, tuna, matches and maize. Getting extra income through wool and wool handicraft sale – e.g. ponchos, socks, and hats - to be sold in local or regional market. Diversifying the economic uses of alpacas, e.g. hide and meat production, instead of only wool production. Shift from pastoralism to agropastoralism.	A-AN A-AN P-AN/R A-AN
Increasing presence of wild predators around domestic animals – e.g. Andean fox, Andean cat, puma.	Increased lack of workforce.	More active role of women in livestock production – particularly in small animals, such as sheep. Maintenance of the communal work – *minka* – to help build infrastructures that benefit the community. Labor exchange between households. Shift from grazing to livestock corralling to improve animal feed and health. Splitting the herd to be managed by different members of the family at different areas. Shift to cattle raising to increase food availability – mainly dairy cattle. Shift from pastoralism to agropastoralism.	A-AN A-AN A-AN P-AN/R A-AN P-AN /R A-AN
HAZARD: Increased seasonal variation in precipitation and snowstorms.			
Increase in torrential rains during the wet season and a decrease to minimum flows during	Soil erosion	Utilization of livestock manure as a household fuel, to reduce firewood collection. Construction of irrigation furrows to increase infiltration of runoff and controlling erosion, while favoring grassland development. Cultivation in terraces. Maintenance of the communal work – *minka* – to help build infrastructures that benefit the community.	A-AN P-R A-AN A-AN

the dry season		Application of some traditional cultural practices of minimum tillage, such as the *chiwa* and *chacmeo* – e.g. for native potatoes cultivation.	A-AN
Pasture damages	Pasture shortage, leading to overgrazing of the best grazing areas – particularly in the dry season in the *pajonal* and the *bofedal*.	Increasing herd mobility. Seasonal use of pastureland, as well as vertical and horizontal transhumance. Modifying livestock diversity, composition and numbers. Adjusting herd composition towards more efficient grazers in the Andean highland conditions - alpaca. Livestock diversification. Maintenance of communal land ownership, particularly of the grazing land. Maintenance of the traditional communal grazing management practices. Irrigation furrows in the highlands for pasture conservation and to maintain wetlands, which are crucial grazing areas during the dry season. Splitting the herd to be managed by different members of the family at different areas. Grassland management with fire to maintain grassland fertility. CAUTION the side effects of this practice are not clear. Destocking and restocking. Pastoralists build their herds when feed is plentiful – particularly breeding animals - and sell them during droughts to cover essential expenses. Pasture enclosures to feed the animals in difficult times. Hay making and forage conservation to prepare for adverse conditions – particularly for weak and lactating animals. Normally these plots are irrigated. Shift from grazing to livestock corralling to improve animal feed and health. Undertaking of rotation grazing. Reducing the number of livestock and converting some of the livestock into fixed assets - e.g. selling animals to build the houses, payment of school fees for children, buying medicines.	A-AN A-AN A-AN A-AN A-AN A/P-AN A-AN A-AN P-R P-AN/R A/P-AN/R P-AN/R P-AN A-AN/R

		Maintenance of the communal work – *minka* – to help build infrastructures that benefit the community. Labor exchange between households. Land resting	A-AN A-AN A-AN
Crop damages	Rising food insecurity - mainly among children, pregnant women and the elderly. This goes with reduced dependence on traditional diet in favor of manufactured foods. Also with a lack of workforce.	Disseminate as much as possible the plots cultivated in terms of altitude, sun exposure and soil fertility to diversify the risk of crop failures. The *allapakuy* tradition means that farmers who experience crop failure can offer their labor in exchange for food to other members of the community. Seed selection. Utilization of frost-tolerant species and varieties. Application of crop rotation and fallow practices. Intercropping. Seed exchange to promote diversity of varieties. Livelihood diversification – e.g. mining, horticulture, construction, small scale livestock trading, running store, hired herder in other farms. Migration of the whole – mainly permanent, but also periodical - to urban areas in search of new income sources. Further inclusion of women in the decision-making processes of the communities. Supporting children's education so they can engage in different income generating activities and support their parents in the future. Maintenance of the communal work – *minka* – to help build infrastructures that benefit the community. Labor exchange between households.	A-AN A-AN A-AN A-AN A-AN A-AN A-AN A-R A/P-AN A/P-AN A-AN A-AN
Better conditions for livestock disease vectors, such as ticks,	Increase in livestock diseases – e.g. pneumonia, mange - and mortality.	Shift from grazing to livestock corralling to improve animal feed and health. Traditional disease-control systems are used when veterinary care is unavailable or too expensive. Splitting the herd to be managed by different members of the family at different areas.	P-AN/R A-AN A-AN

insects and mites.		Supply of feed supplement – mainly oat fodder. Livestock diversification. Pasture enclosures to feed the animals in difficult times. Hay making and forage conservation to prepare for adverse conditions – particularly for weak and lactating animals. Normally these plots are irrigated.	A/P-AN/R A-AN P-AN/R A/P-AN/R
Better conditions for crop pests to develop.	Rising number of pests' appearance.	Seed selection. Utilization of frost-tolerant species and varieties. Intercropping. Planting most susceptible cultivars at higher altitudes. Disseminate as much as possible the plots cultivated in terms of altitude, sun exposure and soil fertility to diversify the risk of crop failures. The *allapakuy* tradition means that farmers who experience crop failure can offer their labor in exchange for food to other members of the community. Application of crop rotation and fallow practices. Seed exchange to promote diversity of varieties. Improved varieties.	A-AN A-AN A-AN A-AN A-AN A-AN A-AN P-AN/R

* Being A, Autonomous; P, Planned; AN, Anticipatory; and R, Reactive.
**The glacier melting process taking place in the Andes in the last decades (Barry, 2006), due to increased air temperature and altered water vapour (Thompson et al., 2003; Vuille et al., 2003), seems to be working as an environmental buffering, since it has been increasing runoff, and thus filling the lakes and wetlands in down slope areas. Consequently, new terrain for colonizing plants and grazing of livestock has been favoured, as well as more water available for irrigation and wetland expansion as long as the process of snow and ice retreat keeps going. Nevertheless, over time, glacier melting will contribute to the temporary increase, eventual reduction and ultimately likely disappearance of high-altitude water bodies (P.rez et al., 2010). In this case all the impacts that we have just mentioned in the table would be exacerbated.

7.5 Case studies: strengthening the role of SSLF in climate change and food security

In this report it is suggested that, in a context of increased climate variability, the livestock sector, in order to guarantee the animal source food security, while minimizing GHG emissions, in the current situation of both lack of natural resources and demographic growth, must shift its focus from increasing production to enhancing resilience. In view of that, it seems that a major shift towards SSLF systems, and a reduction in meat consumption in rich countries, could represent a major contribution. Now we know that the mitigation potential of the SSLF systems, as observed in Turkana, Alaotra Lake region, Khar-o-Touran, and Huancavelica, is enormous. It mainly consists of guaranteeing the maintenance of carbon-rich grasslands and soil fertility, utilization of close markets and little dependence on chemical inputs, and undertaking of carbon smart diets.

We also know, as seen in Turkana, Alaotra Lake region, Khar-o-Touran, and Huancavelica, that SSLF communities are extremely efficient at producing animal source foods. This is due to their enormous ability to take advantage of human-inedible forage and marginal lands, to produce high-quality and human-edible foods; to preserve socio-ecological balances that avoid depletion of natural resources and social arrangements; and to promote diets of moderate meat consumption. As regards the adaptation strategies being implemented, in all four cases a critical trend is observed. The autonomous adaptation strategies of a anticipatory nature, that is, those that are generated by the same SSLF communities to reduce the risk of future changes are being hindered. Thus, mobility is being highly restricted at all levels, through land appropriation and privatization, the emergence of new political frontiers, the scarcity of mobile services (e.g. health care, schooling, etc.), and the political pressures to sedentarize; social collaboration and reciprocity is also highly undermined by the negligence of traditional SSLF institutions and customary practices, and the increased market integration; and promotion and preservation of biodiversity is also being greatly compromised by the loss of local and traditional knowledge This is critical trend for the endurance of SSLF communities, since it implies that nowadays the majority of the adaptation strategies that are being implemented in these communities are either reactive or planned. This implies that either the adaptations strategies are being implemented once the CC damage has already occurred, and attempts only at helping the community to recover (e.g. adoption of multi-activity, food relief, policy measures to enhance market integration, or sedentarization plans); or they are top-down designed, what implies that there is a high risk of not fulfilling the expectation of the SSLF community members or of being designed according to information lowly-adapted to the local conditions (e.g. adoption of fodder crops, offering health care services or schooling).

It should be carefully assessed if the planned adaptation strategies being offered to SSLF communities are effectively empowering the community. It is necessary to take into consideration the social, cultural, economic, and geographical contexts, within which these strategies are being adopted, to identify what unintended consequences might arise, and include the community in the process of policy - planning. However, this does not mean that there are planned adaptation strategies, often of an anticipatory nature, which are successfully strengthening SSLF livelihoods (e.g. mobile health care services and schooling, peace-keeping initiatives, or pastoralist field schools). The endurance of SSLF is being hindered by a set of socio-economic drivers that prevent the development and promotion of this category of livestock farming. Consequently, these drivers are critically undermining the enormous potential of SSLF in enhancing C sequestration, CC-related hazard adaptation, and animal source food security. Accordingly, rising tensions, both within the community and among communities, as well as rising levels of malnutrition, are being identified in all four SSLF communities. To counteract these current damaging trends, a set of recommendations are briefly deployed as follows:

- In general, SSLF communities need to have access to the production resources they need to grow their animals, mostly land and water. This implies specific measures to favour accessibility in terms of rights, but also to facilitate it with adequate infrastructures.
- Promote biodiversity treaties, as well as the policies enhancing the protection and recognizing the value of local breeds of domestic animals.
- Respect and promote traditional institutions, and develop new institutions adapted to their lifestyle. In the case of pastoralists, this would include mobile healthcare services and schools.
- Enhance the existing traditional institutions or customary habits for conflict resolution.
- Recognize local traditional knowledge as a valid knowledge to cope with climate variability.
- Build the capacity of SSLF communities to engage in debates on policy issues which directly affect their lives.
- Set capacity-building strategies, to develop more political influence at country level to protect the interests of the livestock keepers communities.

More specifically, for each case study, other measures would include:

- In Turkana, in two fundamental domains, actions need to be implemented to effectively strengthen the role of SSLF, in this case pastoralism, in enhancing C sequestration, CC-related hazard adaptation, and food security: interceding to reduce violence among neighbouring pastoral communities, and redress humanitarian aid towards more restocking and training for pastoralists rather than food relief.
- In the Alaotra Lake region, three domains were identified as being capable of to effectively boosting the role of SSLF, in this case small mixed farming, in enhancing C sequestration, CC-related hazard adaptation, and food security: again interceding to reduce the violence stemming from livestock raids, control grassland fires, prevent further soil erosion and favour soil preservation measures. As a result of the great levels of uncertainty and ignorance surrounding the causes of grassland fires and livestock raids, it would also be valuable to undertake precise diagnoses of these two phenomena that produce extremely harmful effects for SSLF in the region.
- In Khar-o-Touran, two fundamental domains were identified as being in need of receiving actions to effectively empower SSLF, in this case pastoralism, and thus enhancing C sequestration, CC-related hazard adaptation, and food security: again interceding to reduce violence among pastoralists and settled farmers, and providing more control of the natural resources to pastoralists. An adequate training, particularly to youths is also called for by the pastoralists.
- In Huancavelica, two fundamental domains were identified as being in need of receiving actions to effectively strengthen the role of SSLF, in this case pastoralism, in enhancing C sequestration, CC-related hazard adaptation, and food security: interceding to reduce violence among neighbouring pastoral communities, and favouring grassland degradation prevention and restoration measures.
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8. Conclusions

- The livestock sector as a whole is a major contributor to GHG emissions.

- However, SSLF holds a great potential for both, mitigation and adaptation. Consequently, it is fundamental to distinguish among different existing categories of livestock production.

- From a food system approach, there are three main categories of livestock farming: small-scale livestock farming (SSLF), medium-scale livestock farming (MSLF) and large-scale livestock farming (LSLF). Classification is made according to differences in farm size; utilization of external inputs; the particular utilization they undertake of the land; and the type of market to which they have more access to as suppliers. These three livestock systems show profoundly different approaches to livestock production, and the role this should play in society. This is a crucial distinction since the different categories show radically distinct contributions to the climate and food security issues.

- Although aboveground carbon sequestration has been traditionally prioritized, via reforestation and afforestation; soil represents even a larger carbon sink. There is nearly as much carbon in the organic compounds contained in the top 30 cm of soil as there is in the entire atmosphere. It is estimated that grasslands store up to 30% of the world's soil carbon. Consequently the potential of carbon sequestration through maintenance of carbon-rich grasslands that SSLF systems undertake is remarkable.

- The livestock sector must respond to the challenge of food security and increased CC hazards, in the current situation of both, lack of natural resources and global population growth, by shifting its focus from enhancing production to enhancing resilience, through a food system approach. This is not in contradiction with the possibility to increase production in those farming systems that might require it, as long as resilience remains the primary focus.

- It is estimated that further expansion in industrial livestock production (LSLF) required to meet present as well as projected demands for food will cause enormous environmental problems. Additionally, greater expansion of LSLF system could reduce the amount of human-edible food since it draws on food crops to feed livestock.

- SSLF major counter-argument, i.e. their capacity to feed the world, is controversial. Firstly, the projected demand for meat could be based upon wrong assumptions; secondly, these numbers are not desirable from a human health perspective, not even from an ecosystem health perspective; thirdly, we need to integrate food security into a wider picture which addresses the food system as a whole, looking at the interactions between food security and other social and environmental drivers and outcomes. In this respect, the current global emergency resulting from high food insecurity and unsustainable pressure over environment and natural resources could benefit from a major shift towards SSLF and MSLF systems, and a reduction in meat consumption in rich countries.

- SSLF communities are extremely efficient in enhancing animal source food security, and particularly under variable climate conditions. This is due to their remarkable ability to take advantage of human-inedible forage and marginal lands, to produce high quality and human-edible foods; to preserve socio-ecological balances that avoid depletion of natural resources and social arrangements; and to promote diets of moderate meat consumption.

- SSLF has proved along history, and all over the world, its capacity to enable small-scale livestock farming families to develop their livelihoods in marginal climate regions, and more recently to face increased climate variability, by undertaking GHG efficient and climate resilient livestock productions systems, such as pastoralism, small mixed farming, and backyard pig and poultry production. However, they can only accomplish this task if they keep proud of themselves and are allowed to follow their own institutions and customary practices – or at least these are not scorned- as well as make decisions according to their own expectations and local and traditional knowledge.

- The high climate-mitigation potential of SSLF does not come alone, but with additional advantages. This concerns social, environmental and cultural benefits.

- Several strategies are implemented in livestock farming with the objective of mitigating its GHG emissions. The mitigation strategies have been clustered according to the nature of the changes they entail: (i) mitigation through market mechanisms; (ii) mitigation through technological and managerial schemes; (iii) mitigation through behavioural modification.

- An excessive focus on carbon sequestration and associated offsetting activities detracts attention away from the real challenge: reversing the fossil fuel dependence and changing the consumption patterns it induces. Carbon loss mitigation is as urgent as carbon sequestration. It may be useful to consider carbon sequestration as an outcome of good agricultural practices, rather than a prime goal. SSLF moderate grazing, and livestock/agriculture integration are examples of such good agricultural practices.

- SSLF high mitigation potential consists in guaranteeing the maintenance of carbon-rich grasslands and soil fertility, utilization of close markets, little dependence on chemical inputs and dissemination of carbon-smart diets.

- In Turkana, Alaotra Lake, Khar-o-Touran and Huancavelica, the high prevalence of droughts with occasional floodings, and increasing calendar unpredictability, have been the CC-related hazards identified as affecting SSLF communities.
- SSLF, and particularly pastoralism, is highly dependent on the maintenance of delicate and constantly evolving balance between pastures, livestock and peoples. SSLF communities offer a range of adaptation strategies to maintain that balance. In the communities of Turkana, Alaotra Lake, Khar-o-Touran and Huancavelica, the main adaptation strategies to guarantee the livelihood of small livestock keepers in a context of increased climate variability can be grouped as follows: (i) enhancing mobility; (ii) boosting social collaboration and reciprocity; (iii)

adoption of diversification, multi-activity and multi-purpose schemes as a precautionary strategy to reduce the risk of losses in view of possible unexpected changes; (iv) promotion and preservation of biodiversity, both wild and domesticated; (v) shift towards other types of livestock more adapted to the future socio-ecological conditions ; (vi) adoption of fodder crops and pasture enclosures, that in some cases is associated with livestock corralling, to guarantee more stable feeding conditions for the cattle; (vii) empowerment of community members by offering them services and training, such as schooling, health care, and pastoralist field schools; and finally (viii) providing SSLF with communities schemes of sedentarization, food relief and improved market access, aimed at improving their livelihoods.

- ❖ These adaptation strategies, or at least most of them, have been traditionally implemented by SSLF communities to develop their livelihoods in marginal lands and extreme climate conditions – namely drylands, mountains and cold regions . However, today they are using them to cope with the current increase in climate variability.

- ❖ Planned adaptation strategies offered to SSLF communities should be cautiously implemented. These should be carefully assessed to make sure they really empower SSLF communities. It is necessary to take into account the social, cultural, economic and geographical contexts within which these adaptation strategies are being implemented, so as to assess what unintended consequences might arise, and include pastoralists in the process of policymaking.

- ❖ Climate variability is a never-ending process. Since vulnerabilities and impacts are permanently evolving, this means that adaptation strategies that are appropriate today may not be so in the future. Consequently, anticipatory adaptation strategies must be prioritized.

- ❖ SSLF communities' long-standing experience in overcoming changes is clearly shown by the fact that most autonomous adaptation strategies are anticipatory as well. This is something policymakers have to take into account.

- ❖ It should be reminded that socio-institutional innovation, although being less spectacular and less costly, often strengthens resilience rather than technical innovations. However, it is not less true that not all autonomous innovations end up enhancing community's resilience. While SSLF autonomous innovations should not be romanticized, top-down interventions should always be critically assessed.

- ❖ Similar socio-economic drivers intensifying CC's impacts and hindering SSLF adaptation capacity have been identified in all four case studies of this report that is, Turkana from Kenya, Alaotra Lake from Madagascar, Khar-o- Touran from Iran, and Huancavelica from Peru. These drivers are: (i) a rising population leading to an increased competition for the utilization of grasslands; (ii) the operationalization of top-down policy-making and planning that neglects the traditional institutions and customary practices of SSLF communities; and finally (iii) an increasing integration of SSLF communities within the market economy. This seems to point to the fact that all SSLF types share a common rationality, that is, among other highly-adapted knowledge to the local environment, and in the particular case of pastoralism, communal planning and ownership of natural resources, livestock raising and mobility.

- A critical trend is observed as regards the adaptation strategies being implemented by SSLF communities. The autonomous adaptation strategies of an anticipatory nature, that is, those that are generated by the same SSLF communities to diminish the risk of future changes are being hindered. This is particularly the case of those adaptation strategies based on enhancing mobility, social collaboration and reciprocity, and promotion and preservation of biodiversity.

References

Abolhassani, L., 2011. Rangeland management in Iran a socio-economic analysis and case study of Semnan rangelands. PhD thesis. Universität Freiburg, 265 pp.

Ahuja, V., Gustafson, D., Otte, J., Pica-Ciamarra, U., 2009. *Supporting Livestock Sector Development for Poverty Reduction*. PPLPI Research Report. Rome, Pro-Poor Livestock Policy Initiative, FAO.

Aklilu, Y., Catley, A., 2009. *Livestock Exports from the Horn of Africa: An Analysis of Benefits by Pastoralist Wealth Group and Policy Implications.* Report commissioned by the Food and Agriculture Organization (FAO) under the Livestock Policy Initiative of the Intergovernmental Authority on Development (IGAD).

Almas, R., Bjorkhaug, H., Rivera-Ferre, M.G., 2011. Agriculture and Climate Change: Introduction. International Journal of Sociology of Agriculture & Food 18, 162-166.
Allard, V., Soussana, J.-F., Falcimagne, R., Berbigier, P., Bonnefond, J.M., Ceschia, E., D'hour, P., Hénault, C., Laville, P., Martin, C., Pinarès-Patino, C., 2007. The role of grazing management for the net biome productivity and greenhouse gas budget (CO_2, N_2O and CH_4) of semi-natural grassland. Agriculture, Ecosystems and Environment 121, 47–58.

Allison., I, Bindoff, N.L., Bindschadler, R.A., Cox, P.M., de Noblet, N., England, M.H., Francis, J.E., Gruber, N., Haywood, A.M., Karoly, D.J., Kaser, G., Le Quéré, C., Lenton, T.M., Mann, M.E., McNeil, B.I., Pitman, A.J., Rahmstorf, S., Rignot, E., Schellnhuber, H.J., Schneider, S.H., Sherwood, S.C., Somerville, R.C.J., Steffe, K., Steig, E.J., Visbeck, M., Weaver, A.J., 2009. Copenhagen diagnosis 2009: Updating the world on the latest climate science. University of New South Wales Climate Change Research Centre, Sydney, 60 pp.

Altieri, M., Koohafkan, P., 2008. Enduring Farms: Climate Change, Smallholders and Traditional Farming Communities. Penang, Third World Network.

Altieri, M.A., 1994. Biodiversity and pest management in agroecosystems. Hayworth Press, New York.

Ashley, S., Sandford, J., 2008. Livestock Livelihoods and Institutions in the Horn of Africa. IGAD LPI, Working Paper no. 10-08. Rome, FAO.

Asian Development Bank (ADB). 2010. GenderEquality Results: Case Studies: Nepal. Mandaluyong City, Philippines, Asian Development Bank, 2010.

Aurousseau, B., Bauchart, D., Calichon, E., Micol, D., Priolo, A., 2004. Effect of grass or concentrate feeding systems and rate of growth on triglyceride and phospholipid and their fatty acids in the M. longissimus thoracis of lambs. Meat Science 66, 531–541.

Bakoariniaina, L.N., Kusky, T., Raharimahefa, T., 2006. Disappearing Lake Alaotra: Monitoring catastrophic erosion, waterway silting, and land degradation hazards in Madagascar using Landsat imagery. Journal of African Earth Sciences 44, 241–252.

Barnett, J., O'Neill, S., 2010. Maladaptation. Global Environmental Change 20, 211–213.

Barrow, E., Davies, J., Berhe, S. Matinu, V., Mohammed, N., Olenasha, W., Rugadya, M., 2007. Pastoral institutions for managing natural resources and landscapes. IUCN Eastern Africa Office Policy Brief No. 3 (of 5), Nairobi. (available at http://cmsdata.iucn.org.org/downloads/pastoralist_institutions_for_managing_natural_resources_and_landscapes.pdf).

Barry, R.G., 2006. The status of research on glaciers and global glacier recession: a review. Progress in Physical Geography 30, 285-306.

Beauchemin, K.A., Kreuzer, M., O'Mara, F., McAllister, T.A., 2008. Nutritional management for enteric methane abatement: a review. Aust. J. Ep. Agric. 48, 21–27.

Bellarby, J., Foereid, B., Hastings, A., Smith, P., 2008. Cool Farming: Climate Impacts of Agriculture and Mitigation Potential. Greenpeace, Amsterdam.

Bennett, A., Lhoste, F., Crook, J., Phelan, J. 2006., The future of small scale dairying. In *The Livestock Report 2006* (A. McLeod, ed.). Rome, FAO.

Borron, S., 2006. Building Resilience for an Unpredictable Future: How Organic Agriculture can Help Farmers Adapt to Climate Change. Rome, Food and Agriculture Organization of the United States.

Brenton, P., Edwards-Jones, G., Jensen, M.F., 2010. Can Carbon Labeling be Development Friendly? Recommendations on How to Improve Emerging Schemes, Economic Premise, No. 27 August, The World Bank, Washington, DC.

Browman, D. L., 1974. Pastoral Nomadism in the Andes. Current Anthropology 15, 2188–196.

Cassman, K.G., 2007. Climate change, biofuels and food security, Environmental Research Letters, 2. 3 pp.

Castillo, A.R., Kebreab, E., Beever, D.E., France, J., 2000. A review of efficiency of nitrogen utilisation in lactating dairy cows and its relationship with environmental pollution. Journal of Animal Feed Science 9, 1–32.

Claire, D., Stéfanie, N., 2007. Les paysans de l'Alaotra, entre rizières et tanety. Master Thesis. L'INSTITUT DES RÉGIONS CHAUDES DE MONTPELLIER SUPAGRO. 174 pp.

Coley, D.A., Goodlffe, E., Macdiarmid, J., 1998. The embodied energy of food: the role of diet. Energy Policy 26, 455–459.

Costales, A., Otte, J., Upton, M. 2005. Smallholder Livestock Keepers in the Era of Globalization. PPLPI Research Paper. Rome, Pro-Poor Livestock Policy Initiative, FAO.

CRED, 2011. The International Disaster Database. Centre for Research on the Epidemiology of Disasters, Brussels.

Davies, J., Nori, M., 2008. Managing and mitigating climate change through pastoralism. Policy Matters 16, 127-141.

Defries, R.S., Rudel, T., Uriarte, M., Hansen, M., 2010. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. Nature Geoscience (February).De Haan, S., Juarez, H.S., 2010. Land use and potato genetic resources in Huancavelica, central Peru. Journal of Land Use Science 5, 179-195.

Delgado, C.L., 1999. Rising consumption of meat and milk in developing countries has created a new food revolution. Journal of Nutrition 133, 3907S–3910S

Demirel, G., Ozpinar, H., Nazli, B., Keser, O., 2006. Fatty acids of lamb meat from two breeds fed different forage: concentrate ratio. Meat Science 72, 229–235.

De Schutter, Olivier. 2010. Report submitted by the Special Rapporteur on the right to food to the Human Rights Council Sixteenth session Agenda item 3 (http://www2.ohchr.org/english/issues/food/
docs/A-HRC-16-49.pdf)

Deutsch, L., Kalkenmark, M., Gordon, L., Rockstrom, J., Folke, K., 2010. Water-mediated ecological consequences of intensification and expansion of livestock production. In H. Steinfeld, H. Mooney, F. Schneider & L. Neville, eds. Livestock in a changing landscape, Vol. 1: Drivers, consequences, and responses. Washington, DC, Island Press.

Development Fund /Utviklingsfondet, 2011. A Viable Food Future. Part I. Updated and revised version, November 2011. Development Fund / Utviklingsfondet, Norway.

Dregne, H., Kassa, M. and Rzanov, B. 1991. A new assessment of the world status of desertification. Desertification Control Bulletin, 20, 6–18.

Dufils, J.M., 2003. Forest ecology. In: Goodman, S.M., Benstead, J.P. (Eds.), The Natural History of Madagascar. The University of Chicago Press, pp. 88–111.

Ear, S. 2005. The Political Economy of Pro-Poor Livestock Policy in Cambodia. PPLPI Working Paper no. 26. Rome, Pro-Poor Livestock Policy Initiative, FAO.

Eckard, R.J., Chapman, D.F., White, R.E., 2007. Nitrogen balances in temperate perennial grass and clover dairy pastures in south-eastern Australian Journal of Agriculture Research 58, 1167–1173.

Edwards, P., Roberts, I., 2009. Population adiposity and climate change. International Journal of Epidemiology 1, 1–4.

Eguren, F., 2006. Reforma agraria y desarrollo rural en el Perú. In: Eguren, F. (ed.), Reforma Agraria y Desarrollo Rural en la Región Andina. Centro Peruano de Estudios Sociales, Lima.

Ellis J.E., Swift D., 1988. Stability of African pastoral ecosystems: Alternate paradigms and implications for development. Journal of Rangelad Management 41(6), 450-459

ETC-group. 2009. Who Will Feed Us? Questions for the Food and Climate Crises. (www.etcgroup.org/upload/publication/pdf_file/ETC_Who_Will_Feed_Us.pdf)

European Comission, 2006. Environmental Impact of Products (EIPRO): Analysis of the Life Cycle Environmental Impacts Related to the Total Final Consumption of the EU 25 (2006). European Commission Technical Report EUR 22284 EN.

Fairfield, T. 2004. The Politics of Livestock Sector Policy and the Rural Poor in Bolivia, PPLPI Working Paper no. 15. Rome, Pro-Poor Livestock Policy Initiative, FAO.

Fairlie, S., 2010. Meat: A Benign Extravagance. Permanent Publications, UK.

Farage, P., Pretty, J., Ball, A., 2003. Biophysical aspects of carbon sequestration in drylands. University of Essex.

Fedoroff, N.V., Battisti, D.S., Beachy, R.N., Cooper, P.M.J., Fischhoff, D.A., Hodges, C.N., Knauf, C.F., Lobell, D., Mazur, J., Molden, D., Reynolds, M.P., Ronald, P.C., Rosegrant, M.W., Sanchez, P.A., Vonshak, A., Zhu, J.-K., 2010. Radically rethinking agriculture for the 21st century. Science 327, 833.

Fiala, N. 2008. Meeting the demand: an estimation of potential future greenhouse gas emissions from meat production. Ecological Economics 67, 412-419.

Food and Agriculture Organisation (FAO). 2010. The State of Food Insecurity in the World 2010. FAO, Rome.

Food and Agriculture Organisation (FAO), 2009. The State of Food and Agriculture 2009: Livestock in the Balance. FAO, Rome.

Food and Agriculture Organization (FAO), 2009d. Review of evidence on drylands pastoral systems and climate change. Implications and opportunities for mitigation and adaptation. In: Neely, C, Bunning, S. and Wilkes, A. (eds). Land and water discussion paper, 8. 50 pp.

Food and Agriculture Organisation (FAO), 2009c. Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies. FAO, Rome.

Food and Agriculture Organization (FAO), 2009b. Grasslands: Enabling their potential to contribute to greenhouse gas mitigation. Submission by the UN Food and Agriculture Organization to the Intergovernmental Panel on Climate Change. FAO, Rome.

Food and Agriculture Organization (FAO). 2007. The State of the World's Animal Genetic Resources for Food and Agriculture. Commission of Genetic Resources in Food and Agriculture. CGRFA-11/07/Inf.6. Rome.

Food and Agriculture Organisation (FAO), 2011. World Livestock 2011 – Livestock in food security. FAO, Rome.

FAO. 2006b. World Agriculture towards 2030/2050. Interim report. Global Perspective Studies Unit. Rome, June.

Food and Agriculture Organisation (FAO), 2006. Livestock's Long Shadow. FAO, Rome.

Food and Agriculture Organization (FAO), 2005. Grasslands: Developments, Opportunities, Perspectives. S.G. Reynolds and J. Frame Ed. FAO, Rome and Science Publishers, Inc. Enfield, NH, USA.

Food and Agriculture Organisation (FAO), 2003. Understanding the Indigenous Knowledge and Information Systems of Pastoralists in Eritrea. Rome, FAO (available at http://www.fao.org/docrep/006/y4569e/y4569e04.htm).

Food and Agriculture Organisation (FAO), 1996. World Livestock Production Systems: Current Status, Issues and Trends. FAO animal Production and Health Paper 127. FAO, Rome.

FAO and UNEP. 2000. World Watch List for Domestic Animal Diversity. Third edition. Ed. Sherf, D. Rome, October 2000. 746 pp.

FAO and VSF Belgium, 2009. Pastoralist Field School – Guidelines for Facilitation. ECHO funded Regional Drought Preparedness Project, Food and Agriculture Organization of the United Nations, Rome, Italy and Vétérinaires Sans Frontières Belgium, Nairobi, Kenya.

Foresight, 2011. The Future of Food and Farming. Final Project Report. The Government Office for Science, London.

Galvin, K. A., Boone, R. B., Smith, N. M., Lynn, S. J., 2001. Impacts of climate variability on East African pastoralists: Linking social science and remote sensing. Climate Research 19, 161-172.

Garnett, T., 2011. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? Food Policy 36, 23-32.

Garnett, T., 2009. Livestock-related greenhouse gas emissions: impacts and options for policy makers. Environmental Science & Policy 12 (4), 491–503.

Garnett, T., 2008. Cooking up a Storm: Food, Greenhouse Gas Emissions and our Changing Climate. Food Climate Research Network, Centre for Environmental Strategy, University of Surrey, UK.

Garnsworthy, P.C., 2004. The environmental impact of fertility in dairy cows: a modelling approach to predict methane and ammonia emissions. Animal Feed Science and Technology 112, 211–223.

Gerbens-Leenes, P., Nonhebel, S., 2002. Consumption patterns and their effects on land required for food. Ecological Economics 42,185–199.

Gning, M. 2005. Navigating the Livestock Sector: The Political Economy of Livestock Policy in Burkina Faso: PPLPI Working Paper no. 28. Rome, Pro-Poor Livestock Policy Initiative, FAO.

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, L., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., Toulmin, C., 2010. Food security: the challenge of feeding 9 billion people. Science 327

Goodland, R., Anhang, J., 2009. Livestock and Climate Change. What if the Key Actors in Climate Change Were Pigs, Chickens and Cows? Worldwatch Institute, Washington DC, pp. 10–19.

Grace, J., San Jose, J., Meir, P., Miranda, H., Montes, R., 2006. Productivity and carbon fluxes of tropical savannas. J.Biogeogr. 33: 387–400.

GRAIN, 2009. The climate crisis is a food crisis-Small farmers can cool the planet - A way out of the mayhem caused by the industrial food system. (www.grain.org/front_files/climatecrisisrefs.pdf)

Guèye, EF., 2005. Gender aspects in family poultry management systems in developing countries. World's Poultry Science Journal 61, 39-46.

Haberl, H., Erb, K.H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W., Fischer-Kowalski, M., 2007. Quantifying and mapping the human appropriation of net primary production in Earth's terrestrial ecosystems. Proceedings of the National Academy of Sciences of the USA 104, 12942–12945.

Halderman, M. 2005. The Political Economy of Pro-Poor Livestock Policy-making in Ethiopia. PPLPI Working Paper no. 19. Rome, Pro-Poor Livestock Policy Initiative, FAO.

Hancock, J. 2006. Exploring Impacts of Avian Influenza on Food Security. Internal working paper prepared for the FAO ECTAD socioeconomic working group, November 2006. FAO, Rome.

Harvey, J., 2010. Plenty of guilt and a very heavy footprint. In Business and Food Sustainability. inancial Times Special Report (available at http://media.ft.com/cms/62017148-0b29-11df-9109-00144feabdc0.pdf).

Hellmuth M.E., Mason S.J., Vaughan C., van Aalst M.K. and Choularton R. (eds.) 2011. A Better Climate for Disaster Risk Management. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA.

Henderson B., Gerber P., Opio C., 2011. Livestock and climate change, challenges and options. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 6, 1-11.

Hesse, C., Cotula, L., 2006. Climate change and pastoralists: Investing in people to respond to adversity. Sustainable Development Opinion. London, International Institute for Environment and Development. 2 pp.

HLPE, 2011. Land tenure and international investments in agriculture. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2011.
http://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE-Land-tenure-and-internationalinvestments-in-agriculture-2011.pdf

Hoffman, I., 2010. Climate change and the characterization, breeding and conservation of animal genetic resources. Animal Genetics 41, 32–46.

Hoffmann, I., 2007. The Global Plan of Action for Animal Genetic Resources. After Interlaken. Nordic Gene Bank Farm Animals (NGH), Malmö, 10-11 December 2007.

Hoffmann, U., 2011. Assuring food security in developing countries under the challenges of climate change: key trade and development issues of a fundamental transformation of agriculture. UNCTAD Discussion Papers 201. 40 pp.

Holt-Giménez, E., 2007. Biofuels: The Five Myths of the Agro-fuels Transition. Global Research, June 30. Available at: http://www.globalresearch.ca/

IAASTD, 2009. Agriculture at a Crossroads. The Global Report. International Assessment of Agricultural Knowledge, Science and Technology for Development, Island Press.

IMF. Undated. International Monetary Fund. Primary Commodity Prices, monthly data (available at http://www.imf.org/external/np/res/commod/index.asp).

Instituto Nacional de Estadística e Informática (INEI), 1996. Encuesta Demográfica y Salud Familiar Huancavelica. INEI, Lima.

International Fund for Agricultural Development (IFAD), 2003. Women as agents of change. IFAD Discussion Paper, 25th Anniversary Session of IFAD Governing Council.

Intergovernmental Panel on Climate Change (IPCC), 2011: Summary for Policymakers. In: Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C. B., Barros, V., Stocker, T.F., Qin, D., Dokken, D., Ebi, K.L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S., Tignor, M. and P. M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Intergovernmental Panel on Climate Change (IPCC), 2007. Climate Change 2007: Mitigation of Climate Change. Working Group III Report of the Fourth Assessment Report. Intergovernmental Panel on Climate Change, Geneva.

Intergovernmental Panel on Climate Change (IPCC) (Solomon S, et al., ed.), 2007b. Summary for policy makers. Climate Change 2007: The Physical Science Basis. Cambridge Univ Press, New York.

Intergovernmental Panel on Climate Change (IPCC), 2001. Climate Change 2001: Mitigation. Annex II Glossary. http://www.ipcc.ch/ipccreports/tar/wg3/454.htm

IUCN/World Initiative for Sustainable Pastoralism (WISP), 2010. Building climate change resilience for African livestock in sub-saharan Africa. http://www.iucn.org/wisp/?7943/Building-Climate-Change-Resilience-for-African-Livestock-in-Sub-Saharan-Africa

IUCN - International Union for Conservation of Nature. 2008. Red list of threatened species. (www.iucnredlist.org)

Jabbar, M., Pratt, N., Staal, S.J., 2008. Dairy Development for the Resource Poor (Part 1,2,3), PPLPI Working Paper no. 44. Rome, Pro-Poor Livestock Policy Initiative, FAO.

Jones, M.B., Donnelly, A., 2004. Carbon sequestration in temperate grassland ecosystems and the influence of management, climate and elevated v. New Phytol 164, 423–439.

Junfeng, L., 2007. REEEP: Activities that Support AD Project Development Worldwide. Paper presented at the Methane to Markets Partnership Expo, Beijing, 30 October – 1 November.
(available at http://www.methanetomarkets.org/expo/docs/postexpo/ag_junfeng.pdf).

Kangmin, L. & Ho, M-W. 2006. Biogas China. Institute of Science in Society Report.(available at http://www.i-sis.org.uk/BiogasChina.php).

Kasterine, A., Vanzetti, D., 2010. The Effectiveness, Efficiency and Equity of Market-based Instruments to Mitigate GHG Emissions from the Agri-food Sector. In: UNCTAD, Trade and Environment Review 2009/2010, Geneva.

Kay, C., 1988. Latin America's agrarian reform: lights and shadows. In: FAO, Land Reform, Land Settlement and Cooperatives. FAO, Rome. pp. 11–31.

Kenyatta University, Maseno University, National Environment and Mangement Authority (NEMA), Practical Action and FoodLink Resource Institute, 2008. Enhancing adaptive capacity of pastoralists to climate change-induced vulnerability in Northern Kenya. Meeting: Inception Workshop, Presbyterian Guest House and Conference Centre, January 28th-31st.

Krausmann, F., Erb, K.H., Gingrich, S., Lauk, C., Haberl, H., 2008. Global patterns of socioeconomic biomass flows in the year 2000: A comprehensive assessment of supply, consumption and constraints. Ecological Economics 65, 471–487.

Kull, C.A., 2002. Madagascar's burning issue: the persistent conflict over fire (prescribed burning). Available from: <http://www.findarticles.com>.

Lal, R. 2004. Carbon sequestration in dryland ecosystems. Environmental Managagement 33, 528–544.

Lanly, J.P., 2003. Deforestation and forest degradation factors. (www.fao.org/docrep/article/wfc/xii/ms12a-e.htm)

Leibig, M.A., Gross, J.R., Kronberg, S.L., Phillips, R.L., Hanson, J.D., 2010. Grazing management contributions to net global warming potential: a long-term evaluation in the northern great plains. Journal of Environmental Quality 39, 799–809.

Ly, C., Fall, A., Okike, I., 2010. West Africa: the livestock sector in need of regional strategies. In: P. Gerber, H. Mooney, J. Dijkman, S. Tarawali & C. de Haan, eds. Livestock in a changing landscape, Vol. 2: Experiences and regional perspectives. Washington, DC, Island Press.

Maarse, L., 2010. Livestock a Smart Solution for Food and Farming. In: Farming Matters, March issue. Available at: www.ileia.org.

Maitima, J.M., 2008. Climate Land Interaction Project. International Livestock Research Institute (ILRI). Available at:
http://www.ilri.org/ILRIPubAware/ShowDetail.asp?CategoryID=TS&ProductReferenceNo=TS_080722_001

Mamo, G., 2007. Community? Forest Management in Borana. In: A. Ridgewell, G. Mamo and F. Flintan, eds. Gender & Pastoralism Vol. 1: Rangeland & Resource Management in Ethiopia. Addis Abbaba: SOS Sahel Ethiopia.

Martínez Alier, J., Roca Jusmet, J., 2000. Economía Ecológica y Política Ambiental. Fondo de Cultura Económica, México. 481 pp.

McAlpine, C., Etter, A., Fearnside, P., Seabrook, L., Laurance, W., 2009. Increasing world consumption of beef as a driver of regional and global change: A call for policy action based on evidence from Queensland (Australia), Colombia and Brazil. Global Environ Chang 19, 21–33.

McMichael, A.J., Powles, J.W., Butler, C.D., Uauy, R., 2007. Food, livestock production, energy, climate change, and health. Lancet 6, 1253-1263.

Menzi, H., Oenema, O., Burton, C., Shipin, O., Gerber, P., Robinson, T., Franceschini, G. 2009. Impacts of intensive livestock production and manure management on ecosystems. In H. Steinfeld, H. Mooney, F. Schneider & L. Neville, eds. Livestock in a changing landscape, Vol. 1: Drivers, consequences, and responses. Washington, DC, Island Press.

Moloney-Quinn, J., 2010. Asset Based Community Development (ABCD) within an African Context. Cormac Russell, Kenya. Pp. 36.

Moore, F.C., MacCracken, M.C., 2009. Lifetime-leveraging: an approach to achieving international agreement and effective climate protection using mitigation of short-lived greenhouse gases. International Journal of Climate Change Strategies and Management 1 (1), 42–62.

Morton, J.F., 2007. The impact of climate change on smallholder and subsistence agriculture. Proceedings of the National Academy of Sciences of the United States of America 140, 19680-19685.

Mutschler, T., 2003. Lac Alaotra. In: Goodman, S.M., Benstead, J.P. (Eds.), The Natural History of Madagascar, pp. 1530–1534.

Mutter J., 2010. Disasters widen the rich–poor gap. Nature 466, 1042.

Nassef M., Anderson, S., Hesse, C., 2009. Pastoralism and climate change. Enabling adaptive capacity. Humanitarian Policy Group. Overseas Development Institute. London. 35pp.

Naylor, R., Steinfeld, H., Falcon, W., Galloway, J., Smil, V., Bradford, E., Alder, J., Mooney, M., 2005. Losing the links between livestock and land. Science 310.

Neumann, C., Harris, D.M., Rogers, L.M., 2002. Contribution of animal source foods in improving diet quality and function in children in the developing world. Nutrition Research 22 (1–2), 193–220.

Niamir-Fuller, M., 1999. Managing mobility in African rangelands: The legitimization of transhumance. London, UK, Intermediate Technology Publications Ltd. 240 pp.

Niggli, U., Fließbach, A., Hepperly, P., Scialabba, N., 2009. Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems. FAO, Rev. 2.

NORAD, undated. Basic facts on deforestation and climate change (www.norad.no/_attachment/125166/binary/42394?download=true)

Omolo, N. A., 2010. Gender and climate change-induced conflict in pastoral communities: Case study of Turkana in northwestern Kenya. African Journal on Conflict Resolution 10, pp. 81-102.

Olander, L., Reed., D., Malin, D., Haugen-Kozyra, K., 2010. A model for building collaborative actions and common understanding on agricultural GHG mitigation: C-AGG, T-AGG and M-AGG. CCAFS Working Paper no. 3. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org.

Otte, J. 2006. The Hen Which Lays Golden Eggs: Why backyard poultry are so popular. PPLPI Features. July 2006. Rome, Pro-Poor Livestock Policy Initiative, FAO. (available at http://www.fao.org/ag/againfo/programmes/en/pplpi/docarc/feature01_backyardpoultry.pdf).

Pathak, H., Jain, N., Bhatia, A., Patel, J., Aggarwal, P.K., 2010. Carbon footprints of Indian food items. Agriculture, Ecosystems & Environment 139, 66-73.

Paul, H., Ernsting, A., Semino, S., Gura, S., Lorch, A., 2009. Agriculture and Climate Change: Real Problems, False Solutions. Report published for the 15th Conference of the Parties of UNFCCC in Copenhagen, December. Available at: www.econexus.info/sites/econexus/files/Agriculture_climate_change_copenhagen_2009.pdf.

Pavanello, S., Levine, S., 2011. Rules of the range: Natural resources management in Kenya–Ethiopia border areas. HPG Working Paper. September 2011. Pp. 30. Humanitarian Policy Group, Overseas Development Institute, UK.

Pelletier, N., Tyedmers, P., 2010. Forecasting potential global environmental costs of livestock production 2000–2050. PNAS. Proceedings of the National Academy of Sciences of the USA, 10.1073/ pnas.1004659107.

Perez, C., Nicklin, C., Dangles, O., Vanek, S., Sherwood, S., Halloy, S., Garrett, K., Forbes, G., 2010. Climate Change in the High Andes: Implications and Adaptation Strategies for Small-scale Farmers. The International Journal of Environmental, Cultural, Economic and Social Sustainability 6, 1-16.

Pilling, D., Boerma, D., Scherf, B. and Hoffmann, I. 2008. Sustaining livestock biodiversity – from assessment to action. Biodiversity 9 , 14-18.

Pilling, D., Hoffmann, I., 2011. Climate change and animal genetic resources for food and agriculture: State of knowledge, risks and opportunities. Commission on genetic resources for food and agriculture. FAO, Rome. 42 pp.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., Seidel, R., 2005. Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems. Bioscience 55, 573-582.

Pimentel, D., Pimentel, M. 2003. Sustainability of meat-based and plant-based diets and the environment. American Journal of Clinical Nutrition, Vol. 78, No. 3, 660S-663S, September 2003

Postigo, J.C., Young, K.R., Kelley, A.C., 2008. Change and Continuity in a Pastoralist Community in the High Peruvian Andes. Human Ecology 36, 535-551.

Raas, N. 2006. Policies and Strategies to Address the Vulnerability of Pastoralists in Sub-Saharan Africa. PPLPI Working Paper No. 37. Rome, Pro-Poor Livestock Policy Initiative, FAO.

Rayner, G., Barling, D., Lang, T., 2008. 'Sustainable Food Systems in Europe: Policies, Realities and Futures', J Hunger and Environmental Nutrition, 3, 2/3, 145-168

Reid, R.S., Thornton, P.K., McCrabb, G.J., Kruska, R.L., Atieno, F., Jones, P.G., 2004. Is it possible to mitigate green house gas emissions in pastoral ecosystems of the tropics. Environ. Dev. Sustain. 6, 91–109.

Rivera-Ferre, M.G., 2009. Supply vs. Demand of Agri-industrial Meat and Fish Products: A Chicken and Egg Paradigm? International Journal of Sociology of Agriculture and Food, 16 (2): 90–105.

Rivera-Ferre, M.G., 2010. Livestock. In: Development Fund /Utviklingsfondet, 2010. A viable food future. Part II. Development Fund /Utviklingsfondet, Norway. Pp. 91-102.

Rosegrant, M.W., Cai, X., Cline, S.A., 2002. Global water outlook to 2025, averting an impending crisis. A 2020 vision for food, agriculture, and the environment initiative. Washington, DC: IFPRI and IWMI.

Rosset, P., Altieri, M., 1997. Agroecology versus input substitution: a fundamental contradiction of sustainable agriculture. Society & Natural Resources 10, 1-16.

Rundgren, G., 2011. Garden Earth – From Hunter and Gatherer Society to Global Capitalism and Thereafter (forthcoming).

Runge, C.F., Senauer, B., 2007. How biofuels could starve the poor, Foreign Affairs, May/June.

Sandford, S., 1983. Management of pastoral development in the Third World. New York, Wiley and Sons. 316 pp.

Shiva, V., Panday, P., 2006. A new Paradigm for Food Security and Food Safety. Biodiversity based organic farming. Navdanya (www.navdanya,org)

Small E., Catling, P.M., 2008. Global Biodiversity – The Source of New Crops. Biodiversity 9 (1&2) (http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/Pub/Biodiversity.pdf)

Smith, P., Martino, D., Cai, Z., et al., 2007. Agriculture. In: Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., Meyer, L.A. (Eds.), Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, NY.

Sociedad Peruana de Criadores de Alpacas y Llamas—SPAR, 2005. Plan Estratégico Institucional al 2015. SPAR, Lima.

Speedy, A.W., 2003. Global production and consumption of animal source foods. Journal of Nutrition 133, 4048S–4053S

Spooner, B., Horne, L. (eds.), 1980. Cultural and ecological perspectives from the Turan program, Iran. Expedition, 22/4.

Starkey, P., 2010. Livestock for traction: world trends, key issues and policy implications. AGA working paper series. Rome, FAO.

Stehfest, E., Bouwman, L., van Vuuren, D.P., den Elzen, M.G.J., Eickhout, B., Kabat, P., 2009. Climate benefits of changing diet. Climatic Change 95, 83-102.

Steinfeld, H., 2003. Economic constraints on production and consumption of animal source foods for nutrition in developing countries. Journal of Nutrition 133, 4054S–4061S.

Steinfeld, H., Mooney, H.A., Schneider, F., Neville, L.E., (Eds.) 2010. Livestock in a Changing Landscape. Drivers, Consequences, and Responses (Volume 1). Island Press, Washington.

Steinfeld, H.., Gerber, P., 2010. Livestock production and the global environment: Consume less or produce better? Proceedings of the National Academy of Sciences of the United States of America 107, 18237-18238.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., Haan, C. D., 2006. Livestock's Long Shadow: Environmental Issues and Options. Rome, FAO.

Stephen, M.M., Opiyo, F.E.O., 2010. Resource use planning under climate change: Experience from Turkana and Pokot pastoralists of Northwestern Kenya. ICID+18 2nd International Conference: Climate, Sustainability and Development in Semi-arid Regions August 16 - 20, 2010, Fortaleza - Ceará, Brazil.

Stuart, T. 2009. Waste: Uncovering the global food scandal. London, Penguin Books.

Sustainable Development Commission, 2009. Setting the Table. Advice to Government on Priority Elements of Sustainable Diets. Sustainable Development Commission, London.

Tester, M., 2010. Breeding technologies to increase crop production in a changing world. Science 327, 818.

Tillman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S., 2002. Agricultural Sustainability and Intensive Production Practices. Nature 418, 671–677.

Thompson, L.G., Mosley-Thompson, E., Davis, M.E., Lin, P.N., Henderson, K., Mashiotta, T. A., 2003. Tropical Glacier and Ice Core Evidence of Climate Change on Annual to Millennial Time Scales. Climatic Change 59, 137-155.

Thøy, K., Wenzel, H., Jensen, A.P., Nielsen, P., 2009. Biogas from manure represents a huge potential for reduction in global greenhouse gas emissions. 2009 IOP Conf. Ser.: Earth Environ. Sci. 6 242020.

Tukker, A., Huppes, G.., Guinée, J., Heijungs, R., de Koning, A., van Oers, L., Suh, S., Geerken, T., Van Holderbeke, M., Jansen, M., Nielsen, P., 2006. Environmental impact of products (EIPRO): Analysis of the life cycle environmental impacts related to the total final consumption of the EU25. (European Commission) Technical Report EUR 22284 EN.

Ulyatt, M.J., Lassey, K.R., Shelton, I.D., Walker, C.F., 2002. Methane emission from dairy cows and wether sheep fed subtropical grass-dominant pastures in midsummer in New Zealand. New Zealand Journal of Agricultural Research, 45: 227–234.

United Nations, 2010a. Preliminary study of the Human Rights Council Advisory Committee on discrimination in the context of the right to food. Human Rights Council. Thirteenth session. Agenda item 5. 32pp.

United Nations, 2010b. Resolution 65/2 adopted by the 65th General Assembly (A/RES/65/2).

United Nations (UN), Department of Economic and Social Affairs, Population Division, 2008. World Population Prospect: The 2008 Revision. Population database. http://esa.un.org/unpp/p2k0data.asp

UNCTAD/UNEP, 2008. Best Practice for Organic Policy: What Developing Country Governments Can Do to Promote the Organic Agriculture Sector. Study under the UNEP-UNCTAD Capacity Building Task Force on Trade, Environment and Development (CBTF), Geneva.

UNDP, 2008. Fighting Climate Change: Human Solidarity in a Divided World. United Nations Human Development Report. United Nations Development Programme, Geneva.

UNEP, 2010. Assessing the Environmental Impacts of Consumption and Production: Priority Products and Materials. A Report of the Working Group on the Environmental Impacts of Products and Materials to the International Panel for Sustainable Resource Management. United Nations Environment Programme.

UNFCC, 2008. Challenges and opportunities for mitigation in the agricultural sector UNFCCC:UFCCC/TP/2008/8.

United Nations Population Fund (UNFPA). 2010. State of World Population 2010. New York.

Vandermeer, J., Perfecto, I., 2006. The agricultural matrix and a future paradigm for conservation. Conservation Biology 21 (1), 274–277.

Veterinaires Sans Frontieres-Belgium, 2010. Village Community Banking Associations (VICOBA) methodology. Enhanced local community resilience to climate variability and change. ‘International Conference on Community-based disaster risk reduction and climate change adaptation’, 5th to 11th December 2010, Kisumu, Kenya.

Via Campesina, 2007. Small-scale sustainable farmers are cooling down the earth. Available at: http://viacampesina.org

Von Braun, J. 2008. Rising Food Prices: What Should be Done? IFPRI Policy Brief. Washington: International Food Policy Research Institute. (available at http://www.ifpri.org/ publication/rising-food-prices).

Vuille, M., Bradley, R.S., Werner, M., Keimig, F., 2003. 20th Century Climate Change in the Tropical Andes: Observations and Model Results. Climatic Change 59, 275-299.

Walker, A. 2010. UN calls meeting on food price concerns. BBC World Service. (available at http:// www.bbc.co.uk/news/business-11177346).

Wallace, R., 2009. Breeding influenza: the political virology of offshore farming. Antipode 41, 916-951.

Watson, C., 2003. Pastoral women as peacemakers. Community-based Animal Health and Participatory Epidemiology Unit (CAPE) of the African Union's Interafrican Bureau for Animal Resources (AU/IBAR), Nairobi, Kenya. Available from: <www.eldis.org/fulltext/ PastoralWomenAsPeacemakersApril2003.pdf>

Weber, C., Matthews, H., 2007. Food-miles and the relative climate impacts of food choices in the United States. Environmental Science & Technology 42 (10), 3508–3513.

White, R., Murray, S. and Rohweder, M., 2000. Pilot analysis of global ecosystems: Grassland ecosystems. Washington, D.C., World Resources Institute. 112 pp.

WISP, 2007. Squandered wealth: A global economic review of pastoralism. WISP Policy Issues Paper 2. February 2007. 4 pp.

WISP, 2006. Global Review of the Economics of Pastoralism. WISP, GEF, UNDP, IUCN. Nairobi. 47 pp.

WISP, 2008. A global perspective on the total economic value of pastoralism: Global synthesis report based on six country valuations . WISP, GEF, UNDP, IUCN. Nairobi. 28 pp.

Whitehead, D.C., 1995. Grassland Nitrogen. CAB International, Wallingford, UK.

WRI, 2000. World Resources 2000-2001: People and ecosystems: The fraying web of life. Washington DC, World Resources Institute. 400 pp.

World Bank, 2009. World Development Report 2010: Development and Climate Change.

World Bank, 2007. State and Trends of the Carbon Market 2007. Washington, DC, World Bank in cooperation with the International Emissions Trading Association.

World Health Organization (WHO), UNEP), 2010. Health and Environment Linkages Initiative (http://www.who.int/heli/risks/toxics/chemicals/en/index.html)

Wright, H.T., Rakotoarisoa, J.A., 2003. Human ecology. In: Goodman, S.M., Benstead, J.P. (Eds.), The Natural History of Madagascar. The University of Chicago Press, pp. 112–178.

Yang, X.M., Drury, C.F., Wander, M.M., Kay, B.D., 2008. Evaluating the effect of tillage on carbon sequestration using the minimum detectable difference concept. Pedosphere 18, 421-430.

Yu, S.M., Zhu, L.F., Ouyang, Y.N., Xu, D.H., Jin, Q.Y., 2008. Effects of rice-duck farming system on biotic populations in paddy field. (article in Chinese) Ying Yong Sheng Tai Xue Bao 2008. Apr;19(4), 807-12.

Zwaagstra, L., Sharif, Z., Wambile, A., de Leeuw, J., Said, M.Y., Johnson, N., Njuki, J., Ericksen, P. and Herrero, M., 2010. An assessment of the response to the 2008 2009 drought in Kenya. A report to the European Union Delegation to the Republic of Kenya. ILRI, (International Livestock Research Institute) Nairobi, Kenya, 108 p.

This work aims at contributing to the debate on the relation between Climate Change and the livestock sector, by bringing in a specific focus on the smallest production systems. Their share of responsibility is addressed, as well as their peculiar adaptation and mitigation potential.

As we observed in four case studies, small producers' communities are extremely efficient in producing animal source foods, thanks to their ability to constantly adjust strategy for adapting to environmental variability, and to take advantage of human-inedible forage and marginal lands, to produce high quality and human-edible foods.

Small and medium-scale livestock keepers and their peoples are essential to preserve socio-ecological mechanisms that avoid depletion of natural resources, and guarantee the best conditions for the conservation of thousands of local breeds. Nevertheless, in the last few decades, a significant shift has been reported in livestock production, away from a local multi-purpose activity more into Large-Scale, intensive and market-oriented livestock production systems, located close to urban centres. This shift is combined with a sharp increase in cereal-fed monogastric livestock species and a decrease in ruminants.

According to VSF Europa, it seems no longer acceptable to address the world future demand for animal source food by the same approach that in the last two decades led to increased exploitation of land, fossil fuels, water. In order to guarantee animal source food security in the current situation of shortage of natural resources, population growth, and increasing climate variability, many countries should question their average meat consumption, and the livestock sector must shift its focus from increased production toward enhanced resilience.

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