LIVESTOCK AND CLIMATE CHANGE IN THE NEAR EAST REGION

Measures to adapt to and mitigate climate change

Livestock and Climate Change in the Near East Region

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By

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Cover photos

- *Bedouin providing supplementary feeds to sheep in Syria*
- *Adapted goat breed being characterised in the dry areas of Jordan*

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List of abbreviations

CH_4	Methane
CIAT	International Centre for Tropical Agriculture
CIESIN	Center for International Earth Science Information Network
CO_2	Carbon dioxide
CWANA	Central and West Asia North Africa
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO statistical database
GCM	General Circulation model
GDP	Gross domestic product
GHG	Greenhouse gas
GIS	Geographic information system
ICARDA	International Center for Agricultural Research in the Dry Areas
IFAD	International Fund for Agricultural Development
IFPRI	International Food and Policy Research Institute
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
LU	Livestock unit
MA	Millennium Ecosystem Assessment
NDVI	Normalized difference vegetation Index
N_2O	Nitrous oxide
RNE	Regional Office for the Near East
SRES	Special Report Emissions Scenarios
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
WANA	West Asia and North Africa

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Foreword

Climate change is one of the greatest global challenges of this century. FAO began discussing the issue of climate change a way back in the 1980s. Increasingly, the subject has become a focus of world attention. FAO has been looking more closely at how climate change is affecting agriculture and food security and what can be done to help countries in the region to adapt to impacts and mitigate climate change.

In the Near East region scarce natural resources are already under considerable pressure. Deteriorating climatic conditions are projected for the Region. The threats are already affecting natural resources and agricultural production in the region and will likely worsen with drastic impacts on national economies in general and food security in particular. Conscious of the climate change threats in the region, countries in the region have requested FAO and other partners for help in identifying appropriate actions and developing capacities to adapt to climate change and absorb the potential shocks stemming from these impacts in agriculture sector. In response to this request, the FAO's Regional Office for the Near East has over the last few years dedicated a multi-disciplinary Working Group to climate change issues and established to carry forward an agenda addressing climate change in the region. Adaptation to climate change of the economic sectors directly concerned with food security constitutes one of the main priorities in the Regional Priority Framework with the aim of building greater resilience of these sectors to the impacts of climate change. Over the months, FAO held a regional forums and workshops on climate change in the Near East with the overall goal of advancing the agenda for investment in climate change adaptation and mitigation measures in the broad agricultural sector.

The primary objective of this document is to provide an overview of the actual and potential impacts of climate change and climate variability on livestock sector in the region for adaptation and mitigation measures. It analyses and documents the impacts, past evidences, hotspots of climate change, projections and vulnerability of the sector, and the needed measures to adapt to and mitigate climate change. The authors used an in depth analysis of literature, utilisation of GIS tools and experiences in the region. The draft version of this document was presented for review at an expert meeting held in Amman (Jordan) in October 2011.

This publication is intended to provide a point of departure for identifying and catalysing regional coordinated action to complement and enhance national efforts. The publication will be of interest to specialists and policy-makers in livestock and climate change in the Near East region. Moreover, it will be useful to livestock production and health extension agents, researchers, students, and general audiences interested in learning more about livestock and climate change in the region.

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1. Introduction

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) shows that the global mean surface temperature has increased linearly by 0.74 °C over the last 100 years (IPCC, 2007). Most of the observed increases in global average temperatures since the mid-20th century are very likely a consequence of anthropogenic greenhouse gas (GHG) concentrations. Current global median projections predict an increase in mean temperature and a decrease in mean annual precipitation in many of the already marginal dry areas (IPCC, 2007). These changes will result in lower river flows, an increase in evapotranspiration, drier soils and shorter growing seasons. Moreover, an increase in extreme climatic events, such as longer droughts, more intense storm events and even extreme low temperature spikes that could damage or destroy crops and vegetation, are projected.

Agriculture contributes between 59 percent and 63 percent of the world's non-carbon dioxide (non-CO_2) GHG emissions, including 84 percent of the global nitrous oxide (N_2O) emissions and 54 percent of the global methane (CH_4) emissions (USEPA, 2006a; USEPA, 2006b). Soil emissions of N_2O and CH_4 from enteric fermentation are the two largest sources of non-CO_2 GHGs globally (Verschot, 2007). Livestock contribute to these emissions as well. Livestock production systems, from feeding, importing and marketing animals and animal products, directly and indirectly generate 18 percent of global GHG emissions as measured in CO_2 equivalents (Steinfeld *et al*., 2006). According to estimates throughout the livestock commodity chains, it contributes up to 9 percent of the total anthropogenic CO_2, 37 percent of CH_4, and 65 percent of NO_2 (Steinfeld *et al*., 2006).

Verschot (2007) noted that there are numerous opportunities for mitigating non-CO_2 GHGs in agriculture. The GHG emissions can be reduced by managing carbon and nitrogen more efficiently in agricultural ecosystems; carbon can be sequestered from the atmosphere and stored in soils or in vegetation and crops and residues from agricultural lands can be used as a source of fuel to displace fossil fuel combustion, either directly or after conversion to fuels such as ethanol or diesel (Verschot, 2007). For livestock, there are a wide range of practices associated with grazing land management, manure management and feeding that can reduce emissions and increase carbon sequestration (Verschot, 2007).

In addition to its contributions to GHG emissions, FAO's *Livestock's long shadow* (2006) highlights the livestock sector as a significant contributor to some of the world's major environmental problems. Livestock is also a major consumer of water. Although water for livestock drinking and servicing might be the most obvious water use in livestock production systems, it constitutes only a minor part of the total water consumption (Peden *et al*., 2007). Most of the water consumed by livestock is associated with the transpiration of water for feed production; this amounts to more than 95 percent of the total (Singh *et al*., 2004; Peden *et al*., 2007). Livestock systems depending on grain-based feeds, as is the case in the developed world, are more water intensive than systems relying on crop residues and pasture lands. In those cases where livestock are fed crop residues and graze rangelands which are unsuitable for crop production anyway, they make very efficient use of the available water (Peden *et al*., 2007).

Drought is already a recurrent and often devastating threat to the welfare of countries in the Near East. The effects of drought have been aggravated in the last half century by an increase in human population and increasing livestock numbers (Hazell *et al*., 2001).

Near East region

The Near East region on which this report is based, covers Algeria, Bahrain, Egypt, Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Islamic Republic of Mauritania, Morocco, Sultanate of Oman, Kingdom of Saudi Arabia, Syrian Arab Republic, Tunisia, Qatar, United Arab Emirates (UAE) and Yemen. Most of the region is characterized by a hot and dry climate and the presence of vast deserts and long coast lines. But there is also a great variety in the physical geography with mountain ranges and diverse hydro-climatic conditions. Some of the major transboundary rivers (e.g., the Tigris-Euphrates and Nile) originate outside the region (FAO RNE, 2011).

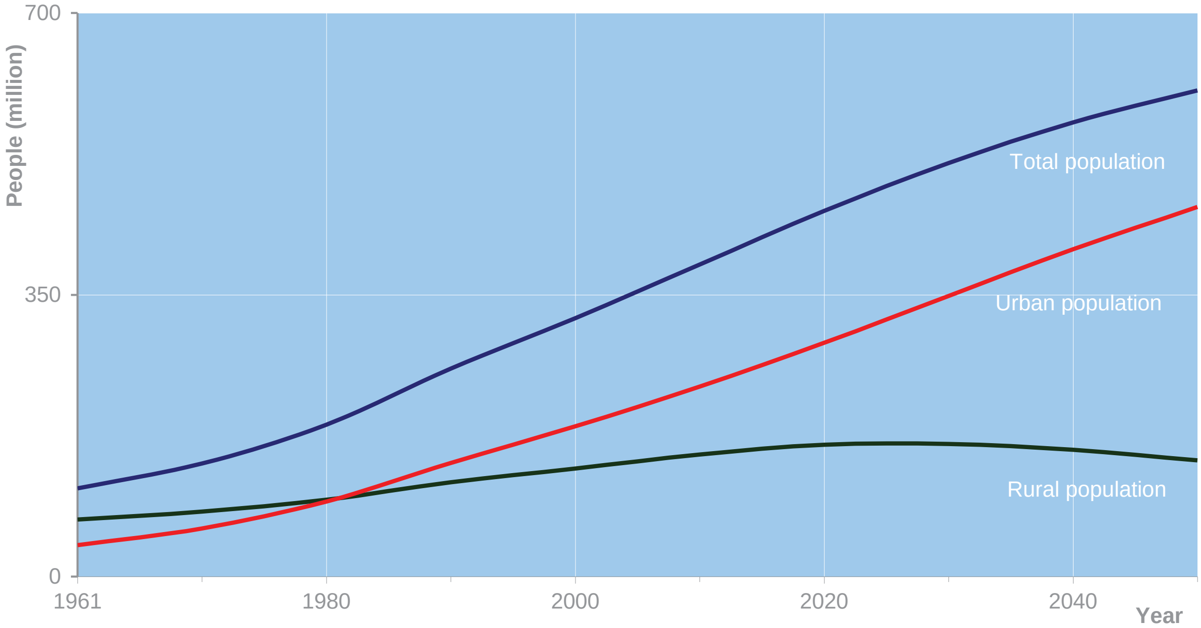
The region supports a population of 387 million people, more than 151 million of whom live in rural areas (Figure 1). Of these, about 78 million are dependent on agriculture – including fishing and livestock (FAOSTAT, 2011). The region has ancient historical settlements. The Near East is an important site of early settled agriculture, the centre of origin and diversity of several major cereal and legume crops and of the early domestication of sheep and goats (Dixon *et al*., 2001).

Compared with other developing areas of the world, the Near East is not a particularly impoverished zone (World Bank, 2007). The early development of irrigation-based civilisations in much of the area laid the foundation for the intensive agricultural systems still in use today (Dixon *et al*., 2001). Historically, irrigation practices, coupled with effective indigenous technologies for managing the limited resources available, have meant that any outright malnutrition in rural areas has been associated mainly with crop failures resulting from droughts, pests or the failure of the annual flood in the Nile Valley (Dixon *et al*., 2001). Rapid increases in population and climate change now threaten this historical equilibrium.

Population projections indicate that populations may almost double between 2000 and 2050 (Figure 1). In the last decades, population growth and urbanization were the main drivers for the increasing demand for livestock products (Delgado *et al*., 1999), the so-called livestock revolution. The increase in population brought about profound changes in livestock production systems, and will continue to do so in the coming decades. Expanding the domestic and export markets for livestock and the rapidly growing demands create growth opportunities for livestock producers in the Near East. However, there are major challenges in ensuring that this growth deals with the negative impacts of livestock as well.

As a result of the dominant desert conditions in most of the region, the extent of agricultural land in the Near East is rather low. The Sahara Desert stretches from the Red Sea in the east to the Atlantic Ocean in the west, representing more than 90 percent of the landmass of northern Africa. The Rub Al Khali Desert, known also as the Empty Quarter, covers an area 1 000 by 500 km^2 in the south of the Arabian Peninsula. Other significant deserts in the region include, the Nefud Desert in the northern part of the Arabian Peninsula and the Dasht-e Kavir and Dasht-e Lut deserts in the Islamic Republic of Iran. Agricultural land covers 38 percent of the region, with an estimated total in 2008 of almost 557 million ha. Of this almost 474 million ha are rangeland (FAOSTAT, 2011). The agricultural sector is the primary source of livelihoods for the majority of the population in many countries. Agriculture employs, on average, 21 percent of the active population and constitutes more than 10 percent of the regional GDP (FAO RNE, 2011). The principal sub-sectors of agriculture in the region are crops and livestock.

Figure 1
Historical and projected rural-urban population in the Near East, 1961-2050



Source: FAOSTAT, 2011

Agricultural production systems can contribute significantly to the mitigation strategies which reduce the adaptations required by, and the catastrophic effects on, the systems and sectors on which lives and livelihoods depend (FAO, 2009b). The FAO (2009b) states that agricultural production systems will also need to adapt to unavoidable climate change effects in order to ensure food security and sustainable development. Most developing countries will need to do both and will need to involve smallholder producers. The challenge, though, is to find an efficient mix of mitigation and adaptation solutions in the Near East which limit climate change and its effects on agricultural production systems in general and the livestock sector in particular.

In agriculture many mutually re-enforcing synergies and benefits exist among mitigation and adaptation actions and overall development goals (Gerber *et al*., 2010). Gerber *et al*. (2010) point out that these benefits include increased agricultural production, improved food security, poverty reduction, biodiversity conservation, improved soil and water management and increased production efficiency. Adaptation to climate change is essential in any effort to promote food security, poverty alleviation or sustainable management and conservation of natural resources. Moreover, it will not be possible to reach the global mitigation target if agriculture is not contributing significantly to mitigation. It is, therefore, critical to generate information on the emissions from different livestock production systems and products in order to determine the most effective mitigation actions and enable informed policy choices (Gerber *et al*., 2010).

Objective of the report

According to the FAO RNE (2010), the agriculture value-added share of GDP, although on the decline, remains well above 10 percent in most of the non-oil countries. During the period 2001 to 2008, agriculture constituted approximately 11.6 percent of the regional GDP. It ranged from 0.5 per cent in Kuwait and 0.9 percent in Bahrain to 34.4 percent in Sudan and 22.3 percent in Syria. It employs on average 21 percent of the active population. In many countries agriculture is still the prime source of livelihoods for a majority of the population.

The value of livestock products accounts for between 30 and 50 percent of agricultural output in the region and this share is expected to increase continuously (FAO RNE, 2011). However, investment in the sector's development is very limited and the sector is being negatively affected by uncertainties, one of which is climate change. Climate change affects livestock production and health in various ways. Droughts and floods will strike more often and so will animal disease epidemics, including vector-borne diseases. Increasing feed shortages are likely to worsen rangeland degradation and neglect is threatening to accelerate the loss of adapted animal genetic resources. Without effective adaptation and mitigation measures, livestock producers in the region will suffer substantial losses.

A systems approach is needed to identify the best and most resilient livestock breeds, rangeland management systems, production strategies, animal disease prevention and control measures and access to animal health care, appropriate policies and institutions, efficient waste management, use of manure, intensive livestock farming systems, land use planning, research into farming methods, incentives for eco-friendly farming, efficient breeding, feeding and management techniques and early warning systems.

In the last five years several international meetings have taken place in the region in which climate change and agriculture in the dry lands have been discussed. Based on these meetings, and taken in combination with information from various sources, this report provides a review of the contribution of livestock to livelihoods and analyses the changes in livestock production systems and demands for livestock products in the region. Moreover it will give an overview on the effects of climate change on livestock productivity and health, and adaptation and mitigation measures in the Near East region.

Section 2 will provide details on different livestock production systems in the Near East. Section 3 will give an overview of the state of knowledge on climate change in the Near East. Section 4 elaborates on adaptation and mitigation measures in different livestock production systems. Finally, recommendations are given in Section 5.

2. Livestock production in the Near East

Agricultural land in the Near East is extremely limited. Arable land and permanent crops comprise only 6 percent of the total land area, 32 percent is classified as pasture – mainly in areas with less than 200 mm mean annual precipitation. Approximately 54 percent is identified as ‘other’ and is unsuitable for agricultural use (FAOSTAT, 2011). This is mostly desert with some extensive grazing.

In many agricultural systems, livestock is a major component. Particularly in arid and semi-arid areas, extensive grazing is the only means of producing (high-value) agricultural products under the given agro-climatic conditions. The low mean annual precipitation in the semi-arid and arid regions is typically associated with high precipitation variability and determines the carrying capacity of the system for livestock (Tietjen & Jeltsch, 2007). Pastoralism and agro-pastoralism are the key agricultural production systems in many dry lands. In these systems, animals have become an essential aspect of the cultural, social and religious life of the people who depend upon them. Specific breeds adapted to the needs of the people and the environmental stressors have been developed (Scherf *et al*., 2009).

The Near East livestock population has more than doubled during the last 40 years from 186 to 412 million head[1] while the number of poultry[2] has increased more than ninefold during the same period – from 0.17 to 1.44 billion (FAOSTAT, 2011). The sector has rapidly responded to the growing demand for meat (Table 1).

The Near East region is classified into three sub-regions – North Africa (Maghreb) including Algeria, Libya, Mauritania, Morocco and Tunisia, Oriental Near East (Mashreq) including Egypt, Iran, Iraq, Jordan, Lebanon and Syria and the Gulf States and Yemen, including Saudi Arabia, Kuwait, Bahrain, UAE, Qatar, Oman and Yemen. Table 1 shows the drastic increase in livestock numbers between 1961 and 2009, particularly for sheep and goats. Table 2 shows the increased livestock production in the Near East, particularly for cattle and sheep meat. An increase in livestock production can be the result of an increase in animal numbers, and/or an increased output per animal (FAO, 2009d). In the Near East, the increase in production can be attributed to the increase in animal numbers, as Table 2 shows that the output per animal lagged behind, as in many developing countries.

Table 1

Livestock populations in the Near East, for the periods 1961-1965, 1986-1990 and 2006-2009

	Number of stock (000s)			Change in number (%)[1]	
	1961-1965	1986-1990	2006-2009	1986-1990	2006-2009
Sheep					
North Africa	25 853	45 844	59 777	77	131
Oriental Near East	47 234	70 365	91 259	49	93
Gulf States & Yemen	4 566	11 240	18 683	146	309
Total Near East	77 652	127 449	169 719		
Goats					
North Africa	12 569	13 126	18 655	4	48
Oriental Near East	18 289	28 753	34 148	57	87

[1] Livestock here includes buffaloes, camels, cattle, goats, pigs and sheep
[2] Poultry includes chickens, ducks, geese, guinea fowl, pigeons, other birds and turkeys

Gulf States & Yemen	4 093	8 275	16 776	102	310
Total Near East	34 951	50 154	69 579		
Cattle					
North Africa	6 282	6 697	7 000	7	11
Oriental Near East	9 160	11 872	15 612	30	70
Gulf States & Yemen	1 526	1 580	2 348	4	54
Total Near East	16 968	20 149	24 960		
Camels					
North Africa	1 399	1 392	2 118	-1	51
Oriental Near East	637	331	354	-48	-44
Gulf States & Yemen	440	779	1 165	77	165
Total Near East	2 476	2 502	3 636		

[1] Change in numbers 1961-1965 = 100%

Source: FAOSTAT, 2011

Most of the small ruminants (sheep and goats) in the region live on farms and rangelands in the lowland semi-arid and arid zones under extensive systems of management. There is also a considerable, but less well-documented, ruminant population on the higher altitude plateaux, mountain regions and forest grazing of Algeria, Iran, Iraq and Morocco (Hazell *et al*., 2001). Small ruminants are a key part of the rural economy and an important source of income and dietary protein for the rural poor (Tibbo *et al*., 2008a). They are particularly important in marginal dry areas, because they require relatively small investments, and can be reared on marginal land, converting low quality feed into high-value milk and meat (Tibbo *et al*., 2008b).

Table 2

Average livestock productions and yields in the Near East for the periods 1961-1965, 1986-1990 and 2006-2009

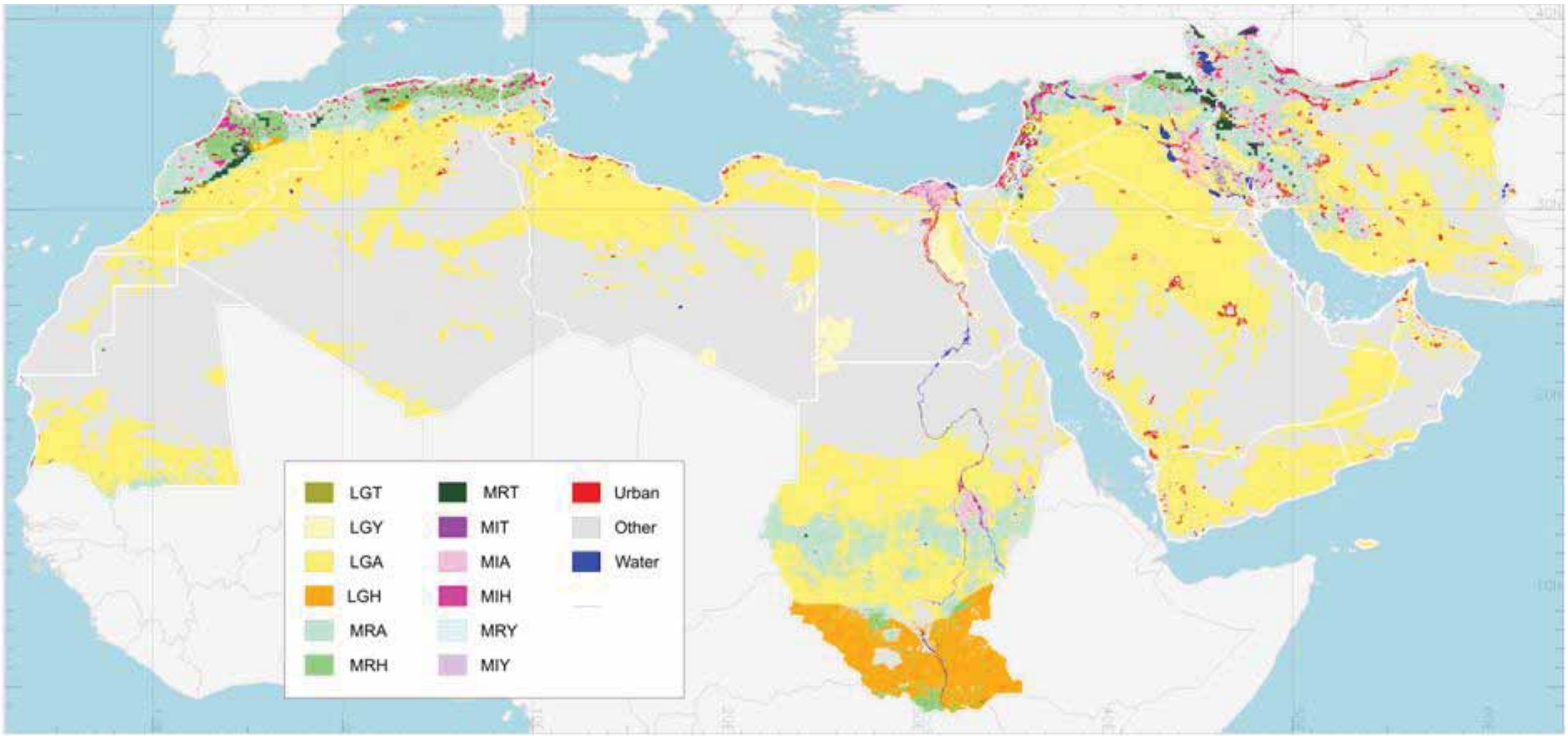
	Production (tonne)			Average yield/carcass weight (kg/animal)		
	1961-1965	**1986-1990**	**2006-2009**	**1961-1965**	**1986-1990**	**2006-2009**
Sheep						
North Africa	105 492	277 482	408 653	133	146	148
Oriental Near East	228 324	415 447	681 439	190	185	223
Gulf States & Yemen	41 144	159 144	178 769	179	181	180
Total Near East	374 961	852 073	1 268 861	167	171	184
Goats						
North Africa	36 367	47 629	74 372	103	127	129
Oriental Near East	92 607	140 572	181 803	154	167	190
Gulf States & Yemen	19 316	42 656	94 742	152	153	154
Total Near East	148 290	230 857	350 917	137	149	158
Cattle						
North Africa	118 170	289 301	374 969	1 164	1 713	1 798
Oriental Near East	230 742	419 088	881 225	1 181	1 115	1 869
Gulf States & Yemen	27 384	71 563	125 128	1 451	1 555	1 646
Total Near East	376 295	779 952	1 381 322	1 265	1 461	1 771
Camels						
North Africa	19 107	30 898	35 160	1 488	1 570	1 737
Oriental Near East	21 280	24 098	46 876	1 852	1 944	1 996
Gulf States & Yemen	20 341	47 534	76 152	2 142	2 181	2 122
Total Near East	60 728	102 530	158 188	1 827	1 899	1 951

Source: FAOSTAT, 2011

The distribution of livestock production systems (Figure 2) shows the large occurrence of agro-pastoral and grassland systems in the Near East. These systems cover 84 percent of the total land area, mixed rainfed crop-livestock systems 8 percent and irrigated systems only 2 percent (Appendix A).

In order to show the spatial distribution of livestock in different agricultural productions systems in the region, it is useful to look at the spatial distribution of livestock production systems in the Near East. Seré and Steinfeld (1996) developed a global livestock production system classification scheme. The system breakdown has four production categories – landless systems (typically found in periurban settings), livestock/rangeland-based systems (areas with minimal cropping, often corresponding to pastoral systems), mixed rainfed systems (mostly rainfed cropping combined with livestock, i.e. agro-pastoral systems) and mixed irrigated systems (a significant proportion of cropping uses irrigation and is interspersed with livestock). All but the landless systems are further disaggregated by agro-ecological potential as defined by the length of the growing period (LGP) – arid–semi-arid (with LGP < 180 days), humid and sub-humid (LGP > 180 days), and tropical highlands/temperate regions. A method was devised for mapping the classification by Kruska *et al*. (2003), and was updated at one kilometre resolution (FAO/ILRI, 2007). The distribution of livestock production systems is presented in Figure 2. The classification system can be applied in response to different scenarios of climate and population change, to give very broad-brush indications of possible changes in livestock system distribution in the future (Thornton *et al*., 2002; Thornton *et al*., 2006; Herrero *et al*., 2009).

Figure 2
The Distribution of Livestock Production Systems for 2000



- LGY, LGA, LGT and LGH are livestock/rangeland-based systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MRY, MRA, MRT and MRH are mixed rainfed systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MIY, MIA, MIT and MIH are mixed irrigated systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively.

Source: FAO/ILRI, 2007

Livestock production systems and livelihoods

Farmers in marginal areas rely largely on highly variable natural resources and have few safety nets. Van de Steeg *et al*. (2009) argue that climate change is likely to affect livestock keepers and the ecosystems on which they depend; in some places reducing the productivity of rainfed crops and forages, reducing the availability of water and increasing the severity and distribution of human, animal and crop diseases. Households will be forced to adapt to changing circumstances by introducing new production technologies, embracing sustainable natural resource management practices and, in some cases, changing the way they make a living.

In order to give an estimate of the number of people living in the different livestock production systems, we overlaid the livestock production system map with a map showing population totals at one kilometre resolution according to CIESIN *et al*. (2004). The dataset includes settlements and their populations in 1995 and 2000.

Appendix B shows the number of people living in the different livestock production systems by country. The Table shows that 38 percent of the rural population lives in agro-pastoral areas. Despite the limited spatial extent, 59 percent of the rural population lives in mixed systems. The Table illustrates as well the large variation between the countries in the region.

In order to determine the distribution of livestock over different farming systems, we overlaid livestock raster layers with the livestock production system map at one kilometre resolution. The numbers of livestock for the year 2000 are derived variables from the FAO Gridded Livestock of the World database (Wint and Robinson, 2007). A few pixels of the cattle raster layers contained more than 500 head/km^2, a density of 6 to 200 times higher than the surrounding pixels. The small ruminant raster layer contained a few pixels with more than 2 500 head/km^2. These pixels were considered to be artificial, model-generated outliers. Upper limit densities of 500 head/km^2 for cattle and 2 500 head/km^2 for small ruminants were used. All raster cells with values higher than these were changed to 500 and 2 500 as appropriate.

The distribution of cattle and small ruminants over the livestock production systems by country are shown in Appendices C and D. Cattle are predominant in agro-pastoral and grassland systems (47 percent) in the Near East. These cattle are mostly used for meat production. In the mixed systems, cattle are often kept for dairy production. The mixed systems in the arid regions contain 38 percent of the total cattle numbers. Small ruminants are predominant in agro-pastoral and grassland systems (51 percent) in the Near East. The mixed systems in the arid regions contain 35 percent of the total number of small ruminant.

Livestock genetic resources

Concerns have been raised in recent years over the loss of agricultural biodiversity through homogenization of agricultural production systems (FAO, 2007a). For crop and livestock genetic diversity, two major concerns are the increasing levels of genetic vulnerability and genetic erosion (FAO, 2007a). Genetic vulnerability occurs where a widely used crop or livestock variety is susceptible to a pest or pathogen that threatens to create widespread losses. Genetic erosion is the loss of genetic resources through the extinction of a livestock variety or crop. The main cause of genetic erosion is the replacement of indigenous varieties with improved ones.

Animal genetic diversity is critical for food security and rural development, as it allows farmers to select stock or develop new breeds in response to changing conditions (Hoffmann, 2010). The FAO (2007a) found, however, that animal genetic diversity worldwide is under threat. International transboundary breeds of the five major species (cattle, sheep, goats, pigs and chicken) have spread globally for use in large-scale, high external input systems to provide products for the market, as many of them are high output, commercial breeds. Local breeds are commonly used in pastoral and small-scale mixed crop-livestock systems. Given the mobile lifestyle of many livestock keepers in the dry lands, the same breed often occurs in more than one country (Scherf *et al*., 2009). The spread of commercial breeds is a result of their perceived economic competitiveness, and has indirectly increased the risk of extinction of local, less productive breeds (Hoffmann, 2010).

The Middle East was the centre of early domestication of sheep and goats. In the Near East 90 percent of all the local breeds are bred and kept in the dry lands (Scherf *et al*., 2009). The region has approximately 75 local breeds of sheep and at least 32 breeds of goats. Some thrive in deserts or steppe areas, while others are adapted to oases or humid coastal regions. Most of these breeds are tolerant to temperature extremes and are able to survive, grow and reproduce on degraded rangeland with poor seasonal nutrition (Tibbo *et al*., 2008a).

Some breeds are widespread (e.g. Awassi sheep, which are found in at least six countries in the region), or are increasing as a result of a growing demand (Tibbo *et al*., 2008b). Over 70 percent of the sheep breeds in the region are fat-tailed, an adaptation that allows them to cope with fluctuations in feed availability (Tibbo *et al*., 2008a). They deposit fat in the tail during periods of feed abundance and mobilize the fat deposits during periods of scarcity. The Shami/Damascus goats from Syria are highly sought after by breeders in North Africa (Tibbo *et al*., 2008b).

Many local breeds are at risk, for a variety of reasons. Some fat-tailed sheep breeds are becoming inbred, for example the Chal, Moghani, Sanjabi and Zel in Iran. Others are in even greater danger. In Turkey, only a few Güneykaraman and Gökçeada sheep remain and the Ödemis is close to extinction (Tibbo *et al*., 2008a). Indigenous goat breeds are under threat because of indiscriminate crossbreeding (e.g. Jabali or mountain goats in Lebanon and Zaraibi goats in Egypt) or small population size (Dihewi, Norduz, Gürcü and Abaza) (Tibbo *et al*., 2008a). Goat meat and milk, in general, are less popular than sheep products; and goat farmers lack the institutional support (e.g. cooperatives) to compensate for this disadvantage (Tibbo *et al*., 2008a).

The FAO (2009c) states that because of a lack of recognition of the multiple contributions of smallholder farmers and pastoralists, policies commonly promote large-scale production to the disadvantage of smallholders and pastoralists. Settlement policies force pastoralists to give up nomadic lifestyles, with negative consequences for their breeds and their environments. Moreover, regulations intended to protect consumers and prevent the spread of diseases put additional responsibilities on smallholder farmers and pastoralists, making it difficult for them to continue using and maintaining their breeds (FAO, 2009c).

Changes in livestock production systems

The population of the Near East has more than doubled in 30 years (Figure 1) reaching 439 million people in 2010 and it is expected to reach 677 million in 2050 (FAOSTAT, 2011). Rosegrant *et al*. (2001) projected that the demand for meat in the WANA region will grow from 7.1 million tonne in 1997 to 13.0 million tonne in 2020. These increases in both human and livestock populations will put increasing pressure on production systems in the Near East.

Herrero *et al*. (2009) studied changes in mixed crop-livestock production systems, one of the predominant forms of agriculture in the developing world. They mapped the projected distribution of livestock production systems over space and time, and the dispersal of people and livestock within these systems. For this purpose they used a simplified classification of the livestock production system map (Kruska *et al.*, 2003) based on the potential for intensification. The simplification divided the classification into four classes, – agro-pastoral and grassland systems, extensively managed mixed crop-livestock systems, mixed crop-livestock systems with potential to intensify the productivity of the system and others.

Table 3 and Table 4 summarize some of these results for the WANA region[3]. Table 3 shows that the two mixed systems together occupy 10 percent of the land area, but contained 54 percent of the region's rural population in 2000 and are projected to contain 52% of the population by 2030 (Appendix B). Table 3 also shows that the population in the two mixed systems will increase by 60 percent by 2030, but will continue to occupy the same amount of land. In the region, a large number of people are found in the (agro-)pastoral areas and the populations in these fragile areas will increase significantly by almost 79 percent. Herrero *et al*. (2009) stress that the large population densities in these systems place, and will continue to exert, a very high pressure on agro-ecosystem services, notably on food production, water resources, biodiversity and others.

Table 3
Area and population by production system for the period 2000-2030

Production system	Population (million people)		Area (million km^2)	
	2000	**2030**	**2000**	**2030**
(Agro-)pastoral	135.4	241.8	10.6	10.6
Mixed extensive	45.4	62.1	0.6	0.6
Mixed potential to intensify	148.4	248.6	0.6	0.6
Other	31.2	45.3	0.2	0.2

Source: Herrero et al., 2009

According to Herrero *et al*. (2009) small ruminants are more numerous in agro-pastoral areas. The authors show that the growth rates in the numbers of small ruminant are higher than those for cattle under all scenarios, with the agro-pastoral systems having the highest rates of growth of all systems. The authors point out that the large increase in lamb production can be associated with the lower feed demands required to produce small ruminants, especially for resource constrained smallholders.

To deal with future increases in livestock production, an increasing productivity is required for all production systems – they have to make efficient use of the available inputs (Hoffmann, 2010). Pilling & Hoffmann (2011) state that there are three main ways of increasing agricultural production to meet projected increases in demand:

1) By bringing new land into agricultural production
2) By increasing the cropping intensity on existing agricultural lands
3) By increasing yields on existing agricultural lands.

Adoption of any one of these strategies will depend upon the local availability of land and water resources, the agro-ecological conditions and the technologies used for crop production, as well as infrastructure and institutional development.

[3] In this case, the WANA region comprises Afghanistan, Algeria, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya and Morocco

LU – Livestock unit. Camel 1.0; Cattle 0.7; Sheep/goat: 0.1

Table 3 shows that livestock production systems are not likely to expand by bringing new land into agricultural production. Kanamaru (2011) states that looking at the FAO data on arable land actually in use from the mid-1990s, it can be seen that Algeria and Iraq probably still have potential to expand their agricultural areas, while countries such as Yemen and Saudi Arabia currently are using all their potential arable land as they have expanded into marginal lands. Despite the fact that in some countries expansion is possible, the increase in livestock production will need to take place by increasing yield and not by increasing the stock numbers as has happened in the past (Table 2).

Table 4
Livestock production by production system for the period 2000-2030

Production system	Livestock production					
	2000	2030	2000	2030	2000	2030
Cattle	LU (million)		Beef (million tonne)		Milk (million tonne)	
(Agro-)pastoral	5.6	7.1	0.83	1.51	14.65	25.84
Mixed extensive	2.0	2.1	0.27	0.43	4.59	6.77
Mixed potential to intensify	3.2	4.0	0.53	1.02	5.86	9.95
Other	0.6	0.7	0.11	0.20	1.30	2.14
Small ruminants	LU (million)		Lamb (million tonne)		Milk (Million tonne)	
(Agro-)pastoral	53.2	78.8	1.21	2.39	-	-
Mixed extensive	10.4	14.8	0.28	0.47	-	-
Mixed potential to intensify	11.2	16.4	0.28	0.54	-	-
Other	2.2	3.1	0.07	0.12	-	-

Source: Herero et al., 2009

Constraints and opportunities

As has been mentioned, livestock is a significant contributor to GHG emissions. However, livestock is also a large contributor to agricultural GDP and many livelihoods depend on livestock in the Near East. Moreover, different livestock production systems have their specific environmental effects and not all systems contribute to the same problems or to the same extent. Therefore, in trying to address climate change, it is crucial to link technologies and policies to specific livestock production systems. In the following paragraphs a brief summary is given of the constraints and opportunities of the main livestock production systems in the Near East.

Agro-pastoral production systems

Pastoral and agro-pastoral production systems are almost exclusively based on livestock production, with little or no integration with crops. They are based mainly on native pastures and rangelands (Dixon *et al*., 2001). Livestock breeds traditionally kept in these systems tend to be well adapted to the harsh conditions (FAO, 2009a). Hazell *et al*. (2001) describe how traditional risk management strategies have proved to be effective in coping with drought and have enabled pastoral societies to survive harsh environments for many centuries. The interplay between drought and traditional management systems has helped to keep total flock sizes in equilibrium with the inherent productivity of the pastures, and so avoided the long-term degradation of grazing areas. Stocking rates would trend upwards between droughts as herders bred more animals, but then would fall when the next drought occurred. Fluctuations in herd size closely followed precipitation patterns, and peak stocking rates rarely reached unsustainable levels.

In terms of total production, the agro-pastoral systems supply 57 percent of the regional meat production and provide a source of income for 135 million pastoral families (Herrero *et al*., 2009). Land use and production systems involving pastoralism can be effective and efficient ways of harnessing the natural resources of the world's dry lands (Dixon *et al*., 2001). Traditional management and mobile grazing strategies, which make efficient use of fluctuating grazing resources, are often abandoned because of restricted access to natural resources, expansion of croplands, population pressure and inappropriate development and land tenure policies (FAO, 2009a).

Intensification of livestock production systems in (agro-)pastoral areas is technically inefficient in terms of the water and feed resources consumed, compared with what could be obtained from direct consumption of crop products (Turral *et al*., 2011). Moreover, technical measures to improve productivity are usually very difficult to implement (FAO, 2009a). The key issues in these systems that need to be addressed, such as access to pastures and water, are often policy or institutional ones (FAO, 2009a). Pastoral communities, however, are often socially and politically marginalized. Their livelihoods are undermined by inappropriate policies and laws and by pressures on their resources from more politically powerful bodies and other competitors. This results in a shift from pastoral to agro-pastoral systems and the pushing of pastoralists towards more marginal areas (Dixon *et al*., 2001).

Increased efforts are needed to develop effective risk management options that help pastoralists to anticipate and cope with a wide range of shocks, and thus enhance their resilience (Ouma *et al*., 2011). Growing emphasis is being placed on alternative livestock functions, such as the provision of environmental services and landscape management (FAO, 2009a).

Mixed crop-livestock production systems

Mixed systems are defined as production systems conducted by households or enterprises where crop cultivation and livestock rearing are more or less integrated components of one single production system (Dixon *et al*., 2001). In mixed crop-livestock production systems, livestock are generally kept for multiple purposes, with the supply of inputs to crop production being an important role. Resource use in mixed farming is often highly self-reliant as nutrients and energy flow from crops to livestock and back. This self-reliance is increasingly under pressure. Technical developments, such as the introduction of mechanized cultivation and the use of mineral fertilizers, tend to narrow the range of services provided by livestock (FAO, 2009a). These production systems contain the largest numbers of rural people, a considerable number of whom depend to some extent on livestock (Herrero *et al*., 2009).

In many regions of the world, farm sizes in these systems are shrinking because of population pressure, urban encroachment and subdivision among heirs (Dixon *et al*., 2001). Where access to markets, income sources and inputs are lacking and population is increasing, mixed systems can be threatened by the severe depletion of soil nutrients and degradation of natural resources (FAO, 2009a). If accompanied by an opening up of market opportunities, crop-livestock systems may separate into specialized crop or livestock activities and new investment opportunities can be directed towards improved, more sustainable land use management systems/techniques. Without incentives for change towards more sustainable land use forms, however, as is the case in many developing countries, intensification will lead to increased rates of nutrient depletion and soil erosion in the arable part of the system (McDermott *et al*., 2010).

Landless production systems

Landless systems are typically found in periurban and urban settings, typically focusing on horticultural and livestock production (Dixon *et al*., 2001). Landless industrial systems are characterized by large, vertically integrated production units in which feed, genetics and health inputs are combined in controlled environments. In the Near East these systems can be found in Bahrain, Kuwait and the UAE. Industrial livestock systems in these countries generate large concentrations of nutrient wastes and GHG emissions.

Apart from industrial systems, more and more small-scale urban and periurban livestock production systems are found in the region. This refers to small areas within the city used for growing crops, mainly vegetables, and raising livestock (small ruminants, dairy cows or buffaloes and poultry) for household consumption or for sale to neighbouring communities or markets. It includes production, processing and distribution activities (Zaroug, 2011). However, information on the extent of urban and periurban livestock production in the region is limited (Zaroug, 2011).

Households with different income and employment backgrounds engage in urban and periurban livestock production. Poor households are involved in livestock rearing with limited alternative livelihood options and food insecurity. For those with other jobs, urban livestock production provides additional income and an opportunity to diversify livelihood activities. A range of products (milk, milk products, eggs, poultry, and fattened animals) are made available to neighbouring communities and urban markets (Zaroug, 2011).

Urban and periurban dairy holdings are the main suppliers of milk to urban populations. Some contribute fattened animals for slaughter in addition. Demand for milk products encourages some pastoral flock owners to stay near the towns for most of the year, only moving to the range when grazing is available (opportunistic grazing). When producer handle their production and deal directly with consumers in the same neighbourhood they are likely to save energy as they do not need mechanical transport or refrigerated storage (Zaroug, 2011).

Urban and periurban livestock production activities (dairy, fattening, broilers, layers and small-scale mixed farming) are common and some large-scale units are very advanced (i.e. Lebanon) (Zaroug, 2011). In most cases, smallholder producers suffer from limited services and urban and periurban producers rarely receive government support services (Zaroug, 2011). In these production systems, large quantities of manure are produced, often causing contamination of the soil and scarce water sources. Air pollution is also associated with these industrial systems (Al-Aboudi, 2011). The close integration with the human population can affect human health.

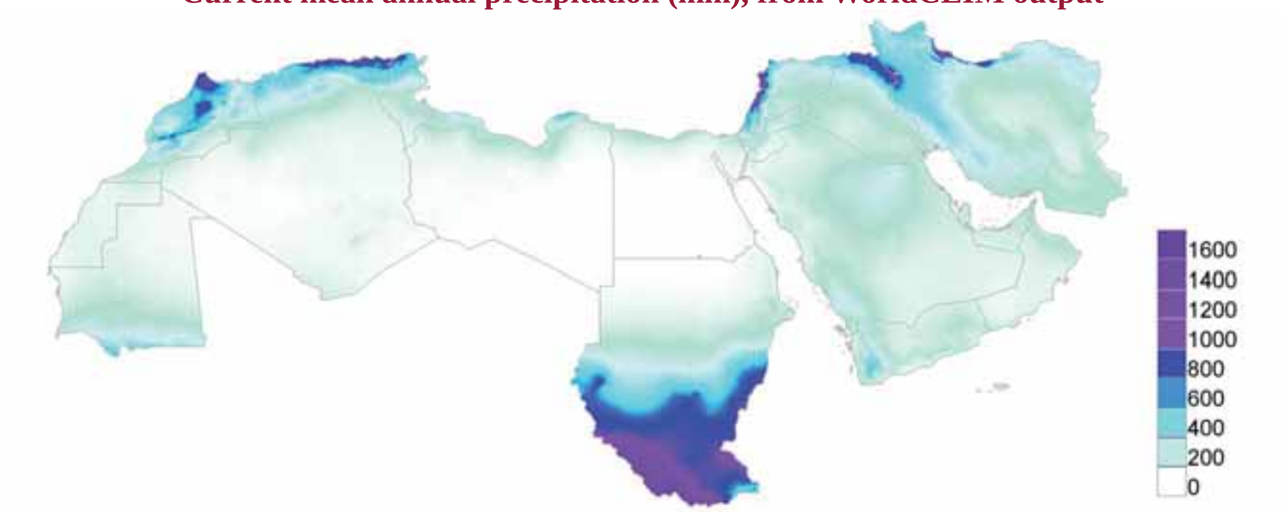
3. Climate change in the Near East

The Near East is characterized by hyper-arid, arid, semi-arid and dry sub-humid lands (Le Houérou, 1997). To identify the spatial allocations of the different climatic zones, we used raster layers at a resolution of 30 arc-second, from WorldCLIM (Hijmans *et al.*, 2005) to generate current climatic layers for the Near East. The data represent climate conditions for the year 2000.

The annual precipitation is shown in Figure 3. Three-quarters of the arable land receives less than 400 mm of annual precipitation and the natural grazing areas less than 200 mm (Le Houérou, 1997). Some regions, however, receive considerably more precipitation than others, resulting in the mixed systems of Morocco, Algeria, Tunis, Lebanon, Syria, Iraq and Iran.

In the Near East, precipitation variability is extremely large. Van de Steeg *et al*. (2009) stress that an underlying and fundamental characteristic of rainfed agriculture that cannot be ignored is the current precipitation variability, both within and between seasons, and the inevitable uncertainty that it imposes on agriculture. Over generations, and especially in the more arid environments where precipitation variability has the greatest impact on livelihoods, farmers and pastoralists have developed coping strategies to buffer against the uncertainties induced by season-to-season variation in water supply and the socio-economic drivers which affect their lives.

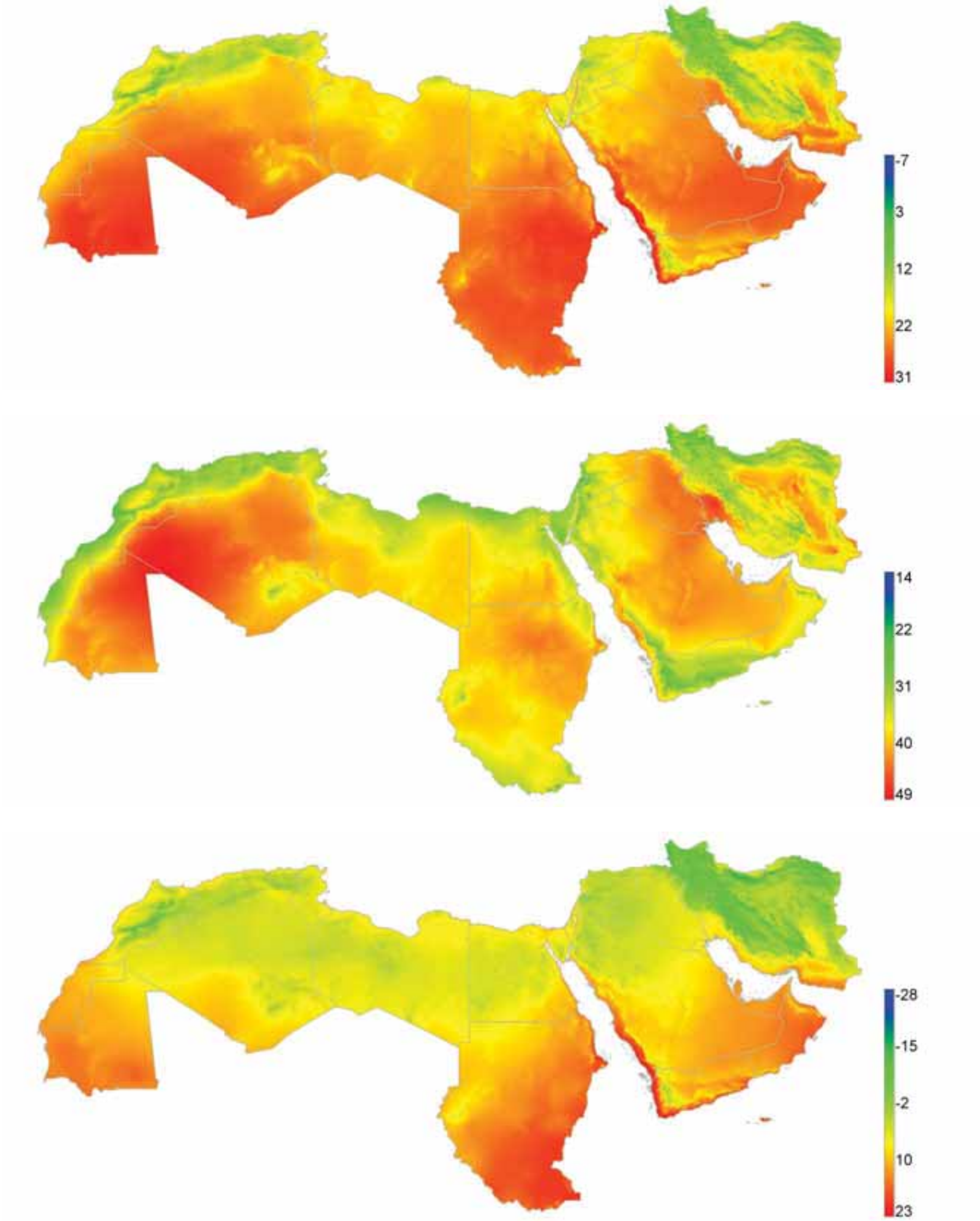
Figure 3
Current mean annual precipitation (mm), from WorldCLIM output



Source: Hijmans *et al*., 2005

Figure 4 shows the large variations in mean temperatures in the region; the mean temperature varying with the elevation. Moreover, the Figure clearly shows the large difference between the minimum and maximum temperatures for specific areas, especially for the arid regions.

Figure 4
Current temperature conditions (°C)



From top to bottom the maps show the mean average monthly temperature, the maximum temperature of the warmest month, and the minimum temperature of the coldest month.

Source: Hijmans *et al*., 2005

Drought is a complex phenomenon that has caused more deaths during the last century than any other natural disaster (FAO/NDMC, 2008). The frequency of droughts in the region is highly variable from location to location and each drought is unique in its intensity, duration and spatial extent. An event may persist for a few months, for several years or, for some locations, for a decade or more, affecting millions of people and many different sectors (FAO/NDMC, 2008).

Past evidence of changes in climate and their effects

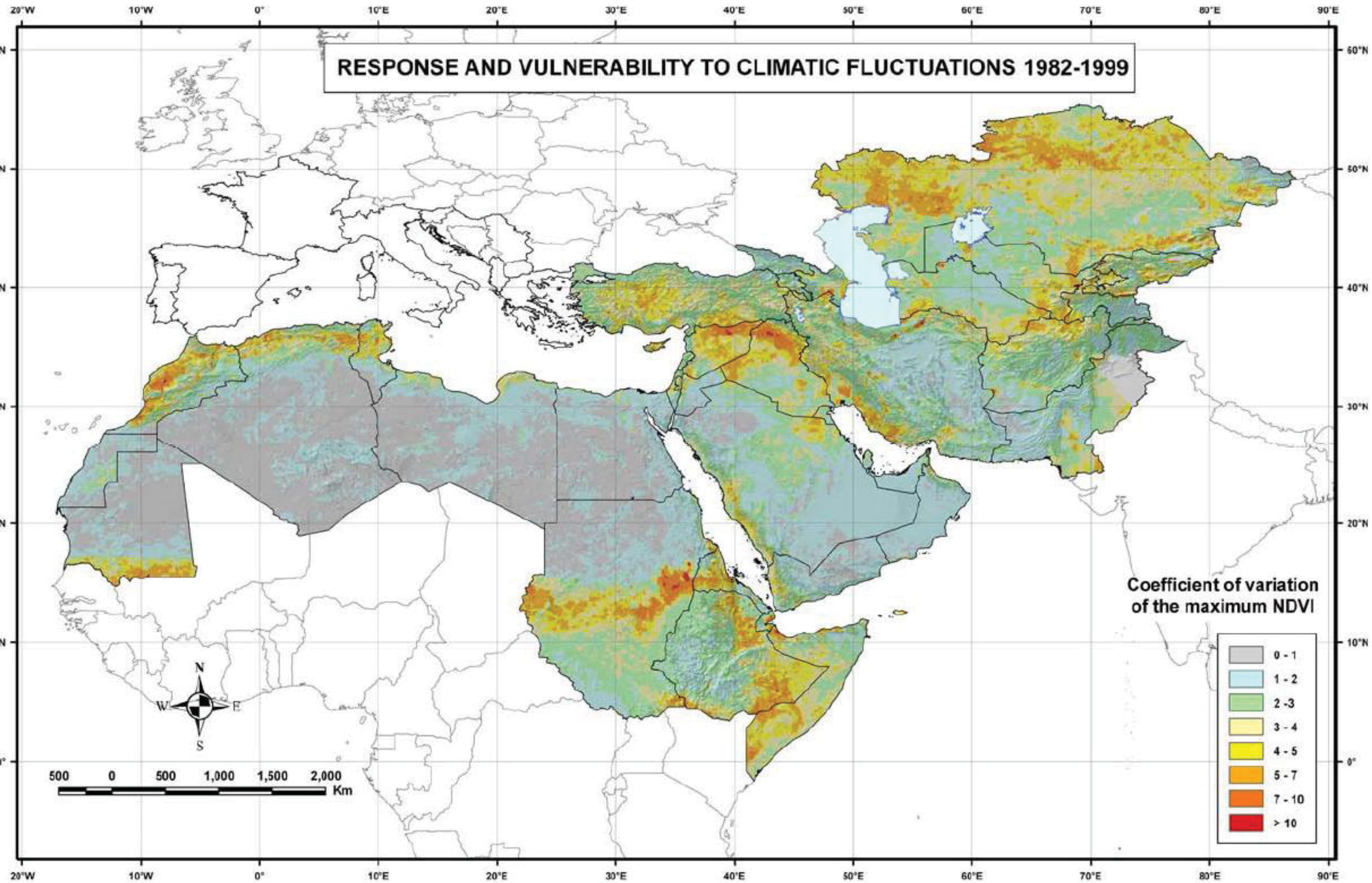
The expected additional stresses from climate change will increase the already evident vulnerability to climatic fluctuation in most of the region. An analysis of the coefficient of variation of the maximum normalized difference vegetation index (NDVI) for the period 1982-2000 in Central, West Asia and North Africa (CWANA) shows that there is already ample evidence of hotspots of response and vulnerability to climatic fluctuations in the region (Celis *et al*., 2007; De Pauw, 2008).

The analysis was based on NDVI, which is a numerical measure of the extent of live green vegetation in an area. Celis *et al*. (2007) produced a raster data set with monthly variation in NDVI. Hot spot analyses were based on the maximum NDVI, which is a spectral measure of peak above-ground biomass, i.e. crops plus natural vegetation. At any given location, changes in maximum NDVI can be the result of changes in land use (e.g. conversion of pastures into crop fields) or to climatic variability. In order to focus on the effects of climatic variability alone, they considered pixels with stable land cover over the period 1982-2000 and then applied a simple statistical measure – the coefficient of variation – which measures the degree of fluctuation in any parameter. The map (Figure 5) shows the coefficients of variation of the maximum NDVI for the period 1982-1999, for the whole CWANA region. The red and orange areas have the highest coefficients of variation, i.e. the largest year-to-year fluctuations in total biomass. This fluctuation is a consequence of current climatic variability, not future climate change.

Places where climate variability is high have to deal with erratic precipitation and a fragile water supply. All these areas are currently characterized by multiple stresses that include severe droughts, degradation of land, water and vegetation resources, and sometimes famines (De Pauw, 2008). Climate change will lead to greater climate variability and the effects of droughts will be more severe. De Pauw (2008) highlights several current hot spots in the Near East:

- The Fertile Crescent, including Jordan, Syria, Iraq and southern Iran
- North Africa, from Morocco into Tunisia
- The Sahel, covering Mauritania for this report.

Figure 5
Response and vulnerability to climatic fluctuations 1982-1999



Source: Celis *et al.*, 2007

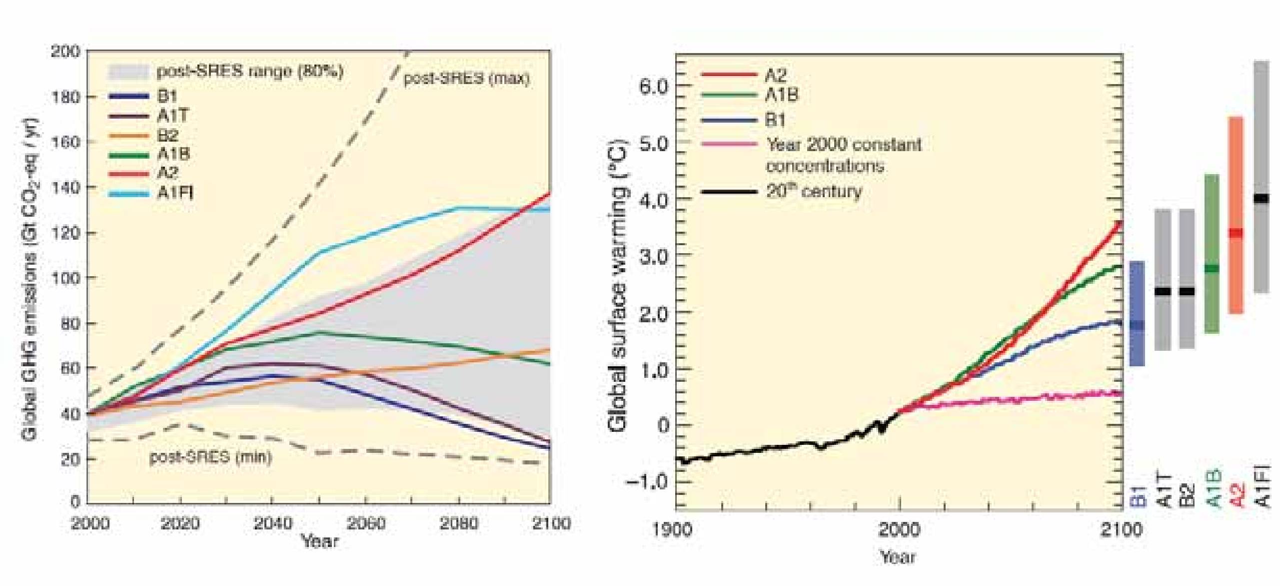
Climate change projections and vulnerability

The IPCC adopted a standard set of scenarios (IPCC, 2001), based on four main storylines (A1, A2, B1 and B2), to enable comparisons to be made between different predictions and scenarios. These scenarios illustrate possible emission trends under a wide range of economic, social and technical assumptions, for the period 2000-2100. Uncertainties in climate projections make it harder to predict the consequences, thus making it even more difficult to develop appropriate and effective adaptation and mitigation strategies. More probable outcomes are obtained from a range of scenarios run through an ensemble of general circulation models (GCMs), so that the different results obtained from individual models (with different algorithms and structures) are 'averaged' (IPPC, 2007).

As Turral *et al* (2011) summarized, future projections of temperatures vary from significant to slight increases for different scenarios (Figure), but with a high likelihood of occurrence, and good consistency between models. By comparison, the predictions of precipitation are far less consistent, with some models predicting increases in precipitation while others predict decreases for the same scenario (IPPC, 2007). Most GCMs agree on a projected decrease in precipitation over much of North Africa and the northern Arabian Peninsula. Projections of precipitation over the areas immediately south of these regions carry large uncertainties (Kanamaru, 2011).

Figure 6

The range of scenario predictions for GHG emissions (right) and global warming (left)

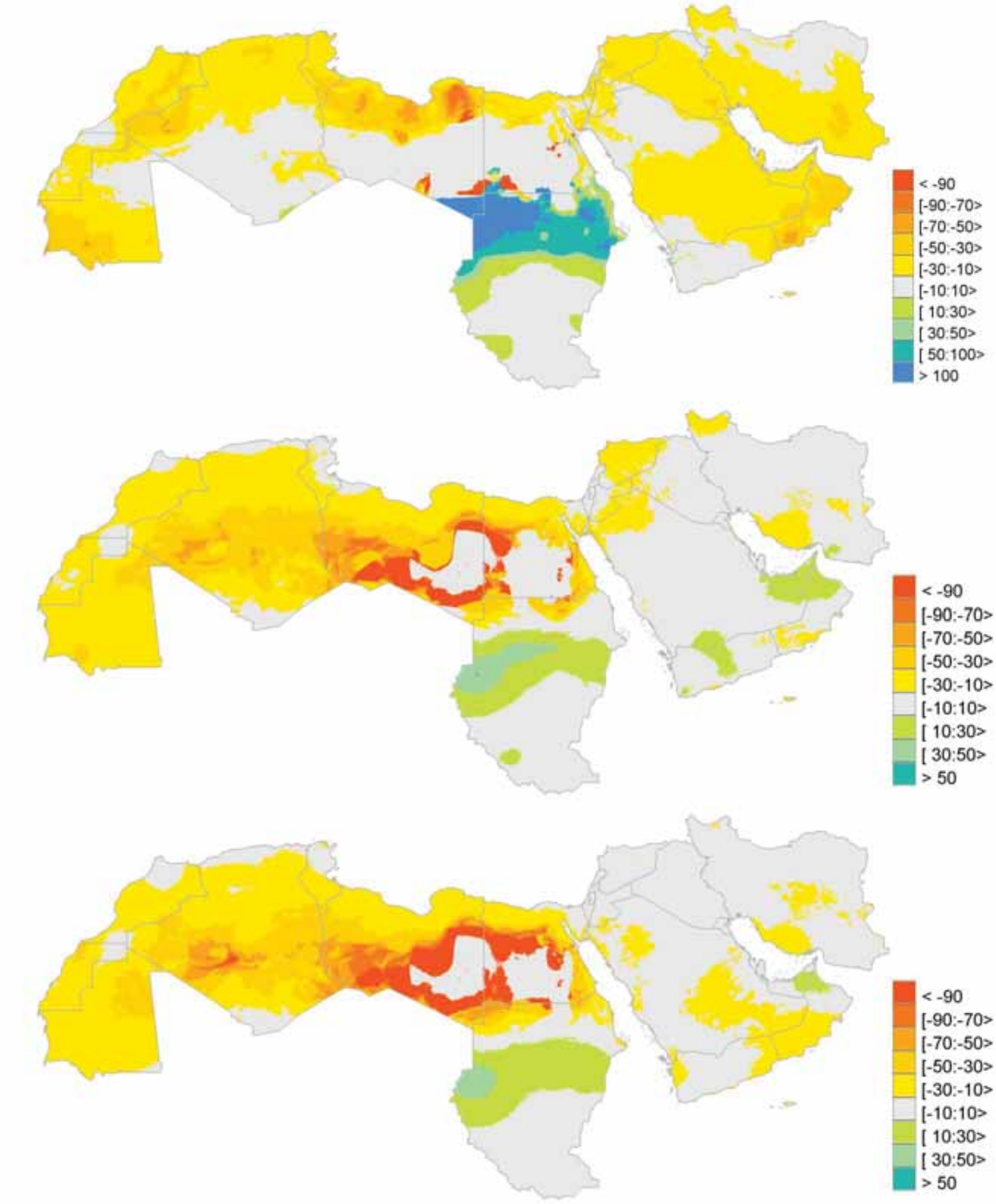


Source: IPCC, 2007

In order to determine the impact of climate change in the Near East, we compared the current distribution of climates developed by Hijmans *et al*. (2005), with the future (2050) distribution of climates determined from statistical downscaled data using Climgen (CIAT, 2011). Appendix E gives an overview of current and projected climatic data for different livestock production systems by country.

Figure 7

The percent change in mean annual precipitation between 2000 and 2050



From top to bottom the maps show scenario A1b, A2a, B2a and GCM HadCM3

Figure shows the percent change for mean annual precipitation, between 2000 and 2050, for three different scenarios, which represent the range of scenario predictions (Figure). The Figure is generated based on Climgen data (CIAT, 2011). All scenarios show a decrease in precipitation for most of the region, but with considerable differences between the scenarios. Kanamaru (2011) summarizes that the likelihood of a decreased rainfall is greater as the Mediterranean coast is approached. The number of precipitation days in a year is very likely to decrease in the Mediterranean area.

By 2050, all countries will experience reduced precipitation amounts, but regional variation is large. There is a large projected variation between and within countries, as well between the models. Appendix E provides more data on the average precipitation for different livestock production systems by country. One should keep in mind that these projections will only give an indication of how precipitation patterns will evolve in the future.

Figure gives an example of the changes in temperature between 2000 and 2050; in this case, the percent change for the minimum temperature of the coldest month for three different scenarios. To highlight the differences in temperature, the data are presented in five classes – ≥ 0 and < 1, ≥ 1 - < 2, ≥ 2 - < 3, ≥ 3 - < 4 and ≥4 ºC increases in temperature. The Figure is based on Climgen data (CIAT, 2011). Appendix E provides more data on the increase in temperature for different livestock production systems by country.

Kanamaru (2011) determines that there is an observed long-term (since 1900) decreasing trend in precipitation in the Mediterranean and that this general trend is supported by a number of individual studies in the region. The rest of the region is very dry and has insufficient data to establish past trends. Generally speaking, increased precipitation is very likely in high latitudes, while decreases are likely in most subtropical land regions. This is in line with observed patterns in recent trends.

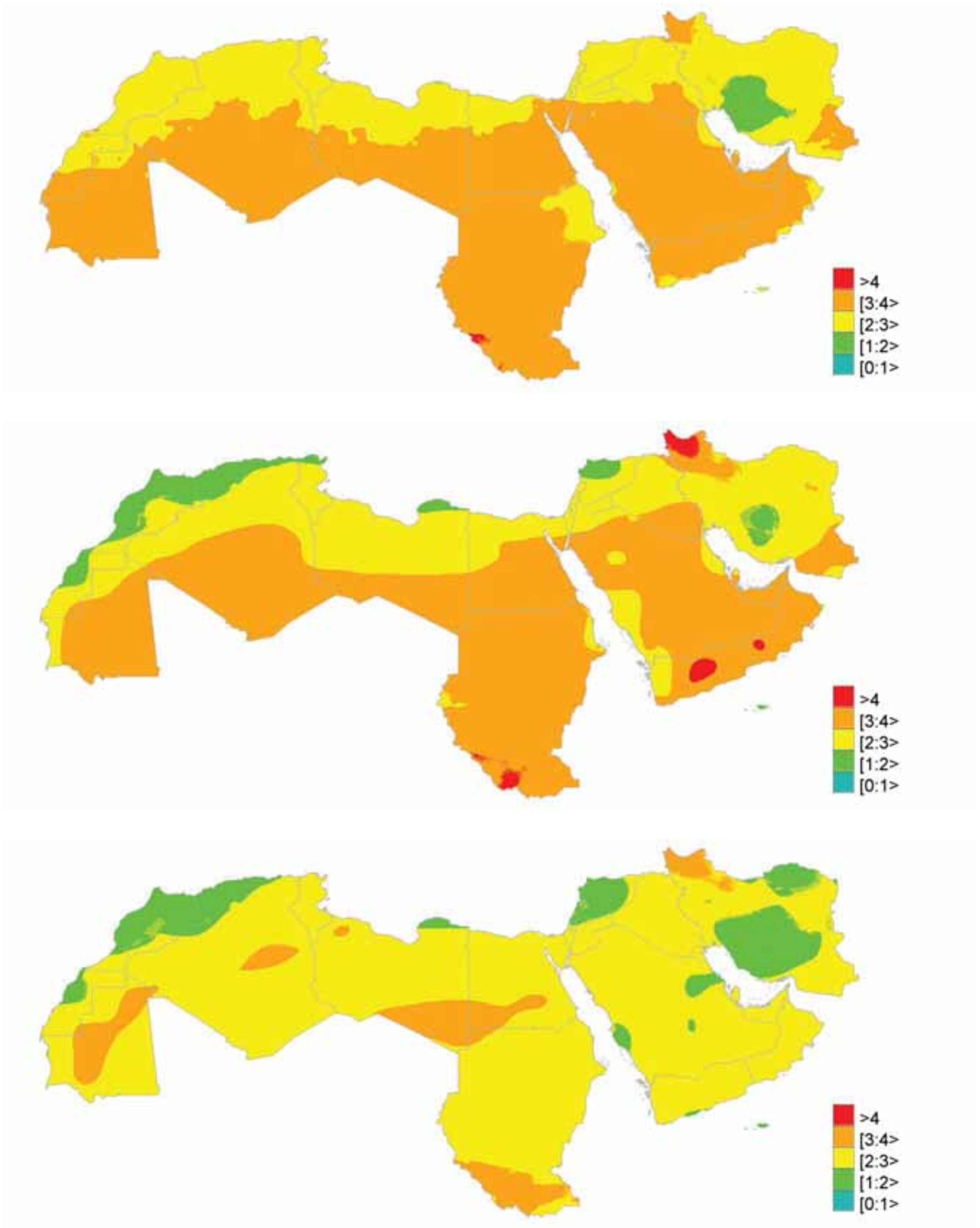
The FAO (2010) summarizes climate change projections for the Near East. They state that some parts of Northern Africa and some parts of the Middle East will experience reduced precipitation amounts – from 20 to 25 percent less than the present mean values. The precipitation projections of Climgen (CIAT, 2011) confirm these reductions. Under scenario A1b, reductions in rainfall increase by 30 percent for Oman and 37 percent for Mauritania. Giannakopoulos *et al*. (2005) state that the Mediterranean will experience precipitation reductions all year round in North Africa and the Levant, with substantial decreases in the summer and more intense and strong rainfall events.

The FAO (2010) states that temperatures are projected to rise between 2 and 2.75 ºC inland and about 1.5 ºC in coastal areas. The warming will be higher inland than along the coast (Giannakopoulos *et al*., 2005). The latest Climgen (CIAT, 2011) temperature projections to 2050 indicate that increases in temperature are more likely to be higher, with an average increase of 2.4 ºC. Regional variation is high. In the coastal areas the increase can be as low as 1.3 ºC, while moving inland the increase can be up to 3.6 ºC. Regionally, there is likely to be an increase in the frequency of hot extremes, heat waves, heavy precipitation and droughts. In contrast, there will be fewer cold days and nights (Kanamarua, 2011).

The widespread and severe droughts in the Near East region at the turn of the twenty-first century caused a broad range of significant effects on people, their livelihoods and the environment. The current trend of reduced precipitation is likely to continue in the south and central parts of the Near East region throughout the twenty-first century. The effects on agriculture and ground water availability follow the same overall geographic pattern (FAO/NDMC, 2008).

Figure 8

The change in the minimum temperature of the coldest month (°C) between 2000 and 2050



From top to bottom the maps show scenario A1b, A2a, B2a and GCM HadCM3

The FAO/NDMC (2008) concludes that drought is a recurrent feature throughout the Near East region, which has significant consequences across a broad range of environmental and social sectors. Both the occurrence and effects of drought could change in the near future because of climate shifts and changing vulnerabilities brought about by growing populations and user groups competing over limited water resources. In order to reduce the threats associated with current and future droughts in the region, it is essential to gain a better understanding of the drought hazard and implement risk reduction actions at the local, national and regional levels.

Hotspots of climate change and impacts on livestock

The FAO (2008) indicated several vulnerable sectors for the countries of the Near East region and the possible effects of climate change. As mentioned, large parts of the region are vulnerable to natural hazards, such as droughts and floods. An overall decrease in precipitation will add additional stress to already scarce water resources, for example in Jordan, Lebanon, Mauritania, Qatar, Saudi Arabia and Tunisia. Extreme events, such as droughts and floods, are likely to become worse. The FAO (2008) indicated a likely reduction in crop productivity and increased water requirements for Egypt. Climate change will shorten the length of the growth period and the number of freezing days, which will affect crop production among others issues in Iran. In Lebanon and Libya, for example, a reduction in precipitation will shift arable land into more arid rangelands. The degradation of arable land will lead to the loss of livestock.

Thornton *et al*. (2009b) provide an overview on the effects of climate change on livestock and livestock production systems. The authors' conclusions are that climate change is expected to directly affect the quantity and quality of available feeds, heat stress, available water, livestock diseases and disease vectors and genetic diversity. Seguin (2008) forecasted a loss of 25 percent in animal production in livestock based mixed crop-livestock systems in developing countries as a consequence of climate change. The loss will result mainly from heat stress and the reduction in feed resources.

The mapping and quantifying of climate data in combination with spatial information on livestock production systems, livestock numbers and people can assist in the identification of hotspots of change and vulnerability. It can also help to determine where the greatest opportunities exist to adapt and mitigate and to see which type of intervention strategy is suitable under the prevailing circumstances.

The previous section shows that all over the region a significant increase in temperature is projected, and in most areas a decline in annual precipitation. To determine hotspots of vulnerability, we identify those areas where most people and livestock will be affected. We present the results grouped by livestock production system, as adaption and mitigation options often will relate to these production systems.

Agro-pastoral production systems

Rangeland-based systems in the arid zones are the predominant livestock production system in most of the countries in the Near East. Turral *et al*. (2011) point out that in the semi-arid and arid rangelands, increased temperatures coupled with decreased and more variable precipitation will result in their abandonment, as productivity will fall off as a result of a decline in available moisture and drought more prominent. Existing cycles of natural resource degradation (declining rangeland quality, increased soil erosion, decreased livestock water availability and declining groundwater recharge) most likely will be exacerbated in the semi-arid rangelands. Small changes in vegetation cover can significantly affect the organic carbon dynamics and storage in the rangeland ecosystem.

Precipitation is projected to decrease in most of these areas. In North Africa (Morocco, Tunisia and Algeria) a decline in precipitation is projected varying from 11 to 28 percent, while the mean temperature will increase between 2.2 and 3.3 ºC. Besides being the predominant production systems, between 15 and 23 percent of the rural population live in these areas. Moreover, these areas are important grazing areas for small ruminants, especially in Tunisia, where 35 percent of all small ruminants graze in these systems, and Algeria, where and the figure is 3 percent.

In the Fertile Crescent a reduction in precipitation is projected to vary from 1 to about 20 percent in these production systems, and the temperature is projected to increase from 2.3 to 3.1 ºC. These production systems are important for small ruminants, especially in Iran – 45 percent reside in these areas. In Jordan, Iraq and Syria this number varies between 35 and 25 percent. Cattle are also kept in these areas – 15 percent of the total cattle population of Syria and Jordan, and 31 percent of that of Iran and Iraq. In Iran 29 percent of the rural population lives in these areas, while in Iraq the figure is 35 percent. In Jordan the figure is only 22 percent and in Syria it is just 8 percent.

There is a large difference between the projected precipitations for the Arabian Peninsula. Where in some areas an increase of up to 7 percent in annual precipitation is projected under one scenario, a decrease of 24 percent is projected under another. The various scenarios are consistent with the projections for temperature. An increase in annual temperature of between 2.2 and 2.9 ºC is projected. The vast majority of rural people live in these areas. And, especially in Yemen, Oman and Qatar, these areas are of major importance for small ruminants as more than 90 percent of all sheep, goats and cattle dwell in the pastoral areas. In Kuwait and the UAE, almost half of the total population of animals is kept in periurban areas. However, the remaining livestock population resides in these arid zones.

In Egypt and Libya large regions are classified as rangeland-based systems in the arid and hyper-arid zones. Both areas will experience a reduction in precipitation, and the temperature is projected to increase by from 2.3 to 2.8 ºC. In Libya 87 percent of all small ruminants and 79 percent of all cattle occur in these areas, while in Egypt the figures are just 47 percent for small ruminants and 13 percent for cattle. In Libya, 88 percent of the rural population lives in these agro-pastoral areas, while in Egypt it is only 22 percent.

Mixed irrigated production systems

Although limited in extent, these production systems are extremely important to crop production. In Egypt, these systems contain 41 percent of the total cattle population and 24 percent of small ruminants. Moreover, 71 percent of the rural population lives in these systems. The precipitation projections for these areas are extremely variable; the projected decrease in rainfall ranging from 5 to 84 percent. As these are irrigated systems, the increase in projected temperature is far more important; this is projected to vary between 2 and 2.8 ºC.

Mixed irrigated systems are, as well, extremely important in the Fertile Crescent. Here precipitation is projected to decrease by up to 20 percent and the mean annual temperature will increase between 1.5 and 3.2 ºC. From 18 to 35 percent of the rural population reside here, with from 11 to 18 percent of the small ruminants and 16 to 28 percent of the total cattle numbers.

In Algeria these areas represent 3 percent of the total and in Tunisia, 12 percent. In these countries the annual precipitation is projected to decline between 7 and 22 percent, while temperatures are forecast to increase from 1.7 to 3.6 ºC. In Algeria, however, these areas only contain 5 percent of the rural population, 3 percent of the cattle population and 2 percent of the small ruminant population. In Tunisia, these areas hold 15 percent of the rural population, 13 percent of the cattle population and 7 percent of the small ruminant population.

Mixed extensive production systems

These production systems cover 8 percent of the area of the Near East, but there are large variations within countries. In Algeria 71 percent of the rural population inhabit these areas, in Tunisia 65 percent and Morocco. 70 percent, while in Mauritania the figure is only 16 percent. The cattle populations vary between 42 and 61 percent, while the small ruminant populations vary between 41 and 49 percent. In these countries in northern Africa, the annual precipitation is projected to decline; in Algeria and Tunisia between 9 to 23 percent, in Morocco between 8 and 26 percent and in Mauritania between 15 and 29 percent. Temperatures are projected to increase; for Algeria between 1.9 to 3.6 ºC, for Tunisia between 1.6 and 2.8 ºC, for Morocco between 1.6 and 3.3 ºC and for Mauritania between 2.3 and 3.2 ºC.

Mixed extensive systems are also extremely important in the Fertile Crescent. In Syria, the temperature is projected to increase between 1.7 and 3.2 ºC, while precipitation will decrease by between 1 and 18 percent. In Iran and Iraq the temperature will increase by from 2.5 to 3.3 ºC and precipitation will decline by between 3 and 14 percent. In Iran, Iraq and Syria between 43 to 47 percent of the rural population inhabit these systems. In Syria slightly more than half of the small ruminant and cattle populations reside in these areas. In Iran 39 percent of cattle and 35 percent of the small ruminants live in these systems, while for Iraq the respective figures are 29 and 50 percent.

Landless production systems

As described by Pilling & Hoffmann (2011) it is relatively easy in landless industrial production systems to introduce technical adaptations for rising temperatures (cooling systems or adjusting the animals' diets), as the animals are confined and the heavy use of external inputs is the norm. This may make such systems relatively insensitive to the local-scale effects of climate change. However, these systems are potentially vulnerable to the effects of climate change on feed prices, which could undermine the economic sustainability of the high external input strategies (Pilling & Hoffmann, 2011)

The small-scale (peri-)urban livestock production systems are of importance in Egypt, Lebanon and Jordan. For example, in Egypt 35 percent of the cattle and 27 percent of small ruminants are reared in periurban production systems (Appendices C and D). As poor households are involved in rearing livestock with limited support services, these systems are vulnerable to fluctuations in feed prices and access to water supplies. These systems quickly are becoming of more importance to many of the poor urban households, therefore it is essential to obtain more information on the actual extent of these systems.

4. Adaptation and mitigation of livestock production systems

'*Adaptation'* and *´mitigation'* are two fundamental concepts in the climate change debate. Adaptation to climate change refers to adjustments in natural or human systems, in response to actual or expected climatic stimuli or their effects, which moderate farm or exploit beneficial opportunities (IPCC, 2007). Mitigation refers to any anthropogenic intervention to reduce the sources or enhance the sinks of GHGs (IPCC, 2007). While mitigation deals with the causes of climate change, adaptation handles the effects of the phenomenon. Climate mitigation and adaptation should not be seen as alternatives to each other, but rather as a combined set of actions within a comprehensive strategy to reduce GHG emissions and cope with the adverse effects that will inevitably occur as a result of past and current trends in anthropogenic GHG concentrations.

Adaptation

Livestock producers have traditionally adapted to environmental and climate changes. McIntire (1991) notes that mixed species herds, widespread and seasonally available pastures, splitting animals into discrete herds and mobility in response to seasonal variations in pasture productivity are key strategies. Where the opportunities exist, working as wage labourers, trading commodities and growing crops are also common. Increased human population, urbanization, economic growth, growing consumption of foods of animal origin and commercialization have made those coping mechanisms less effective (Sidahmed *et al*., 2008). Livestock producers need new technologies, training and technical support to deal with climate change. Governments need to develop better policies and stronger institutions to manage natural resources sustainably.

The interactions of livestock with its environment are complex and depend on location and management practices. Most traditional livestock production systems are resource driven, making use of locally available resources with limited alternative uses. In mixed production systems, traditionally managed livestock often provide valuable inputs to crop production, ensuring a close integration (FAO, 2009d). The rising demand for livestock is changing the relationship between livestock and natural resources. There are a number of ways to increase the adaptive capacity of traditional producers in extensive systems, such production adjustments as diversification, intensification, integration of pasture management and conservation of nature and ecosystems (FAO, 2009d). As indicated by Stern (2006), adaptation should be an extension of good development practice and should reduce vulnerability by promoting growth and diversification of economic activities, investing in health and education, enhancing resilience to disasters and improving disaster management.

Integrated crop-livestock management
Livestock feed security is a major limitation to livestock production in semi-arid lands. Rangeland resources are often insufficient to meet the current demand when coupled with a fall in total feed resources because of overgrazing, ploughing of marginal land and soil erosion (Salem and Smith, 2008). The contribution of rangelands to the diets of small ruminants is decreasing. Moreover, as a result of overgrazing, severe cutting of trees and removal of vegetation valuable species are being replaced by less valuable species unpalatable to livestock (Rischkowsky *et al*., 2008).

Tieten & Jeltsch (2007) describe how more intense precipitation events, with no change in total precipitation quantity, can lead to lower and more variable soil water content. Additionally, higher temperatures are likely to increase water stress through increased potential evapotranspiration. As a consequence, above-ground net primary production is reduced. This reduction is accompanied by a decrease in the livestock carrying capacity, which can lead to overgrazing. Consequently, the livestock in the dry environments are facing serious nutrient shortages.

Climate directly affects the quality and quantity of forage that can be produced in a given area (Pilling & Hoffmann, 2011). They state that high temperatures tend to increase lignifications of plant tissues and hence decrease the digestibility of forage. It is also predicted that climate change will induce a shift from C3 to C4 grasses. C4 plants are more efficient in terms of photosynthesis and water use than C3 plants. The C3 forage plants generally have higher nutritive values, but lower yields, while C4 plants contain large amounts of low quality dry matter and have a higher carbon–nitrogen ratio (Pilling & Hoffmann, 2011). Fibrous forages reduce voluntary feed intake and can increase fermentative heat and the thermoregulatory demand for water (Nardone *et al*., 2010).

Animals often depend on low quality crop residues (e.g. straws, stubbles) and expensive feed supplements. Improved pasture management (e.g. restoring soil organic matter, reducing erosion, decreasing biomass losses resulting from burning and overgrazing) has positive environmental effects (soil carbon sequestration, biodiversity) and a favourable effect on livestock productivity (Smith *et al*., 2007). Technical solutions are available as well; for example the advantageous use of fodder trees, shrubs and cactus has been demonstrated (Salem and Smith, 2008). Conservation through ensiling and the use of feed blocks and pellets gives greater efficiency of use of a wide range of agro-industrial by-products. But their adoption has been slow, often because of a lack of knowledge of the farmers' problems and expectations (Salem and Smith, 2008).

Supplementary feeding
Supplementary feeding is needed for most of the year, especially if animals are being reared for market. In most marginal dry areas, rangelands provide only one-third of the feed that animals need (Tibbo *et al*., 2008b). The cultivation of drought tolerant crops is being practiced by many agro-pastoral communities; the effects of drought, increasing insecurity and famine have led to a growing emergence of crop cultivation. Rischkowsky *et al*. (2008) indicate that several shrubs and drought tolerant species have been introduced or used in the WANA region. This includes the widely known *Atriplex* and Acacia species and cactus. These plants have been found useful for rehabilitating the rangelands, either alone in alley cropping, or as ingredients of feed blocks.

Kitalyi *et al*. (2008) show the potential of tree forages to increase the growth performance of livestock subsisting on low quality forages in agro-pastoral systems and consequently contributing to food security and poverty reduction. However, there are large differences in the tannin concentrations of the different browse species. This is an area of high research priority as it will also support selection of the best bet fodder tree species for scaling up, particularly with the current association of tannins with enteric fermentation efficiency and its contribution to climate change mitigation.

Tibbo *et al*. (2008b) describe the development of low-cost option 'feed blocks'. The feed blocks contain multiple nutrients and are made from cheap, easily available agro-industrial by-products, such as tomato pulp, molasses, burghul derivatives, crude olive cake, sesame cake, citrus pulp, sunflower cake and mulberry leaves. Various combinations have been successfully tested on-farm in Syria, Iraq, Tunisia, Mexico and Central Asia. In one recipe, for example, part of the barley grain in the feed was replaced with molasses and urea. This was used in combination with urea-treated straw (rather than plain straw) for strategic supplementation, i.e. fed to ewes during critical periods in the production cycle. As a result, ewes mated earlier, gave birth at shorter intervals and their lambs were heavier at weaning.

Box 1
New feeding strategies for Awassi sheep

Livestock farmers face high and increasing feeding costs, particularly during the period of milk production. By using cheaper, unconventional ingredients in balanced diets this can be counterbalanced. A study on the use of cost optimized, supplemental diets was tested with Awassi ewes at ICARDA in Syria. While the traditional supplementary feed was based on barley grain, wheat bran and barley straw, the improved diets included other locally available feeds, like cotton seed cake, molasses, sugar beet pulp and ammoniated wheat straw. The study showed that the average daily milk production of Awassi ewes was higher with the improved diets than under the control diet. Moreover, the diets had a positive effect on cheese hardness and yoghurt firmness. The alternative diets, containing agro-by-products and ammoniated wheat straw, are options for resource-poor farmers in the Middle Eastern region by which they can increase their productivity and income without affecting the quality of the products.

Source: Hilali *et al*., 2010

Feed efficiency
Local ruminant breeds, with their relatively lower outputs and higher GHG emissions per kilogram of single food product, are considered unproductive. However, the productivity equation should take into account the multiple products and services provided by livestock in most smallholder and pastoral production systems. Moreover, when considering GHG emissions from enteric fermentation, one should not only take into account the gross efficiency of converting feed inputs to human food, but also the differences in the species' ability to use forages that cannot otherwise be used by humans. Gill & Smith (2008) propose using 'human edible return' as another indicator to assess livestock efficiency. This would favour the return of herbivore livestock species to forage-based feeding and land-based production systems and result in a different breed portfolio than the intensive production pathway.

Herd management
Many livestock farmers in the Near East use multi-species and multi-breed herds as a strategy to maintain high diversity in on-farm niches and to buffer against climatic and economic adversities (FAO, 2009a). Hoffmann (2010a) holds that such traditional diversification practices are useful for adaptation to climate change. Species substitution, because of climate and vegetation changes, has already been observed in the Sahel, where dromedaries have replaced cattle and goats have replaced sheep, following the droughts of the 1980s. In countries such as Niger and Mauritania, and in northern Nigeria, camel rearing is now a common activity. Unlike cattle and sheep, which largely feed on herbaceous vegetation, camels browse on shrubs and trees, while goats use both strata. The use of browsing species has several advantages; the browsing strata cannot easily be used by other species, it tends to offer green forage during the dry season and browsing is increasing in some environments as a result of overuse of the herbaceous layer.

During droughts, large losses of livestock occur because of the decline in feed availability and the significant price increases for feed. Herd management covers various strategies including herd diversity, maintenance of female dominated herds, large herd sizes and herd splitting (Lalani & Al-Zein, 2011). Pastoralists keep both grazing and browsing livestock species to optimize the use of the different rangeland resources and to ensure conservation of the rangeland ecosystem. By keeping more than one species of livestock, pastoralists can generate a wider variety of livestock products, use more of the available forage and different environmental niches and generate livestock products in different seasons. Lalani and Al-Zein (2011) give an example of flock management intervention as an important area of endeavour for finding alternative ways to feed animals during periods of drought and to introduce best practices in the weaning techniques for sheep in Syria.

Pastoral communities are known to maximize stock numbers to ensure the long-term survival of herds despite losses suffered during droughts and disease outbreaks. Splitting household livestock herds into smaller manageable groups and moving them into different areas is used to prevent overgrazing and maintain the long-term productivity of rangelands (Nyariki *et al*., 2002).

Box 2

Herd replacement and mobility in Mauritania

After severe droughts during the 1970s and 1980s, the population of Mauritania strengthened their community management tools and developed new strategies for the use of their natural resources. Encouraging mobility was a strategic reaction to the variability and scarcity of pastures. As a result of this mobility, the nomads adapted their production to the difficult eco-climatic situations and developed a natural resource management system implemented by consensus and pastoral solidarity, as well shared responsibility. The primary adaptation was the replacement of herds by goats because of their capacity for adaptation and their reduced food requirements, with the addition of some camelids and cows.

Source: Khattry Ould Attigh, 2011

Mobility

Morton (2007) affirms that mobility remains the most important pastoralist adaptation to spatial and temporal variations in precipitation. In drought years many communities make use of fall-back grazing areas unused in 'normal' dry seasons because of distance, land tenure constraints, animal disease problems or conflict. Climate change will lead to more scarcity and greater variability, so mobility will become more important than ever. However, encroachment on, and individuation of, communal grazing lands and the desire to settle to access human services and food aid have severely limited pastoral mobility. As many pastoral communities are becoming less mobile, they become more vulnerable to the effects of climate change (Dutilly-Diane, 2008; Morton, 2007).

Pilling and Hoffmann (2011) mention that, because of climate change, livestock may be required to walk longer distances in search of feed and have to cope with less frequent watering. The movement of livestock populations out of drought affected areas can lead to problems of overgrazing in neighbouring areas, as well to problems with diseases and parasites as the animals crowd together or move into areas where unfamiliar diseases are endemic (Pilling and Hoffmann, 2011).

Production and marketing strategies

Production and market interventions seek to generate food and/or income, and ultimately give rise to sustainable livelihoods in a changing environment. The promotion of livestock products to serve certain niche markets is a strategy that holds much promise, although market opportunities vary by region and livestock sector (LPP *et al*., 2010). Mc Dermott *et al*. (2010) describe a number of challenges that need to be overcome in order to enhance market success. These challenges include such technical inputs as feed. The organizational link between farm and market and the overall investments in infrastructure are weak as well. Rischkowsky *et al*. (2008) discuss issues of product quality and safety; both are becoming so important that they may limit smallholders' access to markets. To supply demand and effectively respond to export market requirements, small-scale producers need to deal with health-related trade restrictions for small ruminants, poor market infrastructure and a lack of information about export markets and polices (Aw-Hassan *et al*., 2005).

McDermott *et al*. (2010) describe how most smallholder producers sell their livestock products to low-income consumers through informal markets. Increasing urbanization and rising incomes, however, are increasing the length and complexity of livestock value chains and the quality and safety standards demanded in livestock markets. The arrangements between primary producers, processors and distributors are necessarily becoming more complicated. The authors state that to be competitive, smallholder livestock production, primarily on small mixed crop–livestock farms, will need to intensify and be able to provide higher value products. Major constraints, however, are the higher costs of quality inputs (e.g. improved animals and feed) and the knowledge required to produce more efficiently. Public investment has a role in overcoming these constraints through knowledge and technologies that deliver quality feed, ensure animal health, improve breeding and provide technical advice and other services (McDermott *et al*., 2010).

Box 3
Increasing Livestock Productivity

In the proceedings of an international conference on 'Livestock and Global Climate Change', Rischkowsky *et al*. (2008) gave an example of ICARDA's research on alternative management options for milk production. Weaning lambs at an early stage of 45 days, proved to be an interesting option for increasing milk off-take and lamb weights at weaning. The authors provided details on how to improve the quality and marketability of dairy products through workshops and training on milk hygiene, improved yoghurt processing and culture management. Such steps are essential in order to respond to market demands for food safety and hygiene. By means of simple capacity building activities the competitiveness of smallholders in the market improves and helps them to mitigate the effect of climate change through improved incomes and the added value of their products.

Source: Rischkowsky *et al*., 2008

Heat stress is known to alter the physiology of livestock, reducing production and male and female fertility and increasing mortality rates. The water requirements of the animals increase with temperature, while heat stress suppresses appetite and feed intake (Nardone *et al*., 2010). Heat stress is a major source of production loss in the dairy and beef industries; rising temperatures will increase this problem, and therefore require adjustments to husbandry and production strategies (Pilling & Hoffmann, 2011; Nardone *et al*., 2010).

Many local breeds in the tropics and subtropics are comparatively well adapted to high temperatures. For them, the main climate change related problems are likely to be associated with feed availability. In production systems where use of external inputs is not possible, the importance of well adapted animals is likely to increase (Pilling & Hoffmann, 2011).

Pilling & Hoffmann (2011) indicate that although high output breeds are usually not well adapted to heat stress, the high external input systems in which they are kept often provide several options for alleviating the effects of high temperatures, including the use of cooling systems and adjusting the diet to reduce metabolic heat production. Such production systems are, generally, quite well able to protect animals from the local-scale effects of climate change. The authors stress that these systems rely heavily on external inputs which make them vulnerable to rising prices. In production systems where heavy use of external inputs is not possible, the importance of well adapted animals is likely to increase under climate change.

Adapted livestock breeds

Many of the animals kept by small-scale livestock keepers and pastoralists in the Near East are local breeds. These are vital to food security and livelihoods. Under better conditions, they may not produce as much as their high-yielding relatives, but in severe conditions they can produce under conditions where other breeds cannot survive. They are less prone to fall victim to diseases and are a low-risk proposition for livestock keepers (LPP *et al*, 2010). Many have unique traits, such as disease resistance and drought tolerance, and represent an important source of genetic diversity that animal breeders can use in responding to pest and disease outbreaks and climate change. They are also integral parts of their environment that help sustain biodiversity. Many play a central role in the cultures of the people who keep them (LPP *et al*, 2010).

Most adapted breeds are largely uncharacterized and do not have structured breeding or conservation programmes (Hoffmann, 2010). The performance differentials between local breeds and high output breeds, the long-term commitment required for genetic improvement and the ease of genetic material imports may discourage developing countries from initiating their own breeding programmes. However, for the optimal use of the adaptation traits harboured in all breeds, research into genetic characterization and understanding adaptation in stressful environments needs to be strengthened.

In view of the uncertainty of future developments, the use and non-use values of animal genetic resources should be maintained (FAO, 2007a; Hoffmann, 2010). Conservation measures for threatened breeds have been established in some countries (FAO, 2007a) and are a priority of the Global Plan of Action for Animal Genetic Resources (FAO, 2007b). Loss of animals as a result of droughts and floods or disease epidemics related to climate change may increase. To secure against such disasters, it is necessary to characterize animal genetic resources and, subsequently, to build inventories, including information on the spatial distribution of breeds and valuable breeding stocks (Hoffmann, 2010).

The FAO (2007a) stresses the threats to the continued existence of animal genetic resources and justifies conservation measures. Conservation programmes are most required where valuable genetic resources are in danger of being lost. A number of approaches to conservation are available, including a range of *in vivo* methods (zoos, farm parks, protected areas and payments or other support measures for livestock keepers who maintain animals in their normal production environments), as well as *in vitro* conservation of genetic material in liquid nitrogen. The two approaches are complementary; the *in vitro* collections preserve a static set of genetic resources, while *in vivo* efforts preserve a dynamic process of evolution, as genetic resources adapt to changing pressures from natural and human selection. In the Near East, however, hardly any *in vivo* conservation programmes exist, and no *in vitro* programmes (FAO, 2007a).

Box 4
Breed and species substitution

Species substitution (e.g. increased use of dromedaries) because of climatic and vegetation changes has already occurred in parts of Africa. Changes have also occurred at the breed level. Pilling & Hoffmann (2011) provide the example of the how Fulbe herders in Nigeria, faced with a shortage of grass in the semi-arid zone, switched from the Bunaji breed to keeping the Sokoto Gudali cattle breed, which copes well with a diet of browse.

Source: Pilling& Hoffmann, 2011

If climate change exceeds the adaptive capacity of the currently used genetic portfolio, countries would need to depend on better-adapted genetic resources from other countries to sustain their food and agriculture systems. The importance and value of specific genetics would thus increase. Such changes in the species or breed mix may lead potentially to a reverse in the current flow of genetics. Countries that happen to host sought after resources may then try to take advantage of their scarcity and control access to what will have become crucial genetic resources (Hoffmann, 2010). Pilling& Hoffmann (2011) note that exceeding capacity may also lead to the need for breed or species substitution.

It is possible to model the relationships between climate change and the distribution of animal genetic resources. The model can be used to identify those geographic areas where agro-ecological shifts driven by climate change are likely to be so substantial and rapid that the breeds currently present will no longer be suitable and will not adapt genetically with sufficient speed (Pilling& Hoffmann, 2010). While doing so, vulnerable locations might be identified and practical support in adapting livestock production to changed conditions can be offered. Threatened breeds might as well be identified as targets for conservation programmes. However, detailed studies of a breed's physiological and behavioural adaptations to environmental stresses are rare. Data on breed distributions and production environments, which give an indication of their probable adaptive characteristics, are also generally inadequate and incomplete (Pilling& Hoffmann, 2010).

Available water for agriculture

In terms of renewable water resource availability, the Near East is the most arid region in the world (Oweis, 2008). Water is a key constraint to food production in the region and will remain so in the future as well (Karrou and Oweis, 2011; Turall *et al*, 2011), as the Middle East and North Africa will face great water shortages (World Bank, 2007; Turall *et al*, 2011). The Comprehensive Assessment of Water Management in Agriculture (Molden, 2007) argues for a dramatic improvement in water productivity to be able to feed the world's population by mid-century. Irrigation makes an important contribution to agricultural production, value-added products and employment in the region. The irrigated agricultural land, however, represents only three percent of the cultivated area in the Near East (FAOSTAT, 2011). A large share of food production will need to come from rainfed environments (Chartres *et al*., 2008), and water productivity in these areas needs to improve.

The logical response is to produce more with less water, which means improving water productivity in agriculture. Agricultural water productivity is the return (biophysical, economic, ecological, nutritional, etc.) from a unit of water consumed or depleted (in evaporation, transpiration and/or quality deterioration) (Oweis, 2008). The trade off between water and land productivity depends on which is the more limiting resource; a decision which requires analysis at the specific location. However, in marginal dry areas, as water becomes increasingly more limiting than land, water productivity is gaining greater importance.

Water use efficiency

Turral *et al*. (2011) point out that water use efficiency has long been a measure for improved crop performance, where the main focus was on enhancing the harvestable yield (land productivity). But now, water use efficiency is considered in a wider landscape context, where both land and water resources are limiting. Water use efficiency can be increased by adopting more appropriate technologies (Karrou & Oweis, 2011). In rainfed cultivation, the focus is on increasing yield through good husbandry, the best use of rainwater through soil moisture management and by the provision of more nutrients (Turral *et al*., 2011). In irrigated agriculture, the availability of water will dictate whether to focus on yields (when irrigation is unconstrained by water availability) or on water productivity (when water is scarce), resulting in different combinations of area and water use for an optimum level of production (Turral *et al*., 2011).

Karrou & Oweis (2011) indicate that integrated water harvesting techniques can improve rainwater use efficiency as well as soil moisture levels. Water harvesting can be applied either at the macro level (i.e. runoff from large catchments) or the micro level (catchments adjacent to the cropped areas). At the macro level, runoff water can be collected and stored in small reservoirs to be used for irrigation during dry periods, or allowed to seep into the soil to recharge aquifers. At the micro level, runoff water is trapped and channelled to be stored in the soil profile directly supporting the crop. Rainwater that would otherwise be lost as runoff or evaporation is collected and used by plants, livestock or even people.

Karrou & Oweis (2011) point out that many farmers in the marginal dry areas use full irrigation, i.e. supplying enough water to meet (and often exceed) the entire crop water requirement. A more efficient practice is to apply only supplemental irrigation (limited irrigation for otherwise rainfed crops), carefully timed to avoid water stress during the critical stages, such as flowering and/or grain filling. Supplemental irrigation significantly improved water productivity and achieved saving of water resources without reducing land productivity.

Livestock water productivity

Livestock grazing does affect the hydrological response of pastures and rangelands. Increased grazing pressure leads to a combination of different, interrelated factors, such as decreased vegetation cover, decreased soil organic matter content, soil compaction through trampling, decreased soil structural stability, soil erosion, lower infiltration rates and thus higher runoff (Descheemaeker *et al*., 2010). Moreover, land degradation resulting from overgrazing leads to increased peak flows, reduced base flows and reduced ground water recharge. The grazing pressure on the vegetation cover and the trampling effect of livestock is especially felt around watering points, where land degradation can be severe (Brits *et al*., 2002). Moreover, if watering points are not well protected or managed, water contamination due to the inflow of faecal excretions can also make the water unsuitable for any other productive uses (Wilson, 2007).

Livestock water productivity is defined as the ratio of the sum of the net benefits derived from animal products and services to the amount of water that is depleted or used in the process of producing these goods and services (Oweis and Peden, 2008). Strategic feed sourcing, conserving water and enhancing animal productivity provide multiple options for improving livestock water productivity. Increasing livestock water productivity through better management of livestock water interactions holds a promise for sustainably improving livelihoods and making more fresh water available for other human needs and ecosystem services (Oweis and Peden, 2008). Van Breugel *et al*. (2010) quantified livestock water use and productivity within the Nile basin through a spatially enabled analytical framework that links models on ruminant digestion and crop water requirement and spatial data on dry matter production and evapotranspiration. The study shows that livestock water use at the aggregated basin level is a small proportion of the total water depletion through evapotranspiration. However, differences are considerable across the basin. There are large areas in the arid and hyper-arid regions where the availability of water for feed is limited. In other areas however, livestock water requirements are only a small fraction of the total water that is annually depleted through evapotranspiration.

Livestock insurance scheme

Livestock insurance that compensates for the loss of animals or reduced productivity because of drought has rarely been offered and, seemingly, not at all for herders in traditional pastoral systems. Hazell (2011) summarizes the reasons for this. They include the frequency of drought losses is usually too high to make the insurance affordable, there are too many opportunities for fraud and there is little opportunity for on-farm inspection of management practices or loss assessments, particularly when the animals are on the move.

An index insurance scheme, however, has the advantage of not being based on a direct damage assessment. Index-based livestock insurance is based on cumulative precipitation, cumulative temperature, area average yield, area livestock mortality and related indices (Barrett *et al*., 2008). Like any insurance product, the purpose of index-based insurance is to compensate clients in the event of a loss. Unlike traditional insurance which assesses losses on a case-by-case basis and makes payouts based on individual client’s loss realizations, index-based insurance payouts are based on an external indicator which triggers a payment to all insured clients within a geographically defined space (Ouma *et al*., 2011).

As Ouma *et al*. (2011) point out an index-based insurance product has significant advantages over traditional insurance. Traditional insurance requires that the insurers monitor the activities of their clients and verify the truth of their claims. With index-based insurance products, all one has to do is monitor the index. Index-based insurance products overcome the key problems with traditional insurance contracts of an individual’s experience. Index-based products can be used to insure pastoral and agro-pastoral populations from the significant drought-related losses that they incur as a result of climate risks.

Box 5
Livestock insurance

In Kenya, an index-based livestock insurance (IBLI) scheme has been launched in the arid and semi-arid north to cushion pastoralists against livestock losses resulting from droughts. Satellite technology will be used to monitor the landscape – if the images show a lack of pasture then it will be assumed the animals are likely to die and the owners can receive a pay-out. Despite the contractual advantages of an index-based insurance product, as well as its potential economic and social benefits, some major challenges that face its implementation; high quality data are required to accurately design and price insurance contracts and determine when payouts should be made; design of an optimal insurance index which, to the maximum extent possible, reduces the risk borne by the target population so that the value and potential demand for the product are high; the effective demand for IBLI insurance among a target clientele largely unfamiliar with insurance in general and index-based livestock insurance in particular; and cost effective ways of delivering IBLI insurance to small and medium scale producers in remote locations.

Source: Chantarat *et al*., 2009

Modelling and forecasting emerging infectious animal diseases

Climate factors, such as precipitation and humidity, are often considered as necessary key parameters which modulate the emergence of various human, animal and plants diseases (Lacaux & Tourre, 2008). The authors note that mosquitoes, for example, facilitate the transmission and diffusion of diseases such as Rift Valley fever (RVF), bluetongue, malaria, dengue fever and chikungunya, in response to the spatio-temporal distribution of seasonal precipitation. Perry *et al*. (2011) point out that climate partially determines the distribution of vector-borne diseases and free-living pathogens, and that there is a concern that a warmer, wetter world will also be a sicker world.

Bluetongue and RVF are two examples of emerging, vector-borne livestock diseases with strong economic or public health consequences, particularly for the latter. Lancelot *et al*. (2008) stress that to address this issue, it is necessary to understand and model the underlying epidemiological mechanisms at the agro-ecosystem level, and evaluate the effect of climate and environmental changes. An integrated approach must be adopted that combines field and laboratory studies on vector biology and ecology, the collection of veterinary and human public health data and the associated risk factors (including economic and sociological), remote sensing of environmental features (landscape, land cover, and land use) and statistical and mathematical modelling (Lancelot *et al*., 2008).

Bluetongue

Bluetongue is a viral disease of animals affecting all ruminants, including sheep, cattle, goats and certain wildlife ungulates (Rowlinson, 2008; Gould & Higgs, 2009). Bluetongue does not affect humans. The virus is spread by certain types of biting midges of the *Culicoides* genus (Ceratopogonidae) (Rowlinson, 2008). The link between climate change and disease risks from various pathogens has been increasingly recognized (Rowlinson, 2008).

Bluetongue is endemic to sub-Saharan Africa with economic losses limited to countries using exotic sheep breeds (southern Africa) (Lancelot *et al*., 2008). Climate and environmental changes might significantly alter the transmission pattern and disrupt the local epidemiological equilibrium, as is expected for malaria (Boko *et al*., 2007). The demographic growth of large cities and, more generally, the increase of human populations in northern Africa and the Middle East will result in more intense livestock aggregations around market areas, the merging of populations from different origins and increased trade from sub-Saharan Africa to these regions. Regarding vector competence and habitat suitability, the same comments made about RVF apply to bluetongue (Wittman and Baylis, 2000). It should, however, be noted that there are differences between a sylvatic cycle (*Aedes*) and an urban cycle (*Culex*). With periurban growth and climate change some devastating outbreaks could happen as a consequence of culicoides behaviour being different from culicine behaviour. Culicoides like to deposit their eggs in stagnant or slow moving waters with rich organic material/dung. The RVF virus transmission is transovarial. The virus is deposited in the eggs (notably *Aedes* spp.) and remains ‘dormant’ until the appropriate eclosion of the egg. However, the bluetongue virus is not transmitted transovarially.

Rift Valley fever

Rift Valley Fever is a viral, mosquito-borne disease affecting humans and domestic ruminants which causes abortions and neo-natal mortality (Lefèvre *et al*., 2003). Humans that come into close contact with the blood, excreta and infected mosquitoes associated with clinically infected animals may also become infected (Lancelot *et al*., 2008; Gould & Higgs, 2009). In humans, infection is often not apparent or mild, although in rare cases more severe forms can be observed, such as meningoencephalitis or hemorrhagic fever (Lancelot *et al*., 2008; Gould & Higgs, 2009).

Currently, vaccines are available to immunize animals, but their use is usually confined to limitation exercises after an epidemic arises (Gould & Higgs, 2009). Some side effects of the use of attenuated strains are reported as they have induced abortions or malformations of the foetus. Other limitations are that vaccination in the face of an outbreak can cause iatrogenic spread of the disease. Therefore, international trade in live animals is banned where RVF occurs. Epidemics occur during the rainy season (humidity), but temperature also plays an important role (Lancelot *et al*., 2008; Gould & Higgs, 2009). The RVF outbreaks in East Africa are closely associated with the heavy precipitation that occurs during the warm phase of the natural and relatively regular El Niño Southern Oscillation phenomenon (Lancelot *et al*., 2008; Gould & Higgs, 2009).

Remote sensing satellite imagery is now being used to study a variety of environmental parameters in order to evaluate their potential to predict the emergence patterns of mosquito vectors of RVF (Gould & Higgs, 2009). These models are now used in early warning systems (Anyamba *et al*., 2006), however, their geographic scope is limited and they cannot be used in other African regions (e.g., Egypt, Mauritania) where no correlation between excessive precipitation and RVF outbreaks has been demonstrated (Lancelot *et al*., 2008). It is worth mentioning the FAO’s Emergency Prevention Programme for Transboundary Animal Diseases (EMPRES) activities in the emergency prevention system for food safety and the food chain crisis management framework for capacity development and a project improving the level of preparedness in Somalia for RVF and other climate change-related diseases.

Lancelot *et al*., (2008) highlight that major changes in the African ecosystems are expected with consequent breaks in the unstable epidemiological equilibriums of many vector-borne diseases and more intense livestock movements. These changes probably will result in more frequent RVF epidemics with a wider spread. Given the inter-regional livestock trade movements, northern Africa and the Middle East will be at a higher risk from RVF. Unconfirmed evidence of RVF IgG antibodies in small ruminants of Iraq suggests that the disease was in the region as early as World War II. No occurrence of the disease had been reported until September 2000 when an unprecedented outbreak of RVF in Saudi Arabia and Yemen killed over 100 people prompting a ban on the imports of livestock from the Horn of Africa (Tibbo & Workalemahu 2001; Nin Pratt *et al*., 2005).

Foot-and-mouth disease

Foot-and-mouth disease (FMD) is an infectious viral disease that affects cloven hoofed animals. It is a major epizootic disease in the Middle East region. The virus causes a high fever for two or three days, followed by blisters inside the mouth, on teats and on the feet that may rupture, become infected and cause lameness and secondary mastitis. Numerous virus types are known to circulate in the Middle East region and vaccines, if used, have to be tailored according to the strain.

Foot-and-mouth disease can be a severe disease for animal farming, since it is highly infectious and can be spread by infected animals through aerosols, through contact with contaminated farming equipment, vehicles, clothing or feed. Its containment demands considerable efforts in vaccination, movement control and trade restrictions and quarantines. In countries where vaccination is not practiced, the culling of animals is one mechanism for controlling the disease and regaining freedom from infection. Its control is difficult without concerted regional action because there is a large movement of animals within the region that can also extend to distant countries such as Afghanistan.

Transboundary animal diseases disrupt trade and cause enormous economic damage. Movement, whether of people, livestock or livestock products, is of particular importance in FMD, one of the most infectious diseases known to date.

Old World screwworm

The Old World screwworm (OWS) is primarily a veterinary pest, caused by fly larvae living off fresh tissues. Cases of human myiasis by *Chrysoma bezziana* are common in the orient, but rare in Africa. *C. bezziana (Villeneuve*) is an obligatory parasite belonging to the family of Calliphoridae. The larvae of this dipteran are armed with broad, encircling bands of spines (resembling the threads of a screw) and they tunnel deeply head-downwards into the host’s tissue (like the *Cochlyomyia hominivorax* that causes New World screwworm which was introduced into North Africa in the mid-1980s and eventually eradicated).

Ectoparasitic arthropods live on, puncture or burrow into the surface of their host’s epidermis to feed or shelter. As a result, there may be direct damage to the skin and other subcutaneous tissues. The presence of burrowing ectoparasites and their salivary and faecal antigens can stimulate immune responses in some individuals leading to hypersensitivity. Feeding may also result in significant blood loss, secondary infections, pruritis, and excoriation alopecia and, in some cases, ultimately death. The behaviour of ectoparasites also may cause harm indirectly, particularly when present in high intensities, causing disturbance and increasing levels of abnormal behaviour, such as rubbing, and leading to reduced time spent grazing or ruminating. In some cases infections may lead to self-mutilation.

To successfully develop the OWS requires warm and wet conditions and is sensitive to prolonged cold or dryness. For most of the Middle East, the risk of maintaining OWS has been characterized as generally low. However, at a more local level, climatic conditions may nevertheless present suitable reproduction conditions for several OWS fly generations and thus support the onset of epidemics.

The introduction and subsequent outbreaks of OWS have been reported a number of times in the Middle East, but only translated into important population developments in Oman in 1992, Iran in 1995 and Iraq in 1996. Modelling OWS risk prediction for the Middle East/Arabian Peninsula, shows that relatively few areas are identical to that of the Mesopotamia Valley and thus suited for the permanent/development of OWS. The risk areas identified include a few hotspots in southwest Iran, southwest Yemen and along the south coast of Oman. Suitable condition areas are also observed in parts of Syria, Lebanon, Jordan, Israel, along the Nile Valley in Egypt and in relatively large areas of Eritrea, Ethiopia and Sudan.

Early warning systems

Prediction and forecasting of extreme events is a crucial component for preparedness and response (Hazell, 2011). The ability to provide early warning drought forecasts could be a powerful tool for avoiding problems that arise as farmers, herders and other decision makers must commit resources before the yearly precipitation outcomes are known. The economic value of season-specific forecasts depends on the degree to which farmers can adjust their plans, e.g. date of planting, seeding rate and fertilizer treatment, as the season's precipitation unfolds (Hazell, 2011). Preventive vaccination of livestock in at-risk areas would also need to be planned two weeks to one month before the anticipated season of high incidence; prevention or treatments against ectoparasites and endoparasites should be part of the herd health programmes year-round.

Hazell (2011) points out that reliable drought forecasts could enable governments and relief agencies to position themselves for more efficient and cost effective drought interventions. In Africa, several early warning drought systems have proved successful in giving advance notice of emerging drought situations. However, these programmes are monitoring systems that track precipitation patterns within a season rather than true weather forecasting systems that predict precipitation outcomes for farmers before they even begin (Hazell, 2011).

Effective drought monitoring and early warning systems are integral parts of the efforts worldwide to improve drought preparedness (FAO/NDMC, 2008); timely and reliable data and information are the cornerstones. Most countries in the region do not have well-functioning drought monitoring systems that would allow them to take timely action to mitigate the effects of drought (De Pauw, 2005). Even though the meteorological networks in most Near East countries are adequate and well-equipped, they are poorly prepared to function effectively as drought early warning systems because the analytical tools required for drought monitoring are inadequate, the information products are unsuitable and there is insufficient data sharing (FAO/NDMC, 2008).

Box 6
Livestock Early Warning Information

The Global Livestock Collaborative Research Support Program led by Texas A&M University has developed robust forage monitoring and livestock market information systems covering the eastern African region. The systems systematically and continuously collect and deliver timely information on forage supplies and forecast livestock market prices and volume trends to stakeholders. The analysis and the suite of products generated are intended to enable pastoral communities to respond to crises and thus protect their livelihoods, the communities' assets and sustain their ability to subsist in harsh environments by triggering appropriate and timely responses.

Source: Kaitho et al., 2009.

Further reading: The FAO/OIE/WHO Global Early Warning System for transboundary animal diseases and major zoonoses at www.glews.net

The FAO/NDMC (2008) gives examples of two international programmes useful for monitoring food supply and demand that can be affected by drought conditions. The FAO coordinated Global Information and Early Warning System (GIEWS) was developed in response to the food crisis of the early 1970s (http://www.fao.org/GIEWS). It continuously reviews the world food supply/demand situation and provides early warnings of impending food crises in individual countries. For countries facing a serious food emergency, FAO/GIEWS and the World Food Programme carry out joint crop and food supply assessment missions. These missions provide timely and reliable information so that appropriate actions can be taken by the governments, the international community and other parties. These actions include producing a wide range of regular bulletins on food crop production and markets at the global level and situation reports on a country-by-country basis, including the countries of North Africa and West Asia (FAO/NDMC, 2008).

The United States Agency for International Development's (USAID) Famine Early Warning Systems Network (FEWS NET) is another international food security information system, dsigned to strengthen the abilities of African countries and regional organizations to manage the risk of food insecurity by providing timely and analytical early warning and vulnerability information (http://www.fews.net/). The FEWS NET collaborates with international, national and regional partners to provide timely and rigorous early warning and vulnerability information on emerging or evolving food security issues (FAO/NDMC, 2008).

Income diversification and migration

Farming in dry marginal areas is usually a high-risk and low-profit activity (Aw-Hassan & De Corte, 2008). Households need to supplement farm income with income from off-farm sources – a part-time job or a small business. The diversification of agricultural production can contribute to reducing risks, generating income and, accordingly, helping small-scale farmers to move from subsistence to sustainable livelihoods (Solh, 2011). For example, the inclusion of specific fruit trees and vegetable crops, such as olives, date palms, almonds, figs and pomegranates in the production system can help greatly in improving livelihoods. The livestock sector contributes up to 60 percent of agricultural output in the Near East region.

The importance of off-farm income will increase as urbanization and rural to urban migration increase (Aw-Hassan & De Corte, 2008). High population growth, in general, is associated with a shift towards services and significant wage gaps between agriculture and the service sector will trigger rural to urban migration (Karam & Sarraf, 2011). Hazell (2011) highlights that investments in education and health can increase opportunities for out-migration from marginal dry areas. At the same time, these investments can improve average farm productivity and so reduce vulnerability to droughts.

Appropriate policies and institutions

Hazell (2011) provides an overview of the policy approaches for coping with climate change in dry areas. He describes many interventions from the past that have encouraged farming practices which increase both the extent of future drought losses and the dependence of local people on government assistance. However, he stresses that in recent years institutional, market and technical advances have increased the range of policy options available for assisting farmers and rural communities to manage droughts in dry areas.

The FAO (2009c) describes the policies needed to provide supportive conditions for smallholder farmers and pastoralists; such as guaranteeing access to grazing land and water and facilitating the provision of appropriate services and infrastructure to these livestock keepers. Livestock keepers themselves are in the best position to point out which regulations and policies can help them to maintain threatened breeds. However, smallholder farmers and pastoralists are rarely represented in national and international decision making bodies. It is crucial that these livestock keepers be given a voice in policy making (FAO, 2009c).

The most promising alternatives to assisting farmers and rural communities to manage their risks are, among others, weather index insurance, seasonal weather forecasts and more effective safety net programmes (Hazell, 2011). Hazell (2011) indicates that the public sector has key roles to play in financing key investments (e.g. subsidizing relief programmes) and in creating a supportive environment for market assisted development (e.g. weather insurance and weather forecasting). He points out that in many countries this will require a reform of existing policies towards risk management in dry areas. However, many of these interventions are encouraging farming practices that could increase both the extent of future drought losses and the dependence of local people on government assistance (Hazell, 2011).

Mitigation

A global estimate of the total methane (CH_4) emissions from enteric fermentation in the livestock sector using regional and production system-specific emission factors has been provided by Steinfeld *et al*. (2006). Many of the existing technical options that can mitigate GHG emissions from the livestock sector are discussed in Steinfeld *et al*. (2006). Reid *et al*. (2004) review mitigation options for the pastoral systems of the tropics. In terms of CH_4 mitigation in pastoral systems, probably the only effective way is by reducing livestock numbers. It is not very likely to happen unless levels of compensation for pastoralists are high enough to offset the loss in economic, social and cultural values. While technical options for mitigating emissions do exist, there are problems to be overcome related to, for example, incentive systems, institutional linkages, policy reforms, monitoring techniques for carbon stocks and appropriate verification protocols (Thornton *et al*., 2009b).

Dourmad *et al*. (2008) show that the strategy for mitigation in a given production system will depend on both the contribution of the different activities – including animal raising, manure handling and feed production – to total emissions and the possible improvements within each activity. A marginal improvement of a highly contributing activity might be as efficient as a more drastic improvement in a modestly contributing activity. However this requires information about the variations in emissions between systems; for instance comparing conventional and organic farming and comparisons between farms in a given system, in order to identify the possible improvements (Dourmad *et al*., 2008).

Box 7
Mitigation of climate change

The effect of livestock on climate change is largely through their production of GHGs. The GHGs from the livestock sector can be reduced by such changes as:

- Improved feeding management. Feed composition has an effect on enteric fermentation and the emission of methane; a higher proportion of concentrate in the diet results in a reduction in methane emissions
- Reducing methane emissions from enteric fermentation through improved efficiency and diets using feed additives, antibiotics or vaccines
- Improved feed conversion. Feed efficiency can be increased by developing breeds that are faster growing, that have improved hardiness, weight gain or milk or egg production and by enhancing herd health through improved veterinary services, preventive health programmes and improved water quality
- Improved waste management through enhanced manure management and biogas production for energy
- Grazing management. Increased use of pasture and good pasture management through rotational grazing are potentially the most cost effective ways to reduce and offset GHG emissions. This strategy increases vegetation cover and soil organic-matter content sequesters carbon, while inclusion of high-quality forage in the animals' diets contributes to reducing CH_4 emissions per unit of product
- Reducing deforestation/rangeland degradation by agricultural intensification. Improved pasture management and feed production reduces the land requirements per unit of animal product produced, thus curbing land-use expansion. Improved grazing management, such as optimizing stock numbers and rotational grazing, will result in substantial increases in carbon pools
- Changing consumption from animal products with high associated GHG emissions to products with lower emissions.

Source: Adapted from FAO 2009d & FAO 2006

The CH_4 emissions from enteric fermentation change as production systems intensify and move toward higher feed use and increased productivity. In general, CH_4 output increases with the higher dry matter intake that is linked to high performance. However, the production pathways of different animal products differ in their GHG emissions and this may influence the emphasis given to different production systems (Hoffmann, 2010). For beef cattle, intensive feedlot systems produce less CH_4 per unit of meat than extensive grazing systems, as CH_4 decreases as the proportion of concentrate in the diet increases and because of the faster growth rates and shorter time to market (Hoffmann, 2010). The CH_4 emission per kilogram of milk declines as production increases, but at a diminishing rate (Hoffmann, 2010).

Reducing livestock numbers, increasing the resource use efficiency of individual animals, optimizing feed rations and feed additives or other technologies may be used primarily to reduce CH_4 excretion in ruminants. Emissions from extensive systems can be reduced by improving the genetic potential of the cattle, increasing feed quality and manure management (Hoffmann, 2010).

Animal waste management

The GHG emissions from manure have an important contribution to total emissions and offer mitigation opportunities. The GHGs emitted from manure are mainly CH_4 and nitrous oxide (N_2O) (Steinfeld *et al*., 2006). The CH_4 is produced under anaerobic conditions and is the main GHG emitted from liquid manure. The intensity of production depends mainly on the organic matter content in the manure and on the temperature and length of storage. Systems having long-term storage of liquid manure at high temperatures will result in much higher CH_4 emissions. The production of N_2O requires aerobic conditions which can be found with solid manure or during the spreading of liquid manure, especially on wet soils. The CH_4 may also be emitted from anaerobic zones in solid manure. This means that, depending on litter management, more CH_4 or more N_2O will be emitted (Dourmad *et al*., 2008).

According to Dourmad *et al*. (2008), CH_4 seem to be the main component of the GHGs emitted from litter used by ruminants, suggesting that these conditions are more anaerobic. Consequently, as regards GHG emissions, it seems that litter-based systems should not be recommended. However, other dimensions also have to be considered, such as animal health and welfare which are generally improved by these systems. For liquid slurry the main mitigation options are reduction of storage time, especially in hot conditions, the treatment of the manure and improved spreading techniques (Dourmad *et al*., 2008). In this context a rapid removal of the slurry followed by anaerobic digestion appears to be a very efficient way to reduce, or even nearly suppress, uncontrolled CH_4 emission during storage. Moreover this process results in the production of renewable energy. In the case of ruminants, raising the animals on pasture is an efficient way to reduce CH_4 emissions from the manure because storage is suppressed.

Intensifying livestock production systems

Martin *et al*. (2008) showed that CH_4 mitigation in ruminants is possible through various strategies, of which the feeding management approach is the most developed. Other strategies (biotechnologies, additives) are promising, but the diversity and plasticity of function of the rumen bacterial and methanogenic communities may be limiting factors for their successful application (Martin *et al*., 2008). These authors affirm that the sustainability of CH_4 suppressing strategies is an important issue. Their complete evaluation should include the consequences on animal performance, safety for the ruminant and the consumer and economic viability.

Bell *et al*. (2008) demonstrated that CH_4 emissions from dairy herds can be reduced by decreasing the numbers of young stock and of the milking herd. Milk production can also be increased by improved herd health and minimising involuntary culling. The authors state that if dairy yields are increasing through breed selection, dairy herd numbers could decrease as long as this is accompanied by an improvement in the dairy cows' environment and health (Bell *et al*., 2008).

Production systems, in which locally adapted breeds are kept, normally are not the best suited for achieving high feed conversion ratios and low methane emissions. Pilling & Hoffmann (2011) noted that poor quality (high fibre and low protein content) diets tend to produce more methane per unit of dry matter digested than animals fed on better quality forages or appropriately supplemented with concentrate feed. They stress that technical options to reduce GHG emissions include adjusting the animals' diets so that they better match nutritional requirements and/or can be digested with less production of methane.

Mitigation through feeding
Pilling & Hoffmann (2011) explain that the different feeding capacities and habits of the different types of animal are essential in enabling the livestock sector as a whole to use a wide range of feed resources, many of which are unsuitable for direct consumption by humans. Ruminants as well as camelids are adapted to forage-based diets, i.e. they can convert grasses and other fibrous plant materials that are inedible to humans into meat, eggs, milk and other products. Monogastrics, such as chickens, need diets that are lower in fibre and are closer to those of humans (Pilling & Hoffmann, 2011).

Pilling & Hoffmann (2011) identified that different ruminant and camelid species have different feeding habits and tend to utilize different types of vegetation; goats and camels browse more than sheep and cattle. Keeping browsing animals has certain advantages when feed is in short supply as they make use of forage that cannot easily be used by other species –there are complementarities if grazing and browsing animals are kept together – and because shrubs tend to provide a source of green forage during the dry season.

The efficiency of the conversion of feed to animal products depends on the relative contributions of maintenance and production to the total requirements (Dourmad *et al*., 2008). When the animal production rate is low, maintenance plays a higher role, resulting in more feed required per kilogram of product and consequently in more emissions (Dourmad *et al*., 2008). In the production of meat, efficiency is also affected by the composition of the meat, as the amount of energy required to produce fat is much higher than that for lean tissues. Dourmad *et al* (2008) conclude that all the practices, including genetics, nutrition, reproduction or health improvement, that result in the improvement of feed efficiency are potential ways to reduce GHG emissions.

In monogastric animals, although some improvements may be expected, the effect is limited because of their rather low contribution of enteric CH_4 to total emissions (less than 5 percent) and because the possible variation in diet composition is limited. In ruminants the effect of feed composition is much higher (Dourmad *et al*., 2008). Dourmad *et al*. (2008) show that nutritional management opportunities, like increasing concentrates and lipid supplies, are readily available.

Improved land use planning
'*The state of food and agriculture: livestock in the balance*', (FAO, 2009), states that there are three major trends relating to pasture lands; valuable ecosystems are being converted to pasture lands, pasturelands are converted to other uses and pasture lands are being degraded. The latter is the main problem in the Near East. Pasture degradation is generally the consequence of a miss match between livestock densities and the carrying capacity of the pasture. Pasture degradation leads, among other things, to soil erosion, vegetation degradation, reduction in biodiversity, impaired water cycles and the release of carbon from organic matter (FAO, 2009).

The carbon sequestration potential of pastures and rangelands could be used to partly mitigate the GHG emissions of the livestock sector, by avoiding land use changes that reduce soil carbon stocks (e.g. ploughing up long-term grasslands) and cautious management of pastures (Soussana., 2008). Soil carbon sequestration (enhanced sinks) is the mechanism responsible for most of the mitigation potential in the agriculture sector, with an estimated contribution to the technical potential of 89 percent (IPCC, 2007). Souzana *et al*. (2010) determined that soil carbon sequestration by the world's permanent pastures could potentially offset up to four percent of global GHG emissions.

All soils contain some carbon. The amount of additional carbon that can be sequestered depends both on local geophysical conditions and the cropping system (FAO, 2007c). Soil and crop management technologies that can increase soil carbon sequestration are, for example, no-tillage farming with residue mulch and cover cropping, integrated nutrient management which balances nutrient application with the cautious use of organic manures and inorganic fertilizers, various crop rotations (including agroforestry), the use of soil amendments (such as zeolites or compost), improved pastures with recommended stocking rates and controlled fire as a rejuvenating method (Lal, 2009). Another good strategy for soil carbon sequestration is the restoration of degraded/desert soils, which can be achieved through afforestation and reforestation (Lal, 2009). The technical potential for soil carbon sequestration through the restoration of degraded/desert soils, which cover approximately 2 billion ha worldwide, is estimated to 0.6 billion to 1 billion tonne of carbon per year (Lal, 2009).

Carbon trading-related payments to farmers and pastoralists in semi-arid areas could provide an important incentive for those producers to adopt land management practices that build soil carbon pools. At the same time, a higher carbon content in soils enhances land productivity and food security (Perez *et al*., 2007), which in turn can contribute to poverty reduction. Furthermore, payment schemes for carbon sequestration in rangelands offer options for diversifying pastoral systems and thus providing opportunities for income diversification (Reid *et al*., 2004). Income diversification is considered an important method for increasing the resilience of poor farmers and livestock keepers and improving their abilities to escape from poverty. Therefore, these schemes offer opportunities for addressing the objectives of poverty reduction and improved environmental management in an integrated way.

Significant amounts of soil carbon could be stored in rangelands or in silvo-pastoral systems through a range of management practices suited to local conditions. However, in many places pastoral lands are being converted into croplands. This conversion of rangeland into cropland can have a large effect as such conversion can result in a 95 percent loss of the above-ground carbon and a 50 percent loss of below-ground carbon (Reid *et al*., 2004). Stopping, or at least slowing down, this conversion can, therefore, significantly reduce the carbon emission that would otherwise take place in these areas.

Pilling and Hoffmann (2011) stress that it is difficult to generalize about the influence of livestock grazing on carbon sequestration in grasslands, as overgrazing increases the loss of soil carbon, but well-managed grazing can increase carbon deposition. Considerable amounts of carbon can be sequestered from the improved management of grasslands. This not only improves carbon sequestration, but could also turn into an important diversification option for sustaining the livelihoods of smallholders and pastoralists through payments for ecosystem services. Such management would include converting cropland to grassland, reducing grazing intensity and biomass burning, improving degraded lands, reducing erosion and making changes in the species mix. Large gains could result from converting the wetter grasslands back to woodlands or forest, although gains in woodland services would have to be balanced against the loss of the grassland services (Reid *et al*., 2004).

Research into farming methods

Better technologies and better ways of managing farm inputs can make rainfed farming more sustainable. *Agriculture for Development* (World Bank, 2007) describes conservation (or zero-tillage) agriculture as one of agriculture's major success stories in the past years. It states that widespread adoption of more sustainable approaches is often hindered by inappropriate pricing and subsidy policies and the failure to manage externalities. Strengthening property rights and providing long-term incentives for natural resource management with off-farm benefits (such as matching grants for soil conservation) are necessary in both intensive and extensive farming areas (World Bank, 2007).

In this paper, we have mentioned already that more knowledge is needed about the genetic diversity of locally adapted livestock. Limited knowledge is available on local livestock and, for example, their resistance and tolerance to specific diseases, adaptation to poor quality diets or to feeding in harsh conditions and tolerance of climatic extremes (Pilling & Hoffmann, 2011). As livestock are often well adapted to harsh local conditions, it is important to characterize the genetic diversity as well as the production environment they live in. As in production systems where heavy use of external inputs is not possible, the importance of well adapted animals is likely to increase under climate change (Pilling & Hoffmann, 2011).

But there are knowledge gaps on other issues as well. Thornton *et al*. (2009a) summarized the general knowledge gaps in climate change effects on livestock based livelihoods. As indicated earlier, rangelands are already under severe pressure because of land degradation and the increasing human and livestock populations. To develop appropriate interventions and policies, it is necessary to obtain information on increasing CO_2 levels arising from (changes in) the primary productivity of species, their distribution and the carrying capacity of the rangelands.

Livestock systems are of major importance to many livelihoods in the region. The magnitude and consequences of changes in livestock production and their effects on livelihoods is still uncertain. Household-level analysis could assess the effects of climate on food security, livelihoods and household trade-offs and explore feasible options for reducing vulnerability and increasing the capacity to adapt to the adverse outcomes of climate change (Thornton *et al*., 2009a).

Thornton *et al*. (2009a) highlight as well the importance of knowing under what conditions which specific livestock-related risk management options work. Adaptation processes need to be location- and context-specific, integrated and flexible. This is achieved by basing them on climate monitoring, location- and context-specific effects and vulnerability assessments and, at the same time, engaging and working with stakeholders to develop institutional capacity and identify, evaluate, prioritize and select available adaptation options and tools (FAO, 2011a). Adaptation is not accomplished through a single intervention. Rather, it is a continuous process which incorporates interventions that range from those that address underlying drivers of vulnerability to those designed exclusively to respond to climate change effects (FAO, 2011a).

Improved policies

Although technical options for mitigating emissions from agro-pastoral systems in developing countries do exist, there are various problems to overcome (Gerber *et al*., 2010). For pastoral lands, given the relatively weak institutions and the immediate needs for improving access to food, Reid *et* *al*. (2004) conclude that mitigation activities have the greatest chance of success if they build on traditional pastoral institutions and knowledge, while at the same time providing pastoralists with food security benefits.

Gerber *et al*. (2010) assess the main policy instruments available for controlling emissions and promoting carbon sinks, and discuss the main issues and challenges surrounding international efforts to mitigate GHG emissions. There is a substantial potential to reduce the sector's contribution to climate change through policies that foster the adoption of a wide range of technologies and management practices that are available to reduce emissions from livestock farming and to increase carbon sequestration in agro-pastoral systems (Gerber *et al*., 2010; Gill *et al*., 2010). The great diversity of livestock production systems, each requiring adapted technical packages and policy instruments, and the large number of livestock holders often owning a small number of animals make implementation difficult (Gerber *et al*., 2010). To be feasible, policies must impose limited administrative costs on governments and limited transactions costs on producers (World Bank, 2009). With much of the expected growth in livestock-related GHG emissions expected to occur in developing countries, a challenge also exists to provide incentives for producers in countries without United Nations Framework Convention on Climate Change (UNFCCC) obligations to reduce emissions, and to design policies that promote economic development and the livelihoods of smallholders (Gerber *et al*., 2010).

Enabling conditions

National politics and policies have a major effect on the livelihood of livestock keepers (FAO, 2009c). Supportive policies stimulated, for example, the import of live animals into Jordan and Lebanon. Jordan relies on importing beef cattle for slaughter and meat (Al-Aboudi, 2011). Lebanon imports more than twice the amount of cattle which it rears and more than half the amount of sheep (Zaroug, 2011). These import numbers are high, partly because local production is not supported by regulations and policies and partly because of consumer preference for imported livestock products. Because the import of live animals is cheaper than local production, local food production is declining. The economics of these live imported animals may be affected by the effect of climate change on the price of feed. This latter may arise in several ways, including the direct effects of climate on the production of feed-crops, the influence of climate on alternative demands for feed inputs (e.g. bio-fuels) and climate change mitigation measures introduced in the crop sector (Zaroug, 2011).

In order to respond to the increasing demand for livestock products, local production systems should be stimulated by national politics and policies. Moreover, one should take into account the GHG emissions of the various production systems. The import of live animals for local slaughter ignores the GHG emissions of livestock production elsewhere.

In order to meet increasing demand, more information is required on the fast growing periurban production systems. Human populations are increasing in the urban areas, a trend expected to continue in the coming decades. Unfortunately rapid urbanization has not been coupled with equitable economic growth and sufficient employment, resulting in increased poverty and marginalization (Zaroug, 2011). Low-income households engage in rearing livestock to meet direct food requirements as well as to obtain a source of income. Reliable data and statistics at the national and sub-national levels are fundamental for policy making and strategic planning, in addition to monitoring poverty, food insecurity and other socio-economic factors objectively. Information and analysis across institutions are often incomplete, inconsistent or incompatible, impeding appropriate and efficient decision making for enhanced food security and poverty reduction (Zaroug, 2011).

Another aspect, not included yet in this report is gender. In many countries the role of women in livestock production systems is significant (FAO, 2011b). In general, women are often responsible for nurturing livestock and on-farm duties like feeding, watering, collecting fodder, cleaning stables, milking, processing the milk and traditional animal health care. Men are usually responsible for activities like marketing, purchasing animal feed, procuring veterinary services and herding. While men's tasks are seasonal, most women's tasks are daily (IFAD, 2009).

Women are affected already by several issues that make them more vulnerable to food insecurity and environmental changes and which have a bearing on their capacity to reduce poverty (FAO, 2011b). Climate change is likely to intensify the existing inequalities and have different effects on the capacity of women and of men to cope with additional stresses. In view of their roles as the most significant suppliers of family labour and as efficient managers of household food security (IFAD, 2009), more emphasis needs to be placed on ensuring that any adaptation and mitigation strategies developed take into account these differences and the increased needs of women. Supporting the empowerment of women is a means of building community resilience to climate change (IFAD, 2009).

5. Conclusions and recommendations

In many agricultural systems in the Near East, livestock is a major component. In arid and semi-arid areas extensive grazing is the only means of producing (high-value) agricultural products under the given agro-climatic conditions. Because of a lack of recognition of the multiple contributions of smallholder farmers and pastoralists, policies commonly promote large-scale production to the disadvantage of smallholders and pastoralists. Settlement policies force pastoralists to give up nomadic lifestyles, with negative consequence for their breeds and their environments. Moreover, regulations intended to protect consumers and prevent the spread of diseases, put additional responsibilities on smallholder farmers and pastoralists, making it difficult for them to continue using and maintaining their breeds.

Urban and periurban dairy holdings constitute the main suppliers of, for example, milk to urban populations. In most cases smallholder producers suffer from limited services and urban and periurban producers rarely receive government support services. In these production systems, large quantities of manure are produced, often causing contamination of soil and scarce water sources. Air pollution is also associated with these industrial systems. The close proximity of animal raising facilities and people can affect public health.

A significant increase in temperature is projected for the entire region and in most areas this is accompanied by a decline in annual precipitation. In the semi-arid and arid zones, increased temperatures coupled with decreased and more variable precipitation will result in reduced productivity. Large parts of the region are vulnerable to natural hazards, such as droughts and floods. An overall decrease in precipitation will add additional stress to already scarce water resources; moreover it will most likely result in a reduction in crop and feed productivity.

Livestock producers in the Near East have traditionally adapted to environmental and climate changes. Increased human population, urbanization, economic growth and a growing consumption of livestock products have made those coping mechanisms less effective. Livestock producers need new technologies, training and technical support to deal with climate change. Governments need to develop better policies and stronger institutions to sustainably manage natural resources.

There are a number of ways to increase the adaptation capacity of livestock producers. These include such production adjustments as diversification, intensification, integration of pasture management and conservation of nature and ecosystems. These adaptation measures should be an extension of good development practices. They should include access to veterinary services and prevention measures to ensure the good health of the livestock and, in some cases, the public, and should reduce vulnerability by promoting the health, growth and diversification of economic activities.

As livestock is a large contributor to GHG emissions, mitigation is needed to cope with the adverse effects of past and current trends in anthropogenic GHG concentrations, especially with CH_4 emissions from enteric fermentation. The CH_4 emissions from enteric fermentation change as production systems intensify and move toward the greater use of feed and increased productivity. Moreover, the carbon sequestration potential of pastures and rangelands could be used to partly mitigate the GHG emissions of the livestock sector by avoiding land use changes that reduce soil carbon stocks and the cautious management of pastures.

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Glossary

Adaptation	Adjustments in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.[1]
Adaptive capacity	The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with the consequences.[2]
Adaptation strategies	All initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects.[2]
Climate	The long-term average weather of a region including typical weather patterns, the frequency and intensity of storms, cold spells and heat waves. Climate is usually defined as the 'average weather' or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years as defined by the World Meteorological Organization (WMO). These relevant quantities are most often surface variables, such as temperature, precipitation and wind.[3,1]
Climate change	Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the UNFCCC, which defines climate change as, 'A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time periods.'[1]
Climate proofing	Ensuring that climate risks are reduced to acceptable levels through long-lasting and environmentally sound, economically viable and socially acceptable changes implemented at one or more of the stages in the project cycle.
Climate variability	Variations in the mean state and other statistics (e.g. standard deviations or the occurrence of extreme events) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system or to variations in natural or anthropogenic external forcing.
Coping	The use of existing resources to achieve various desired goals during and immediately after the unusually abnormal and adverse conditions of an event or process. The strengthening of coping capacities, together with preventative measures, is an important aspect of adaptation and usually builds resilience to withstand the effects of natural and other hazards.[4]
Drought	The phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems.[1]
Emissions	The release of a substance (usually a gas when referring to the subject of climate change, e.g. the release of CO_2 during fuel combustion) into the atmosphere. Emissions can be either intended or unintended releases.[3,5]

Evapotranspiration	The process by which water re-enters the atmosphere through evaporation from the ground and transpiration by plants.[6]
GCM	General circulation model. A computer model of the basic dynamics and physics of the components of the global climate system (including the atmosphere and oceans) and their interactions which can be used to simulate climate variability and change.[6]
Global warming	Global warming is an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere which can contribute to changes in global climate patterns. Global warming can occur from a variety of causes, induced by both natural and human activities. In common usage, global warming often refers to the warming that can occur as a result of increased emissions of GHGs from human activities.[3]
Greenhouse gases	Those gases in the atmosphere which absorb and emit radiation at specific wavelengths within the spectrum of infra-red radiation emitted by the Earth's surface, the atmosphere and clouds. Water vapour, carbon dioxide, nitrous oxide, methane and ozone are the primary GHGs in the atmosphere.[1]
Impacts	The consequences of climate change on natural systems and human health. Depending on the consideration of adaptation, we can distinguish between potential impacts and residual impacts. Potential impacts are all impacts that may occur given a projected change in climate, with no consideration of adaptation. While residual impacts are the impacts of climate change that can occur after adaptation.[1]
IPCC	The Intergovernmental Panel on Climate Change was established in 1988 by the WMO and the United Nations Environment Programme (UNEP). The IPCC is responsible for providing the scientific and technical foundation for UNFCCC, primarily through the publication of periodic assessment reports.[3]
Mitigation	An anthropogenic intervention to reduce the sources or enhance the sinks of GHGs.[1,7]
Projection	A potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Projections are distinguished from 'predictions' in order to emphasize that projections involve assumptions concerning, for example, future socio-economic and technological developments that may or may not be realized; they are therefore subject to substantial uncertainty.[1]
Resilience	The level of disturbance that an ecosystem can undergo without crossing a threshold to a situation with a different structure or outputs. Resilience depends on ecological dynamics and the organizational and institutional capacity to understand, manage and respond to these dynamics.[7]
Risk management	Risk management is an activity directed towards assessing, mitigating (to an acceptable level) and monitoring risks. In some cases the acceptable risk may be near zero. Risks can come from accidents, natural causes and disasters and from deliberate attacks from an adversary.
Scenarios	A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces and relationships. Scenarios are neither predictions nor forecasts and may sometimes be based on a narrative storyline.[1]

Uncertainty	An expression of the degree to which a value (e.g. the future state of the climate system) is unknown. Uncertainty can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g. a range of values calculated by various models) or by qualitative statements (e.g. reflecting the judgment of a team of experts).[1,2,7]
UNFCCC	UN Framework Convention on Climate Change. A Convention signed at the United Nations Conference on Environment and Development in 1992. Governments that become Parties to the Convention agree to stabilize GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.[1,2]
Vulnerability	The degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity.[2]
Weather	Describes the short-term (i.e. hourly and daily) state of the atmosphere at any given time or place. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness and precipitation. In most places, weather can change from hour to hour, day to day, and season to season. Weather is not the same as climate.[3,7]

[1] IPCC Third Assessment Report Working Group III: Mitigation.

[2] IPCC Third Assessment Report Working Group II: Impacts, Adaptation and Vulnerability.

[3] Glossary of US Environmental Protection Agency, EPA: http://www.epa.gov/climatechange/glossary.

[4] Agrawal, A. 2008. *The role of local institutions in adaptation to climate change*. Washington, DC, The World Bank.

[5] Glossary of UNFCCC, http://unfccc.int/resource/cd_roms/na1/ghg_inventories/english/8_glossary/Glossary.htm#E.

[6] Glossary of PEW Centre on Global Climate Change, http://www.pewclimate.org/global-warming-basics/full_glossary.

[7] Millennium Ecosystem Assessment Ecosystem and Human Well-being: Policy responses.

Appendices

Appendix A

Total land area (km^2) of region/country by production system

Country	LGA	LGH	LGT	LGY	MIA	MIH	MIT	MIY	MRA	MRH	MRT	MRY	Other	Urban	Total
Algeria	2 100 681	3 386	0	10 265	3 834	2 814	0	0	91 206	47 908	2 589	0	21 792	21 011	2 305 486
Egypt	331 579	0	0	591 521	21 211	0	0	686	1 826	0	0	667	6 287	24 178	977 955
Iran	1 059 391	24	2 133	0	107 719	2 712	3 315	0	326 422	3 836	16 196	0	27 413	59 768	1 608 929
Iraq	286 893	0	7	0	35 322	280	562	0	77 464	10 059	11 181	0	614	9 488	431 871
Jordan	73 185	0	231	639	1 093	0	0	58	9 928	0	350	25	114	3 041	88 663
Kuwait	13 144	0	0	0	3	0	0	0	189	0	0	0	97	3 778	17 210
Lebanon	1 601	443	2 083	0	256	775	366	0	975	941	667	0	80	2 140	10 328
Libya	1 280 958	0	0	317 594	1 269	0	0	38	3 513	0	0	22	1 547	9 618	1 614 560
Mauritania	1 008 703	0	0	1 398	398	0	0	0	26 494	0	0	0	1 345	545	1 038 882
Morocco	208 216	4 460	3 148	0	13 633	6 768	18	0	79 242	54 751	15 057	0	16 984	10 959	413 237
Oman	302 509	0	0	0	7	0	0	0	342	0	0	0	235	5 254	308 347
Saudi Arabia	1 866 606	0	0	51	5 813	0	0	0	2 534	0	0	0	789	31 815	1 907 608
Syria	75 469	875	338	0	17 797	6 979	348	0	63 728	8 962	569	0	733	9 121	184 919
Tunisia	102 133	0	0	0	2 888	2 960	0	0	20 879	11 628	0	0	4 737	9 288	154 512
UAE	70 261	0	0	0	31	0	0	0	37	0	0	0	221	7 685	78 234
Yemen	441 833	0	0	0	1 671	0	0	0	3 757	0	0	0	502	3 880	451 643
Total	10 882 874	435 447	9 239	1 116 445	242 401	23 292	4 610	783	1 068 716	190 314	47 019	736	142 289	226 785	14 390 950
Percent of total	76	3	0	8	2	0	0	0	7	1	0	0	1	2	

- LGY, LGA, LGT and LGH are livestock/rangeland-based systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MRY, MRA, MRT and MRH are mixed rainfed systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MIY, MIA, MIT and MIH are mixed irrigated systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively.

Appendix B
Number of people (000s) by country and production system

Country	LGA	LGH	LGT	LGY	MIA	MIH	MIT	MIY	MRA	MRH	MRT	MRY	Other	Urban	Total
Algeria	2 509	48	0	0	281	247	0	0	4 180	3 513	158	0	1 831	16 678	29 445
Bahrain	1	0	0	0	0	0	0	0	0	0	0	0	31	566	598
Egypt	1 718	0	0	422	5 648	0	0	61	64	0	0	0	2 525	57 330	67 768
Iran	10 108	0	34	0	4 839	165	134	0	12 575	319	699	0	1 320	39 802	69 998
Iraq	2 078	0	0	0	1 674	9	32	0	2 481	329	501	0	704	15 139	22 947
Jordan	241	0	0	40	204	0	0	7	618	0	8	2	6	3 753	4 879
Kuwait	205	0	0	0	0	0	0	0	46	0	0	0	32	1 611	1 893
Lebanon	0	0	0	0	28	109	16	0	124	155	46	0	38	2 908	3 425
Libya	369	0	0	0	11	0	0	0	38	0	0	0	38	4 437	4 892
Mauritania	625	0	0	3	4	0	0	0	119	0	0	0	37	340	1 128
Morocco	1 825	62	96	0	933	567	1	0	4 202	3 417	758	0	1 173	15 829	28 863
Oman	578	0	0	0	0	0	0	0	3	0	0	0	47	1 864	2 493
Qatar	42	0	0	0	0	0	0	0	0	0	0	0	4	500	546
Saudi Arabia	3 919	0	0	1	15	0	0	0	8	0	0	0	25	16 113	20 081
Syria	612	0	2	0	1 559	583	17	0	4 269	702	30	0	117	8 288	16 180
Tunisia	613	0	0	0	160	308	0	0	1 223	795	0	0	354	5 779	9 232
UAE	477	0	0	0	0	0	0	0	2	0	0	0	6	2 105	2 591
Yemen	13 090	0	0	0	192	0	0	0	513	0	0	0	31	4 366	18 192
Total	47 026	2 304	133	506	17 606	1 988	200	69	38 954	10 152	2 210	4	10 137	214 346	345 634
Percent of total	14	1	0	0	5	1	0	0	11	3	1	0	3	62	

- LGY, LGA, LGT and LGH are livestock/rangeland-based systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MRY, MRA, MRT and MRH are mixed rainfed systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MIY, MIA, MIT and MIH are mixed irrigated systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively.

Appendix C

Number of cattle (000s) by country and production system

Country	LGA	LGH	LGT	LGY	MIA	MIH	MIT	MIY	MRA	MRH	MRT	MRY	Other	Urban	Total
Algeria	160	5	0	0	19	38	0	0	278	530	11	0	372	163	1 576
Bahrain	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Egypt	597	0	0	356	1 775	0	0	63	18	0	0	3	76	1 560	4 449
Iran	2 757	0	15	0	1 224	55	64	0	3 190	96	161	0	722	526	8 811
Iraq	506	0	0	0	463	1	1	0	325	42	101	0	5	196	1 641
Jordan	9	0	0	2	7	0	0	0	33	0	0	0	0	10	62
Kuwait	12	0	0	0	0	0	0	0	0	0	0	0	0	10	22
Lebanon	11	3	10	0	6	12	3	0	8	8	3	0	1	16	79
Libya	102	0	0	0	1	0	0	0	6	0	0	0	8	12	130
Mauritania	930	0	0	0	3	0	0	0	673	0	0	0	5	2	1 613
Morocco	224	4	14	0	201	155	0	0	873	702	88	0	289	148	2 698
Oman	273	0	0	0	0	0	0	0	3	0	0	0	0	22	298
Qatar	7	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Saudi Arabia	311	0	0	0	13	0	0	0	2	0	0	0	0	29	355
Sudan	15 619	6 966	19	22	1 605	0	0	0	12 667	1 343	9	0	1 567	138	39 955
Syria	160	2	1	0	206	44	0	0	494	66	1	0	8	102	1 085
Tunisia	56	0	0	0	22	70	0	0	137	210	0	0	99	92	685
UAE	72	0	0	0	0	0	0	0	0	0	0	0	0	39	111
Yemen	1 280	0	0	0	25	0	0	0	61	0	0	0	4	50	1 420
Total Near East	23 088	6 980	59	382	5 631	375	68	63	18 854	2 997	375	3	3 155	3 310	65 341
Percent of total Near East	35	11	0	1	9	1	0	0	29	5	1	0	5	5	

- LGY, LGA, LGT and LGH are livestock/rangeland-based systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MRY, MRA, MRT and MRH are mixed rainfed systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MIY, MIA, MIT and MIH are mixed irrigated systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively.

Appendix D

Number of small ruminants (000s) by country and production system

Country	LGA	LGH	LGT	LGY	MIA	MIH	MIT	MIY	MRA	MRH	MRT	MRY	Other	Urban	Total
Algeria	8 598	212	0	0	248	150	0	0	7 062	3 705	261	0	1 181	1 002	22 420
Bahrain	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Egypt	2 767	0	0	1 406	1 987	0	0	99	52	0	0	5	91	2 398	8 806
Iran	33 983	2	117	0	8 253	160	229	0	24 816	154	1 372	0	2 964	2 802	74 850
Iraq	2 717	0	0	0	972	15	14	0	2 879	490	580	0	20	162	7 847
Jordan	892	0	7	83	98	0	0	8	966	0	14	5	4	256	2 333
Kuwait	439	0	0	0	0	0	0	0	3	0	0	0	0	362	803
Lebanon	133	30	171	0	23	73	35	0	85	80	71	0	6	145	853
Libya	5 027	0	0	9	73	0	0	0	180	0	0	0	61	426	5 776
Mauritania	10 053	0	0	0	99	0	0	0	4 016	0	0	0	67	20	14 255
Morocco	4 034	198	216	0	1 393	706	1	0	7 096	4 789	1 182	0	1 678	867	22 161
Oman	1 765	0	0	0	0	0	0	0	20	0	0	0	10	68	1 863
Qatar	267	0	0	0	0	0	0	0	1	0	0	0	0	0	268
Saudi Arabia	8 180	0	0	0	509	0	0	0	127	0	0	0	9	908	9 733
Sudan	34 580	19 971	60	21	2 674	0	0	0	25 872	3 879	28	0	3 627	836	91 548
Syria	4 931	163	31	0	2 668	884	16	0	9 264	1 245	81	0	160	706	20 147
Tunisia	3 048	0	0	0	317	299	0	0	2 104	1 462	0	0	466	894	8 589
UAE	1 192	0	0	0	0	0	0	0	3	0	0	0	0	795	1 990
Yemen	9 728	0	0	0	254	0	0	0	471	0	0	0	9	201	10 663
Total Near East	132 411	20 576	601	1 619	19 729	2 287	295	108	85 888	15 805	3 591	14	10 362	13 188	306 474
percent of total Near East	43	7	0	1	6	1	0	0	28	5	1	0	3	4	

- LGY, LGA, LGT and LGH are livestock/rangeland-based systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MRY, MRA, MRT and MRH are mixed rainfed systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MIY, MIA, MIT and MIH are mixed irrigated systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively.

Appendix E

Mean average precipitation, monthly temperature, maximum temperature of the warmest month and minimum temperature of the coldest month for 2000 and projections to 2050 for three scenarios, GCM HADCM3

Country	System	Precipitation (mm)				T_{mean} (ºC)				T_{min} (ºC)				T_{max} (ºC)			
		2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050		
			A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a
Algeria	LGA	42	35	33	34	23.7	27.0	26.7	26.4	5.3	7.8	7.7	7.4	42.5	46.5	46.2	46.0
	LGH	300	200	266	272	15.1	18.8	17.6	17.4	2.8	4.6	4.2	4.2	31.2	37.0	34.7	34.6
	LGY	13	11	7	6	23.6	26.7	26.6	26.1	5.9	8.7	8.5	8.1	38.6	42.3	41.6	41.1
	MIA	356	278	316	327	17.2	20.7	19.6	19.5	5.6	7.3	6.9	6.9	31.1	36.6	34.9	35.0
	MIH	598	494	556	558	16.6	19.9	18.5	18.4	4.6	6.4	6.0	6.0	32.0	37.1	34.3	34.2
	MRA	357	275	308	319	15.0	18.6	17.7	17.5	2.1	3.9	3.5	3.5	31.9	37.4	36.2	36.1
	MRH	540	434	490	493	15.1	18.4	17.1	16.9	2.5	4.3	3.9	3.9	31.7	37.0	34.5	34.4
	MRT	495	395	432	449	14.3	17.9	16.8	16.6	1.4	3.1	2.6	2.7	31.5	37.0	35.0	34.8
	Other	755	652	695	693	15.7	18.7	17.6	17.4	4.0	5.8	5.5	5.5	31.0	35.6	33.4	33.2
	Urban	406	333	368	372	17.7	21.1	20.2	20.0	4.4	6.3	5.9	5.9	34.2	39.1	37.7	37.7
	Total	386	311	347	352	17.4	20.8	19.8	19.6	3.9	5.8	5.5	5.4	33.6	38.6	36.8	36.7
Egypt	LGA	31	24	25	25	20.5	23.2	23.0	22.8	6.0	8.5	8.3	8.1	34.1	37.9	37.6	37.2
	LGY	1	1	1	1	22.8	25.6	25.5	25.2	5.3	8.1	7.9	7.7	38.2	41.8	41.7	41.2
	MIA	78	63	67	69	20.3	22.8	22.3	22.3	7.2	9.6	9.1	8.9	32.6	36.2	35.2	35.2
	MIY	2	2	1	0	22.3	25.1	25.0	24.8	5.0	7.6	7.5	7.3	37.8	41.5	41.6	41.2
	MRA	105	81	92	97	19.6	22.2	21.7	21.6	7.4	9.7	9.2	9.1	31.2	34.9	33.8	33.7
	MRY	0	0	0	0	23.0	25.8	25.7	25.4	5.1	7.8	7.6	7.4	38.8	42.5	42.5	42.0
	Other	25	19	21	22	23.9	26.7	26.4	26.2	8.6	11.3	11.0	10.8	37.5	41.2	40.7	40.4
	Urban	29	24	25	26	22.0	24.7	24.4	24.3	6.4	9.0	8.7	8.5	36.1	39.7	39.3	39.1
	Total	34	27	29	30	21.8	24.5	24.2	24.1	6.4	9.0	8.7	8.5	35.8	39.5	39.0	38.7
Iran	LGA	145	120	139	138	18.5	21.5	21.2	20.9	0.4	2.4	2.5	1.9	37.3	40.8	40.6	40.1
	LGH	441	361	388	410	13.5	16.7	16.7	16.4	-1.8	0.7	1.6	0.8	32.7	37.6	37.7	37.5
	LGT	482	431	486	475	13.1	16.2	15.9	15.6	-5.5	-3.6	-3.3	-3.9	35.1	39.2	39.1	38.5
	MIA	318	276	306	306	14.2	17.3	17.0	16.7	-3.6	-1.6	-1.1	-1.7	34.8	39.1	38.8	38.4
	MIH	874	852	888	888	15.5	18.6	18.3	18.1	2.0	4.2	4.2	4.0	31.6	36.1	36.0	35.8
	MIT	436	382	416	424	13.2	16.4	16.2	15.9	-3.6	-1.5	-0.7	-1.4	33.8	38.5	38.7	38.3
	MRA	316	275	308	306	13.5	16.7	16.3	16.0	-4.5	-2.5	-2.1	-2.6	34.2	38.4	38.1	37.7
	MRH	804	788	821	820	15.7	18.7	18.4	18.2	2.6	4.6	4.5	4.4	31.2	35.6	35.3	35.2
	MRT	496	432	489	484	13.9	17.1	16.9	16.6	-3.9	-2.0	-1.4	-2.0	35.8	40.4	40.3	39.8
	Other	375	357	379	379	15.5	18.5	18.1	17.8	-1.0	1.0	1.1	0.7	34.0	38.1	37.6	37.4
	Urban	325	294	322	321	16.7	19.8	19.4	19.1	-0.9	1.0	1.3	0.9	36.2	40.3	39.9	39.5
	Total	456	415	449	450	14.8	18.0	17.7	17.4	-1.8	0.2	0.6	0.1	34.2	38.6	38.4	38.0

Appendix E

Mean average precipitation, monthly temperature, maximum temperature of the warmest month and minimum temperature of the coldest month for 2000 and projections to 2050 for three scenarios, GCM HADCM3 (continued)

Country	System	Precipitation (mm)				T_{mean} (ºC)				T_{min} (ºC)				T_{max} (ºC)			
		2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050		
			A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a
Iraq	LGA	116	92	109	113	21.9	25.1	24.9	24.6	3.6	5.9	6.0	5.4	41.8	45.9	45.8	45.2
	LGT	828	749	757	784	12.4	15.7	15.5	15.2	-5.3	-2.9	-2.7	-3.1	33.1	38.4	38.2	37.6
	MIA	185	149	179	181	22.8	26.1	25.8	25.5	4.5	6.7	6.9	6.3	43.4	47.6	47.5	47.0
	MIH	617	562	569	581	19.7	23.0	22.8	22.5	2.0	4.1	4.2	3.8	41.9	47.1	46.7	46.1
	MIT	752	701	727	717	18.4	21.7	21.5	21.2	0.6	2.7	3.1	2.6	39.5	44.3	44.1	43.5
	MRA	382	329	360	365	20.1	23.4	23.1	22.8	2.4	4.3	4.6	4.2	41.2	45.8	45.7	45.2
	MRH	652	589	599	612	19.3	22.6	22.4	22.1	2.0	3.9	4.1	3.8	41.1	46.3	45.9	45.4
	MRT	804	742	761	764	14.8	18.1	17.9	17.6	-3.1	-0.9	-0.6	-1.1	36.1	41.1	40.9	40.3
	Other	400	353	372	379	20.6	23.9	23.7	23.4	2.7	4.8	5.0	4.6	41.6	46.1	45.9	45.4
	Urban	213	178	202	205	22.5	25.7	25.5	25.2	4.2	6.4	6.5	6.0	43.1	47.3	47.2	46.6
	Total	495	444	463	470	19.2	22.5	22.3	22.0	1.4	3.5	3.7	3.2	40.3	45.0	44.8	44.2
Jordan	LGA	77	66	69	76	18.3	21.3	20.7	20.6	1.9	4.2	4.1	3.6	35.3	39.2	38.5	38.3
	LGT	205	181	201	214	15.5	18.5	17.8	17.7	1.9	4.4	4.1	3.7	30.3	34.1	33.4	33.2
	LGY	118	82	114	124	23.3	26.2	25.2	25.2	9.1	11.3	10.9	10.7	38.1	41.9	40.5	40.6
	MIA	290	241	279	303	19.8	22.7	21.5	21.6	6.2	8.2	7.9	7.7	34.6	38.4	36.4	36.8
	MIY	160	111	155	170	24.1	27.0	25.8	25.9	9.8	11.7	11.5	11.3	39.5	43.2	41.3	41.7
	MRA	237	202	230	248	17.5	20.5	19.4	19.5	3.7	5.9	5.5	5.3	32.1	35.9	34.4	34.6
	MRT	291	261	288	305	14.8	17.7	17.0	16.9	1.6	4.1	3.6	3.3	29.3	33.1	32.3	32.1
	MRY	129	84	124	136	24.2	27.0	26.0	26.0	9.9	11.9	11.5	11.4	39.2	42.9	41.2	41.4
	Other	91	66	87	94	22.9	25.8	25.0	25.0	8.5	10.9	10.4	10.1	37.7	41.5	40.2	40.3
	Urban	274	241	265	287	17.3	20.2	19.2	19.2	3.6	5.7	5.4	5.2	32.0	35.8	34.3	34.4
	Total	187	153	181	196	19.8	22.7	21.8	21.8	5.6	7.8	7.5	7.2	34.8	38.6	37.3	37.3
Kuwait	LGA	110	84	103	101	24.7	27.5	27.6	27.2	6.9	9.4	9.5	8.7	43.9	47.4	47.4	46.9
	MIA	94	73	87	84	24.7	27.3	27.4	27.0	8.1	10.2	10.5	9.7	42.3	45.4	45.5	45.1
	MRA	131	101	123	121	25.2	27.7	27.9	27.5	7.6	9.8	10.0	9.3	43.6	46.6	46.9	46.4
	Other	119	90	110	109	25.3	27.8	28.1	27.7	7.9	10.1	10.3	9.6	43.6	46.5	46.9	46.3
	Urban	102	77	94	93	25.0	27.7	27.8	27.4	7.7	9.9	10.2	9.4	43.5	46.7	46.8	46.4
	Total	111	85	103	102	25.0	27.6	27.7	27.4	7.7	9.9	10.1	9.4	43.4	46.5	46.7	46.2

Appendix E

Mean average precipitation, monthly temperature, maximum temperature of the warmest month and minimum temperature of the coldest month for 2000 and projections to 2050 for three scenarios, GCM HADCM3 (continued)

Country	System	Precipitation (mm)				T_{mean} (ºC)				T_{min} (ºC)				T_{max} (ºC)			
		2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050		
			A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a
Lebanon	LGA	734	638	665	706	12.5	15.5	14.0	14.2	-0.6	1.2	1.0	1.0	27.7	31.8	28.9	29.2
	LGH	947	849	861	915	15.8	18.8	17.4	17.5	3.6	5.3	5.2	5.0	29.9	33.8	30.9	31.3
	LGT	714	621	648	690	11.5	14.6	13.1	13.2	-1.5	0.2	0.1	0.0	26.5	30.6	27.7	28.0
	MIA	821	731	753	807	16.3	19.2	17.8	17.9	4.4	6.1	5.9	5.9	29.4	33.3	30.4	30.9
	MIH	821	729	739	791	17.9	20.8	19.5	19.6	6.0	7.7	7.5	7.5	30.6	34.3	31.7	32.0
	MIT	624	532	569	607	15.2	18.2	16.7	16.8	1.7	3.4	3.2	3.1	31.4	35.4	32.4	32.8
	MRA	852	763	783	838	16.1	19.0	17.5	17.7	4.4	6.1	5.9	5.8	29.4	33.3	30.4	30.9
	MRH	894	803	814	869	17.3	20.2	18.8	18.9	5.7	7.4	7.2	7.1	30.0	33.7	31.0	31.4
	MRT	850	763	781	836	12.9	15.9	14.4	14.5	0.5	2.2	2.0	1.9	27.0	31.0	28.0	28.5
	Other	793	696	708	755	16.8	19.7	18.4	18.5	4.3	5.9	5.8	5.7	30.2	34.1	31.4	31.7
	Urban	932	834	844	900	17.1	19.9	18.5	18.7	5.5	7.2	7.0	6.9	30.1	33.8	31.0	31.4
	Total	816	723	742	792	15.4	18.4	16.9	17.0	3.1	4.8	4.6	4.5	29.3	33.2	30.4	30.7
Libya	LGA	36	24	28	27	21.4	24.1	24.1	23.8	4.7	7.1	6.9	6.9	37.3	40.6	40.3	40.1
	LGY	1	1	0	0	22.8	25.6	25.6	25.2	5.4	8.3	8.1	7.8	39.0	42.1	41.7	41.6
	MIA	152	118	132	128	21.0	23.5	23.4	23.2	6.0	8.1	7.9	8.1	35.7	38.9	38.7	38.5
	MIY	0	0	0	0	23.4	26.1	26.2	25.8	5.9	8.8	8.6	8.4	39.7	42.6	42.2	42.3
	MRA	214	170	178	178	20.2	22.4	22.3	22.1	6.4	8.4	8.2	8.3	33.5	36.2	36.1	36.0
	MRY	0	0	0	0	23.4	26.1	26.2	25.8	5.9	8.8	8.6	8.4	39.7	42.6	42.2	42.3
	Other	395	317	310	317	17.9	19.9	19.7	19.6	6.2	7.9	7.6	7.7	29.2	31.6	31.4	31.2
	Urban	213	163	183	179	20.1	22.5	22.3	22.1	6.4	8.5	8.2	8.4	33.5	36.7	36.5	36.3
	Total	126	99	104	104	21.2	23.8	23.7	23.4	5.9	8.2	8.0	8.0	36.0	38.9	38.6	38.5
Mauritania	LGA	85	60	65	67	27.6	30.7	30.2	29.9	12.4	15.1	15.0	14.7	42.8	46.3	45.4	45.0
	LGY	18	12	15	14	22.1	24.6	23.5	23.5	13.4	16.2	15.0	15.0	31.1	33.7	32.4	32.3
	MIA	205	108	154	173	27.2	30.0	29.0	29.0	14.7	17.9	16.8	16.6	37.5	40.4	39.3	39.2
	MRA	328	232	245	280	28.8	32.1	31.6	31.1	14.7	17.7	17.5	16.9	41.1	44.4	43.4	43.3
	Other	180	107	130	147	27.0	29.8	29.1	28.9	14.7	17.6	17.1	16.7	38.0	40.8	39.8	39.7
	Urban	170	108	128	140	27.4	30.2	29.6	29.4	14.5	17.4	16.9	16.6	38.8	41.7	40.8	40.5
	Total	165	104	123	137	26.7	29.6	28.8	28.6	14.0	17.0	16.4	16.1	38.2	41.2	40.2	40.0

Appendix E

Mean average precipitation, monthly temperature, maximum temperature of the warmest month and minimum temperature of the coldest month for 2000 and projections to 2050 for three scenarios, GCM HADCM3 (continued)

Country	System	Precipitation (mm)				T_{mean} (ºC)				T_{min} (ºC)				T_{max} (ºC)			
		2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050		
			A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a
Morocco	LGA	175	130	147	151	18.2	21.4	20.4	20.3	2.4	4.5	3.9	3.8	36.3	40.2	38.8	38.9
	LGH	277	175	236	248	14.3	17.9	16.7	16.6	-0.1	1.8	1.2	1.1	32.5	37.1	34.9	34.8
	LGT	566	458	484	500	10.4	13.8	12.4	12.3	-5.3	-3.3	-3.8	-3.9	30.5	34.7	32.3	32.5
	MIA	314	228	256	267	18.5	21.8	20.2	20.1	5.3	7.5	6.6	6.5	33.9	37.6	35.4	35.3
	MIH	537	409	486	500	18.6	21.9	20.2	20.1	5.9	7.8	7.1	7.1	34.4	38.2	35.6	35.5
	MIT	875	726	822	857	16.6	19.9	18.2	18.2	4.1	6.0	5.2	5.3	32.5	37.0	34.3	34.2
	MRA	345	256	283	295	16.2	19.5	17.9	17.9	3.2	5.3	4.4	4.4	31.5	35.3	33.1	33.0
	MRH	515	392	458	475	16.9	20.2	18.7	18.7	3.7	5.7	4.9	4.9	33.7	37.8	35.4	35.4
	MRT	586	461	508	525	12.6	16.0	14.7	14.6	-2.5	-0.5	-1.0	-1.1	32.2	36.5	34.1	34.4
	Other	686	555	624	648	15.5	18.8	17.2	17.2	2.5	4.5	3.7	3.8	31.8	35.8	33.4	33.3
	Urban	431	326	376	390	17.9	21.1	19.5	19.5	5.4	7.5	6.7	6.7	32.5	36.2	33.9	33.8
	Total	482	374	425	442	16.0	19.3	17.8	17.8	2.2	4.2	3.5	3.5	32.9	36.9	34.6	34.6
Oman	LGA	59	39	61	56	26.3	29.0	29.2	28.7	14.4	17.0	17.6	16.4	37.7	40.4	40.8	40.4
	MIA	80	50	80	81	27.3	30.0	30.1	29.7	16.5	18.6	19.1	18.4	38.1	40.8	40.8	40.4
	MRA	153	116	172	161	22.3	25.0	25.2	24.7	10.3	12.8	13.3	12.4	33.6	36.6	36.6	36.2
	Other	100	72	109	103	25.5	28.2	28.4	28.0	14.9	17.2	17.8	16.9	36.0	38.9	39.1	38.7
	Urban	88	61	101	95	26.6	29.4	29.6	29.1	15.0	17.5	18.1	17.1	37.9	41.0	41.1	40.7
	Total	96	67	104	99	25.6	28.3	28.5	28.0	14.2	16.6	17.2	16.3	36.7	39.5	39.7	39.3
Qatar	LGA	73	57	74	70	26.8	29.7	29.5	29.0	13.0	15.6	15.6	14.8	40.4	43.9	43.5	43.0
	MRA	74	59	76	71	26.7	29.6	29.4	28.9	13.0	15.5	15.5	14.7	40.2	43.7	43.4	42.9
	Other	75	59	76	71	26.8	29.5	29.4	28.9	13.2	15.6	15.6	15.0	40.1	43.4	43.1	42.6
	Urban	76	59	77	72	26.9	29.8	29.5	29.0	12.9	15.5	15.5	14.7	40.7	44.3	43.7	43.2
	Total	75	59	76	71	26.8	29.6	29.4	29.0	13.0	15.5	15.5	14.8	40.4	43.8	43.4	42.9
Saudi Arabia	LGA	94	82	92	87	24.6	27.6	27.5	27.0	8.6	11.3	11.3	10.3	39.9	43.7	43.4	42.8
	LGY	5	5	3	4	23.1	26.1	25.9	25.6	10.1	12.9	12.7	12.3	34.8	38.8	38.7	38.2
	MIA	128	119	128	121	23.3	26.4	26.3	25.8	5.9	8.6	8.6	7.7	40.3	44.2	44.0	43.4
	MRA	117	106	113	109	22.4	25.4	25.1	24.8	6.3	9.0	8.7	8.1	38.0	41.8	41.4	40.9
	Other	83	72	79	76	24.2	27.3	27.0	26.6	9.1	11.9	11.6	11.0	38.4	42.0	41.7	41.1
	Urban	119	106	114	110	24.6	27.7	27.3	26.8	9.4	12.1	11.7	11.0	39.4	43.0	42.5	42.0
	Total	91	82	88	84	23.7	26.7	26.5	26.1	8.2	11.0	10.8	10.1	38.5	42.2	41.9	41.4

Appendix E

Mean average precipitation, monthly temperature, maximum temperature of the warmest month and minimum temperature of the coldest month for 2000 and projections to 2050 for three scenarios, GCM HADCM3 (continued)

Country	System	Precipitation (mm)				T_{mean} (ºC)				T_{min} (ºC)				T_{max} (ºC)			
		2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050		
			A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a
Syria	LGA	149	122	132	140	17.7	20.8	20.2	20.1	1.3	3.1	2.9	2.7	36.7	40.7	40.1	39.8
	LGH	769	683	682	723	17.0	20.2	18.9	18.9	4.0	5.5	5.5	5.3	30.6	34.8	32.2	32.3
	LGT	313	283	293	315	14.1	17.1	16.0	16.0	-0.8	1.1	0.9	0.7	29.6	33.6	31.6	31.8
	MIA	322	267	283	298	18.5	21.8	21.3	21.1	2.2	3.9	3.8	3.7	38.8	43.4	43.1	42.7
	MIH	552	467	484	509	18.2	21.3	20.8	20.7	3.0	4.6	4.6	4.5	36.6	41.0	40.5	40.2
	MIT	484	417	445	480	14.7	17.7	16.2	16.4	1.2	2.9	2.7	2.6	30.7	34.6	31.9	32.2
	MRA	242	198	211	223	17.8	20.9	20.4	20.2	1.4	3.1	2.9	2.7	37.6	41.9	41.3	41.1
	MRH	673	584	586	616	17.1	20.2	19.5	19.4	2.5	4.0	3.8	3.7	34.2	38.3	37.6	37.4
	MRT	535	466	491	530	13.6	16.6	15.2	15.3	0.3	2.1	1.9	1.7	29.2	33.1	30.3	30.8
	Other	907	799	788	825	17.5	20.6	19.8	19.7	3.9	5.4	5.2	5.1	32.6	36.8	35.6	35.4
	Urban	321	268	281	298	17.9	21.0	20.3	20.2	2.3	4.0	3.8	3.7	36.4	40.5	39.6	39.4
	Total	479	414	425	451	16.7	19.8	19.0	18.9	1.9	3.6	3.5	3.3	33.9	38.1	36.7	36.7
Tunisia	LGA	116	84	104	99	20.0	23.0	22.9	22.7	4.6	6.7	6.6	6.8	37.6	41.9	42.2	42.4
	MIA	336	263	302	304	17.8	20.6	20.0	19.8	4.3	6.3	6.0	6.1	35.3	39.4	38.4	38.4
	MIH	504	414	453	453	17.6	20.1	19.4	19.2	5.2	7.0	6.6	6.8	34.0	37.7	36.2	35.9
	MRA	358	285	322	324	17.2	20.0	19.5	19.2	3.8	5.7	5.5	5.6	34.5	38.6	37.8	37.8
	MRH	558	463	503	503	17.0	19.7	18.9	18.7	4.2	6.1	5.6	5.8	34.4	38.4	36.8	36.5
	Other	643	554	582	579	16.8	19.3	18.7	18.5	4.5	6.4	6.0	6.1	33.1	36.8	35.7	35.4
	Urban	315	255	285	283	18.5	21.1	20.8	20.6	5.5	7.4	7.2	7.4	34.2	37.9	37.6	37.5
	Total	404	331	364	364	17.9	20.6	20.0	19.8	4.6	6.5	6.2	6.4	34.7	38.7	37.8	37.7
United Arab Emirates	LGA	70	54	82	75	27.1	30.1	30.0	29.5	13.2	15.9	16.4	15.4	40.1	43.8	43.7	43.1
	MIA	75	57	89	85	27.1	30.0	30.0	29.5	13.5	16.2	16.8	15.8	39.8	43.5	43.5	42.8
	MRA	111	89	127	118	25.6	28.6	28.4	28.0	12.0	14.6	15.0	14.2	38.3	41.7	41.4	40.9
	Other	78	60	87	81	26.9	29.9	29.8	29.3	13.0	15.7	16.1	15.3	40.2	43.5	43.4	42.9
	Urban	99	78	113	108	26.9	29.8	29.7	29.2	13.4	16.0	16.5	15.7	39.6	42.7	42.7	42.2
	Total	86	68	100	93	26.7	29.7	29.6	29.1	13.0	15.7	16.2	15.3	39.6	43.0	42.9	42.4

Appendix E

Mean average precipitation, monthly temperature, maximum temperature of the warmest month and minimum temperature of the coldest month for 2000 and projections to 2050 for three scenarios, GCM HADCM3

Country	System	Precipitation (mm)				T_{mean} (ºC)				T_{min} (ºC)				T_{max} (ºC)			
		2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050			2000	Scenario 2050		
			A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a		A1b	A2a	B2a
Yemen	LGA	111	108	114	104	22.9	25.9	25.7	25.2	11.6	14.6	14.6	13.3	33.6	36.9	36.4	35.9
	MIA	159	168	160	137	26.7	29.6	28.7	28.4	16.3	19.4	18.1	17.8	36.5	39.9	38.7	38.4
	MRA	196	204	205	183	25.8	28.8	28.1	27.7	15.6	18.6	17.8	17.3	35.6	39.2	38.0	37.6
	Other	97	91	92	87	26.9	29.2	29.0	28.6	19.3	21.4	21.2	20.7	35.3	38.1	37.6	37.1
	Urban	208	217	217	195	22.6	25.5	24.9	24.6	11.8	14.7	14.1	13.4	32.9	36.6	35.4	34.9
	Total	154	158	158	141	25.0	27.8	27.3	26.9	14.9	17.7	17.2	16.5	34.8	38.1	37.2	36.8

- LGY, LGA, LGT and LGH are livestock/rangeland-based systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MRY, MRA, MRT and MRH are mixed rainfed systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively;
- MIY, MIA, MIT and MIH are mixed irrigated systems in hyper-arid, arid, temperate/tropical highlands and humid/sub-humid areas, respectively.

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