CHAPTER 1

Drylands, people and land use

CHARACTERISTICS OF DRYLANDS

There is no single agreed definition of the term drylands. Two of the most widely accepted definitions are those of FAO and the United Nations Convention to Combat Desertification (UNCCD, 2000). FAO has defined drylands as those areas with a length of growing period (LGP) of 1–179 days (FAO, 2000a); this includes regions classified climatically as arid (Plate 1), semi-arid and dry subhumid. The UNCCD classification employs a ratio of annual precipitation to potential evapotranspiration (P/PET). This value indicates the maximum quantity of water capable of being lost, as water vapour, in a given climate, by a continuous stretch of vegetation covering the whole ground and well supplied with water. Thus, it includes evaporation from the soil and transpiration from the vegetation from a specific region in a given time interval (WMO, 1990). Under the UNCCD classification, drylands are characterized by a P/PET of between 0.05 and 0.65.

PLATE 1
A view of dryland (with village in the background) in the Sahel, southern Niger (P. Cenini)

According to both classifications, the hyperarid zones (LGP = 0 and P/PET < 0.05), or true deserts, are not included in the drylands and do not have potential for agricultural production, except where irrigation water is available.

While about 40 percent of the world's total land area is considered to be drylands (according to the UNCCD classification system), the extent of drylands in various regions ranges from about 20 percent to 90 (Table 1 and Figure 1).

Drylands are a vital part of the earth's human and physical environments. They encompass grasslands, agricultural lands, forests and urban areas. Dryland ecosystems play a major role in global biophysical processes by reflecting and absorbing solar radiation and maintaining the balance of atmospheric constituents (Ffolliott *et al*., 2002). They provide much of the world's grain and livestock, forming the habitat that supports many vegetable species, fruit trees and micro-organisms.

High variability in both rainfall amounts and intensities are characteristics of dryland regions, as are the occurrence of prolonged periods of drought. A drought is defined as a departure from the average or normal conditions, sufficiently prolonged (1-2 years - FAO, 2004) as to affect the hydrological balance and adversely affect ecosystem functioning and the resident populations. There are actually four different ways that drought can be defined (National Weather Service, 2004). Meteorological drought is a measure of the departure of precipitation from normal. Due to climatic differences, a drought in one location may not be a drought in another location. Agricultural drought refers to situations where the amount of soil water is no longer sufficient to meet the needs of a particular crop. Hydrological drought occurs when surface and subsurface water supplies are below normal. Socioeconomic drought describes the situation that occurs when physical water shortages begin to affect people. This report is primarily concerned with agricultural droughts.

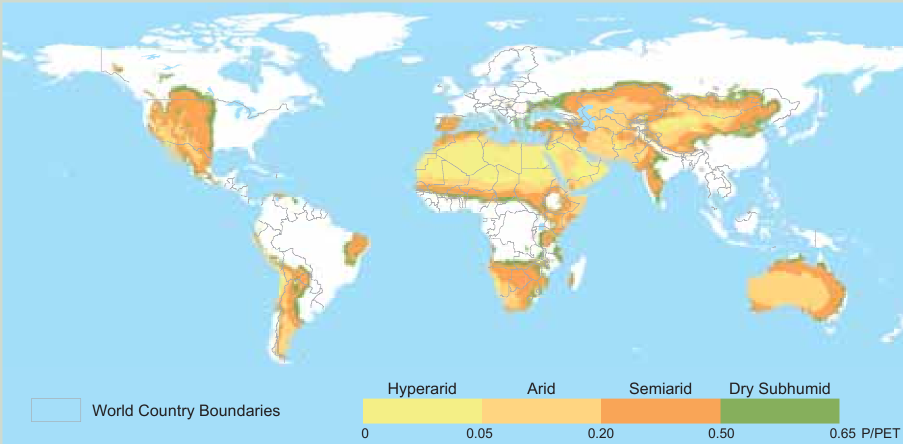
The terms drought and aridity are sometimes used interchangeably, but they are different.

TABLE 1
Regional extent of drylands

	ARIDITY ZONE							
	Arid		Semi-arid		Dry subhumid		All drylands	
REGION	(1 000 km²)	(%)	(1 000 km²)	(%)	(1 000 km²)	(%)	(1 000 km²)	(%)
Asia (incl. Russia)	6 164	13	7 649	16	4 588	9	18 401	39
Africa	5 052	17	5 073	17	2 808	9	12 933	43
Oceania	3 488	39	3 532	39	996	11	8 016	89
North America	379	2	3 436	16	2 081	10	5 896	28
South America	401	2	2 980	17	2 223	13	5 614	32
Central America and Caribbean	421	18	696	30	242	10	1 359	58
Europe	5	0	373	7	961	17	1 359	24
World total	**15 910**	**12**	**23 739**	**18**	**13 909**	**10**	**53 558**	**40**

Source: UNSO/UNDP, 1997.

FIGURE 1
Distribution of drylands in the world



Source: IIASA/FAO, 2003.

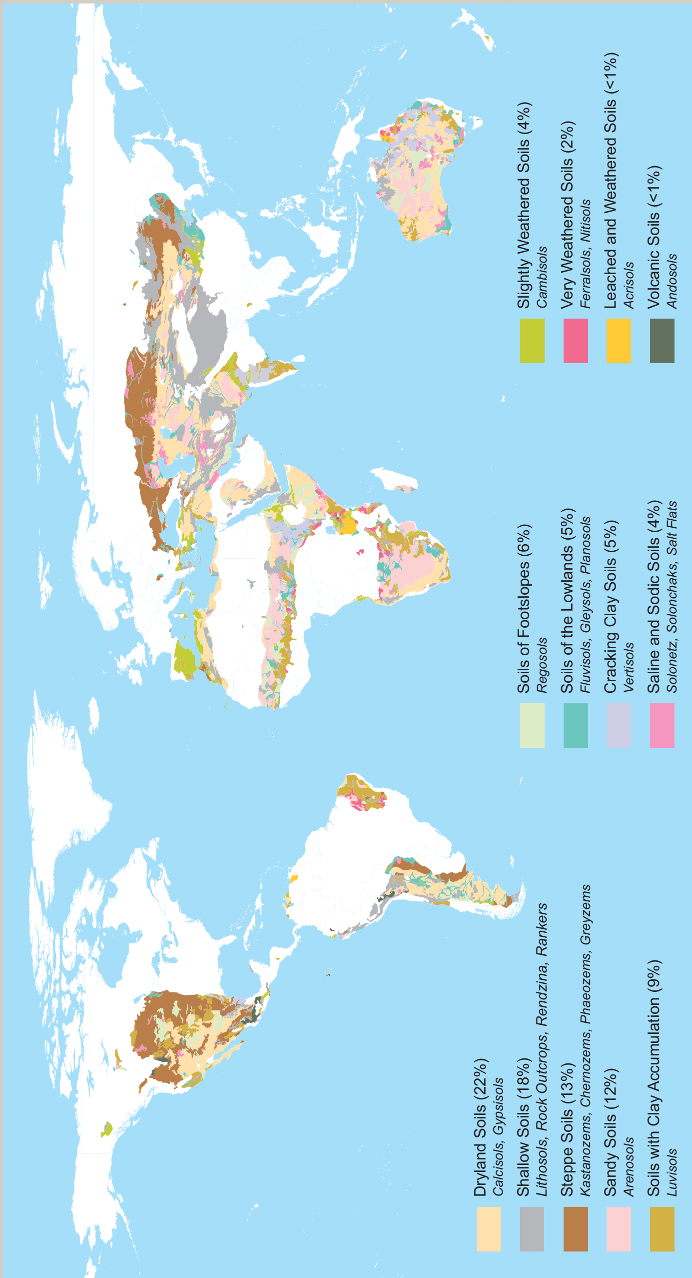
Aridity refers to the average conditions of limited rainfall and water supplies, not to the departures from the norm, which define a drought. All the characteristics of dryland regions must be recognized in the planning and management of natural and agricultural resources (Jackson, 1989). Because the soils of dryland environments often cannot absorb all of the rain that falls in large storms, water is often lost as runoff (Brooks *et al.*, 1997). At other times, water from a rainfall of low intensity can be lost through evaporation when the rain falls on a dry soil surface. Molden and Oweis (2007) state that as much as 90 percent of the rainfall in arid environments evaporates back into the atmosphere leaving only 10 percent for productive transpiration. Ponce (1995) estimates that only 15 to 25 percent of the precipitation in semiarid regions is used for evapotranspiration and that a similar amount is lost as runoff. Evapotranspiration is the sum of transpiration and evaporation during the period a crop is grown. The remaining 50 to 70 percent is lost as evaporation during periods when beneficial crops are not growing.

Three major types of climate are found in drylands: Mediterranean, tropical and continental (although some places present departures from these). Dryland environments are frequently characterized by a relatively cool and dry season, followed by a relatively hot and dry season, and finally, by a moderate and rainy season. There are often significant diurnal fluctuations in temperatures which restricts the growth of plants within these seasons.

The geomorphology of drylands is highly variable. Mountain massifs, plains, pediments, deeply incised ravines and drainage patterns display sharp changes in slope and topography, and a high degree of angularity. Streams and rivers traverse wide floodplains at lower elevations and, at times, are subject to changes of course, often displaying braided patterns. Many of these landforms are covered by unstable sand dunes and sand sheets. Dryland environments are typically windy, mainly because of the scarcity of vegetation or other obstacles that can reduce air movement. Dust storms are also frequent when little or no rain falls.

Soils in drylands are diverse in their origin, structure and physicochemical properties. In general, they include Calcisols, Gypsisols. Leptosols and Steppe soils (FAO, 2004) (Figure 2). Important features of dryland soils for agricultural production are their water holding capacity and their ability to supply nutrients to plants. As there is little deposition, accumulation or decomposition of organic material in dryland environments, the

FIGURE 2
Major soil types of drylands



Source: World Soil Resources Map. FAO/EC/ISRIC, 2003.

organic content of the soils is low and, therefore, natural soil fertility is also low.

Much of the water that is available to people living in drylands regions is found in large rivers that originate in areas of higher elevation (e.g. the Nile, Tigris-Euphrates, Indus, Ganges, Senegal, Niger and Colorado Rivers). Groundwater resources can also be available to help support development. However, the relatively limited recharge of groundwater resources is dependent largely on the amount, intensity and duration of the rainfall and soil properties, the latter including the infiltration capacity and waterholding characteristics of the soil, which also influence the amount of surface runoff. With current management practices, much of the rainfall is lost by evapotranspiration or runoff. As a result, groundwater is recharged only locally by seepage through the soil profile. Surface runoff events, soil-moisture storage, and groundwater recharge in dryland regions are generally more variable and less reliable than in more humid regions. In some areas, important reservoirs of fossil ground water exist and continue to be used by human population. Fossil water is groundwater that has remained in an aquifer for millennia. Extraction of fossil groundwater is often called mining because it is a non-renewable resource. For such aquifers, including the vast U.S. Ogallala aquifer, the deep aquifer under the North China Plain, and the Saudi aquifer, depletion can bring pumping to an end. In some cases, farmers can convert to dryland farming, but in arid regions it is the end of farming. Brown (2008) cited a 2001 China study that showed the water table under the North China Plain is falling fast and this area produces over half of the country's wheat and a third of its maize. He also cited a World Bank study that reported 15 percent of India's food supply is produced by mining groundwater. Even in areas where groundwater is recharged, it is frequently used at rates that exceed the recharge rate. Water that is available for use in many drylands regions can be affected also by salinity and mineralization (Armitage, 1987).

DRYLANDS PEOPLE

Drylands are inhabited by more than 2 000 million people, nearly 40 percent of the world's population (White and Nackoney, 2003). Dryland populations are frequently some of the poorest in the world, many subsisting on less than US$1 per day (White *et al.*, 2002).

The population distribution patterns vary within each region and among the climate zones comprising drylands. Regionally, Asia has the largest percentage of population living in drylands: more than 1 400 million people, or 42 percent of the region's population. Africa has nearly the same percentage of people living in drylands (41 percent) although the total number is smaller at almost 270 million. South America has 30 percent of its population in drylands, or about 87 million people (Table 2).

Rural people living in drylands can be grouped into nomadic, semi-nomadic, transhumant and sedentary smallholder agricultural populations. Nomadic people are found in pastoral groups that depend on livestock for subsistence and, whenever possible, farming as a supplement. Following the irregular distribution of rainfall, they migrate in search of pasture and water for their animals. Semi-nomadic people are also found in pastoral groups that depend largely on livestock and practice agricultural cultivation at a base camp, where they return for varying periods. Transhumant populations combine farming and livestock production during favourable seasons, but seasonally they might migrate along regular routes using vegetation growth patterns of altitudinal changes when forage for grazing diminishes in the farming area. Sedentary (smallholder) farmers practise rainfed or irrigated agriculture (Ffolliott *et al.*, 2002) often combined with livestock production.

The human populations of the drylands live in increasing insecurity due to land degradation and desertification and as the productive land per capita diminishes due to population pressure (Plate 2). The sustainable management of drylands is essential to achieving food security and the conservation of biomass and biodiversity of global significance (UNEP, 2000).

LAND USE SYSTEMS IN DRYLANDS

Dryland farming is generally defined as farming in regions where lack of soil moisture limits crop or pasture production to part of the year. Dryland farming systems are very diverse, including a variety of shifting agriculture systems, annual croplands, home gardens and mixed agriculture–livestock systems, also nomadic pastoral and transhumant systems (Figure 3 and Plate 3). They also include fallow systems and other indigenous intensification systems (FAO, 2004) for soil moisture and soil fertility restoration. Haas, Willis and Bond (1974) defined fallow as a farming practice where and when no crop is grown and all plant growth is controlled by tillage or herbicides during a season when a crop might normally be grown

The major farming systems of the drylands vary according to the agro-ecological conditions of these regions. A recent study of the Land Degradation Assessment in Dryland projects (LADA, 2008) identified the major farming systems in drylands according to socio-economic information, agro-ecology and possibilities for irrigation. The majority of the drylands used for agriculture is under cereal cultivation. Annex 2 summarizes farming practices in some of the major dryland areas of the world.

Successful dryland farming requires the integrated management of soil, water, crops and plant nutrients. Small-scale, resource-poor, usually subsistence-based farmers, widely referred to as small-holders, operate and survive in these varied, changeable and hazardous environments by being able to manage the multiple risks (FAO, 2004) through diversification, flexibility and adaptability (Mortimore and Adams, 1999). Stewart and Koohafkan (2004) and Stewart, Koohafkan and Ramamoothy (2006) have also reviewed the importance and some of the constraints of dryland farming. Expansion of cropland areas in dryland regions can fail owing to overexpansion of inappropriate production technologies into the drylands environment. Increased population pressures and human expansion into drier areas during long wet periods leave an increasing number of people vulnerable to drought. Removing critical production elements (e.g. dry-season grazing areas) from the traditional complex land-use systems through the introduction of irrigated and non-irrigated crops, or the increased industrial and urban use of water, break links in traditional production chains.

One of the reasons why dryland farming has generally been inefficient is the poverty trap. Resource-poor people living in marginal environments try to survive by avoiding damage resulting from hazards. Avoiding risks often entails maximizing the use of labour while minimizing the use of capital-intensive resources as the poor cannot afford to invest sufficiently

TABLE 2
Human populations of the world's drylands

REGION	ARIDITY ZONE							
	Arid		Semi-arid		Dry subhumid		All drylands	
	(1 000)	(%)	(1 000)	(%)	(1 000)	(%)	(1 000)	(%)
Asia (incl. Russia)	161 554	5	625 411	18	657 899	19	1 444 906	42
Africa	40 503	6	117 647	18	109 370	17	267 563	41
Oceania	275	1	1 342	5	5 318	19	6 960	25
North America	6 257	2	41 013	16	12 030	5	59 323	25
South America	6 331	2	46 852	16	33 777	12	86 990	30
C. America and Caribbean	6 494	6	12 888	11	12 312	8	31 719	28
Europe	629	0	28 716	5	111 216	20	140 586	25
World total	222 043	4	873 871	4	941 922	17	2 038 047	37

Source: UNSO/UNDP, 1997.

PLATE 2
Bedouin families use the meagre vegetation of the steppes for cooking and heating. The deterioration of the fragile dryland ecosystem has also led to their impoverishment (M. Marzot)

in their crops or in their natural resource base. This leads not only to economic inefficiency but also to exploitation and degradation of the resource base, both of which in turn sustain their poverty. Evidence is often contradictory, for example, Mazzucato and Niemeijer (2000) found little evidence of widespread degradation of crop and fallow land discussing conditions in Burkina Faso. However. they do not dispute localized areas of severe degradation, nor suggest that Sahelian soils are particularly fertile. Mazzucato and Niemeijer (2000) do question the widespread belief that low-external-input practices used by West African farmers are leading to region wide land degradation and also argue that degradation assessments need to deal better with the spatial and temporal dimensions of the observed problems and land uses (Fresco and Kroonenberg, 1992; Rasmussen, 1999).

PLATE 3
An example of dryland agriculture in the Asia-Pacific region

Dryland farming is dependent solely on the water available from precipitation. However, dryland farming often depends on having stored soil water at the time of seeding a crop to supplement the rainfall received during the growing season (Dregne and Willis, 1983). This is particularly true in Canada and the United States of America, also to some extent in Australia and Argentina, where dryland farming, at least until recently, depended largely on fallow conserving soil moisture. Thus, limited and high-risk production in one season is forfeited in anticipation that there will be at least partial compensation by increased crop production in the following season.

With the development of dryland farming in the steppe, water-conservation techniques had to be developed because moisture from seasonal precipitation was usually inadequate for crop growth and maturation (El-Swaify *et al*., 1985). The practice most widely adopted was summer fallow. Practised in areas around the Mediterranean for centuries, summer fallow became practical in the steppes and grew rapidly with mechanization. Summer fallow systems are inefficient because often only 15–20 percent of the precipitation occurring during the fallow period is actually saved as stored water. The remainder is lost through evaporation and runoff. However, summer fallow is very effective in reducing risk and ensuring some yield even in low-rainfall years (Lal and Pierce, 1991). Careful farming practices such as weed control, maintenance of a stubble mulch and leaving the surface in large clods can result in larger amounts of stored water.

Dryland farming is at best a risky enterprise. A favourable pattern of precipitation during the growing period can result in good yields even when the annual total is much below average. In contrast, there is no assurance of good production in years even when precipitation is greater than average if it occurs at times when crop water requirements are low.

LAND DEGRADATION IN DRYLANDS

The rapid population growth in drylands due to improvements in health conditions and other factors has placed tremendous pressure on the natural-resource base. Often, the inevitable result of increasing population in resource-poor areas is land degradation defined as the loss of production capacity of the land (FAO, 2000a). In this context, this should be understood as a result of a combination of natural processes and human activities that cause the land to become unable to properly sustain its ecological and economic functions. Traditionally, simplistic, explanations confused the issue,where the land users were considered the “guilty” - and blamed for the degradation (Gisladottir and Stocking, 2005). However, studies over the last ten to fifteen years conclude that the causes of land degradation are far more complex and that land degradation may result from much higher level policy and market failure rather than from failures of the poor land user (Gisladottir and Stocking, 2005). In the past drylands have been neglected by national and international development policies - adequate investments to generate positive results and reverse land degradation have been deficient (Johnson, Mayrand and Paquin, 2006).

Desertification (Plate 4) is defined as land degradation in drylands caused by climate variability and human activities (UNCCD, 2000; FAO, 2000a). In the case of drylands, land degradation results in desertification (Stewart and Robinson,1997). Droughts, common to these areas, exacerbate the degradation processes.

It is estimated that almost 75 percent of the cropland in Central America is seriously degraded; 20 percent in Africa (mostly pasture); and 11 percent in Asia (IFPRI, 2001). These data suggest that, globally, up to 40 percent of agricultural land is seriously affected by soil degradation.

Oldeman *et al.* (1991) suggest that land degradation can result in the following reductions in agricultural productivity:

- light: somewhat reduced agricultural productivity;
- moderate: greatly reduced agricultural productivity;
- strong: biotic functions largely destroyed, non-reclaimable at farm level;
- extreme: biotic functions fully destroyed, non-reclaimable.

Agricultural productivity is affected by many factors apart from soil quality, e.g. rainfall, deforestation, population pressures, climate, labour and technology. Because of the interdependent nature of land and its productivity, it is necessary to base claims of land degradation on multiple, complementary proxies that include properties of land (e.g. of soil, water and vegetation) as well as productivity indicators.

Tobler *et al.* (1995) stated that the increase in

FIGURE 3
Land Use Systems

PLATE 4
Desertification in the Sudan. Goats feed on a solitary *Acacia* shrub (R. Faiduttti)

population density is a major factor influencing land degradation, particularly in semi-arid and arid regions. Kirschke, Morgenroth and Franke (1999) claim that data from 73 developing countries have shown that deforestation is a causative factor for both wind and water erosion under arid and semi-arid conditions. Overexploitation of vegetation for domestic uses such as fuelwood and domestic timber is also a cause of degradation of the resource base, particularly in the Sahel belt of Africa, western Argentina, the Islamic Republic of Iran, and Pakistan (Kruska, Perry and Reid, 1995). Hazell (1998) stated that, despite some out-migration, human populations continue to grow in many less-favoured areas, but crop yields grow little or not at all, resulting in worsening poverty, food insecurity and widespread degradation of natural resources.

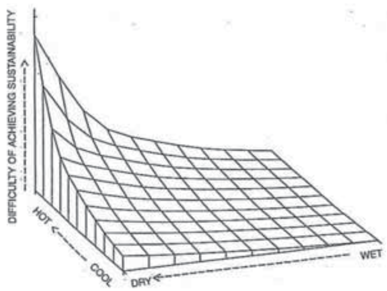
Another common problem associated with land degradation in drylands is the development of salt-affected soils (saline, saline–sodic and sodic soils) resulting from changes in the local water balance and the accumulation of excess salts in the rootzone. Dregne, Kassas and Rozanov (1991) estimated that about 41 million ha of irrigated land in the world's dry areas are affected by various processes of degradation, mainly waterlogging (20 million ha) and salinization and sodication (21 million ha). In the 11 countries surveyed with a total irrigated area of 158.7 million ha (70 percent of the world's irrigated land), 29.6 million ha (20 percent) are salt-affected soils.

Salinity also poses a major management problem in many non-irrigated areas where cropping relies on limited rainfall (FAO, 2005). Although dryland salinity has been a threat to land and water resources in several parts of the world, it is only in recent years that the seriousness of the problem has become widely known. In rainfed agriculture, intrusion of saline seawater to areas lying near the sea can cause land salinization during dry periods (Ghassemi *et al*., 1995). Based on the FAO/UNESCO Soil Map of the World, the total area of saline soils is 397 million ha and that of sodic soils is 434 million ha that are not necessarily arable but cover all salt-affected lands at global level. If it is accepted that 45 million ha of the current 230 million ha of irrigated land are salt-affected soils (19.5 percent), then in the global total of the almost 1 500 million ha of dryland agriculture, 32 million ha are salt-affected soils (2.1 percent) caused to varying degrees by human-induced processes (Ghassemi, Jakeman and Nix, 1995). Salt-affected soils have lower productivity and need careful management but can be improved. Although many countries are using salt-affected soils because of their proximity to water resources and the absence of other environmental constraints, there is a clear need for a sound scientific basis to optimize their use, determine their potential, productivity and suitability for growing different crops, and identify appropriate integrated management practices.

All continental regions have experienced

PLATE 5
Salinization in Iran

FIGURE 4
Conceptual model of the effects of temperature and precipitation on the difficulty of developing sustainable agro-ecosystems in semi-arid regions



Source:Stewart, Lal and El-Swaify, 1991

a decrease in arable land per capita in every 5-year period reported. From 1965 to 1995, the decrease was 40 percent in Asia and more than 50 percent in Africa (FAO, 2000a). Sung-Chiao (1981) identified resource degradation as a major limitation to productivity in many arid and semi-arid regions of China.

In the past, under lower population density and with intensification of agriculture, drylands generally recovered following long droughts. However, under current conditions, they tend to lose their biological and economic productivity more rapidly and seriously. Stewart, Lal and El-Swaify (1991) developed a simplified conceptual model of the potential for soil degradation as the climate becomes hotter and drier. The relationships presented in Figure 4 suggest that soil degradation processes are more rapid in hotter and drier climates, making it more difficult to sustain the soil-resource base. Whenever an ecosystem such as a grassland prairie in a semi-arid region is transformed into an arable system for food and fibre production, several soil degradation processes are set in motion (Stewart, Lal and El-Swaify, 1991). This is particularly the case where raindrops fall directly onto the bare soil surface, not protected by vegetation, crop residues, mulches, etc. Other effects are a decline in soil organic matter (SOM), increased wind and water erosion, deterioration of soil structure, salinization and acidification.

EFFECTS OF LIVESTOCK ON THE RESOURCE BASE

Livestock have both positive and negative effects on the resource base, particularly the soil in drylands. They trample the soil which, depending on the soil type and status, frequently leads to compaction. The resulting higher bulk densities lower yields by inhibiting root development, reducing infiltration and waterholding capacity. Compaction also makes cultivation (mechanical or manual) more difficult and energy intensive.

Sandford (1988) reported that livestock, mainly cattle, consume up to 60 percent of the crop residues remaining on the surface after a grain harvest. Unless the manure is recycled, removal of crop residues by livestock (or for fuel uses) increases losses of nitrogen and phosphorus by 60–100 percent over the amounts removed in the grain. Where crop residues are burned on the land, most of the nitrogen and organic matter (on the surface and within the upper cms of the soil profile) are lost, but most of the other nutrients are recycled.

In some countries where dryland ecosystems predominate, overgrazing (Plate 6) is the major cause of land degradation, e.g. in the Libyan Arab Jamahiriya, Tunisia, the Islamic Republic of Iran, Iraq, the Syrian Arab Republic, and virtually the whole Sahel belt of Africa (FAO, 1998a). Overgrazing is also a major cause of land degradation in many parts of Central Asia, South America such as Brazil and Argentina, as well as in some developed countries including Australia and the western United States of America.

Drought presents major challenges for mixed farming operators in semi-arid regions. Mixed farming is defined here as involving crops, livestock and/or trees (ASA, 1976). Mixed farming systems include those in which more than 10 percent of the dry matter fed to animals comes from crop by-products/stubble or where more than 10 percent of the total value of production comes from non-livestock farming activities (FAO, 1996b).
In a drought situation, overgrazed mixed-farming systems can undergo the removal of much of the surface vegetation, increasing the soil's vulnerability to serious wind erosion (Dregne, 2002). A producer anticipating this

PLATE 6
The result of overgrazing on the outskirts of Amman city (R. Faidutti)

problem should reduce the number of livestock, or remove them from the grazed areas and feed them a balanced ration for survival. Lot feeding and zero grazing become increasingly important strategies to retain plant cover and structural stability of the surface soil in order to sustain resources in the long term. These options are unlikely to be available to smallholders or pastoralists in developing countries.

With careful attention to the plant-nutrient balance, mixed farming is, environmentally, probably the most desirable system (Powell *et al*., 2004). Where appropriate, it should be the focus for farmers, agricultural planners and decision-makers. The challenge will be to identify the technologies and policies that enable sustained growth to satisfy the increasing demand for meat and milk. Despite the advantages of mixed farming, current trends in drylands point towards farmers choosing to specialise in either crop or livestock production. It is recommended that these trends should be resisted. It is being increasingly recognised that livestock play a vital role in stabilizing production and income in cereal-producing regions. Livestock graze crops/ residues and provide some income in years when climate conditions are so adverse that grain production is unprofitable. Livestock increase the sustainability of livelihoods in drylands, particularly in years of low precipitation.

EFFECTS OF CLIMATE CHANGE ON DRYLANDS

The global increase in atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases (particularly methane) over the past 250 years are attributed primarily to fossil fuel combustion and land use change (including *inter alia* deforestation, biomass burning, draining of wetlands, ploughing and use of fertilizers) and now far exceed pre-industrial values determined from ice cores spanning many thousands of years (IPCC, 2007). The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005 (IPCC, 2007). The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores (IPCC, 2007).

There is substantial scientific evidence that the recent (and predicted future) rapid changes in the earth's climate are human-induced, caused by these accumulations of CO_2 and other greenhouse gases (GHGs) and have become a serious and urgent issue (Stern, 2006). Widely accepted predictions show that the on-going pattern of climate change will not only raise temperatures across the globe, but will also intensify the water cycle, reinforcing existing patterns of water scarcity and abundance, increasing the risk of droughts and floods. In addition, as the world warms, the risk of abrupt and large-scale changes in the climate system will rise – also the frequency and intensity of extreme events are likely to increase (Stern, 2007). The summary of the IPCC Fourth Assessment report (2007) states that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent. Increases in the amount of precipitation are *very likely* in high latitudes, while decreases are *likely* in most subtropical land regions (by as much as about 20 percent in the A1B scenario in 2100), continuing observed patterns in recent trends. Tubiello and Fischer (2007), however, stated after taking into accout anticipated impacts of climate change and mitigation that in terms of cereal production, the impact on risk of hunger is only felt after 2050.

Climate change poses a real threat to the developing world which, unchecked, will become a major obstacle to continued poverty reduction (Stern, 2006). Developing countries are especially vulnerable to climate change because of their geographic exposure, low incomes, and greater reliance on climate sensitive sectors such as agriculture (Stern, 2006). The impacts of climate change in drylands are likely to lead to still more people and larger areas of land being affected by water scarcity and the risk of declining crop yields – with the peoples of drylands in developing countries least able to adapt due to poverty.

Adoption of any strategy(ies) to increase agricultural production in drylands provides a much needed route to adapt to the effects of the current period of rapid climate change, which otherwise will become a major obstacle to poverty reduction. The options outlined in Chapter 4, offer approaches by which smallholders and other land users in drylands can adapt to cope with changing climate, including improved *in situ* water conservation, water harvesting and reduction in evaporation. Improved management of soil organic matter and conservation agriculture will not only help small holders and pastoralists adapt to climate change, but also involve changing traditional agricultural practices to increase storage of C in soils and on the soil surface, contributing to mitigating emissions of GHGs. Shifting agricultural zones, planting of drought resistant/fast maturing strains of crops and protection of local agro-biodiversity offer other ways by which smallholders and pastoralists can cope with the rapid rate of human-induced climate change.