DEGRADATION OF THE DRYLANDS OF ASIA

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Center for Environmental Remote Sensing (CEReS),
Chiba University, Japan
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Cover photo

25 August 1996
N 47° 15′ 19″ E 74° 47′ 50″
Near Lake Balkhash, Kazakhstan

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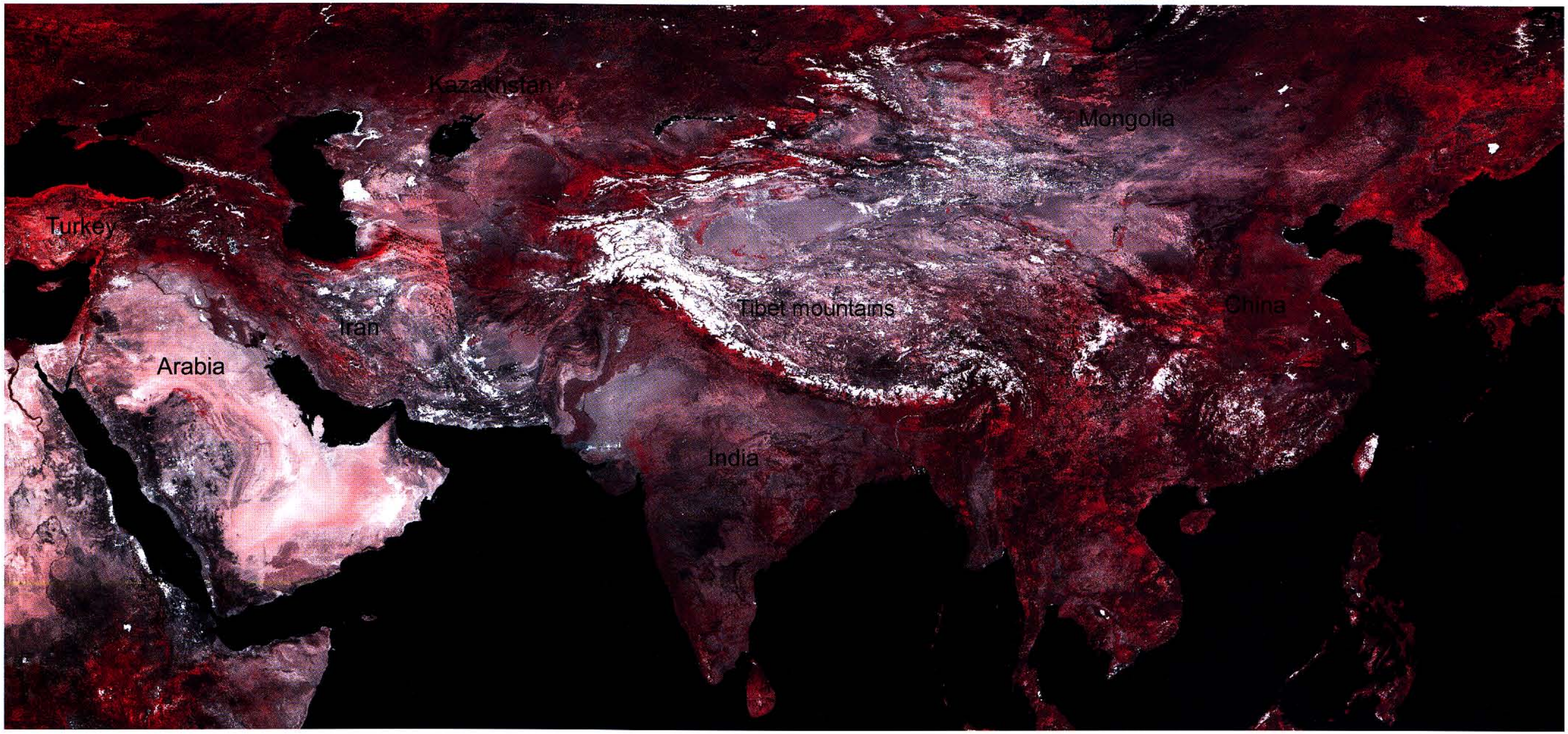

Color composite NOAA AVHRR image of Asia. Blue and green for channel 1 and red for channel 2.
The composite period of the image is 1-31 May 1992 (Source: U.S. Geological Survey. Processing: CEReS, Chiba University).

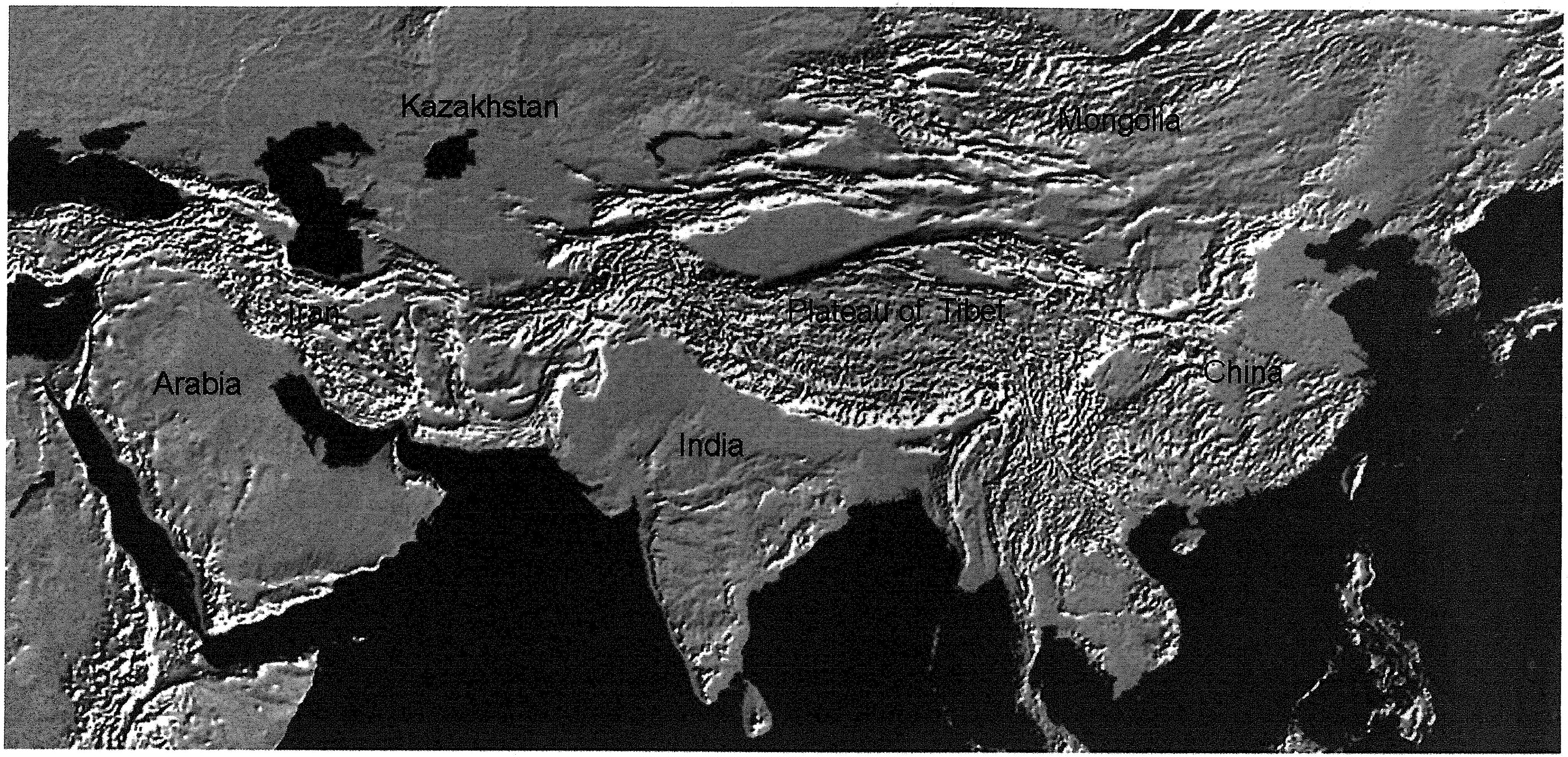

Figure 1.1 Shaded relief image of Asia (Source: U.S. Geological Survey)

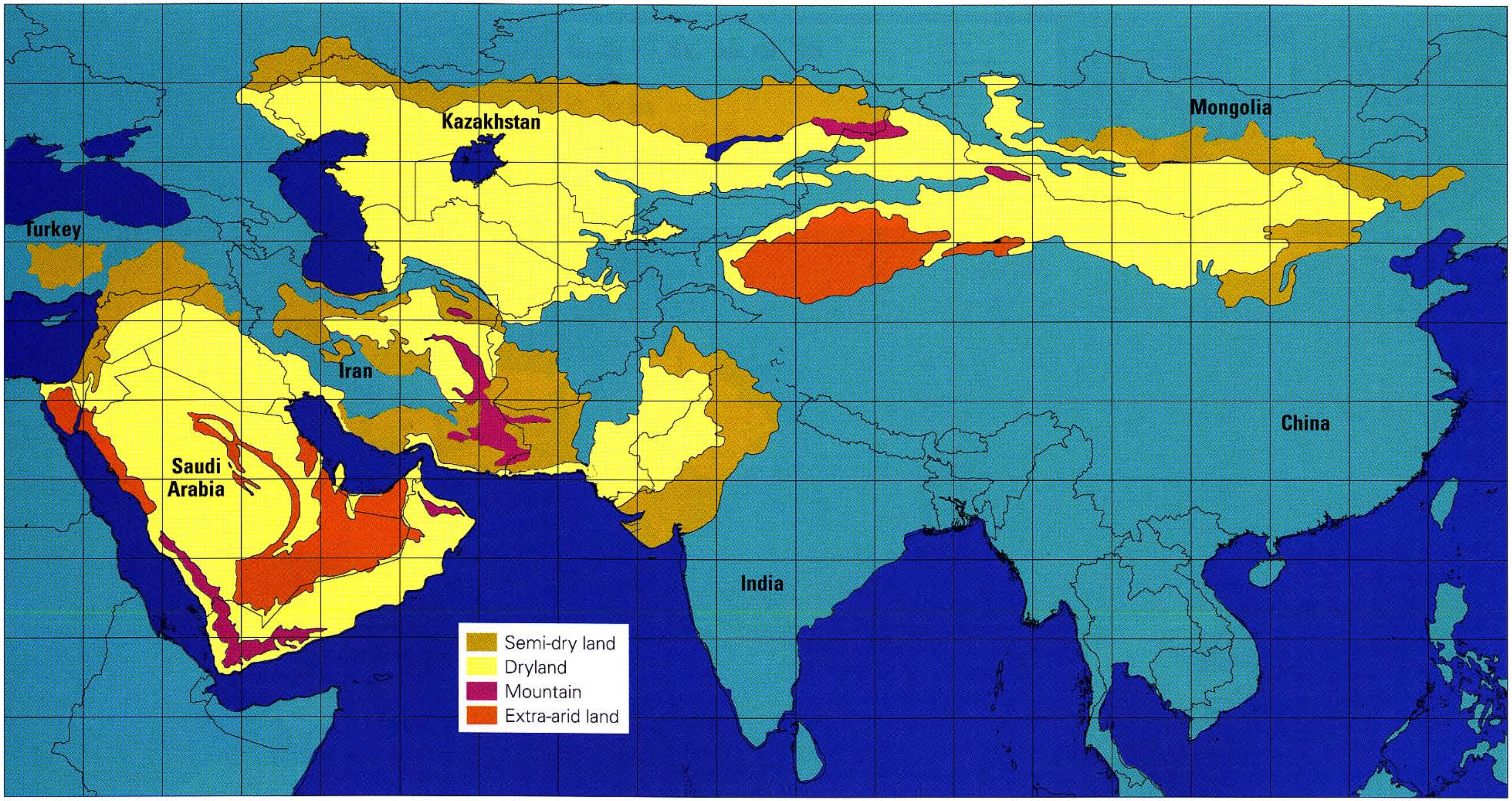

Figure 1.2 Regional map of semi-dry lands and drylands of Asia (Source: Kharin et al., 1993, modified by authors)

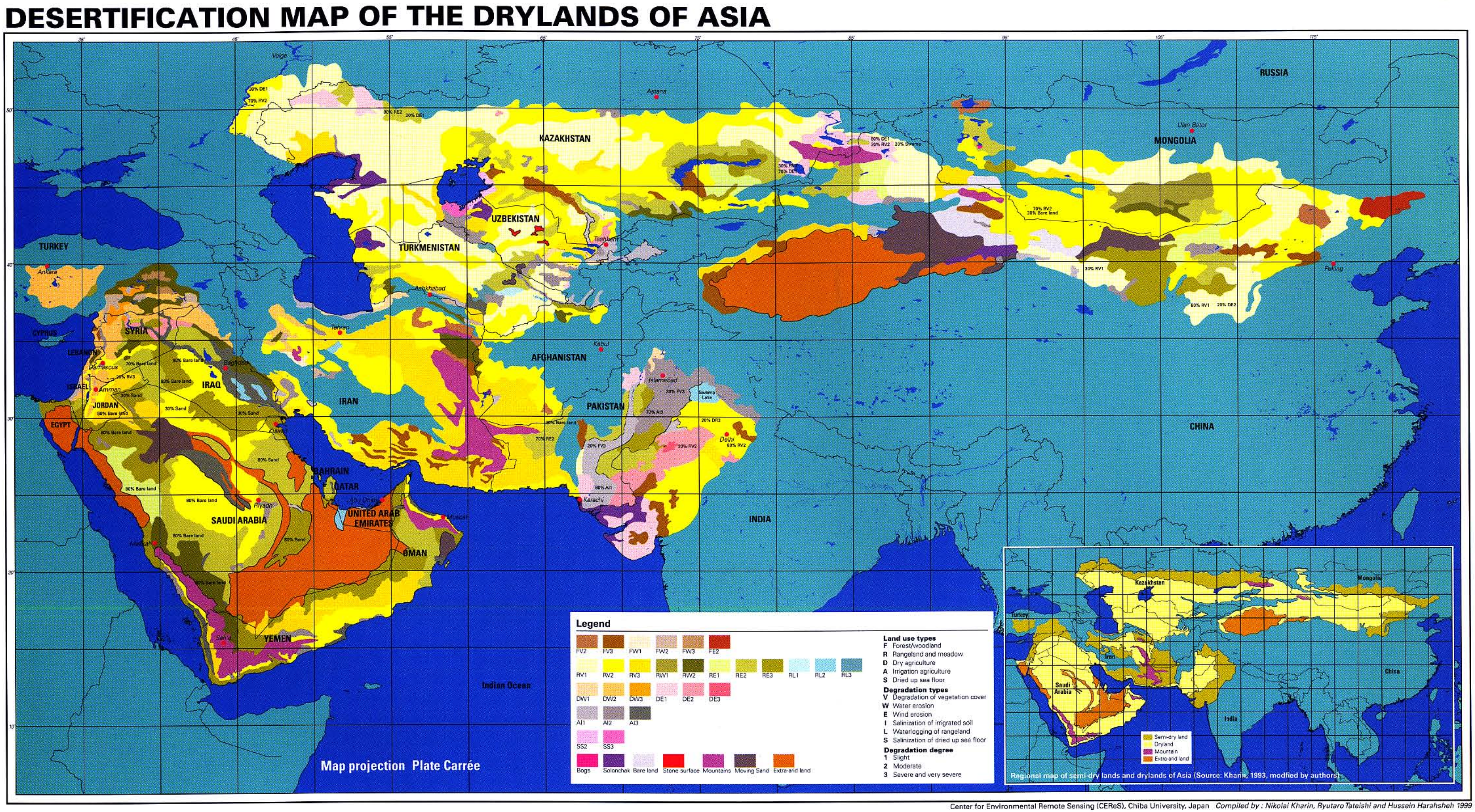

Figure 7.1 Desertification map of the drylands of Asia, a reduced size version of the final map product.

Everything is transient, and nothing enduring

Buddha

Degradation of the Drylands of Asia

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INTRODUCTION

Desertification is a global problem, not only because of the vast areas of drylands, which occupy about one third of the Earth's surface. The process of land degradation initiated in deserts can expand like a cancer to bordering areas. For example, particles of dust and salt blown off from the dry, exposed floor of the Aral Sea are transported by wind over great distances reaching Russia. International Convention to Combat Desertification (CCD) adopted in 1994, defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climate variations and human activities". Loss of productivity in arid regions creates the major environmental constraints for sustainable development. Hundreds million of people in the countries affected by desertification suffer directly from shortage of food and environmental quality. Several million of ecological refugees (a category of people not recognized by UN agencies!) seek asylum in neighboring countries. So the problem of desertification has transformed to social and political problem.

The peoples of the world recognize the importance of this problem. The International Convention to Combat Desertification (CCD) gave a new hope for the people suffering from desertification. CCD recommends creating a monitoring system of desertification control. Assessment and mapping of desertification is the first step of this monitoring. As known, the assessment and mapping of desertification can be conducted on different levels: global, regional (CCD recognized Asia as one region), national and local.

Study of scientific publications has shown that scientists and experts of different countries have developed different methodologies for desertification assessment. From this point of view, authors approve the efforts of FAO and UNEP in the standardization of this methodology. Desertification maps published in the countries of Asia in several cases are not comparable. Remote sensing data have been used to make the final decision in all questionable cases. The authors proceed from the assumption that changes in spectral reflectance measured by space images are indicatives of real changes in desert environment.

Small scale desertification maps can not describe local phenomena in desert environmental change. This should be taken into consideration by analysis of the proposed map.

The authors hope that this map will pave the way for further perfection of the methodology of desertification assessment and mapping.

CHAPTER 1

CRITERIA AND METHODOLOGY FOR DESERTIFICATION ASSESSMENT

1.1 Criteria of desertification assessment

Criteria for desertification assessment must take in consideration the local conditions of the study area. These conditions should be investigated through field observations, with the help of remote sensing tools. The results of such investigation can be interpreted according to the type and degree of desertification. The types of desertification considered in this study are as follows:

1- Vegetation cover degradation.
2- Wind erosion
3- Water erosion
4- Soil salinization
5- Soil salinization caused by the drop of Aral Sea level
6- Rangeland waterlogging in Central Asia

Criteria for the assessment and small scale mapping of desertification were developed for each land use type. The following categories of land use were identified: forest/woodland, rangeland and meadow, dry agriculture, irrigation agriculture and the dry, exposed bottom of the Aral Sea. Because absolute figures of these characteristics vary from region to region, the criteria are given in relative figures (for example, percentage of the area covered with moving sand dunes).

Vegetation cover degradation is considered to be the main form of desertification. The major causes of this type of degradation are overgrazing, fuel wood, fires of forests and heavy traffic machines, which compact the soil and kill the roots of plants. **Table1.1** summarizes the criteria for assessing of the vegetation cover degradation. Five criteria were developed to analyze the status of vegetation degradation:

1- Plant community: this criterion analyzes the existing types of climax plants if it is climax, or secondary.
2- Percentage of climax species: The distribution and the density of climax species reflect clearly the overgrazing of an area. If 75% or more of climax plants remain in the land, it is considered slightly desertified, while 75-25% is considered as moderate range of desertification. If the remaining climax species are less than 25%, the situation is considered to be severe to very severe.
3- Decrease of total plant cover: This criterion is addressed to quantify the decline in vegetation density, and is divided in three degrees: less than 25%, 25-75% and more than 75%.
4- Loss of forage on rangeland: Rangeland is the main source of livestock forage and occupies a large part of many regions. Rangeland condition is then for considered to be an important indicator of desertification, the criteria for this assessment is the

quantity of forage loss within rangeland, with the categories for percentage of loss as in plant cover decreasing (third criteria).

5- Loss of current increment of wood: The estimation of this loss in woodland classified using the same percentage categories as above.

Soil erosion by **wind** or **water** actions results from a set of complex processes, which can be grouped into three phases: physical detachment, transportation and deposition of a soil particle. The term soil loss is the quantifying of material exported at a specified point at the boundary of an area, and can be expressed in units of tones per square kilometer. This results in removal of the topsoil, damage to soil structure and detrimental changes in texture. The main causes of soil erosion are overgrazing, which leads in particular to a reduction in the plant cover. Uprooting of shrubs leads to the destruction of the soil structure and thus to accelerated erosion of the soil by wind and water. If plants, which had previously protected the soil, are removed by uprooting, the infiltration of precipitation water into the soil decreases and surface runoff increases, "enhanced floods" occur.

Drought years are a normal phenomenon, during which rainfed cultivation takes place below the safe rainfall limit, especially in marginal lands. Once ploughing has destroyed the stability of soil and the field lies fallow, soil particles are then exposed to wind erosion. The soil particles are carried away by dust storms or accumulate to form sand dunes.

The following criteria are important for assessing the magnitude of soil erosion:

1- Percentage of area covered with sand dunes: This criteria is considered for non-arable areas exposed to wind erosion in the form of sand dune movement or regression. It is assumed that if more than 70% of the under area consideration is covered with sand, then the area is severely affected by wind erosion. A percentage of 30-70 of sand dunes indicates moderate wind erosion and less than this percentage indicates slight wind erosion.
2- Percentage of area covered with sod forming plants: In the non-arable land it is important to consider the parts of land having a potential for planting cultivation. A non-arable land having 30-50% grassland is considered to be slightly affected by wind erosion. If the sod covering an area of 10-30%, then it has a moderate degree of desertification and less than 10% is a severe to very severe desertification.
3- Type of water erosion in percentage: The type of water erosion reflects clearly the magnitude of problem. If sheet erosion is the dominant form, and then it is considered to be classified as slight water erosion, if the dominant water erosion is rill erosion with formation of gullies, then it is moderate water erosion. The formation of network of gully erosion together with other types of water erosion leads to severe water erosion or severe desertification.
4- Removal of topsoil horizon of arable land, the amount of removed topsoil either by wind erosion or water erosion is a very important indicator of soil degradation. A disappearance of 25% of topsoil or less is considered to be in the slight soil erosion category, a percentage of 25-50 indicates a moderate soil erosion, while if 50% of topsoil or more are removed then the situation is severe degradation.

5- Blow-outs of the area (a blow-out is a small hollow made by turbulent stream of wind): If 10% or more of an arable land is affected by blow-outs, then it has a severe wind erosion. If percentage of 5-10 of area has blow-outs feature, so it is a moderates wind erosion caused by blow-outs, and less than 5% it is slightly affected by wind erosion.
6- Loss of yield of main crop in percentage: The main consequence of soil erosion is a reduction of field yield. If the reduction is estimated to be more than 50%, then this indicates a severe to very severe desertification by soil erosion, a loss of 25-50% of yield crop indicates a moderate degradation, and a loss of 25% or less indicates a slight soil erosion.

Table 1.2 & Table 1.3 summarize the criteria for assessment of the soil erosion.

Soil salinization is the accumulation of soluble salts (chlorides, sulfates, carbonates) of sodium, magnesium, or calcium. Alkalinization or sodification involve an enrichment in sodium ions. A high concentration of salts in the soil gives rise to saline or alkaline soils. This is the result of irrigation without adequate drainage and water with a high mineral content; the water is transpired while the minerals increase in concentration. If the soil solution becomes more concentrated than the solute concentration of the plant cell, water is unable to pass into the plant and reverse movement of water and nutrients can occur, causing wilting and death to the plant. According to the FAO, a soil is considered as saline when its content in soluble salt exceeds 1 to 2% in the 20 upper cm, and the accumulation of salt becomes harmful to plant growth.

If the salty water table in arid and semi-arid areas comes within 1 to 4m of the roots, some of the water can rise through capillarity and cause damage because it inhibits the plants ability to absorb moisture. The plants become stunted or die depending on the salt concentration. If the salty groundwater reaches the soil surface it evaporates and leaves salt crystals on the surface of the fields and if the quantity of salty water reaching the surface is great enough, a relatively impermeable salt crust will form over the soil, diminishing infiltration and natural leaching.

The criteria adopted to assess soil Salinization are described as follows:

1- Solid residue: This criterion quantifies the percentage of soluble salt in the upper topsoil. If it is range between 0.20 and 0.40, this means a slight degree of salinization, the range of 0.40 – 0.60% means a moderate degree of salinization and a percentage more than 0.60 considered being severe to very severe degree of salinization.
2- Salinity of ground water: For this criterion, an amount of 3-6 g/liter indicates a slight salinization, from 6 to 10 refers to moderate soil salinization and from to 10 to 30 a severe to very severe soil salinization.
3- Salinity of irrigation water: Water is the second source of salt after the soil itself, the assessment is made by the estimation of salt content of irrigation water in gram per liter. If the salt content range 0.50 to 1.0 g/liter, the salinization is slight, an amount of 1.0 to 1.5 of salt indicates a moderate Salinization, and more than 1.5 of salt in irrigation water leads to severe salinization.
4- Salt accumulation: The amount of salt accumulation is estimated in tons per hectare. If the accumulated salt ranged from 16-30 ton/ha, it is considered as slight

salinization, an amount of 30-45 of salt accumulation refers to moderate saliniation and from 45 to 90 refers to severe to very severe saliniztion.

5- Loss of yield of main crop: If the reduction of yield of main crop is estimated to be more than 40%, then this indicates a severe to very severe desertification by salinization. A loss of 15-40% of yield crop indicates a moderate degradation and a loss of 15% or less indicates a slight salinization.

Table 1.4 summarizes the criteria for assessment of the soil salinity.

Drying up the Aral Sea affected significantly the hydrological situation in the Turan Lowland. Drying up the Aral Sea was caused by withdrawal of water of the Amudarya and the Syrdarya rivers for irrigation. A new anthropogenic desert has been formed on the former Aral Sea bottom. That resulted in development of desertification processes, in particular: blow-outs and accumulation of salt and dust, formation of solonchaks, change of environmental in river deltas, degradation of vegetation in the low flow of the rivers discharged into the Aral Sea. **Table 1.5** explains criteria for the assessment of salinization caused by the drop of Aral Sea level.

Waterlogging is happened when the porosity of the soil is entirely filled with water, which leads the raising of the water table. The degradation appears when the water brings salts towards the surface and when the excess water in the soil horizon limits the aerobic life. In all oases of Central Asia excessive irrigation and leaching of saline soils are the reasons of accumulation of plenty of water. Great amount of this water is not only conducted by special canals but also penetrates to the desert. This uncontrolled water floods rangelands and forms many new streams and small lakes. As a result the productive desert rangelands are put out of operation. Palatable forage plants are replaced by hydrophytes and phreatophytes. New streams, bog and lakes hinder the movement of flocks. The criteria for the assessment of rangeland waterlogging in Central Asia are the depth of fresh ground water; changes of dominant plants and the plant cover percentage. **Table 1.6** explains these criteria.

Table 1.1

Criteria for assessment of the vegetative cover degradation

Status criteria	Desertification classes		
	Slight	Moderate	Severe and very severe
1. Plant community	Climax or slightly changed	Long existing secondary	Ephemeral secondary
2. Percentage of climax species	>75	75 – 25	<25
3. Decrease of total plant cover	<25	25 – 75	>75
4.Loss of forage on rangeland,%	<25	25 – 75	>75
5.Loss of current increment of wood, %	<25	25 – 75	>75

Table 1.2
Criteria for assessment of wind erosion

Status criteria	Desertification classes		
	Slight	Moderate	Severe and very severe
Non-arable land			
1. Percentage of area covered with sand dunes	<30	30 - 70	>70
2.Percentage of area covered with sod forming plants	50 - 30	30 – 10	<10
Arable land			
1.Removal of top horizon, %	<25	25 – 50	>50
2. Blow-outs, percentage of the area	<5	5 – 10	>10
3.Loss of yield of main crop, %	<25	25 – 50	>50

Table 1.3
Criteria for assessment of water erosion

Status criteria	Desertification classes		
	Slight	Moderate	Severe and very severe
Non-arable land			
1.Type of erosion	Sheet erosion, single rills	Sheet erosion and rills, formation of gullies	Sheet erosion, rills, network of gullies
2.Removal of top soil horizon, %	<25	25 – 50	>50
Arable land			
1.Removal of top soil horizon, %	<25	25 – 50	>50
2.Loss of yield of main crop, %	<25	25 – 50	>50

Table 1.4
Criteria for assessment of salinization of irrigated land

Status criteria	Desertification classes		
	Slight	Moderate	Severe and very severe
1.Soil salinization, solid residue, %	0.20 – 0.40	0.40 – 0.60	>0.60
2. Salinity of ground water,g/liter	3 - 6	6 – 10	10 – 30
3.Salinity of irrigation water, g/liter	0.5 – 1.0	1.0 – 1.5	>1.5
4.Seasonal salt accumulation, ton/ha	16 - 30	30 – 45	45 – 90
4.Loss of yield of main crop, %	<15	15 – 40	>40

Table 1.5
Criteria for assessment of soil salinization caused by the drop of Aral Sea level

Status criteria	Desertification classes		
	Slight	Moderate	Severe and very severe
1.Change of soil	Formation of coastal desert soil partially covered with barkhans	Coastal solonchak	Formation of deep solonchak
2.Amount of salts in soil layer 0-100 cm, ton/ha	<130	130 – 290	290 - 370
3.Change of the vegetative cover	Formation of shrub (Haloxylon species) and semi-shrub vegetation	Psammophilous vegetation, Tamarix species	Fragments of halophytes

Table 1.6
Criteria for assessment of rangeland waterlogging in Central Asia

Status criteria	Desertification classes		
	Slight	Moderate	Severe and very severe
1.Depth of fresh ground water, m	10 - 5	5 – 2	<2
2.Change of dominant plants	Tamarix ramo-sissima, Alhagi persarum	Tamarix ramo-sissima,Alhagi persarum, Karelinia caspia	Fragmitis australis
3.Plant cover, %	<30	30 – 70	>70

For developing the criteria, experimental data collected in Central Asia and Mongolia were used, as well as literature sources. Some desertification maps and experimental studies covering the areas of Syria, Saudi Arabia, China, India and Iran were also used in our project.

1.2 Collection of ground truth and mapping

Assessment and mapping desertification in the framework of this project was based on application of low-resolution space images. NOAA/AVHRR data were found to be useful for the analysis of desertification. Normalized Difference Vegatation Index (NDVI) was computed by the following formula:

$$NDVI = (NIR - RED)/(NIR + RED)$$

Where : NIR – reflectance in near infrared spectral band (channel 2 of AVHRR)
RED – reflectance in red spectral band (channel 1 of AVHRR)

Two types of NOAA/AVHRR data were used :

- 21 – 31 May (1992 – 94) data, 4 arc-minute resolution NDVI data
  The original data is NOAA/NASA Pathfinder AVHRR Land Data Set, which has a nominal 8-km resolution. This data were geometrically registered to a 4 arc-minute grid.
- April 1992 – March 1993 data, 30 arc-second resolution NDVI data.
  The original data is the Global Land 1-km AVHRR data set produced by the United States Geological Survey (USGS) which consists of 10-day composite, nominally 1-km resolution data. From this data set, monthly composite 30 arc-second data were derived.

The first type of data was used because in Central Asia and adjoining areas the maximum growth of vegetation takes place in the end of May, after intensive winter and spring precipitation.

Thematic maps and publications were used for collection of the ground truth (See the list given in the end of this chapter). 662 plots of approximately equal area were selected from these sources. For each sample plot, the mean NDVI (4 arc-minute imagery) was calculated from 5 pixels:

	North	
West	Central	East
	South	

Each sample plot contains the following information: coordinates of the central points, land use type (see **Table A.3** of Appendix A), and desertification class and the causes of desertification (see **Table A.4** of Appendix A). The sample plots were distributed across the region in the following way: Central Asia – 280, Middle East – 154, China – 94, Mongolia – 66, Afghanistan, Pakistan and India – 66.

Interpretation of small-scale image was conducted by the following procedure:

1. Unsupervised classification of 4 arc-minute NDVI images,
2. Land cover classification by 30 arc-second monthly NDVI data and surface temperature derived from channel 4 & 5 data (Tateishi, 1999),
3. Visual interpretation of different classes of imagery within landscape – analogues in each geographical zone.

The assessment of desertification in this study is concerned only with the drylands and semi-drylands of Asia (about 9,804,700 km^2). And the assessment excluded the following classes: Bogs, Solonchaks, Bare land, Stones, Mountains, Moving sand and Extra-arid lands. Mountains here mean mountain areas excluded from assessment because they do not belong to drylands (Kharin et al, 1993).

Classification of the drylands of Asia used in this project is based on the landscape theory of Soviet geographers (Kharin et al, 1993). **Table 1.7** shows the areas of drylands classification of Asia. **Figure 1.1** (cover page) is a shaded relief image of Asia, which shows the morphology of different features in Asia, and **Figure 1.2** (cover page) is the drylands map used in this study.

Table 1.7

Statistics of regional drylands map of Asia

Class name	Area, km^2	Percentage
Semi-arid land	3,040,189	25.49
Arid land	7,294,219	61.14
Extra-arid land	1,194,563	10.01
Mountains	401,148	3.36
Total	11,930,119	100.00

Legend for small scale mapping of desertification was developed for each land use type. The following categories of land use were identified: forest/woodland, rangeland and meadow, dry agriculture, irrigation agriculture, and dried up sea floor of the Aral Sea. Land use type and the dominant land degradation type define desertification class. **Table 1.8** shows the land use types and their areas considered for assessment and **Table 1.9** shows the land cover type excluded from assessment. The details for legend of desertification map and drylands map are given in **Appendix A**.

Table 1.8
Land use types considered for the study

Land use	Area km^2	Percentage
Forest/woodland	408,421	4.17
Rangeland and medow	7,996,532	81.56
Dry agriculture	675,790	6.89
Irrigation agriculture	704,315	7.18
Dried up sea floor	19,642	0.20
Total	9,804,700	100.00

Table 1.9
Classes excluded from assessment

Class name	Area km^2	Percentage
Bogs	514	0.02
Solonchak	121,568	5.72
Bare land	113,091	5.32
Stone surface	4,249	0.20
Mountains	401,148	18.87
Moving sands	290,286	13.66
Extra-arid land	1,194,563	56.20
Total	2,125,419	100.00

1.3 Data sources

The following sources have been used for the compilation of the desertification map of Asia.

Methodological publications

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(In Russian).

The map of aeolian landforms in Taklimakan desert. Desert Research Institute, Lanzhou, 1980.

The national economic atlas of China. Oxford University Press, Oxford,1994. 314 p.

The Times atlas of the world. Comprehensive eddition. Times Books, London, 1989. 225p.

Tubengen Atlas of Middle East, Tubengen University, Stuttgart, Germany, 1978-1987. 30 p.

World atlas of desertification. UNEP, 1992, 69 p.

CHAPTER 2

CENTRAL ASIA

2.1 Physical environment and population

The region of Central Asia includes five newly independent countries (the former Soviet Republics of the Soviet Union): Kazakhstan, Turkmenistan, Kirgyzstan, Uzbekistan and Tajikistan. The area and population of these countries are given in **Table 2.1.**

Table 2.1

The area and population of Central Asian countries (Kharin, 1996)

Countries	Land area, $x10^3$ km^2	Population, $x10^3$				
		1959	1970	1979	1989	1996
Kazakhstan	2,713.3	9,293	13,009	1,468	16,538	16,791
Uzbekistan	447.4	8,119	11,799	15,391	19,906	22,193
Kirgyzstan	198.5	2,006	2,934	3,529	4,291	4,461
Turkmenistan	488.1	1,516	1,159	2,759	3,534	4,500
Tajikistan	143.1	1,981	2,900	3,801	5,112	5,707
Total	3,994.4	22,975	32,801	40,161	49,381	53,786

Central Asia (called Middle Asia by Russian geographers) is located within vast Aralo - Caspian basin. Vast desert and semi-desert plains, piedmont plains and oases of irrigated soils are the main landscapes of the region. The new five countries mentioned above form a separate geopolitical region.

These countries have much in common: the physical environment, economic heritage from the former Soviet Union, similar traditions in agriculture, and a similar culture and religion (Islam).

The deserts of Central Asia are located in the temporal belt of the continental climate. Summer is hot, dry and cloudless. Winter is mild, except the northern part of the region where winter is cold. These climatic features are intensified by geographic barriers, which isolate the territory from the south. So the temperature regime in summer does not strongly differ from the neighboring countries - Iran and Afghanistan. Climatic indices of the region are given in **Table 2.2**.

Dust storms are one of the most characteristic features of the region. Dust storms begin by the wind velocity 9 - 14 m/sec and sometimes with a lower velocity of about 6 - 8 m/sec. The greatest number of days in a year with dust storms was registered in the following stations: Cheshme – 113 days (1948), Repetek – 106 days (1939), Molla - Kora - 146 days (1938), Muinak - 121 (1958). High albedo is also a characteristic feature of the desert. It totals 30 -34% for barkhan sands, 20 - 25% for dry sand and 25 - 35 % for pebble surface. For sand dunes grown by vegetation albedo falls to 20%. Albedo of cultivated vegetation is much lower, about 5% (Babaev et. al, 1993).

The main features of soil cover in Central Asian plains are in close correlation with a zonal factor i.e., the small quantity of precipitation. According to "Soil map of Central Asian Republics" (Lobova, 1971) the following soils are common in the plains region of Central Asia: gray brown typical, gray brown solonets-like, gray brown solonchak-like, desert takyr-like, takyr, desert sandy soil. Gray brown soils are mainly common in the Usturt and Krasnovodsk peninsula, in some parts of the Karakum and the Kyzylkum desert and in piedmont plains as well. Dwarf semi-shrub vegetation is the most common for these soils (*Artemisia kemrudica, A. terra-alba, Salsola gemascens, S. orientalis and Anabasis salsa*). Communities of *Haloxylon persicum* and other desert shrubs are confined to desert sandy soils. Takyr-like soils are mainly common in the ancient delta plains of the Amudarya, the Tedzhen and the Atrek rivers, where *Haloxylon aphyllum, Salsola orientalis* and *S. gemascens* are the dominant species.

Distribution of agricultural land by land use types is given in **Table 2.3.** Cotton is the main cash crop of the region. Irrigated farmland occupies 8.672 million ha. The production of cotton in 1992 was 315.0 thousands of tons in Kazakhstan, 68.0 in Kurgyzstan, 6,292.0 in Uzbekistan, 1,457.0 in Turkmenistan, 920.0 in Tajikistan. Livestock numbers totaled by million heads 17.4, 64.1, 4.9, 2.0 and 0.23 for cattle, sheep and goats, pigs, horses and camels respectively (Kharin, 1996).

Table 2.3

Distribution of agricultural land of Central Asia by land use types, ha (Kharin, 1996)

Land use Types	Countries					
	Kazakhstan	Kirgyzstan	Uzbekistan	Turkmenistan	Tajikistan	Total
Arable land	36,000	537	4,183	1,233	822	42,775
Haymaking Land	300	166	119	9	30	624
Rangeland	180,000	5,233	23,144	34,527	3,436	246,340
Total	216,300	5,936	27,446	35,796	4,288	289,739

As **Table 2.1** shows, the population more than doubled over the last 30 years. In general the demographic process in Central Asia is following a pattern of "high birth rate - high mortality", which is common to all developing countries, with contrary to the model "low birth rate - low mortality" of developed countries. But this official statistics do not reflects the real situation.

By rough estimation, from 4 to 5 million people (mainly Russians) have emigrated from the countries of Central Asia since 1991.

2.2 Soil degradation

The drying up of the Aral Sea was caused by withdrawal of water from the Amudarya and the Syrdarya rivers for irrigation. By the assessment of 1993 (Kharin et al., 1993) salinization of soils due to the drop of the Aral Sea level occured in an area of 49, 197 km^2. A new anthropogenic desert was formed in this vast area. Razakov (1994) found that 75 million tons of salts were blown off from the dried floor of the Aral Sea. These salts were transported by wind over great distances.

Wind erosion mainly occurs in sandy desert. Tracts of moving sand dunes of anthropogenic origin are confined to the areas of active human interference in desert environment (roads, canals, construction sites etc.). In Kazakhstan, wind erosion affected 20.5 million ha of plough land and 25 million ha of rangeland. Technogenic desertification occurred in the area of 181.3 thousand ha. These areas include gas pipelines, mining sites and military test sites of the former USSR (Baitulin and Bekturova, 1997).

In the Karakum desert, natural erosion (deflation) is observed on 15% of sands grown by vegetation. These eroded areas include blow-outs, single barkhans (moving sand dune) and groups of barkhans. Their location can be studied only by large-scale mapping.

Tracts of moving sands of natural origin have been excluded from assessment. For example, Dzhillikum sands (lit. "Furious Sands") are known in the Karakum desert. These sands are inaccessible for people.

Water erosion develops on the mountain slopes and in the piedmont plains of Central Asia. According to the map of Kharin et al. (1993), water erosion in the Aral Sea basin was registered in the area of 82,578 km^2. The slightly eroded area dominated (64 %), the remaining area is moderately degraded. Nurberdyev (1982) studied soil erosion in the Kopetdag pidmont plain. Wheat, barley and local varieties of pears were cultivated in this belt. The intensity of water erosion is dependent upon slope, exposure and technique of tillage. According to Baitulin and Bekturova (1997), water erosion in Kazakhstan affected 20.5 million ha, among which 5.2 million ha were affected severely. Annually in this country 60 million tons of soil material was washed away from ploughland.

The construction of grandiose irrigation canals in Central Asia and reclamation of new lands have led to changes of physical environment. Some areas have been transformed to zones of ecological catastrophe, such as the Tedzhen oasis in Turkmenistan. Dukhovnyi (1980) has developed a classification of change in irrigated soils (**Table2.4**). The author of this Table considers those changes as stable, which always take place by irrigation. Non stable changes do not always occur. Some 90% of irrigated farmlands in Central Asia are affected by Salinization. Poor agrotechniques, insufficient drainage networks and lack of crop rotation are the main factors stimulating soil degradation in cotton oases of the region.

Table 2.4
Change of environmental factors under the impact of irrigation (Dukhovnyi,1980)

Type of changes	Factors of changes	Positive effect	Negative effect
Stable, Non-controled	Milding the climate	+	
	Change of natural vegetation	+	
	Change of microorganisms	+	
	Change of wildlife	+	
	Lowering the force of wind	+	
	Change of river flow	+	
	Change of cultural vegetation	+	
	Lowering non productive evaporation	+	
Non-stable, Controled	Change of ground water level	+	-
	Change of humidity in aeration zone		
	Change of ground water mineralization	+	-
	Changr of river water mineralization	+	-
	Change of physical property of soil	+	-
	Change of salt content in aeration zone	+	-
	Erosion of slopes		-

Use of mineralized water for irrigation, absence of crop rotation and application of large amount of fertilizers has led to severe soil degradation in Turkmenistan (Desert Research Institute, 1996). As known, an optimal quantity of fertilizer stimulates the productivity of agricultural crops and soil fertility. But if an overly abandant amount of fertilizer is applied the surplus of nitrogen can depress soil biota. The severity of soil salinization in irrigated farm-lands of Turkmenistan are distributed in the following way: non saline 4.6%, slightly saline 28.5%, moderalely saline 53.8%, severely saline 13.1%.

Salinization of irrigated soils is a serious problem in Kazakhstan. The soils of the secondary salinization occupy 376.7 thousand ha, which constitutes 20% of all irrigated land. About 0.5 million ha of irrigated land have become unused because of salinization and problems with irrigation systems. The size of the area of unusable land, increased five times after 1990 (Baitulin and Bekturova, 1997).

2.3 Degradation of the vegetative cover

The causes of land degradation in Central Asia, with percentage of affected areas, are as follows : vegetation clearing 28%, overgrazing 29%, excessive irrigation 9%, construction of roads and canals 8%, hay production 3%, undergrazing 3%, water filtration 2%, other causes 18% (Kharin et al., 1993). The category of other causes includes fires, mine working, movment of transportation vehicles, and other non-identified causes. Degradation of the vegetative cover is the main type of land degradation in Central Asia. Usually, vegetation damage is the initial stage of human interference in the desert environment vegetation.

Degradation of forests in Central Asia is one of the most disastrous processes. According to the classification of forests in the former USSR, the majority of Central Asian forests belong to the first category - protective forests. Information on the area and growing stock of forests in the region is given in **Table 2.5**. The table testifies to poor forest resources of Central Asia. During 1981 through 1989, the size of forest area diminished in all Republics, except Kazakhstan (**Table 2.6**). In Turkmenistan, the reduction of the forested land occured largely as a result of wood cutting for fuel.

Table 2.5

Areas of forests and growing stock in Central Asian Republics
(National Economy of the USSR, 1991)

Republics	Percentage of forested Land	Forest area per inhabitant, ha	Growing stock, million m^3
Kazakhstan	3.16	6.3	366.0
Kirgyzstan	3.30	6.3	23.0
Uzbekistan	11.60	0.6	11.0
Tajikistan	1.60	0.1	6.0
Turkmenistan	12.10	3.0	14.0

Table 2.6

The size of industrial wood cutting in Central Asian Republics
(National Economy of the USSR, 1991)

Republics	Industrial wood cutting, thousand ha						Forested area, thousand ha		
	1981	1983	1984	1987	1988	1989	1983	1989	Change
Kazakhstan	85.4	87.2	72.7	71.8	71.2	65.9	9,353	9,643	+288
Kirgyzstanan	0.7	-	-	-	-	-	737	729	-8
Uzbekistan	8.4	10.0	10.1	10.2	4.3	5.8	1,909	1,302	-392
Tajikistan	0.2	36.1	31.1	32.5	32.5	32.5	458	410	-48
Turkmenistan	-	-	-	-	-	-	5,121	4,127	-994

According to Sukhikh (1991), the productivity of forests in Central Asia has declined during the last 50 years. During 1950 through 1990, efforts of afforestation were conducted in an area totalling 5.7 million ha. From this area, only 1.7 million ha were conserved and registered as productive forests. Sukhikh (1991) also indicated the principal causes of forest degradation in the region: animal grazing, unwarranted cutting, poor scientific justification of measures on forest regeneration, and low salary of rangers and other forest personal. Many cases of unwarranted cutting were registered in Turkmenistan. A total of 603 cases of violation of the Forest Code were registered in 1991 and 905 cases in 1992 (Desert Research Institute, 1996).

Degradation of desert rangeland is a result of the over-exploitation of forage resources. The degree of degradation in grazing land depends upon the composition of livestock and the intensity of grazing. Sheep mainly graze herbaceous plants, camels feed on shrubs and semishrubs, and goats can consume all types of vegetation. A system of free ranging dominates the range management of Central Asia. Sheep can move from watering points maximum at 5 ~ 7 km (Nikolaev, 1972). Rangeland around watering points can be divided into the following zones :

1. The third stage of land degradation (very severe pressure), 0.5-1.5 km,
2. The second stage of land degradation (severe pressure), 1.5-3.5 km,
3. The first stage of land degradation (moderate pressure), 3,5-7.0 km.

Bereznev (1995) found that in several provinces of Kazakhstan forage production in desert rangelands was exhausted even by the 1960's. Neglectfully, the number of livestock increased by 40% during the last 25 yeras. Currently, 25% of rangelands, that have watering points, are subject to degradation. In general livestock is provided with pasturage by 51.8%. In Turkmenistan, 50.5% of rangelands are slightly desertified, 45% moderately desertified and 4.5% are severely desertified (Desert Research Institute, 1996). In Uzbekistan, 58% of the vegetation is slightly degraded, 37% are moderately degraded and 5% are severely degraded (Kharin, et al., 1993).

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CHAPTER 3

MIDDLE EAST
-Asian Countries-

3.1 Introduction

The present study is concerned with the desertification in the Asian part of Middle East. The region consists of four sub-regions: 1- Turkey, 2- Iran, 3- Arabian peninsula, which includes the countries of Saudi Arabia, Yemen, UAE, Oman, Kuwait, Qatar and Bahrain, and 4- The Fertile Crescent countries, which includes Iraq, Syria, Jordan, Israel, Sinai of Egypt and the occupied territory by Israel.

With this definition the total land surface is approximately 6.262 million km^2. The total population is about 240 million in 1999 as estimated by the author, and the annual population growth rate is 3%.

The problem of desertification in Middle East has a long history through the past centuries. It has been subject to long-term changes in climate and human activities. The rising human population and, the associated growth in consumption of limited resources by human activities has led to severe degradation of vegetation and soil, and to shortage water resources, which compose the essential natural resources for human existence. Within the region, desertification is one of typical forms of environmental degradation.

3.2 Physical and natural characteristics

3.2.1 Relief features

In general Middle East region can be divided into simple zones, northern mountain belt, comprising the states of Turkey, Iran and northern part of Iraq. The second zone formed by plains and dissected plateaus (Beaumont et al., 1978). **Figure3.1** shows the distribution of these features.

In the mountain part, the Pontus Mountains in Turkey, an interrupted chain of highlands parallel of Black Sea coasts, rise in altitude more than 3000 m south of Rize. The highest peak of this chain is 5165 m at Ararat Mount in the east part. In the southern coast of Turkey, the Taurtus Mountains intersect with the Pontus Mountains and present a natural barrier to human movement. The Anatolian Plateau occupies the central part of Turkey; it is found at about 500 m elevation and relatively isolated from the coasts.

In Iran, mountains are divided into two parts along a southwest-to-northeast transect. In the north of Iran and along the southern shorelines of Caspian Sea are located the Elburz Mountains, which rise to an elevation of 5510 m at Damavand Mount. In the southwest of Iran, overlooking the Tigris-Euphrates lowlands and Persian Gulf, the Zagros Mountains stretch along the Iraqi-Iranian boundaries. The highest elevation reaches 4548 m at Mount Zardkuh. The east of Iran is occupied by the "Eastern Iranian Highlands", which form a natural borders between Iran and Afghanistan and

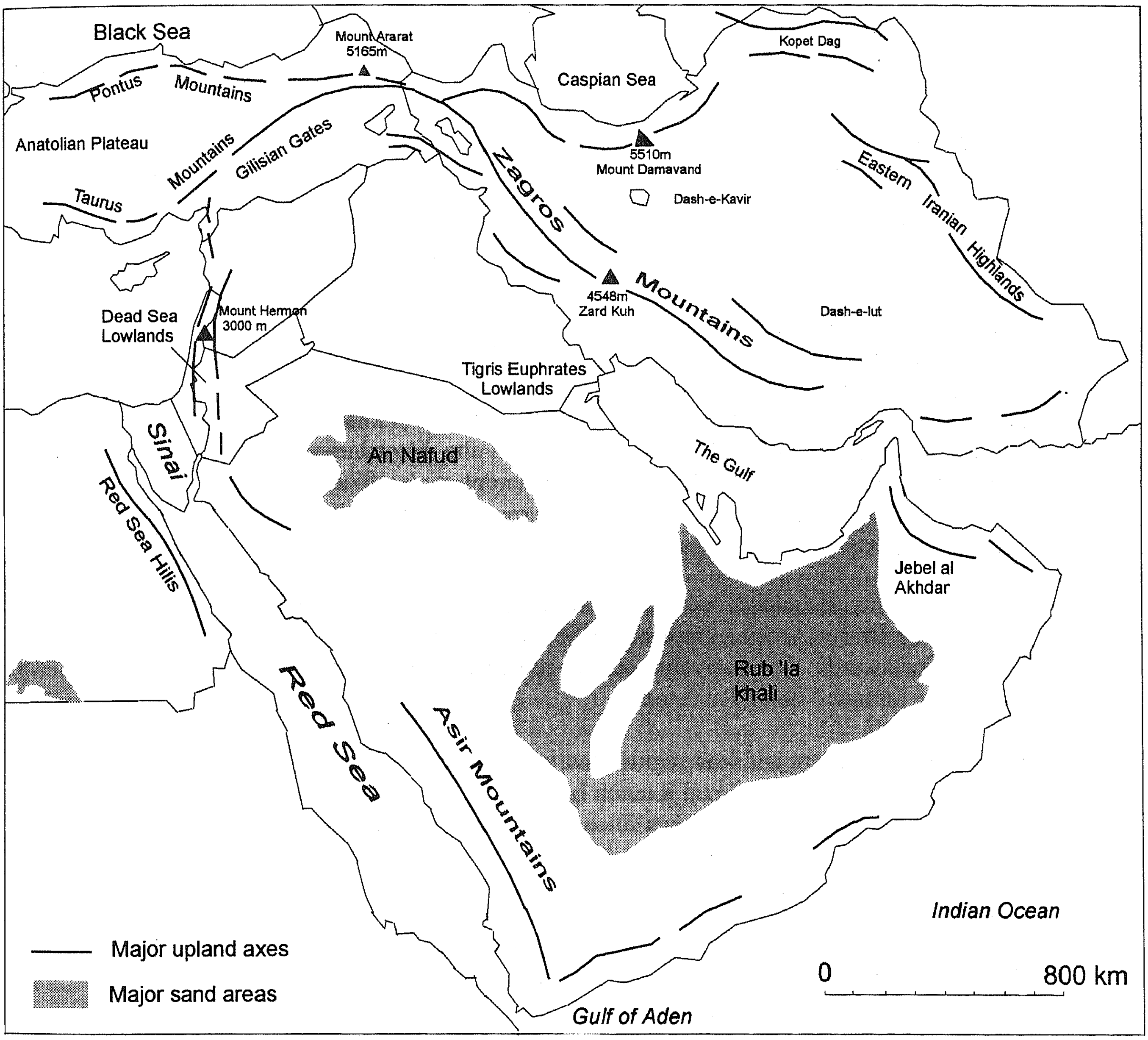

Figure 3.1 Major relief feature of the Middle East (Beaumont, 1978, modified by authors)

attain an altitude of 2500 m. The central plateau of Iran is divided into two major basins both with inland drainage. The Dasht-e-Kavir forms a huge salt desert in the north, while the Dasht-lut forms the southern basin.

In the East of the Red Sea in the Arabian Peninsula, highlands along the Red Sea are found where the highest peak is more than 3700 m in Yemen. From this corner the relief generally declines in elevation toward the north and east of the peninsula. In central Arabia, the relief forms series of westward facing escarpments in an arc-like form around the main highland mass of the West Coast. Upland areas are found in the proximity to the Mediterranean eastern coast, with a gradual decline in altitude towards the interior. These highlands attain a maximum of 3000 m at Mount Hermon. The pattern of relief in this region is complicated by the existence of the north-south fault zone of the Dead Sea low-lands, which has dissected the upland belt to form a trough-like region descending to 410 m below sea level at the surface level of the Dead sea. This is the lowest point in the globe.

The largest lowland belt of the region stretches from north of Iraq to the mountains of Oman. In Iraq it is crossed by the large rivers of Tigris and Euphrates whereas in the southern part the relief is minimal. The lowland belt continues as an attenuated zone along the western shore of the Gulf to broaden into an extensive plain in southeastern Arabia, where the largest sand Sea in the world, the Rub'al khali is found. Here some dunes are more than 200 m in height. Finally, the Mountains of Oman reach a maximum of 3000 m at Gebel Al Akhdar (Beaumont *et al.*, 1978).

3.2.2 Geology

In general terms, the oldest rocks of Pre-Cambrian and Paleozoic ages are found on the stable masses of Arabian Peninsula. These basement rocks are exposed in western Arabia. Northwards, progressively younger rocks mostly of sedimentary origin occur such as the famous Nabian Sandstone.

In the Fertile Crescent and Iran regions marine sediments, in particular limestone and marls of Mesozoic age make up a much larger proportion of the outcrop. Calcareous sediments are of an economic importance, as they constitute reserves for oil. Rocks of Tertiary age consist mostly of marine sands, clays, marls and limestone. These rocks occur along a wide zone paralleling the Gulf and in the inland basins of Iran and Turkey.

Thick Quaternary sediments are confined to the upland basins, where the major valley systems of Tigris, Euphrates and others are formed. Eruptive rocks, mainly basalt are found in the highland zones of Turkey and Iran, and in the adjacent area to the major faulting zones of the Dead Sea lowlands and Red Sea region. Volcanic peaks are seen in Mount Ararat and Mount Damavand. In other places, lava upwelling has occurred along fissures rather than from single vents. These cases are found around Jebel ed Druze in Syria and in the uplands of western Saudi Arabia.

3.2.3 Geomorphology

Geomorphic hazards play a significant role in landforms formation and strongly affect human activities. Most of these hazards are a direct result of water action. In upland areas, landslides, erosion and mudflows are common occurrences on unstable slopes with little vegetation cover. Frequent floods can devastate rivers and lowland areas.

With the long dry season that prevails almost everywhere during summer, wind erosion is a major hazard, winds cause the movement of large quantities of fine-grained materials, leaving behind a concentration of coarse-grained sediments. Sandy deposits are common throughout the eastern part of Middle East.

In Iran salt weathering has been discovered to be an important process in the breakdown of rocks crossing the alluvial fans and plains on the margin of Dash-e-Kavir(Beaumont *et al*, 1978). Further evidence of the importance of this process is found in a description of cracking parallel stone on pavement surfaces in Sinai (Yaalon, 1970). As in Iranian example, the growth of gypsum and salt crystals in fine crevices seems to be the prime cause of salt weathering.

Beaumont *et al.*, (1978) employed a simple basin model to describe the geomorphology in Middle East. This simple model divides the basin into four environmental zones: upland, alluvial fan, alluvial plain and salt lake or salt desert. The upland zone is characterized by steep outcrops, which are usually resistant rock types. Generally this zone has an erosive activity resulting from severe weathering conditions, fluvial activity and mass movement on steep slopes.

The three other morphological zones are essentially depositional in nature. The alluvial fan zone is situated at the margin of the upland zone and characterized by slopes of 3 to 15 degrees, with coarse materials brought out by fluvial and mudflow activity.

The alluvial plain possesses lower slope than that of alluvial fan, and in many case of Middle East, forms the major morphological zone. It is chiefly formed by water action deposition, but wind erosion also occurs here. The finer surface material is generally removed by the wind, leaving a stone or pavement desert behind, and forming deposits of loess or sand dunes in the lower parts of the zone, or on the margins of the adjacent salt desert.

The salt lake and salt desert zone occur only in basins without drainage outlets. Materials in this zone is normally fine grained, of silt or clay size, with the coarser material having been deposited during passage over the alluvial fan and plain zones. Salt crusts are often found on ground surface and a saline deposit occurs in the soil profile. Slopes are very gentle, and as a consequence water bodies are very shallow and cover extensive areas. Water movement into this zone from adjacent uplands takes place mostly in late winter and early spring. By late summer all standing water has normally evaporated and salt crusts are formed. The Dash-e-Kavir of central Iran and the River Jordan illustrate very well this model.

3.2.4 Soil

Soil is one of the most vital natural resources in any region, because, without it, agricultural activity is not possible. It is also relatively easily destroyed by the careless actions of man. Basic factors controlling soil formation are climate, parent materials, vegetation, slope, hydrology, micro-organisms, human activity and time. Parent material and climate conditions are usually the most significant factors influencing soil types.

In the Middle East, a number of soils type stand out exceptionally importance with regard to either their total area of occurrence or their agricultural productivity. In terms of the Great Soil Group classification, these types are the Red Desert soils (including lithosols and sand); Sierozems (including lithosols and sand); Reddish Prairie, Reddish Chestnut and Reddish Brown soils; Terra Rossa, and Rendzinnas; Chestnut and Brown soils; and alluvial soils (Beaumont *et al.*, 1978).

The Red Desert soils are the most widely occurring soils in Middle East, most of the Arabian Peninsula, Iraq, Jordan and southern Iran. Owing to the dryness of the region in which these soils are found, animal and plant growth within them is minimal and consequently the humus content is very low. Soil horizons are poorly developed and the texture is coarse with many unweathered materials.

Sierozems or Grey Desert soils are confined to the northern and central parts of Iran where temperature conditions are cooler. They are characterized by the accumulation of calcium carbonate just below the surface. Neither the Red Desert soils nor the Grey Desert soils are of great agricultural significance.

Reddish Prairie, Reddish Chestnut and Reddish Brown soils are found in the region of the "Fertile Crescent" of northern Iraq and Syria. The Reddish Prairie soils appear to have been developed under grassland conditions and are of great agricultural productivity particularly for cereals. In slightly drier areas, Reddish Chestnut and Reddish Brown soils occur. These seem to form under a range of vegetation conditions, but all show the development of a calcium carbonate horizon at depth.

Terra Rossa soils are of exceptional agricultural importance and developed on hard, pure crystalline limstones under a Mediterranean climatic regime, and occur extensively in Turkey, Syria, Lebanon, Jordan and Israel. The deep red color of these soils is thought to be due to the presence of sesquioxides of iron in considerable quantities. Their clay content is commonly above 50% and because of this, their moisture holding capacity is good. Due to their unstable structure, these soils are susceptible to water erosion when vegetation cover is removed.

Rendzina soils possess dark grey or black surface layers overlying lighter colored material, which is highly calcareous. Such soils are found only on soft limestones and marls, usually in association with Terra Rossa soils, which form on more resistant calcareous formations.

In the transitional zone between grassland soils and arid desert soils, Chestnut and Brown soils are found. They are best developed in central Anatolia. In more arid regions, the Chestnut soils are replaced by Brown soils, which are similar in profile characteristics, but contain less humus and consequently are of a lighter color. Both of these soils tend to be found in regions, which are marginal for dry-land farming.

Alluvial soils are the most fertile soils found in the Middle East. They occur along the major river systems, and are especially well developed in the Tigris-Euphrates lowlands. The texture of this type of soil varies considerably, depending upon local sediment supply conditions. In the larger river basins silty-clays, silty-loam, and silty-clay-loams tend to be predominant. Where poor drainage occurs, salinity can be a problem.

3.2.5 Climate

The Middle East has a special and unusual climate. Most parts of the world experience their rainfall either mostly during summer (the warm season) or distributed throughout the year. Only in a very few areas is there a maximum rainfall in winter (the cold season). This is the so-called "Mediterranean" climate, which is typified by a long intensely hot and dry summer, and a relatively mild, rainy winter, with occasional cold spells.

The contrast between these two seasons conditions plant life and thus agriculture. Native plant rest in the hot season, which is opposite to what happens in cooler temperature climate. Some plants such as cereals mature quickly to complete the growth cycle before the onset of hot weather; others, chiefly bulbs, flower in spring or autumn, whilst some, such as the citrus bear fruit in winter. All these have a marked effect on agricultural routines and general living habits, like the summer siesta, which involves breaking the day into rest periods, with a very early morning start, and continuance of work in the evening. Autumn is warm and sunny, while spring is changeable and subject to cold spells, both are short, intermediate season.

Temperatures are far higher than those at the Equator. Day maximum of 38°C to 46°C is usual, and a figure of over 52°C. is known. In winter, the interior land can be cold, especially at higher elevations. Snow can fall in mountains in Turkey, Iran, Syria, Lebanon, Jordan and Yemen. The plateaus of Turkey and Iran experience severe winters, with several months of frost and up to 120 days of snow cover a reminder of their geographical position adjacent to Russia. The minimum temperature ranges from 4°C to 10°C depending upon the geographical location. Wide fluctuations temperature between day and night are characteristic of the interior, but not close to the coast (Fisher, 1980).

An important characteristic of Middle East climate is the scant and irregular rainfall. Much of the entire region has less than 250mm annually. This deficiency is intensified by the highly sporadic and irregular nature of the autumn, for instance, in 1972 Kuwait and parts of the Gulf coast had unprecedented floods that washed away parked cars. In Jordan official statistics mentioned a daily rainfall of 158 mm Naour, south of Amman (Qudah, 1998). Also there can be heavy rain in one locality and none a few kilometers away. On the other hand, there are a few regions where produce annual totals of 750-1000 mm. These are usually upland areas close to large seas northern Israel, Lebanon, and western Syria, south and west Turkey and north of Iran close to the Caspian Sea. The extreme south and east of Arabia can brushed by monsoonal current from Indian Ocean, and thus have a local summer rainfall: parts of

Yemen and Oman are influenced in this way. Normally, the winter rains begin in October, with a series of storms. Heaviest rain falls during January in the west, and February or March in the east. Towards the end of April these may be the final onset of rain, and from June to September no rain whatsoever in the south, and only very small amounts in the north.

Two other phenomena may be mentioned: the occurrence of hot and dust or sand-laden winds from desert areas, and the prevalence of high atmospheric humidity near the coasts. The sand winds, known as Khamasins, are unpleasant visitations that can last up to 48 hours and their main effect, apart from human inconvenience, is to wither growing crops on a large scale. High humidity, especially in summer makes living conditions difficult in such areas as the Persian Gulf, the Red Sea and parts of Lebanon. Another effect is the intense evapotranpiration due to the high temperatures and low precipitation. Detailed work on potential evapotranspiration amounts in the Middle East revealed marked variations throughout the region. The highest values of mean annual evapotranspiration, of more than 1140mm, are confined to the areas south of 30 degrees latitude. Medium values, between 570 and 1140 mm, occur throughout much of Turkey, the eastern Mediterranean coastal region, Syria, northern Jordan, northern Iraq and in the highlands of Iran, while figures below 570mm are found only in the highest upland regions of Turkey and northern Iran (Beaumont *et al.*,1978).

3.3 Social and economic feature

3.3.1 Population

One of the acute issues, which exert a profound influence on desertification in Middle East countries, is population pressure. This problem arises as a result of a high birth rate, together with a fairly low death rate. This situation has multiplied demands on natural resources to fulfill people's needs in water, food and space, which means more direct or indirect pressures on the land and its available resources of water, soil and vegetation. Studies mentioned that the needs of increasing population is more than double of the productivity (AOAD, 1994).

As a consequence of this process, desertification or more generally environmental degradation has attacked millions of hectares in the Middle East, of which more than 70% are severely degraded compared to the situation in 1960 of low density of population when desertification was slight to moderate.

Historically, the Middle East counties have had a population of 14 million in 600 AD (Beaumont, 1970), the same author arrived at low estimate, which he adopted, of 20 million for 1920 (including Egypt and Libya). By 1950, the same region contained approximately 44 million people.

In this study, several sources have been examined to compile estimates of population growth by decade from 1960 to 2000. **Table 3.1** and **Figure 3.2** explains these investigations, from which several conclusions may be made.

Table 3.1

Population growth of Middle East

Country	Country Surface $x10^3 km^2$	Population in Millions from 1960 to 2000						Growth -rate % 1998
		1960	1970	1980	1990	1995	2000	
Saudi Arabia	2,149.90	4.85	6.43	8.50	14.20	18.73	22.20	3.68
Yemen	527.97	5.30	7.03	8.90	10.50	14.73	18.00	3.30
Kuwait	17.82	0.56	0.76	1.60	2.10	1.82	2.08	3.80
Oman	312.50	0.46	0.66	0.90	1.50	2.13	2.60	3.71
Bahrain	0.62	0.14	0.19	0.43	0.50	0.58	0.70	2.58
Qatar	11.00	0.05	0.10	0.30	0.40	0.54	0.80	2.74
UAE	75.58	0.14	0.19	0.92	1.60	2.93	3.00	3.50
Iraq	437.00	6.90	9.83	13.80	18.90	20.65	23.80	3.70
Lebanon	10.40	1.85	2.46	3.00	3.00	3.67	4.07	2.15
Syria	185.18	4.57	6.24	8.60	12.50	15.45	17.50	3.30
Jordan	89.20	1.00	1.35	2.20	3.50	4.10	4.90	3.40
West Bank & Gaza	6.22	0.56	0.75	1.35	1.89	2.13	2.80	4.02
Turkey	780.58	26.70	35.53	46.20	58.00	64.57	69.50	2.00
Iran	1,650.00	21.75	28.53	36.80	48.40	64.40	70.30	3.40
Israel	20.77	1.50	2.80	4.00	4.70	5.17	5.90	1.91
Total	6,274.74	76.60	103.20	137.50	184.69	221.54	248.20	2.98

The population of the Middle East was trebled from 1960 with 76.6 million to 240 million in 1999, and is expected to be 480 million by 2020. Compared to other countries, Middle East countries have a high population growth rate, about 2.98% as average. The world population growth rate is about 1.7%. **Figure 3.2**, with its exponential shape, shows clearly this population increasing and the high value of population growth rate. The conditions of life are very difficult in Middle East with low individual income. This situation increases the population pressure on the available natural resources and leads to land degradation. It is worth noting that in the past this region had high agricultural productivity.

3.3.2 Agriculture – Land use & Livestock–

Agriculture has a fundamental importance in the life of the region. **Table 3.2** gives some indicators for the importance of agriculture. Over the whole region, agriculture contributed directly to about 15% of the GDP in 1968-1969(Beaumont *el al.,* 1978). In 1994-1995, the contribution of agriculture is estimated for the whole region to be about 15.5%, with a net decrease in the agricultural labor force between 1970 and 1995, which may again be interpreted as increasing of pressure on natural land resources. Low productivity is one of the region's major economic problems, and this is due to physical conditions.

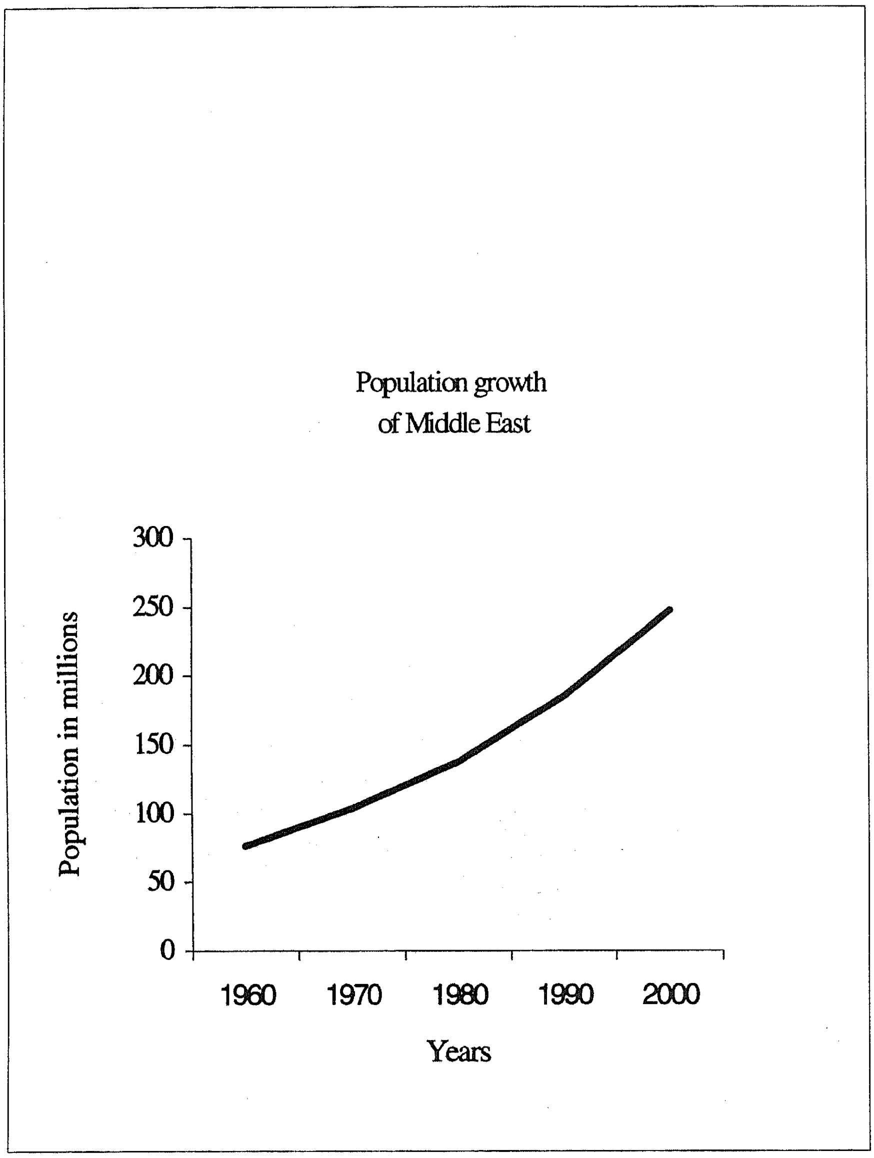

Figure 3.2 Population growth of Middle East

Table 3.2
Importance of agriculture in Middle East

	Percentage contribution to GDP before 1970	Percentage of labor force before 1970	Percentage contribution to GDP-after 1995	Percentage of labor force after 1995
Saudi Arabia	6.0	60.0	8.8	5.5
Yemen	-	67.0	20.0	62.0
Iraq	19.0	47.0	5.0	20.0
Syria	26.0	49.0	28.0	22.5
Jordan	15.0	39.0	6.0	10.0
Lebanon	10.0	47.0	8.8	9.0
Iran	19.0	46.0	23.0	29.0
Turkey	28.0	69.0	16.0	44.0
Israel	6.0	10.0	2.0	2.6

(a) Land use

Water availability is the most important constraint on agricultural land use. A winter or spring maximum and a long summer drought characterize the precipitation regimes. This pattern largely determines the time available for crop growth, though low temperature in winter and high evapotranspiration in summer restrict rapid growth to the period from February to May in Fertile Crescent and from April to July in the high central parts of Turkey and Iran.

Wheat and barley are the most important crops in terms of the area devoted to them as well as their prominence in the diet. As indigenous plants, they are well adapted to local conditions.

The critical conditions are met in parts of the region where mean annual precipitation exceeds 240 mm and relative inter-annual variability less than 37%. Most of the region cannot support dry farming (rainfed farming) and permanent cultivation depends largely upon the availability of water for irrigation, and this is restricted. The situation of agricultural land use is presented in **Table 3.3**.

As it is shown in **Table 3.3**, human uses only part of the Middle East area. The mountains are too high in places for comfortable use, and in winter they are too cold. Tracts of sand and stone desert provide physical contrast, but human use is generally restricted to when an occasional shower has produced a flush of herbage. In spite of these conditions, farming is still basic to the socio-economic life of the Middle East.

However, annual cropland covers a very small part of the region, estimated at an average of 6.5% of total land. The rangeland, however, is considerably wide (**Table3.3**). Everywhere the arable area has been increasing. Former grazing land has been ploughed up in the dry farming areas, and irrigation has been extended into the arid parts of the region. The use of the cultivated area is also changing. The cropping pattern is dominated by wheat and barley, which occupy more than 50% of the field crop area and reached over 80% in Iran, Iraq, Jordan, Turkey and Yemen (Beaumont *et al.*, 1978).

Table 3.3
Land use distribution in thousand km²

	Country Surface $x10^3$ km²	Permanent cultivation	Annual crops	Irrigated area		forest	rangeland
				Surface	%*		
Saudi Arabia	2,149.90	0.95	15.30	16.08	100.0	0.87	764.40
Yemen	527.97	2.00	8.50	3.80	45.7	20.00	158.40
Kuwait	17.82	-	0.04	0.05	100.0	-	1.34
Oman	312.50	0.43	0.18	0.62	100.0	-	10.60
Bahrain	0.62	0.02	0.02	0.03	100.0	-	0.11
Qatar	11.00	0.02	0.06	0.13	100.0	-	0.50
UAE	75.58	0.33	0.20	0.67	100.0	-	1.52
Iraq	437.00	2.70	34.60	36.26	94.5	13.11	39.33
Lebanon	10.40	0.93	1.10	0.86	46.2	0.80	0.10
Syria	185.18	6.70	42.00	10.13	20.5	5.55	78.70
Jordan	89.20	0.94	1.20	0.68	29.9	1.40	7.81
West Bank & Gaza	6.22	0.12	0.48	0.12	-	0.06	1.88
Turkey	780.58	34.93	174.50	40.70	20.4	202.00	125.00
Iran	1,650.00	16.50	127.30	72.60	50.5	115.00	445.00
Israel	20.77	0.80	0.35	1.80	-	1.25	1.45
Total	6,274.74	67.37	405.83	184.53	-	360.04	1,636.14
Percent of total	100	1.10	6.50	2.94		5.70	27.29

* Irrigated area as % of cultivated area (FAO, 1997)

In contrast with the area under field or annual crops, that devoted to permanent crops, principally fruit trees, is small, about 1.1% of total land surface. Olives, vines and figs are the most common since they have the advantage of being deep-rooted and thus able to draw moisture from depth during the long, arid summers, which characterize the region. However, the extreme aridity of the interior and the winter coldness of the mountains and high plateaus make them a typical combination of the region, and permanent crops occur only in areas adjacent to the Mediterranean, chiefly Israel, Jordan, Syria, Lebanon and coastal Turkey.

Irrigated crops cover 184.53 thousands km² in the study area, which accounts for 3% of total area. The vast majority of the irrigated areas (95%) are concentrated in five countries: Iran, Turkey, Iraq, Saudi Arabia and Syria in the order of importance. Iran alone contains 40% of the total irrigated area (**Table 3.3**). As mentioned by FAO, 1997, in the Arabian Peninsula as a whole, 80% of the cultivated area is under irrigation. In all of countries within this sub-region except Yemen, the entire cultivated area is under irrigation. As shown in **Table 3.3**, cultivated area under irrigation is important for all of the countries, and is crucial for some countries like Iraq, where almost 95% of the cultivated area is under irrigation.

Only a small areas of forest survive today (**Table 3.3**), much of which consists of little more than scrub. In the Middle East, 87% of the forest area in Iran and Turkey, and Arabian Peninsula practically has a very little of forest at present. It is important to indicate that forests in the Middle East today are facing serious problems. The major destructive activities in the forests are cutting timber to provide lumber and firewood, producing charcoal for cooking and extracting resins for adhesives. Forest destruction has been aided by the activities of nomadic pastoralists who, on occasion, willfully burn forest to extend the open grazing and frequently had no alternative but to graze their animals amongst the trees as they passed through, thereby hindering regeneration. The consequences have not only been the loss of a valuable resource, but extensive erosion in the mountains and increased flooding in the valleys and plains.

As for rangeland, it is well known that this resource provides the main part of fodder materials for livestock in the Middle East region, and may be more than 65% of agriculture labor force is involved in rangeland. Rangeland provides an additional income for rural people. We should keep in mind that rangeland plays an important role in environmental protection, as well as keeping the natural resource and realizing a climatic balance. In our estimation of rangeland areas, we do not consider lands receiving rainfall below 100mm per years. **Table 3.3** shows that almost 27% of the Middle East area is considered as rangeland, which is about 164 million hectares distributed mainly in Saudi Arabia with 46%, followed by Iran with 27%, Yemen with 10% and Turkey with 7.6%.

(b) Livestock

Livestock is one of the main users of natural resource. As a global level, livestock make use of more than two-thirds of the global land surface under agriculture (grazing and croplands), and one third of the total global land area (FAO, 1994). The same author reported that the demand on livestock products (meat and milk) would increase strongly especially in Asia and Africa, where the demand for meat is expected to triple. FAO (1994) mentions that the productivity of livestock increases by 2.6%, while the demand increases by 4.4%, whereas the prices will be multiple. Studies of IFPRI (1995) estimated a regional growth in the demand for meat over the period 1990-2020 from 104% to 157%, and for cereals 74% to 100% for the region of west Asia and north Africa. These are indicators of the colossal problems of nutrition and environmental deterioration due to these human pressures.

In the Middle East region, the situation exactly reflects what is going on at global scale. Livestock is an important sector for investment and insurance for millions of rural poor people. Except for the small Gulf states, livestock production is an important sub-sector of agriculture, many farmers depend largely on livestock production for food, additional income and work power. Livestock is the major source of livelihood for the nomadic population.

The livestock population in the Middle East region was estimated in 1990 at 262 million heads, whereas in 1980, it was estimated at 198 million heads, an increase of 32% per decade (**Table 3.4**). Statistics of livestock include mainly sheep, goats, cattle, camels, buffalo, donkeys, horses and mules. Poultry population was not taken in account.

Table 3.4
Livestock statistics in thousand head

	1976*	1980**	1990**	1994***
Saudi Arabia	4,353	6,354	12,492	11,440
Yemen	15,057	15,155	19,620	7,820
Kuwait	230	277	252	320
Oman	370	526	1,219	1,880
Bahrain	10	22	31	30
Qatar	99	125	241	222
UAE	500	559	1,005	1,365
Iraq	19,300	18,941	13,635	12,400
Lebanon	674	661	699	655
Syria	8,313	11,493	16,507	14,300
Jordan	1,410	1,512	1,769	2,878
West Bank & Gaza	-	-	-	-
Turkey	77,829	84,200	120,934	-
Iran	44,690	57,500	72,450	-
Israel	705	550	550	-
Total	173,540	197,875	261,404	-

Sources: *Fisher (1980), **FAO (1990), *** Gilani (1997)

This increase of livestock caused serious pressure on rangeland with land degradation as a consequence. One of the more important forms of vegetation degradation is the disappearance of natural vegetation, which is originally palatable species for animals. This phenomenon is followed by the subsequent dominance of other herbaceous vegetation, less palatable or unpalatable. This process leads to reduction in the carrying capacity of rangeland and soil deterioration by the loss of its fertility. Another form of this process is the appearance of outcrop, calcium sediments, gypsum or sand.

3.4 Desertification assessment

The Middle East region is facing environmental problems of land degradation and possibly desertification. Most of Arabian Peninsula is free of perennial vegetation, with most areas containing shifting sand dunes that are incapable of sustaining plant life. Most of the marginal lands in west Asia are permanent pastures of 1.64 millions km^2, and 85% of this surface is considered in danger of desertification. These marginal lands are subject to human activities and susceptible to inappropriate land use practices, such as overgrazing, fuel cutting and inadequate cultivation. As our concept in this study is based on human activities as main cause of desertification, the extra-arid land, the high mountains and sand dunes areas are excluded from assessment and analysis, because we consider these areas to be practically empty of population.

It is important to note that there are no complete studies about the different types of desertification that may occur throughout a whole country. The statistics, which followed in the next paragraphs, are indications about what is going on in term of land degradation, but they do not reflect the real situation. In addition, we found several contradictions in these statistics, which reduce its reliability, despite the fact that these statistics have been adopted by international and regional organizations like FAO and ACSAD (The Arab Center for the Studies of Arid Zones and Dry Lands). Nevertheless all of statistics indicate that the majority of surface undergoing desertification in the Middle East is exhibiting a moderate to severe degree of desertification.

3.4.1 Vegetation degradation

The Middle East region once supported forests in some places and was generally characterized by highly productive native pastures (Pearse, 1971). This native pasture had been under the control of a grazing system known as Al-Hima, which is a very efficient way of environmental protection. In this study we consider two forms of degradation that affect vegetation, these are rangeland degradation and forest/woodland degradation.

(a) Rangeland degradation

The continued over-exploitation and overgrazing over prolonged periods of time has led to the depletion and exhaustion of rangeland. Many of the palatable plants have disappeared and only a few sparsely scattered annuals and thorny and unpalatable perennial species remain. The degradation of rangeland has deprived the livestock sector of inexpensive and important animal fodder, and has led to soil erosion and subsequently to desertification. The main causes of rangeland deterioration that persist in the Middle East are overgrazing, firewood gathering and marginal cultivation.

Generally, grazing in the Middle East region is carried out without regard to the carrying capacity of the land or any consideration to its future regeneration. An indication of both the available animal food and the risk of rangeland degradation is the number of grazing animals, which indicates that grazing intensity increased considerably between 1980 and 1990. This grazing intensity is expressed in terms of number of sheep per hectare, as shown in **Table 3.5** (ESCWA, 1993).

Table 3.5
Grazing intensity expressed in terms of sheep per hectare

Countries	Sheep head/hectare	
	1980	1990
Saudi Arabia	0.10	0.14
Yemen	0.81	0.98
Kuwait	2.53	2.47
Oman	1.02	2.35
Bahrain	4.40	9.00
Qatar	3.88	6.93
UAE	4.41	6.97
Iraq	3.32	2.47
Lebanon	3.52	2.75
Syria	1.04	1.53
Jordan	1.22	1.66

Table 3.6 shows the average productivity in kilogram per hectare from the dry matter in the rangeland of some countries. It is clear that this productivity is small, and reflect the status of rangeland degradation, which is indication of vegetation cover reduction. The same table shows the reduction of the proportion of rangeland contribution for animal feeding (AOAD, 1994).

Table 3.6

Productivity of rangeland in kg/hectare from dry matter

Country	Rangeland surface(hectare)	Productivity kg/hectare	Rangeland contribution (%) 1972	1993
Iraq	3,933,000	110.0	90	40-20
Jordan	8,500,000	79.4	87	40-20
Syria	10,179,000	196.5	60	20

By the study of Gilani (1997) about desertification in Arabic countries, which reviewed results of studies related to land degradation, rangeland degradation affects 28% of total land surface in Saudi Arabia, with the production of rangeland reduced during 1986-1994, from 700kg/ha to 113kg/ha. In Lebanon the degradation affected about 2240 hectares. In Iraq 200,000 hectare/year of rangeland are degraded during the decade of 1970s. The same study reported that moderate to severe land degradation affects more 90% of rangeland in countries of Iraq, Jordan, Lebanon, Oman, Qatar and Syria. In Oman, the degradation of Jable Dufar rangeland is noted. Balba(1994) mentioned the increased degradation of rangeland in Oman, and the main causes for this degradation are overgrazing, fuelwood gathering and the movement of sand dunes, especially in the eastern part near the Wahiba desert.

In Syria, the degradation of vegetation cover has accelerated during the last few years, mainly due to human activities. Dry farming and overgrazing are the main causes of rangeland degradation, and the productivity of rangeland was reduced by 70% during 8 years. Palatable plants have been seriously reduced or have disappeared in large areas, and replaced by unpalatable species, which have become dominant in large steppe areas. Statistics of land use between 1985 and 1989 showed a clear decline (approximately 339,000 hectares) in cultivable lands, and increased of uncultivable land (Ilaiwi et al., 1992).

In Iraq, as reported by Fadhil and Farrajii(1998), the productivity of pasture land gradually declined as a result of intensive overgrazing, cutting of trees and shrubs, marginal cultivation, irregular distribution of wells and lack of green feedstock, which has led to increased stress on pastures in desert areas.

The disappearance of palatable species and their replacement by unpalatable species, is a form and indication of moderate or severe vegetation deterioration. Examples of palatable species occurring in Mediterranean countries are *Salsola vermiculata, Poa sinaicia, Stipa barbata* and *Rhanterium epapposum*, these species were replace by other less palatable or unpalatable or thorny plants such as *Noea, Peganum harmala* and *Alhagi maurarumu.*

(b) Woodland and forests deterioration

As mentioned in the above paragraph, forests occupy a small area of the Middle East region, about 5.7%. Forests are facing serious dangers. In fact while some of these forests are subject to deterioration, others are already disappeared.

Yemen is the more affected area in terms of forest degradation. Al-Dubaie(1998) described the situation of woodland degradation in Yemen. The evergreen broad-leaved woodlands and the draught-deciduous woodlands are located in the high and mountains areas in the west of the country. Most of the natural vegetation in Yemen has been strongly disturbed and degraded and in some areas it has been replaced by introduced species. Studies conducted in Tihama during 1973-1992 indicate that Acacia woodlands showed a noticeable decrease (20-30%). Aerial photos on Jabal Bura (Western Mountain) showed that woodland has been reduced by an annual rate reaching up to 4% of the woodland area. During the period 1973-1988, woodland degradation in Jabal Bura reached about 60%. The woodlands in Jabal Eraf (Taiz governorate) are strongly affected by cuttings. The study mentioned the woodcutting and overgrazing are the main causes of forest degradation. Studies indicated that nearly the whole Yemen, with the exception of rock, sand dunes, salt pans and the highest mountain peaks, was at one time covered with forest (Hepper, et al., 1997). Recent studies showed that the remaining forest is nearly less than 7% compared to the forests of Yemen in the past.

The study conducted by Gilani (1997) mentioned the destruction of the "Al atlasy" forest in Syria, which in the past covered 300,000 hectares, but now has been reduced to just a few hundreds hectares. A general reduction of 50% of forest is mentioned for Syria. The cedar forest, which covered a large part of Lebanon, is now covering only small patches, which contain a limited number of trees. The same author notified that the forest covering the highlands of southwest Saudi Arabia and extending into southeast of Yemen are undergoing of deterioration, and are reaching the point of extinction. In Iraq the remaining forest between Tigris and Euphrates rivers is about 40,000 hectares. In Jordan, Qudah (1998) reported that overgrazing inside forests during the year of 1991 has led to the destruction of one million trees, including small trees. The same report mentions that 20-30 thousand trees, annually are damaged by firewood gathering, 10-20 thousands trees damaged by illegal cutting and 5-10 thousands trees by illegal grazing.

Mesopotamia, the land between the two rivers of Iraq, was known in the past as "Black valley", owing to its originally thick and extensive forest cover. These forests have, however, disappeared under deforestation caused by the increase of population pressures. As a consequence, two major problems appeared leading to large-scale degradation: salinization and mobile sand dunes (Abul Gasim et al., 1998).

3.4.2 Soil degradation

The soil constitutes the top layer of the earth crust, in which plants grow and extend their roots. The success of agriculture depends largely upon soil type, its texture, depth, structure, organic matter and other environmental factors. Thus soil degradation affects directly the agriculture sector, which is directly related to desertification. The soil degradation could be defined as a process or as a state, which results from a lowering of the current or potential capability of the soil to support plant growth. In this study, we recognize three types of soil degradation: water and wind erosion and salinization with or without alkalization.

(a) Water and wind erosion

Soil erosion occurs when vegetation cover is disturbed or removed, exposing the top layers of soil to the actions of water and wind. Throughout most of the mountain in the Middle East region water erosion predominates. Gully erosion is especially dramatic on soft materials, while almost imperceptible sheet erosion occurs nearly everywhere (Beaumont et al., 1978). Although water action reaches its maximum during the wet winter months, the converse is true of the wind. The greatest effect of this is felt in the dry summer, when surface soils become dust-like and so are easily transported by strong winds.

The world atlas of desertification shows clearly that mountain region in Turkey, east Mediterranean countries, north Iraq, west Iran, southwest of Saudi Arabia and Yemen are the most affected by water erosion. While the region of Arabian Peninsula, south part of Crescent fertile and central and east part of Iran are dominated by wind erosion (UNEP, 1992).

Mitchell (1978), in his study "Soil degradation mapping from Landsat imagery in north Africa and the Middle East", mentioned that wind erosion is predominant over water action on Landsat images. There is often a zone of tension where both wind and water actions are important. The amount of wind erosion is a function of the climatic, soil and land use factors.

Gilani (1997) estimated that the surface wind erosion degradation in Arabic countries of west Asia is 110 million hectares, and the area affected by water erosion is 21 million hectares. This area is increasing gradually because of the marginal cultivation and the movement of sand dune towards agricultural and rangeland areas. The same author lists some examples: Qatar lost 13,600 hectares by water erosion when rainfall storm occurs, while the sand dune covers 21,000 hectares, with moving rate reaches 8m/year. In Saudi Arabia, the sand dune movement reaches 10m/year. In Syria, 50% of total land is undergoing erosion. The amount of removed dust in one stormy day in 1987 was estimated by 0.57 million ton from the topsoil. Syrian Badia and Wadi Khabour between Dair Zour and Gamishly are seriously affected by wind erosion.

Ilaiwi (1992) examined the problem of desertification in Syria, especially wind erosion, and reported that the frequency, duration and severity of atmospheric dust loads and dust storms have increased remarkably during the last few years in the eastern part of the country. Two regions are mostly affected by wind erosion, the plains of southern Mesopotamia and Bichri Mountain and surrounding areas. The first area is subjected to marginal cultivation and maximum wind speed ranged from 16 m/s to 27 m/s, which is very high. The area is flat, permitting the transport of sand grains, which accumulate on villagers' houses. In some places, sand reaches to roof level. The gypsiferous soils are the dominant soils in this region, and if rainfed agriculture is continuously practised in such area, wind erosion will quickly expose the gypsum (in quite a short time). Bichri Mountain is characterized by high soil erodibility in ploughed areas. Rainfed barley cultivation was introduced many years ago, and the shrubby cover is seriously damaged by tillage. Wind erosion has increased remarkably during the last few years. Because of its geographical location and its geomorphological characteristics, Bichri Mountain is believed to be the major source for sand movement and sand accumulation in the country.

In Iraq, 21% of the total surface affected by erosion (Gilani, 1997). The sand dune covers 60,000 hectares in central and southern Iraq. The shifting of sand dunes and the increase of sandstorms are the main features of wind erosion in Iraq. The Ministry of Irrigation in Iraq has implemented various projects to stabilize sand dunes and reduce their impact on strategic projects (Fadhil et al., 1998). The same author mentioned the army conflict and economic sanction as having intensified the problem of desertification in Iraq.

In Yemen, the Al-Rubu-Alkhali and Ramlat Al-Sabatain(east of Ma'rib) are considered areas of sand accumulation and a dangerous source of sand. The encroachment of sand can be seen in Tihama plais, Ma'rib, Al-Jawf, Hadramout, Iahj, Abyan, Shabwa and Al-Mahara. This phenomenon of wind erosion covers about 4 millions hectare and its annual rate 40m/year. In the coastal areas of the country, studies (Al-Dubai, 1998) indicated that sand covers about 600-950 hectares and threatens about 2,000 hectares. In the early of 1970s, sand covered about 2,250 hectares in Wadi Abeda (Ma'rib), which reached up to 9,840 hectares in 1990.

In Jordan, the movement of sand dunes affects the areas located east of Al-Azraq and the area stretching through Wadi Araba to south of Jordan. The marginal area in Jordan, which is defined by the range of rainfall between 250 mm and 100 mm, is affected simultaneously by water erosion and wind erosion. The main cause of soil erosion in this area is related to the physical and chemical characteristics of soils type occurring (Taimeh, 1997). The western highlands are undergoing the effects of water erosion, with a rate of 200 ton/ha/year. The studies (Qudah, 1998) mentioned that sheet erosion affects 90% of Zarqa river basin, and gully erosion affects 20% year. In Jordan valley, the water erosion reaches a mean value of 415 ton/ha/year. In the area of southern Ghour, this value decreases to 204 ton/ha/year (Saleh, 1971). In this same area (southern Ghour), the studies mentioned a loss of 11,000 hectares after several floods during the period of 1958-1965 (Saleh, 1989). And severe water erosion affects 3,000 hectares of this region, while just 600 hectares are moderately affected.

(b) Salinization

Soil salinity is most clearly seen in lowland and riverine areas where irrigated agriculture is practised and drainage systems are inadequate. The major cause of soil salinity is the use of saline groundwater. Under these conditions, water is drawn upward to the surface by capillary action, and evaporates into the atmosphere. When it does so, it leaves behind any dissolved chemicals to form a surface crust, or saline horizon, in the top few centimeters of the profile. Salt can also be added directly to the soil through poor quality irrigation water. Even though satisfactory drainage systems practiced, salinization occurs when the use of insufficient water does not permit full leaching.

The use of saline groundwater in irrigation could add tons of salt to soil in short time. For example, if irrigation water contains 1g soluble salt per liter, 1,000 m^3 water in hectare means adding 1,000 kg of salt per hectares, and after 20 times of irrigation, this amount will be 20 tons of salt added to every hectare (Saleh, 1989).

The major salts found in soils are chlorides and sulphates of sodium, calcium and magnesium. In arid soils, sodium ions tend to present the greatest problem as they cause the breakdown of soil structure and a great reduction in permeability. These ions are also toxic to most plant species when present in large quantities. The reclamation of saline soils is a straightforward process if sufficient water is available for leaching away the soluble salt, and provided an adequate drainage system exists (Beaumont et al., 1970).

Waterlogging, salinity or alkalinity affects all irrigated areas in the Middle East, and several examples can be noted. In Syria, 40% of irrigated areas are affected by salinity. The surface, which is excluded from cultivation because of salinity, is estimated at about 3,000-5,000 hectares per year. The surface affected by waterlogging and salinity is about 366,000 hectares, 77% of this surface is affected by salinity. In Saudi Arabia, the affected area by salinity is estimated by 24,000 hectares, 90% of this area are severely and very severely affected. In Oman, the salinity of agricultural land enforced farmers to abandon their fields, and this situation has led the rural people to immigrate towards cities. In Kuwait, an estimated 85,000 hectares has been severely affected by salinity. As in Qatar, 113,000 hectares of irrigated areas and rangeland are affected by salinity. The affected areas by waterlogging and salinity in Iraq are estimated to be 366000 hectares. (Gilani, 1997) and Abul Gasim (1998) reported that salinization in Iraq is caused mainly by the continuously rising groundwater table (about four meters below ground surface) and poor management of irrigation. Soil salinity currently affects about 8.5 million hectares or 64% of total arable land surface in Iraq. It is reported also that 20-30% of irrigated lands have been abandoned because of salinization (Abul Gasim et al., 1998).

Al-Dubaie (1998) reported that 90% of the land in the southern part of the country is threaten by salinity. This situation is noticed especially in Wadi Hadramout and other coastal areas such as Al-Hodiedah, Al-Makhah, Abyan and Dawhan.

In Jordan, Qudah (1997) noticed that the salt content in Jordanian soil types, the evaporation and the salts brought by the inadequate irrigation practices, are the main causes of the salinity problem in Jordan. In the Jordan Valley, the soil salinity varies from slight to moderate, with an affected area of about 1350 hectares. The salinity increases in the marginal lands, as well as in the Jordanian Badia. Studies of Ministry of Agriculture mentioned the overgrazing, the over-pumping of underground water and the presence of cemented crust prevents a good leaching of soil, are principally responsible of soil salinity in this particular region. It is noticed by the field survey the presence of white layer of salts in vast area of Qa' Al-Dissi, Al-Mudaoureh, Qa' Al-Jafer and Qa' Al-Azraq. Studies conducted by MacDonald and Hunting (1965) showed that the Wadi Dhuleil area is seriously affected by salinity where 15% of total studied area (30,000 hectares) is affected. The soil in this area has weakness in texture and structure, and the permeability is low, which increases the salinization.

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CHAPTER 4

CHINA

4.1 Physical factors of desertification

The intensity and development of desertification depends, first of all, on physical factors that can be divided into two groups: climatic factors and site conditions. Precipitation, temperature, wind and combination of these indices are the main climatic factors. As Wang Lixian (1995) indicates, precipitation in the drylands of China declines gradually from the east to the west, being mostly below 400 mm per year. But there are some local differences, for example in the western parts of Ningxia and Gansu, annual precipitation is only 50 - 100 mm per year. In the Taklimakan Desert, the annual precipitation is only about 25 mm. This extra-arid region was excluded from desertification assessment because the human activity practically does not take place here.

Frequent strong winds and sand devils stimulate the development of desertification. Especially the spring season is a windy time when wind erosion is very active. **Table 4.1** confirms this feature.

Table 4.1
Spring winds in total percentage of annual winds in desertification prone areas in Horquin and Ulan Qab Steppe (Zhu Zhenda, et al., 1988)

Regions	Spring winds, annual percentage	Regions	Spring winds, annual percentage
Tongliao	61.71	Erenhot	49.7
Ganqika	64.86	Jurihe	40.7
Lubei	42.20	Darhan Muminggan	42.9
Bayartuheshi	43.07	Shangdu	41.2

The spring season is also characterized by sparse precipitation. The same author gives information on precipitation in Horquin and Ulan Qab Steppe (**Table 4.2**). Under these conditions, the sand surface is easily eroded.

Site conditions include soil, vegetation, topography and slopes, and in combination these factors determine the inherent risk of desertification. The main part of the sandy desert is located in the vast inland intermountain basins that contain loose sandy deposits. The depth of these deposits total 130 - 400 m (Wang, 1995).

Under the dry climate conditions this loose material is subject to long-term wind erosion. There are several ephemeral rivers in the desert zone of China, which have been formed because of low precipitation, high evaporation and quick infiltration. Sparse vegetation consisting of shrubs, semi shrubs and grasses worsen the inherent risk of desertification.

Table 4.2
Spring precipitation in the total percentage of the annual rainfall in Horquin and Ulan Qab Steppe (Zhu et al.,1988).

Regions	Percentage of spring rainfall	Regions	Percentage of spring rainfall
Tongliao	11.90	Erenhot	10.9
Kailu	10.54	Sonid Youqi	11.7
Lubei	8.51	Mandula	12.9
Ganqika	12.81	Jurihe	12.3
Naiman	11.80	Huade	12.8
Hure	11.40	Darhan Muminggan	8.2
Baokang	12.40	Shangdu	13.1

The Yellow River often bursts through its dikes. In the great flood in 1931, 88 000 square km below Iching were flooded, and as a result 10 million people lost their homes, and 50 million were directly affected. Above that the river deposits considerable amount of silt over the fields. Until the present time it has been impossible to control this natural force completely.

Drought is another scourge of nature. In 1959 - 1960 the provinces Hubei, Shantung, Shansi and Hunan had no precipitation for 200 days. The Yellow River ceased its flow for 40 days. Droughts and flooding are not only the results of the monsoon climate, but also people are responsible. The cutting of forests and construction of the irrigation canals, terracing and other activities stimulate droughts and floods.

According to "The National Economic Atlas of China" (1994), the lands in arid and semiarid regions have the following limitations for production of crops, forests and livestock:

Class 1 (no limitations): paddy soil (oases), pluvioaquis soil (plains), irrigated farm lands (oases).

Class 2 (low limitations): beach, meadow soil (plain), castanozem (valleys), chernozem (valleys).

Class 3 (moderate limitations): castanozem (plain), sierozem (plain, mountain), meadow soil (plain), salinized meadow soil (plain), dark loessal soil (terrace), brown pedocal (mountain), gray desert soil (mountain, plateau).

Land unsuitable for production: gray brown desert soil (gobi), brown desert soil (gobi), solonchak (bare plain), takyr (bare plain), shifting sandy soil, salt crust, low wet land.

4.2 Population and environment in Chinese history

The People's Republic of China is one the greatest superpowers of the world. The interrelation between population and the environment, i.e., the pressure of population on the environment is the major constraint for sustainable development. Further economic and political development of China will depend upon the progress in solving the population/environment problem. Degradation of the drylands in China is a historical process documented for 2000 – 2500 years.

Population in China totaled 549 million people in 1949 when the People's Republic of China was founded. The Communist government declared a "new era" in the country. But as known the "Golden Era" in the history of China was four thousand years ago. Population growth only stimulated the ecological crisis. The policy of agrarian radicalism proclaimed by Mao Zedong could not solve the ecological problem (Zweig, 1989). By July 1, 1990, the population of China reached 1.16 billion, or 21.9% of the world population. **Figure 4.1** represents the growth of Chinese population. The growth of population has continued despite the introduction of birth control.

Population growth can not be considered now as a demographic problem. As Qu and Li (1994) said "population control and environmental protection are two sides of the same coin". During the last 4000 years, population pressure on the environment in China was different in different periods of history. That demonstrates **Figure 4.1**. The same authors have identified the following periods of environmental degradation (**Table 4.3**).

Kang (1986) argued that since 200 B. C. China was very close to a market economy because the country had countless small production units – either free holders or tenants. In the course of further development, the situation drastically changed and the 12th century was the crucial point. Population pressure gradually increased and Chinese agriculture shifted to labor intensive farming. Overpopulation, according to Kang (1986), induced the adoption of more labor – intensive technology, which in turn raised tolerance for overpopulation. His study proved that, especially after the 17th century, the standard of living in rural China worsened.

The same author published very interesting information about the frequency of floods and drought in the whole of China for the past 500 years (**Table 4.4**). This information was based on data from the Chinese Bureau of Meteorology.

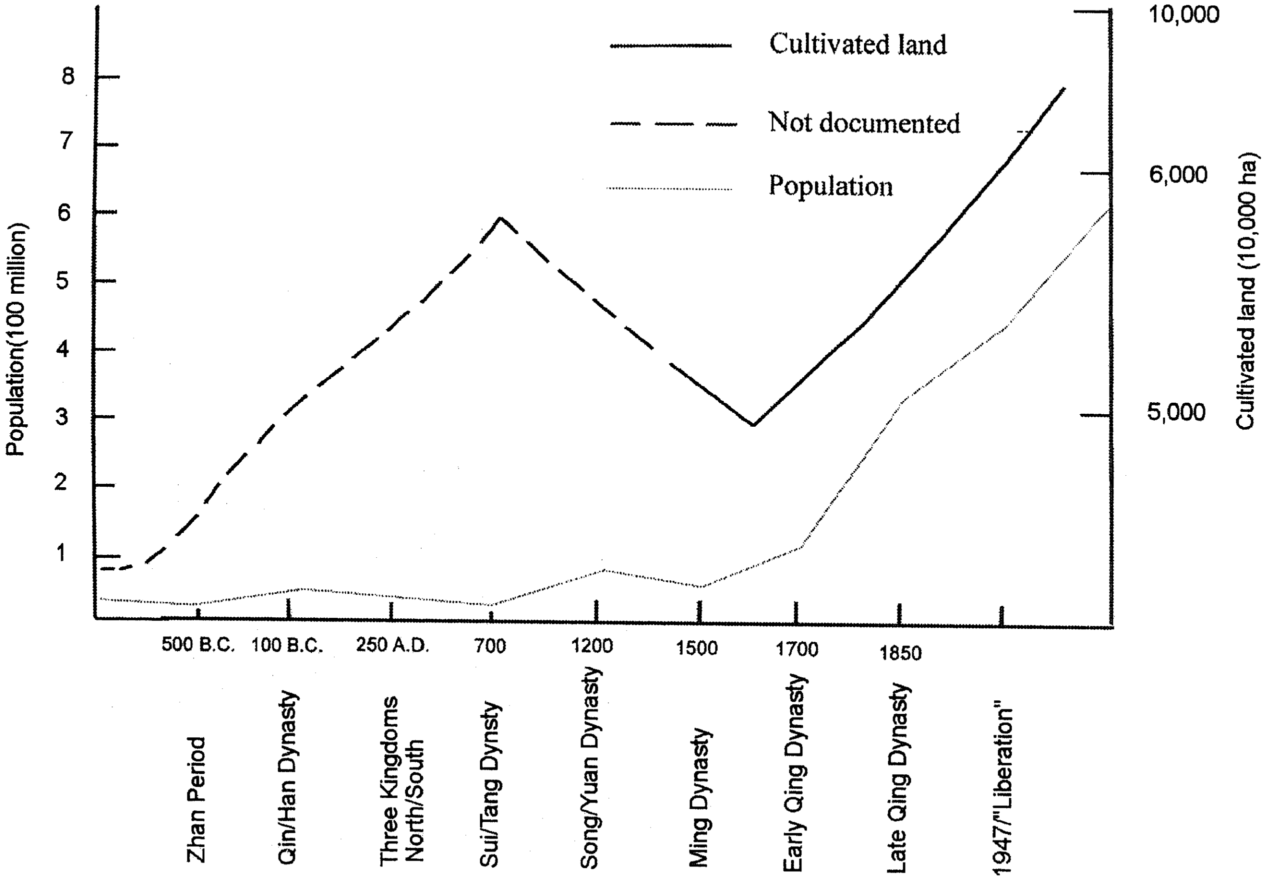

Figure 4.1 Population growth and the size of cultivated land in China in Historical restrospective (Qu and li, 1994, modified by authors)

Table 4.3
Change in population and environmental in Chinese history (Qu and Li, 1994)

Stages	Periods	Years	Representative Dynasties	People (10000)	Status of Environment
I	Pre-Qin	2205-2198 B.C	Xia and Yu	1,355	"Golden Era"
		1115-1079 B.C	West Zou (King Chen)	1,371	
		684 B.C.	East Zhou (13th Year, King Zhuan)	1,184	
II	Qin to West Han	221 B.C.	Qin (26 year of Emperor Shihuang)	2,000	Signs of Degradation
		2 A. D.	West Han (2nd year)	5,959	
III	East Han to Sui	57	East Han (2nd year Ji-Anwu Zhongyan	4,500	Signs of recovery
		220-280	Three States	4,000	
		606	Sui (2nd year of emperor Yang)	3,050	
IV	Tang to Yuan	755	Tang (14year of Tianbao)	5,291	Signs of secondary degradation
		1195-1223	South Song (1st year of Quingyuan)	7,881	
		1290	Yuan (27th year of Zhiyuan)	5,883	
V	Ming and Qing to before liberation	1403	Ming (1st year of Yongle)	6,659	Escalated degradation
		1651	Qing (8th year of Shunzhi)	5,300	
		1684	Qing (23rd year of Kangxi)	10,170	
		1762	Qing (27th year of Qianlong)	20,047	
		1790	Qing (55th year of Qianglong)	30,148	
		1834	Qing (14th year of Daoguang)	40,100	
		1919	Republic of China (8th year)	50,600	
		1947	Republic of China (36th year)	54,887	

The territory of China is divided into120 districts, each covering one or two prefectures. The author processed these data statistically and found that the frequency of major floods in the whole country has increased by 2.5 occurrences every twenty years, convincing statistical evidence of worsening ecological conditions in China. The number of major floods and major droughts increased during 1870 – 1909.

Kang Chao (1986) also indicates that as a result of accelerated deforestation, land in north China lost its natural productivity many centuries ago and became vulnerable to floods and droughts. He says, "Farmland along the northern frontiers gradually converted into semi desert". Forest areas in this region shrank and finally completely disappeared by Ming times (1369 – 1644).

Table 4.4
Frequency of major floods and major droughts in China by twenty – year periods, 1470 – 1909 (Kang, 1986)

Periods	Number of major floods	Number of major droughts
1470 - 1489	91	129
1490 - 1509	63	123
1510 - 1529	105	157
1530 - 1549	113	102
1550 - 1569	143	81
1570 - 1589	127	144
1590 - 1609	152	90
1610 - 1629	118	108
1630 - 1649	124	220
1650 - 1669	198	103
1670 - 1689	119	128
1690 - 1709	111	94
1710 - 1729	100	106
1730 - 1749	137	73
1750 - 1769	132	66
1770 - 1789	92	113
1790 - 1809	109	88
1810 - 1829	125	108
1830 - 1849	192	99
1850 - 1869	140	94
1870 - 1889	177	115
1890 - 1909	165	163

4.3 Land degradation in the main regions of China

According to Zhu et al. (1988) desertification- prone land in China totally cover 334,000 km^2, in which desertified land area is 176,442 km^2 and the land of desertification risk is 158,000 km^2, involving 212 counties in 13 provinces and autonomous regions. These areas include: Liaoning, Jilin, Heilongjiang, Hebei, Shanxi, Inner Mongolia, Shaanxi, Ningxia, Gansu, Qinghai and Xinjiang. They distinguish the following desertification types: on-going type (45.9%), severe type (34.4%), and most severe type (19.7%).

The leading causes of land degradation in China are given in **Table 4.5.**

Table 4.5
Leading causes of desertification (Qu and Li, 1994)

Anthropogenic factors of desertification	Percentage of desertified land
Irrigation reclamation	25.4
Excessive grazing	28.3
Lumbering of woods	31.8
Industrial, mines and communication construction	0.7
Improper use of water resources	8.3
Total proportion	94.5

4.3.1 Desertification in the marginal zones of extra-arid regions

All arid regions of China are affected by land degradation. The marginal zones of the Tarim Basin are severely affected by desertification. The Tarim Basin occupies the area of 530,000 km^2, from which 338,000 km^2 belong to extra-arid land of the Taklimakan Desert. Desertification in the marginal zones is a result of changes in hydrological environment and human activities.

According to Takamura and Qong (1997) about 857,000 ha have been desertified by wind erosion during the last 100 years. More than 60% of the alluvial plain of Tarim River have also been degraded. Vegetation degradation has been also recognized to have occurred. At least 285,000 ha of Populus euphratica woodland were transformed to a real desert. Severe aridization has affected the surrounding territories of the Taklimakan Desert. In 1921, the Tarim River changed its course and flowed to the old Lop Nur Lake, and the size of the lake grew to 200,000 ha. But in 1972, the lake disappeared because of decrease of water runoff. Ground water levels lowered from 3 - 5 m in the 1950s to 8 – 10 m in the 1980s. Many years ago, water in the Tarim River was fresh, with a mineral concentration being lower than 1 g/l. But now the water is fresh only three months a year, and during the rest of the year is brackish or salt-laden.

The Tsaidam Basin occupies the area of 270,000 km^2. It is a huge confined basin with extremely dry climate, precipitation being 200 mm in the highland and 20 mm in the center. The population is small, totaling 271,700 people, and the cultivated area is 38,200 ha. At the present time, the rate of exploitation of water resources is 15.8% in the whole area, while the utilization rate of underground water is considerably lower, at just 1.6%. In spite of this, some farmland have been subject to secondary soil salinization because of the rise of ground water and poor drainage. Many districts have been forced to cease cultivation because of secondary soil salinization (Liang, 1997).

4.3.2 Secondary soil salinization in arid inland river basins

Irrigated soils in arid river basins are under the double impact of human activity and the ecological environment. In artificially created oases, natural ecological systems are replaced by man-made agricultural systems. Such large scale reclamation has caused the destruction of natural vegetation. Data on secondary soil salinization are given in **Table 4.6.**

Table 4.6

Secondary soil salinization in some inland river basins of China (Wang and Cheng, 1997)

Rivers	Salinized soil area, km^2	Ratio to total land, %	Cultivated soil, km^2	Ratio to total cultivated soil,%
Shiyang	2098.81	4.98	295.37	11.54
Heihe	1584.21	2.27	256.73	10.75
Shule	4713.64	4.57	273.21	21.70
Urumqi	796.80	5.65	275.02	19.24

The areas of salinization and vegetation degradation are rapidly expanded in lower reaches. In order to eliminate the negative environmental changes of, it is necessary to promote rational utilization of water resources in whole river basins.

4.3.3 Land degradation in Huang – Huai – Hai plain

This plain, also known as three river plain, covers an area of 350,000 km^2, with 18 million ha of arable land. Population totals 200 million people. In this agricultural region, are produced 20% of grain, 57% of cotton, 17% of oil and 14% of meat for the whole China (Tian, 1997).

The climate of the region is mild. Precipitation varies in the area from 400 to 600 mm, but the annual variation is very large. Cultivation of the majority of crops requires irrigation. The present situation regarding water resources needs improvement. During the previous period, a certain amount of water could be transferred from the Big Canal. But because of the shortage of water in the Yellow River, this water transfer was stopped in 1980. In recent years, the Yellow River dries up in spring so the water available for transfer is limited.

Additional problems exist, in particular, declining water table levels and soil salinization. Ground water tables have dropped at a rate of 1 m per year to the present 35 – 55 m, most natural lakes, such as Ningjinbo and Daluze have dried up.

4.4 Ecological disaster in loess plateaus

The ecological situation in loess plateaus can be characterized as catastrophic. Loess lands cover more than 500,000 km^2, comprising one of the most important cultural and agricultural regions of China. Kolb (1971) calls the loess plateaus "the cradle of Chinese civilization". Population density in some areas is 1000 people per 1 km^2. Irrigation schemes in the valleys of the Wei Ho and the Fen Ho extend back to the second millenium B. C. Most precipitation occurs in summer as torrential downpours. Erosion is very rapid, and in the Wei Ho area some 150 million tons of loess are annually washed away. Special terraced fields have been constructed to prevent erosion. The irrigation area has more than doubled since 1952.

Eckert (1998) who visited the area in 1998 described the ecological situation in the region. Natural vegetation covers only 10% of the total area. Since 1949, the eroded land area increased by 30%. Winds carry so much dust that villagers often have lunch by the light of lanterns. The disastrous collective farming of Mao Zetong worsened the situation. The living standard of peasants is very low, their income being only $20 per year per person, So most are involved in a daily struggle to fill their stomachs.

Under such ecological and social conditions, only extraordinary measures can improve the situation. The government of China has received a loan from the World Bank for afforestation in Shanxi province and in three other provinces of the plateaus.

4.5 Shortage of water resources

Shortage of water resources is discussed in many publications of Chinese scientists. Water is not only a valuable natural resource, but also an important ecological factor because of the dry climate and its propensity for desertification. Feng and Cheng (1997) described the situation of water resources in Gansu province. In this region water resources are distributed unevenly throughout the territory. The seasonal distribution of water is also very uneven: dry in spring, flooding in summer, water shortage in autumn and waterless in winter. But the existing water resources are misused. Much water is wasted by irrigation. The water utilization factor is very low, in canals, it is 0.3% – 0.45%. Desertified land areas in the province total 2.7%. About 50% of farmland is affected by salinization. The output of agricultural products has decreased by 30%. Feng and Cheng (1997) have calculated the deficit of water for future development (**Table 4.7**).

Table 4.7

Shortage of water resources in the Gansu province in future, $1x10^8$ m^3

(Feng and Cheng, 1997)

Water demand	Industry	2.10
	Agriculture	72.30
	Forestry and grassland	6.00
	Population and animals	0.94
	City	0.10
	Others	0.05
	Total	81.49
Water supply	Surface runoff	51.36
	Ground water	24.00
	Total	75.36
Shortage		6.13

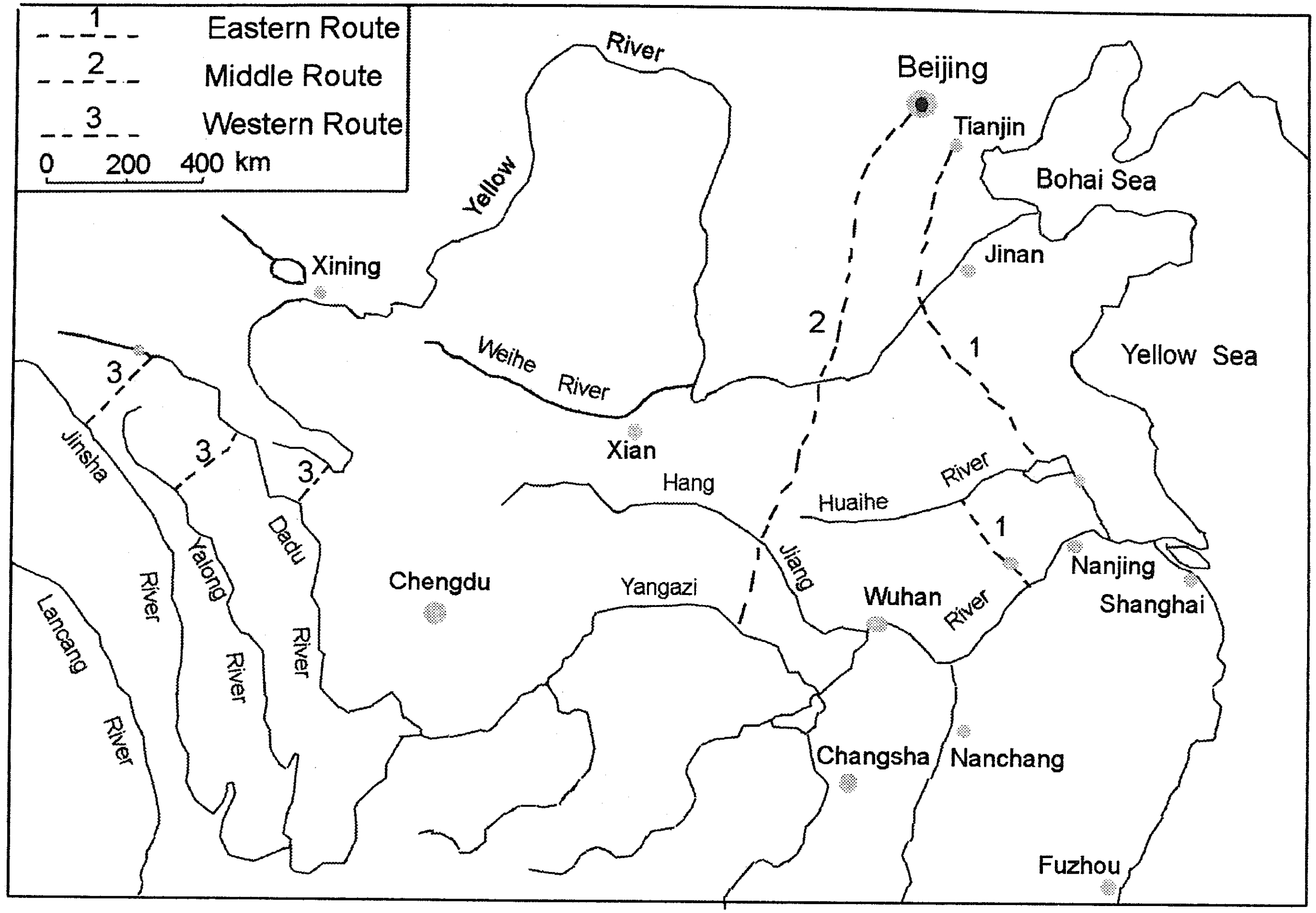

Figure 4.2 Proposed routes for south-to-north Water-Transfer Project (Feng and Cheng, 1997)

Water and land resources of China as a whole are also very uneven. The water resources of the Yangtze River basin comprise 80% of China's total yet it represents less than 40% of the arable land. But runoff of the Huanghe and other rivers in the north amount only 6.5% with almost 40% of the arable land. To address these problems, the idea of a South-to-North Water Transfer Project (SNWTP) was suggested, first in the 1950s. Special state agencies of China were involved in an integrated survey and put forward a preliminary design for transferring water resources to the north (**Figure4.2**). The annual total transferable water quantity would be more than 50 billion m^3.

But as yet the project has been not realized. Some Chinese scientists say that further study is needed to better understand the impact of the water transfer on the environment. Lui (1997) has developed three scenarios of the environmental changes. The transfer of water resources may induce an annual temperature change of 1.80 °C over vast areas.

The lessons of the past should be also taken into consideration. As known, construction of the Karakum Canal in Central Asia caused the drying up the Aral Sea. Vast areas in Central Asia have been transformed into zones of ecological disaster. The second grandiose project of transfer of Siberian rivers to Central Asia was developed during the rule of L. Brezhnev, but it was never realized. And the second ecological catastrophe in Central Asia was thus avoided.

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CHAPTER 5

MONGOLIA

5.1 Natural features

Mongolia occupies an area of 1,566,500 km^2, of which 14.6% belong to the arid zone. The country is located in the heart of Asia. High mountains ranges isolate the country from the influence of the Atlantic and the Pacific climates. The climate of Mongolia is severe continental. The Siberian anticyclone determines the low temperature in winter, (-45°C) and also the low precipitation (**Figure5.1**). The temperature in summer can vary from 30°C during the day to 5 °C at night. The 40 years climatic cycles that have been described by many scientists can be also divided into 20-year cycles and within them 11-year cycles can be identified (Kharin, et al., 1992).

Jenkins (1974) has identified the long climatic cycles associated with the activity of glaciers (**Figure5.2**). The period between 1175 – 1300 A.D. was characterized by low temperatures and he supposed that the conquests of Chinggis Khan were stimulated by a long and severe drought and cold winter which caused dzhut (the loss of livestock in the desert during dry and cold years). During the last 60 years, dry periods were recorded several times. The years 1940, 1949 and 1950 were especially dry. For example, some 8 million livestock died in Mongolia in 1948. Severe drought also occurred in 1986 – 1987. According to the forecasts by Kharin et al. (1992), the period of years through 2010 will be comparatively wet. But even during this period, drought is expected to occur in some years.

Concerning physical factors, the strong winds causing soil erosion should be mentioned here. Strong winds (with the velocity of 20 m/sec and more) are common in spring and summer. These wind dust storms, which are real disasters for people and animals. The number of days with dust storms is indicated in **Table 5.1**.

Table 5.1
The mean number of days with dust storms in the arid zone of Mongolia (Kharin, et al., 1992)

Stations	Months		
	March	April	May
Ulangom	0.0	1.8	4.0
Khovd	2.4	4.1	3.6
Ulyasutai	0.2	1.5	0.7
Altai Kheer	1.1	3.3	1.3
Arval Kheer	0.6	1.3	0.7
Dalan Dzagad	1.4	3.9	3.3
Mandal Gobi	2.2	3.8	3.6
Sain Shand	2.1	4.1	4.2
Zamyn Uud	6.2	12.5	4.2

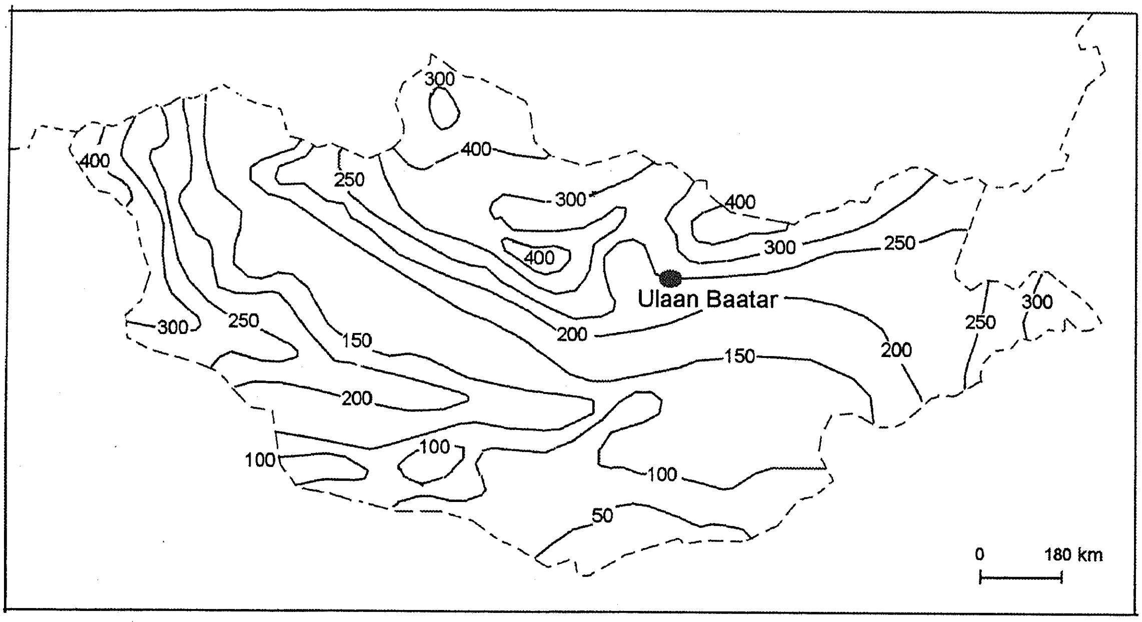

Figure 5.1 Annual precipitation in Mongolia in mm (Lavrenko, 1978)

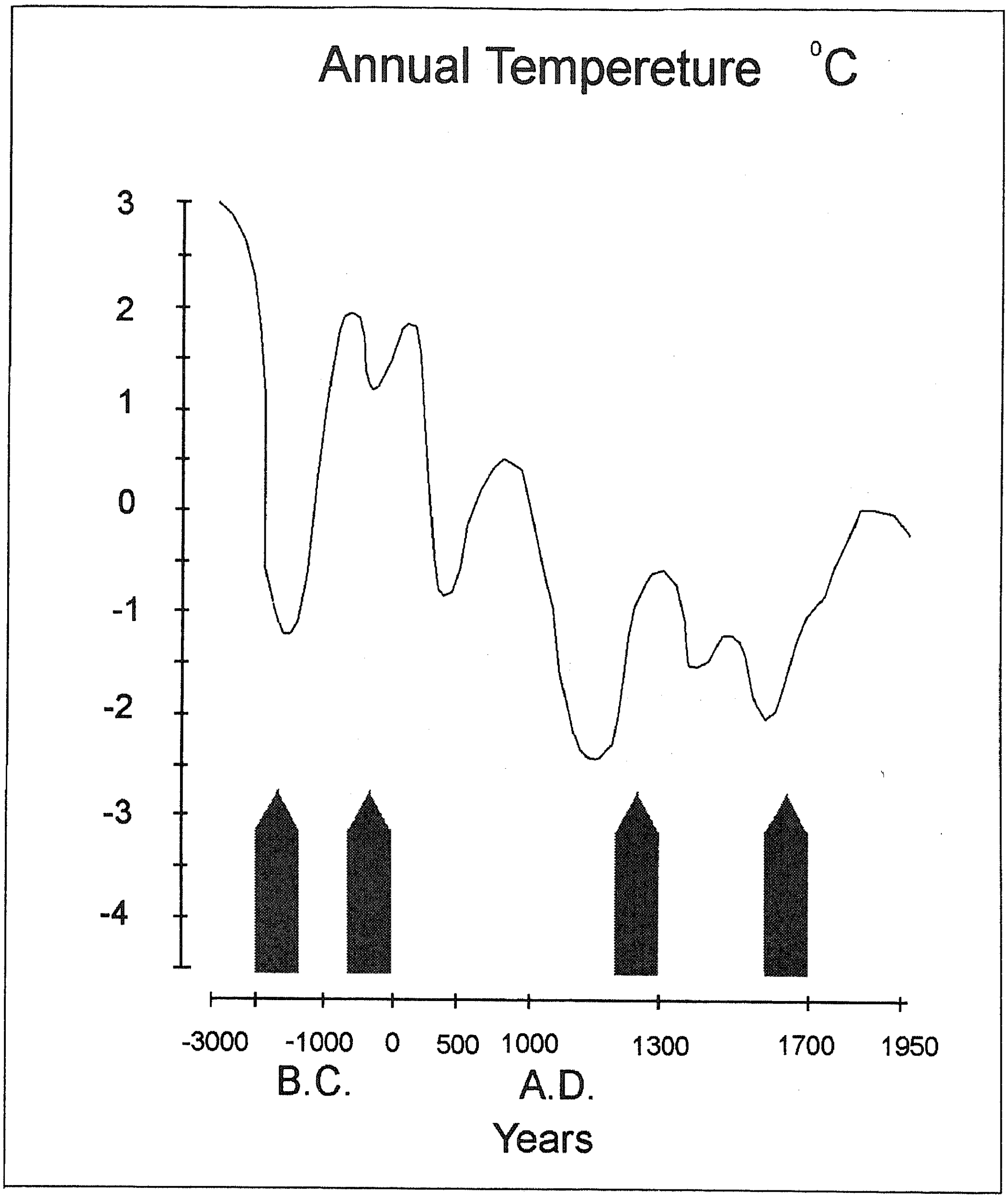

Figure 5.2 Variation of mean annual temperatures in the north of China. Arrows show the periods of glacier activities in the north Hemisphere (Jenkins, 1974)

Geographers has divided the territory of Mongolia into two types of landscape, using the local geographical terms:

Khingai – the territory is rich in water and has good grazing.

Gobi - the desert lands with sandy, stony or gravel soil, poor in good grazing lands and forest.

The dry lands of Mongolia are located in gobi (this local term is the name given to the Gobi desert). Murzaev (1948) and some other geographers have said that it is not a true desert, it is rather a desert steppe because it contains an abundance of shallow wells and comparatively rich vegetation, especially during the wet years. Plant ecologists (Lavrenko, 1978) indicated three main factors that complicate distinguishing the desert and the steppe in Mongolia. They are the following:

1. Specific features of Mongolian desert and steppe different from that in other arid regions of Eurasia.
2. Mountain topography
3. Continental climate and variations in annual precipitation.

Some 400 plant species have been recorded in the Gobi desert. Perennial sod forming grasses are common here like *Stipa glariosa, S.gobica, S. orientalis* and *Cleistogenes squarrosa*. Several species of *Allium*, used by people as food plants are also found. *A. mongolicum* and *A. polyrrhyzum* form mighty roots in many places of the Gobi desert.

Anabasis brevifolia, Salsola passeriana, Nanophyton erinaceum are common *Chenopodiaceae* species. In sandy and gravel desert, *Haloxylon ammodendron* (known in Central Asia as *saxaul)* form dense thickets, which are severely cut for fuel. *Nitraria sibirica* and *Calligonum mongolicum* are the main co-dominants of *saxaul*. The bushes of *N.sibirica* with a height of 1.5 m form characteristic landscape features in these areas.

The *Compositae* species are also very common, especially *Artemisia frigida, A. xerophytica, A.arenaria* and *A. pectiana*. The distribution of these species is mainly determined by the intensity of rangeland utilization.

5.2 Social and political factors of desertification

The mountain ranges mentioned above have historically served as physical and political barriers that fostered the political and cultural isolation of the country. Historically, the Mongols were always nomads and lived in *yurta* (felt tents). According to Groum-Grzhimailo (1933), the expansion of deserts in Asia after the 7th century A. D. was connected to the activities of nomadic peoples. But we have a little information today about the interrelation between the natural environment and the sociopolitical economy during that period. Such ecological relationships can tell us about historical changes in Mongolian steppe. Przhevalsky (1883), who traveled in Mongolia more than 100 years ago, said at that time all suitable agricultural lands were reclaimed and all grazing lands were overloaded by livestock. Clearly, desertification is a historical phenomenon, and not a phenomenon limited only to the present time.

We do not know the actual figures for the population in Mongolia before 1918. The available statistics given in **Table 5.2** show that during 1918- 1990, the population of the country increased nearly three-fold. Being a satellite of the USSR, the country developed the economy rapidly because of the help of "the elder brother".

Table 5.2
The population growth in Mongolia (Kharin, et al., 1992)

Years	Population, thousand	Population density, Persons per 1 km^2
1918	647.5	0.41
1925	651.9	0.42
1936	738.2	0.47
1940	738.6	0.47
1944	759.2	0.48
1950	845.5	0.54
1956	758.7	0.48
1960	936.9	0.60
1963	1,017.1	0.65
1969	1,197.6	0.76
1970	1,230.5	0.79
1979	1,596.0	1.02
1980	1,639.7	1.05
1988	2,074.0	1.33

The mode of life changed, many people left yurta and concentrated around Ulan Bator and in provincial and district centers. Now about 25% of the population live in Ulan Bator, the capital of the country. The percentage of the population living in towns has changed as follows: 1919 – 9.0, 1956 – 21.6, 1969 – 44.0, 1986 – 50.0. In 1990, population growth reached 26.8 persons per 10,000 habitants. During the same period, the number of livestock increased 2.3 times (**Table 5.3**).

Table 5.3
The number of livestock in Mongolia (Kharin, et al., 1992)

Years	Number of livestock, thousand heads					
	Camels	Horses	Cows	Sheep	Goats	Total
1918	228.7	1,160.5	1,078.4	5,700.1	148.9	9,645.6
1924	275.0	1,339.8	1,512.1	8,444.8	2,204.4	13,776.1
1961	751.7	2,889.3	1,637.4	10,981.9	4,732.6	20,392.9
1970	638.5	2,317.9	2,107.8	13,311.7	4,204.0	22,574.9
1980	591.5	1,985.4	2,397.1	14,230.7	4,568.7	23,771.4
1985	559.0	1,971.0	2,408.1	14,429.8	4,298.6	22,485.5

The Mongols themselves call their country as "the country of five animals". Usually each nomad had a herd consisting of five animal species: horse, cow (or yak in mountain regions), sheep, camel and goat. This herd composition evolved through experience of many generations of people (Kharin, 1997). There were three main reasons for this structure:

1. Each animal had a unique function in the nomadic life,
2. Different animals provided the nomads with different products,
3. Each animal consumed its own type of forage.

The last reason was harmful from the ecological point of view because it has led to severe exploitation of grazing lands. Goats are responsible for great damage to desert vegetation as a result of their proficiency in climbing up and down to get any kind of forage.

Mongolian nomads also developed a specific system of transhumance in the desert. As a rule, three or four families consisting of close relatives move together as one group of *yurta* (Kharin, 1991). That was so called *sur* – a joint camping group of nomads. Their movement lasted the whole year, and they changed the camping places 5 – 6 times annually. In case of severe drought or cold winter, they lived on the principles of "a primitive communism", in which food was divided equally between all members of the community. In such a way, not a single person but the *sur* as a whole survived.

During the "period of socialism" *sur was* conserved by being transformed into a productive unit of collective farms (*kolkhoz*). One of the greatest achievements of the Mongolian people is their ability to survive not only under the conditions of dry climate but also their ability to adapt to severe communist system…

In range management, the problem of water supply has always been present. In Mongolia special measures were taken to improve the water supply systems, especially in the arid zone. Two types of measures were taken:

1. Conservation of existing wells and protection of all other watering points.
2. Construction of new wells.

The present status of watering desert rangelands is given in **Figure 5.3**. One can see that the south and the east parts of the country are poorly provided with water.

The hard surface of the Gobi desert, except the solonchak and sandy areas, present no obstacles to the movement of cars and lorries. Drivers can select the best way for movement, and in the process destroy the plant cover. In general, about 500 thousand hectares of productive grazing lands were destroyed by a free movement of transportation vehicles.

5.3 Degradation of the drylands

Desert rangelands are the dominant land cover type in the arid zone of Mongolia. Small patches of cultivated land occupy very small areas and in this book they were not taken into consideration. Soviet and Mongolian scientists implemented a project on desertification assessment and mapping in 1986 – 1990. According to the published

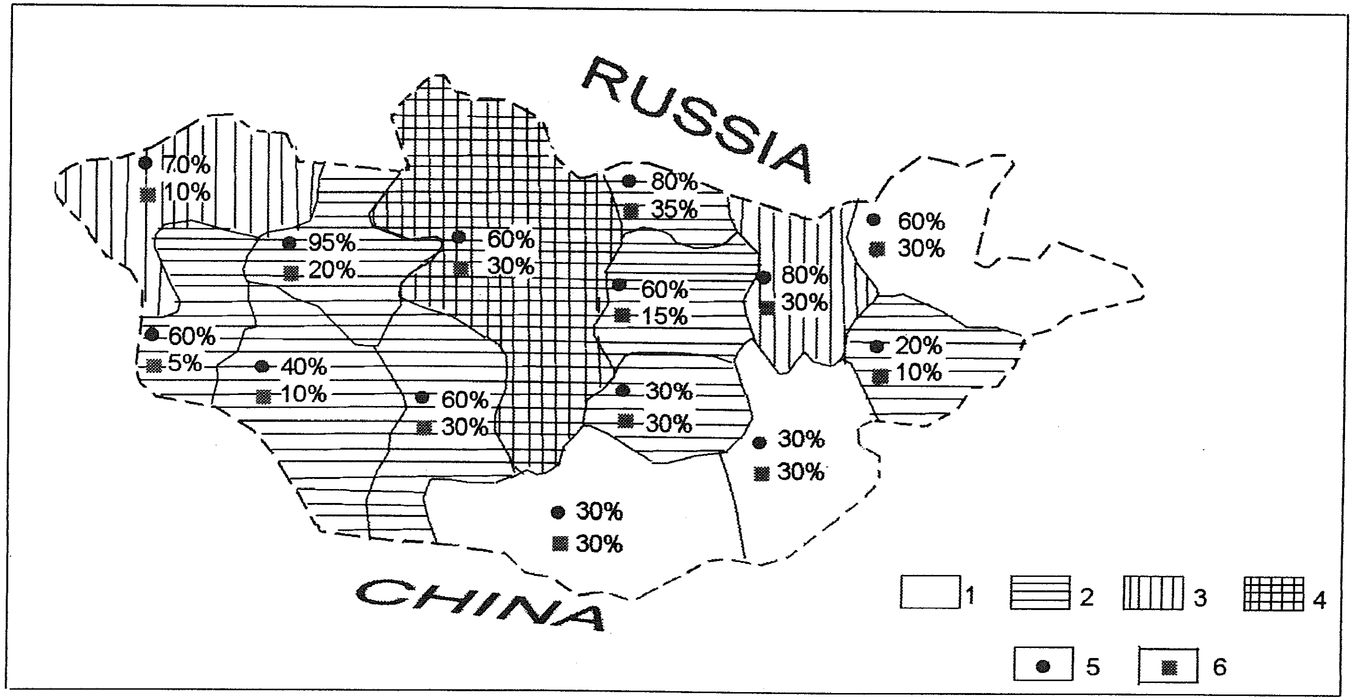

Figure 5.3 Schematic map of animal pressure and watering rangelands in Mongolia (Kharin et. al., 1992)

Animal pressure: 1- less than 20 heads per $1km^2$, 2- 21-40 heads per $1km^2$, 3- 41-60 heads per $1km^2$, 4- more than 60 heads per $1km^2$,

Watering rangelands: 5- provided with water in winter and spring, 6- provided with water in summer and autumn.

results of this study (Kharin et al., 1992, Kharin, 1997), the main three types of land degradation were recognized in Mongolia:

1. Degradation of the vegetative cover (25% of the drylands were prone to this type of land degradation),
2. Water erosion (37% of the drylands),
3. Wind erosion (18% of the drylands).

Mongolian and Soviet scientists have developed several measures for improving the range management system in Mongolia. From these measures, the works on construction of wells have a practical importance. Some successful experiments on pasture melioration have been also conducted. However wide practical changes in the grazing system have been virtually impossible because of the vast areas of grazing land, the lack of money, severe physical conditions, and dominance of the traditional way of thinking. The used nomadic system of grazing has proven to be the most adaptive system. But sooner or later, this system can lead to land degradation.

5.3.1 Degradation of the vegetative cover

Overgrazing, cutting trees and shrubs for fuel are the main reasons of this degradation. By rough estimation some 700 - 800 thousand tons of wood is cut in the arid zone of Mongolia annually. Above that, the Mongols use, for heating and cooking, *argal* (dried excrements of animals, mainly that of cows). The unpleasant work of collecting and storing *argal* is performed by old people and children. The removal of this organic matter from the natural cycling in ecosystems is undesirable from an ecological standpoint, since it promotes desertification.

Areas of degraded vegetation have been formed around population centers and around wells. The number of district centers total 145 in the arid zone. By rough estimation the size of degraded range lands around these centers total 200 thousand hectares. And other 400 thousand hectares of degraded rangelands are located around numerous desert wells.

Three zones can be usually identified around the population centers:

1. The zone of fully degraded grazing land where only non-palatable plants grow.
2. The zone of moderate degradation, where non-palatable plants replace dominant species. Productivity of this land reduced one-fifth or one-seventh.
3. The zone of slightly degraded land where productivity reduced by 10 – 30%.

Localized desertification is the first stage of the vegetative cover degradation. In the second stage, the separate areas join to form large areas of degraded land.

5.3.2 Wind erosion

Destruction of vegetation in sandy desert contributes to the development of wind erosion. As known, the velocity of wind and the wind regime determines the intensity of the wind erosion. For wind velocity $v > 6$ m/sec, sand particles can be blown aloft, and clay particles start their movement by v > 10 m/sec. Four stages of wind erosion are identified in Mongolia:

1.Erosion hollows with gentle slopes occupy less than 10% of the eroded area,
2. Steep erosion hollows occupy 10 – 20 % of the eroded area
3.Steep erosion hollows occupy 20 – 30% of the eroded area,
4.Full destruction of the plant cover, movement of sand dunes on the whole area.

Sand dune areas have been appeared in various parts of Gobi. Usually livestock herds are concentrated in these areas because they commonly seek protection among the dunes. Consequently, the area of sand dunes is enlarged from year to year.

5.3.3 Water erosion

Water erosion has been observed on 37% of the drylands of Mongolia. In many places, this type of land degradation is combined with degradation of vegetation and by small scale mapping it was very difficult to distinguish them. Water erosion in Mongolia is mainly a natural, but not a man made process. The erosion net has been formed by so-called *sair* - dry channels and gullies. In the arid zone of Africa these formations are known as oud or wadi.

Dry channels are formed under the action of heavy rains. Based on field studies, the following geometric forms of these dry channels can be distinguished (**Figure 5. 4**):

1. Separate *sair,* several hundred meters in length and 0.5 – 3.0 m in depth. They are common in the Bowl of the Big Lakes and on piedmont plain of the Mongol Altai,
2. Parallel *sair,* which have been formed on piedmont plains and reach several kilometers in length,
3. Multiple sair, they have been formed in the first stage of formation of proluvial deposits and reach 0.7 – 1.5 m in depth,
4. This type of *sair* is usually confined to alluvial fans, being 0.7 – 1.5 m in depth and 4 – 6 m in width,
5. *Sair* of this type are common on piedmont plains and in hilly country. These dry channels have gentle slopes and flat bottoms.
6. Dendritic *sair system* has the main channel and side washes. They are formed on comparatively flat plains and on piedmont plains of the Gurvan – Saikhan Mountains.

The density of channels can be used as a quantitative criterium for water erosion. For slight water erosion the length of the dry channels is less than 0.5 linear km per 1 km^2, for moderate erosion, 0.5–1.5 and for severe erosion 1.5 – 3.0. If the density of *sair* is more than 3.0 linear km per 1 km^2, the land is unsuitable for any kind of human activities without special protective measures. Cutting vegetation can only exacerbate the formation of the erosion net.

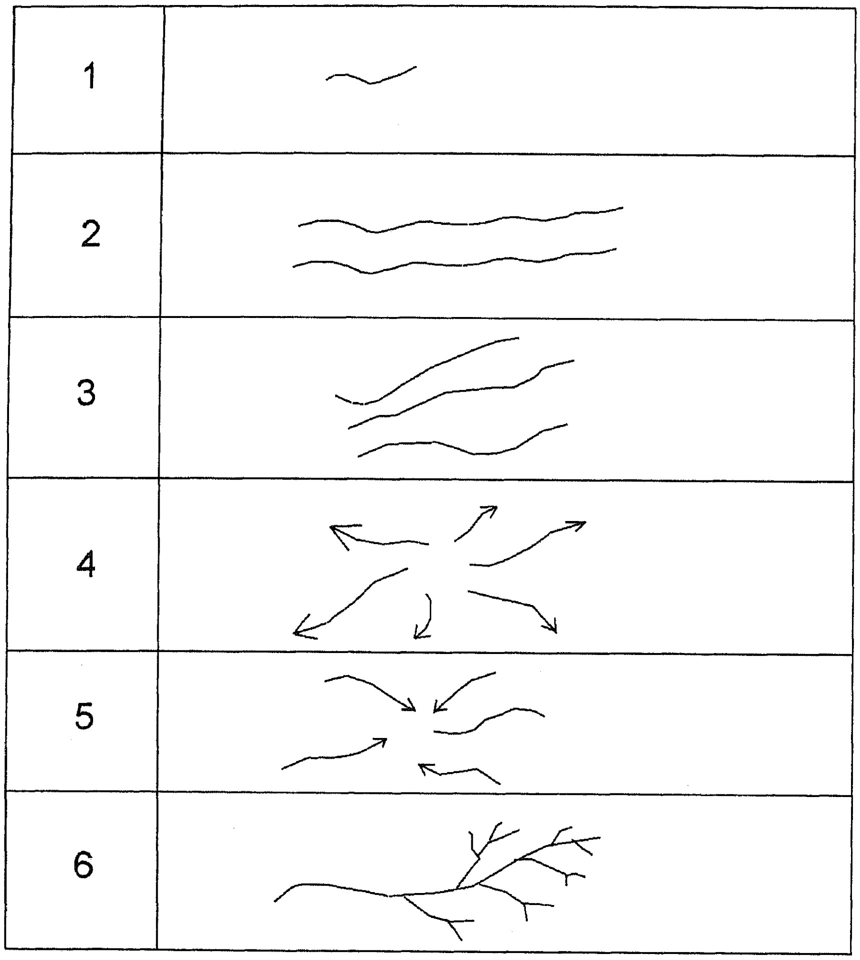

Figure 5.4 The main types of sair in Mongolia
(See the explanation in the text)

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CHAPTER 6

AFGHANISTAN, PAKISTAN AND INDIA

6.1 Desertification of the drylands of Afghanistan

Afghanistan is a country located in the heart of south Central Asia. It occupies an area of 652.225 km^2, with a population totaling 15.50 million in 1979 (Sen Gupta, 1986). Afghanistan is a pastoral country. Only 12% of the land is arable, and only 29% of the arable land was cultivated before the Soviet intervention. The majority of the population lives in the rural areas, the mode of life is a peasant tribal society that determines the patriarchal character of this community. Approximately 2 million people are nomads (Murtaza, 1981). But the current, reliable figures on population and economy of the country are unknown at present time because of a long war, which has been continuing. A new type of land degradation- war desertification, is a characteristic feature of Afghanistan. As a result of the war flourishing oases were destroyed, agricultural fields were abandoned, gardens and tree plantations were cut and the social infrastructure in vast areas was completely destroyed. Three million people immigrated to Pakistan, a half million took refugee in Iran, and a half million were killed or wounded (Sen Gupta, 1986).

The climate of the country is dry and subtropical. The mean temperature in July is between 24 – 32°C (beyond the high mountains). Winter in the plain is mild, with a mean temperature in January of 8 – 10°C. The maximum precipitation occurs in winter and spring as a result of cyclonic activities. 40 – 50 mm of precipitation fall in the southern plain, and 200 – 250 mm in the interior highlands (**Table 6.1**).

Table 6.1

Climatic indices of the arid regions of Afghanistan and Pakistan (Petrov, 1973)

Stations	Temperature, °C.			Precipitation, mm
	January	May	Annual	
Afghanistan				
Herat	2.0	30.5	16.4	201
Kandagar	5.5	31.5	18.9	192
Girigkh	8.5	33.5	20.7	168
Pakistan				
Mushkichah	-	-	-	40
Chaman	6.3	31.5	19.2	180
Dalbandin	-	-	-	123

The Seistan Desert is one of the main arid regions of Afghanistan. According to Petrov (1973), the climate of this region is continental. The annual precipitation is 50 mm. Winter months (December, January and February) are cold, the day temperature falls below the zero. Air humidity is very low, in summer usually less than 10%. In summer, a hot wind occurs, this wind is called "Sado-Bistoruz", which means "the wind of 122 days". During this period the day temperature rises to 43 – 45 ° C.

The flora is steppe and desert type. Xerophytes (*milk wetch*, *Acantholimon, Alhagi persarum, Kuzinia*) are dominant in the interior plateaus. In the desert there is wormwood and salt-marsh vegetation, *saxaul* and *ephemerae* grow in the sands. In the Parapamisus, there are sparse juniper and pistachio trees, and in the northern foothill plains, there are subtropical plant communities of grasses and herbs. Forest cover 17,300 square miles. They grow mainly in the eastern part of the country and on the south slopes of the Hindu Kush.

Droughts, which occur periodically in Afghanistan, facilitate the process of desertification. For example, in early 1970s, a severe drought compelled many peasant families in rural areas to mortgage their land for loans. Debts and mortgages resulted in a heavy alienation of land (Glukhoded, 1981). Wheat is the main staple crop, also corn, barley and rice are cultivated. Cotton before the war was also an important cash crop.

According to statistics, 30% of irrigated farm-lands were salinized before the Soviet-Afghan war. On the area of 42 million ha, 30 million head of livestock were grazed. Overgrazing was one of the causes of desertification in arid regions of Afghanistan (Zonn, et al. 1984). In several places nomadic stock raising is combined with mixed farming. Historically, this process has been reversible. Survival of nomads in dry years depended on activity on which they could fall back. Livestock includes sheep, cattle, goats, donkeys, horses, camels, buffalow and mules.

According to Sayed Murtaza (1981), land degradation in the inland Siestan Desert became a serious problem. Before the Soviet intervention in this area, 212.000 ha in size, 15 .000 ha were irrigated and 52,000 ha were used for grazing. A special project was proposed to combat desertification in this region, but it was not implemented because of military operations.

6.2 Desertification of the drylands of Pakistan

From the total area of Pakistan, 80.4 million ha, arid and semi-arid lands occupy 68.3 million ha with the population more than 55 million. Arid and semi-arid regions of Pakistan include the Thar Desert and the Thal Desert. The Thar Desert occupies an area of 300.000 km^2, of which 120,000 are in the state of Rajastan, India (Petrov, 1973). These deserts are located in the vast alluvial plain of the Indus River and its tributaries. The alluvial plain has a homogeneous extensive sloping terrain, broken by ravines along rivers. In the plain, sierozem and grayish brown soil dominate. The Thar Desert has a sandy soil, and in the intermountain depression of Balujistan sandy desert soil alternate with solonchak. The Thal Desert is located in the Pakistan part of Punjab. Sandy desert landscapes and savannah are common here.

The climate of these deserts is dry and continental. Summer is hot, but winter is rather cool with the temperature sometimes falling below the zero. Climate data for these regions are given in **Tables 6.1 and Table 6.2.**

Table 6.2
Climate indices of the deserts of Indostan (Petrov, 1973)

Stations	Elevation above the sea level,m	Temperature, °C			Precipitation, mm
		January	May	Annual	
The Thar					
Jeikobad	56	14.6	35.2	27.0	92
Heiderabad	29	17.5	34.2	26.0	179
Bikoner	245	14.7	33.3	26.4	292
Hampur	99	13.3	25.8	25.7	164
Sukkur	74	13.8	30.1	26.8	94
The Thal					
Multan	128	13.6	34.6	25.3	182

In the Thar Desert, xerophytic shrubs are common, mainly *Calligonum* and *Acacia* species. In the Indus plain, where desert-like savannah is met, there are common *Stipa splendid, Artemisia* species and *Astragalus* species. Tugai vegetation consisting of thickets of shrubs occurs in places of the Indus delta and along the seacoast.

In the Indus valley, land has been irrigated since ancient times. Crops are grown for spring (Rabi) and fall (Kharif) harvests. The first category includes wheat, gram (chickpeas), barley and oil-bearing plants. Rice, cotton, sugarcane and corn belong to Kharif harvest. Millet is the chief crop on the dry agriculture lands in arid and semi-arid regions.

In the area of 20 million ha, about 4.5 million have poor drainage, they are prone to salinization and water logging. Irrigation water is conducted by 42 canals, 60,000 km in length. 6.5 million ha of irrigated farmlands are subject to salinization. Wheat, barley, maize, oil-bearing plants and sugarcane are cultivated on theses soils.

Rafiq and Tariz (1983) describe the rainfed cultivation and well-irrigated cultivation in foothill country. Summer cropping is of limited extent because of high evapotranspiration and the damage of sandblasts. Gram, mustard, barley and wheat are grown using summer precipitation. But dry farming is unreliable between 160 – 200 mm. Well-irrigated agriculture is practiced in comparatively limited areas. The productivity of agricultural crops in Pakistan is low **(Table 6.3**).

Table 6.3
Unachieved productivity of crops in Pakistan, Punjab province (Kobayashi, 1989)

Crops	Farm level yield (kg/ha)	Recommended level (kg/ha)	Unachieved potential (%)
Wheat (irrigated)	2,717.5	3,913.5	44.0
Rice (Basmati)	2,239.0	3,320.6	40.7
Rice (Irrig – 6)	4,135.2	5,646.2	36.5
Groundnut	1,655.5	2,536.5	56.2
Maize	2,125.0	3,754.0	76.7

Grazing is practiced in comparatively small areas. Rangeland has a high animal pressure, which is higher than the carrying capacity of this land. Livestock raising is not a significant component of the economy. Most animals are used for draft. In arid regions there is nomadic herding of sheep and camels.

The campaign to increase agricultural crop production (so called "Green Revolution") started in the late 1960s, but it hasn't completely solve the problem of satisfying food needs of country.

6.3 Desertification of the drylands of India

6.3.1 Natural features and population

Indian drylands occupy the west regions of the country. These regions include the territory with precipitation less than 400 mm. The drylands are the main parts of the following four states : Punjab, Hariana, Rajastan and Gujarat. The distribution and timing of precipitation depends upon two monsoons: the southwest (June to September) and northeast (October to December). The main part of these lands lay in the zone of mean annual temperature 25 – 27 °C. According to Social and Economic Atlas of India (1987), the maximum temperature in Rajastan is 45°C., and minimum 17°C.

Data of population in the above mentioned four states are given in **Table 6.4.**

Table 6.4
The area and population of four states of India
(A Social and Economic Atlas of India, 1987)

States	Area, km^2	Population, thousand.	Population density, Persons per 1 km^2
Punjab	50,362	16,789	201 – 300
Haryana	44,212	12,912	201 – 300
Rajastan	342,239	34,261	51 – 100
Gujarat	196,024	33,985	101 – 200

Population growth is the biggest problem in India. It is the result of combined action of traditions, natural and socioeconomic factors **(Table 6.5)**

Table 6.5
Population growth in India, thousand (A Social and Economic Atlas of India, 1987)

States	1951-1961	1961-1971	1971-1981	1981-1991 (Projection)	1991-2000 (Projection)
Country as a whole	78,147	108,925	137,025	152,000	148,000
Punjab	1,975	2,416	3,238	3,000	2,300
Haryana	1,917	2,446	2,886	3,600	2,400
Rajastan	4,185	5,610	8,496	10,300	11,300
Gujarat	4,300	6,065	7,388	6,900	5,500

After 1920, life expectancy in the country increased because of improvement of living conditions. Life expectancy has been extended: in 1921 – 20 (years), in 1940 – 32, in 1961 – 41, in 1981 – 51. Life expectancy by the turn of the century is expected to be 65 years.

6.3.2 Land development and desertification

In the western Rajastan, the following land use types dominate: irrigated cropland, rainfed cropland, rangeland and forest. In all four states, cultivated areas are shown in **Table 6.6**.

Table 6.6

Cultivated areas in 1981 – 1982, thousand hectares

(A Social and Economic Atlas of India, 1987)

States	Total reporting area	Cultivated area		% net cultivated area to total reported area	Area under Food grain	% area under food grain to gross cropped area
		Net	Gross			
Punjab	5,033	4,210	6,.929	83.6	4,996	72.1
Haryana	4,405	3,660	5,826	83.1	4,342	74.5
Rajastan	34,234	15,577	18,596	45.5	13,026	70.0
Gujatar	18,826	9,670	10,903	51.4	4,743	43.5

Note : Net area is the total cultivated area. Gross area is net area plus area cultivated more than once a year.

Animal husbandary is also a vital part of the rural economy. Data on livestock number are given in **Table 6.7**.

Table 6.7

Number of livestock and poultry in four states of India, thousand heads

(A Social and economic Atlas of India, 1987)

States	Cattle	Buffalo	Sheep	Goat	Other livestock	Poultry
Punjab	3,320	4,110	498	722	355	5,540
Haryana	2,442	2,940	542	519	461	1,403
Rajastan	12,896	5,072	9,938	12,307	1,146	1,590
Gujarat	6,006	3,473	1,592	3,084	251	3,426

Cattle and buffalo in particular are the main source of draft power in agricultural operations and rural transportation. Livestock density per one hectare of arable land is rather high : in Haryana 10 head/ha, in Rajastan 5 head/ha, in Gujarat 3 head/ha.

According to the published map (Singh, et al., 1992), the following types of desertification have been identified in Western Rajastan : wind erosion/deposition, water erosion, salinity/alkalinity and water logging. The severity classes identified are slight, moderate, severe and very severe.

According to classification of NRSA (National Remote Sensing Agency) of vast category of Indian land is defined as wasteland. Wastland includes the land, which at present is not used, or land, which is not being used to its optimum potential because of various constraints, or land, which cannot be used. The size of wasteland in four states of India is given in **Table 6.8.**

Table 6.8

The size of wasteland in four states of India, thousand hectares
(A Social and Economic Atlas of India, 1987)

States	Cultivable						Non culti-vable
	Salt affected	Gullied or ravineous	Water-logged or marshy	Undulated up-land	Forest blanks	Sandy area or desert	
Punjab	123.1	-	45.0	4.0	2.2	177.8	-
Haryana	69.4	-	25.9	12.4	-	166.1	59.6
Rajastan	62.9	915.9	28.4	1,067.0	14.4	9,798.0	1,062.0
Gujarat	2,061.0	316.0	-	837.8	-	38.0	58.7

Wasteland is divided into two categories: cultivable and non-cultivable. In Rujastan and Gujarat, large area of cultivable wasteland was recorded. But from this category, salt-affected land, gullied land and waterlogged land can be only partially considered as desertified land. Forest blanks or *jhum* are the result of human activity (*jhum* means shifting cultivation practice). As to the vast sandy area, this category is a physical attribute, and only in case of human activity can this land be transformed to desertified land. Non-culturable wasteland includes barren land, such as rock outcrops, which cannot be used in agriculture.

The shortage of rainfall is very problematic for the rural poor. Small landholders do not have access to sources of reliable irrigation. Annual fluctuations in rainfall also have an important negative effect. The food situation in India in mid-1960s was the result of consecutive drought years and low productive agriculture. The government of India had to obtain food aid from abroad, first of all from the USA. Aid was accepted with a commitment to treat production and growth as priority goals of the agrarian policy. Kohli (1987) studied the poverty in India, especially in rural country. He published a very interesting table about the distribution of land size holdings in India (**Table 6.9**).

Information about the number of the rural landless was not included in this table. The same author gives more interesting data, presented here in **Table 6.10**, which characterizes the level of poverty in rural country of India.

The percentage of the poor in rural country has fluctuated, but it does not reflect any clear trend over time. That supposes, in spite of agricultural reforms, the proportion of people living under the conditions of absolute poverty has neither increased nor decreased.

Table 6.9
Distribution of operational holdings in India by size groups (Kohli, 1987)

Size of holdings, acres	1953 – 1954, %		1961 – 1962, %		1970 – 1972, %	
	Number of Holdings	Area operated	Number of Holdings	Area operated	Number of holdings	Area operated
< 2.5	54.80	5.93	39.07	6.80	60.30	9.20
2.5-5.0	15.91	10.86	22.62	12.32	16.40	14.90
5.0- 10.0	14.87	19.63	19.80	20.70	12.90	22.60
10-15	10.51	30.30	13.99	31.17	8.10	30.40
>25.0	3.01	33.28	4.52	28.95	2.20	22.80

Table 6.10
Rural poverty in India (Kohli,1987)

Years	Percentage of rural population in poverty
1956 - 1957	54.1
1957 - 1958	50.2
1958 - 1959	46.5
1959 - 1960	44.4
1961 - 1962	38.9
1962 - 1963	39.4
1963 - 1964	44.5
1964 - 1965	46.8
1965 - 1966	53.9
1966 - 1967	56.6
1967 - 1968	56.5
1968 - 1969	51.0
1970 - 1971	47.5
1973 - 1974	46.1

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CHAPTER 7

CONCLUSION

Desertification, being a global process, is one of the most urgent ecological problems in Asia. Droughts and over-exploitation of natural resources are the main causes of desertification in Asia and are exacerbated by the inherent fragility of arid ecosystems. We have compiled a desertification map of Asia and have calculated the size of degraded areas. The mapping of desertification hazards in drylands of Asia shows a total area of 9,804,700 km^2 as being subject of land degradation. **Figure 7.1** (cover page) shows the desertification map of the drylands of Asia, which is a reduced size version of the final map product of this research. A map of the final product is attached to this book.

Table 7.1a, 7.1b, 7.2 and Table 7.3 summarize the statistical results of our research. From these tables, we can conclude the following:

The rangeland areas occupy about 81.56% of the total area, followed by Irrigation agriculture and dry agriculture, which occupy respectively 7.18% and 6.89%. The forest/woodland areas occupy 4.17% of the total area (**Table 7.1a**).

The results from desertification mapping by type of land degradation shows that vegetation degradation, with 58.97% of total area, occupies a high rank of importance. Wind erosion becomes second in rank of importance with 25.43% of the total area. Water erosion and salinization have approximately the same level of importance with 7.73% and 7.18% respectively (**Table 7.2**).

Vegetation degradation affects 78.13% of the forest/woodland areas, while the affected area of rangeland is 68.72% (**Table 7.1b**). But as rangeland occupies most of the total study area (81.56%), the effect of vegetation degradation is more clear here. Vegetation degradation touches 5.46 million $km^2$of rangeland, which constitutes 94% of areas affected by vegetation degradation (**Table 7.3**) and 55.72% of the total area (**Table 7.1b**)

The statistics show that 55.64% of dry agriculture and 26.15% of rangeland is subject to wind erosion (**Table 7.1b**). Comparing to the area affected by wind erosion, 83% of this area is assigned to rangeland (**Table 7.3**), which also represents 21% of total area (**Table 7.1a**).

Dry agriculture is the most subject to water erosion, with 44.36% and 12.43% of dry agriculture and forest/woodlands respectively affected (**Table 7.1a**). If we compare all areas affected by water erosion, the degradation of rangeland appears more important than other land use types, with a percentage of 53.78% of areas affected by water erosion, followed by dry agriculture with a value of 39.53% (**Table 7.3**). Relatives to the total area (9.8 million km^2), rangeland and dry agriculture are in the same order of importance regarding water erosion, with percentages of 4.16% and 2.80% respectively (**Table 7.1a**).

All the irrigated agricultural land is facing a problem of salinization. The irrigated agricultural land constitutes 7.18% of the total area (**Table 7.1a**). The salinization of dried up sea floor in this study is related to the Aral Sea; it is important here to link the salinization problem with the recession of Aral Sea shoreline. The phenomenon of recession occurs also in the case of the Dead Sea.

The analysis of severity of desertification by land use type in Asia leads to the following remarks:

The actual forest/woodland areas are the most influenced by desertification and may be considered to be in a dire situation. About 66.07% of the forest/woodland area is undergoing severe to very severe land degradation, and 32.45% of forest/woodland areas has a moderate degree of desertification (**Table 7.1b**). This situation may be explained by the fact that it is very difficult to reclaim or rebuild the forest, and the reversibility process takes a long time. We note from the literature that there is a large known area, which had been considered forest and nowadays is considered as rangeland or bare land. The rate of desertification is very high.

The severity of desertification for rangeland is less than that of forest/woodland. About 50.45% of rangeland has a moderate degree of desertification, and 24.16% has a slight degree of desertification (**Table 7.1b**). This situation suggests that it is still possible to enhance the rangeland through a careful land management and reclamation.

The severity of salinization in irrigated agriculture is comparable to the situation for rangeland. The difference is in the extension of the problem.

The majority of dry agriculture (60%) generally exhibits a moderate degree of desertification, with an additional 36.82% showing a slight degree of desertification (**Table 7.1b**). This means that the degradation of dry agriculture is still under control, which gives hopes for communities to undertake rehabilitation of dry agriculture land.

We also want to discuss several specific features of the desertification process in different countries of Asia.

Central Asia refers to a specific geopolitical region that includes the former Soviet Republics of the USSR. The newly independent countries inherited the problem of desertification from the past. Construction of the Karakum Canal and the drying up of the Aral Sea transformed the territories of these countries to a veritable ecological catastrophe zone. The situation was aggravated after 1991 when the former Soviet Republics became independent states. The Karakum Canal has been filled with silt and increasingly was being shallow, because the administration of Turkmenistan does not have money for melioration.

The Middle East countries have their own problems. As known, one of the cradles of human civilization was located in this region. Irrigation agriculture was developed here four or five millennia ago. From a historical perspective, desertification underlied the downfall of ancient empires in Mesopotamia. At present time degradation of pastures and soil salinization are urgent problems in these countries. Wealthy countries like Saudi Arabia and Kuwait can reclaim land for agricultural production. In case of need they can purchase food abroad. But poor countries, like Jordan and Yemen, suffer from the effects of desertification.

China also has a long history of land reclamation. But according to historical sources the country was closed to market relations 2,000 years ago. Since the 12th century poverty in China increased because of population growth. This process is being continued in spite of special measures on birth control. The main part of population in arid region of China lives in poverty. As was mentioned in this book, a project on water transfer from south to north is now being developed in China. Realization of this project may induce a new ecological catastrophe in China.

Afghanistan is a country where the war desertification (a new type of land degradation) destroyed agriculture. The war continues, so the rehabilitation of productive land is impossible.

Desertification in India threatens the living conditions of the people in rural regions where 46.1% of population live in poverty. The situation in Pakistan is not any better. Military clashes between these two countries took place of the end of May 1999. Such conflicts could only aggravate the ecological situation in Jammu and Kashmir provinces.

During several decades Mongolia was a satellite of the USSR. The equilibrium between nomadic society and desert was destroyed during this period. These pastoral communities can survive under severe physical conditions only if they rehabilitate the traditional range management system.

Desertification is not only an ecological problem, but also brings social, economic and political problem. International agencies, national governments and local administration need information about the size and the degree of desertification to plan measures on land rehabilitation.

International Convention to Combat Desertification recommends the creation of monitoring system for desertification. Our desertification map is a first step toward monitoring at a regional level. Compilation of desertification maps of larger scales is the next step.

Table 7.1a

Desertification assessment by land use types (km^2)

Land use/ land degradation type	**Land degradation areas - km^2**				**Percentage**	
	Slight (1)	**Moderate (2)**	**Severe and very severe(3)**	**Subtotal**	**Percentage of subtotal**	**Percentage of total**
Forest, woodland / Vegetation degradation	0	61,765	257,333	319,098	78.13	3.25
Forest , woodland/ Water erosion	6,041	32,198	12,521	50,760	12.43	0.52
Forest, woodland/ Wind erosion	0	38,563	0	38,563	9.44	0.39
Subtotal	**6,041**	**132,526**	**269,854**	**408,421**	**100.00**	**Subtotal 4.17**
Rangeland & meadow/ Vegetation degradation	1,636,595	2,634,915	1,191,224	5,462,734	68.31	55.72
Rangeland & meadow / Water erosion	8,6021	321,795	0	407,816	5.10	4.16
Rangeland & meadow / Wind erosion	190,582	1,026,945	861,628	2,079,155	26.00	21.21
Rangeland & meadow / Waterlogging	7,363	27,206	12,258	46,827	0.59	0.48
Subtotal	**1,920,561**	**4,010,861**	**2,065,110**	**7,996,532**	**100.00**	**Subtotal 81.56**
Dry agriculture/ Water erosion	32,405	251,114	16,232	299,751	44.36	3.05
Dry agriculture/ Wind erosion	216,432	155,130	4,477	376,039	55.64	3.84
Subtotal	**248,837**	**406,244**	**20,709**	**675,790**	**100.00**	**Subtotal 6.89**
Irrigation agriculture/ Salinization	191,697	337,378	175,240	704,315		**7.18**
Dried up sea floor/ Salinization	0	10,335	9,307	19,642		**0.20**
Total	**2,367,136**	**4,897,344**	**2,540,220**	**9,804,700**		**100.00**

Table 7.1b

Desertification assessment by land use types (%)

Land use/ land degradation type	**Land degradation areas in percentage**				**Percentage of total**	
	Slight (1)	**Moderate (2)**	**Severe and very severe(3)**	**Subtotal**		
Forest, woodland / Vegetation degradation	0.00	15.12	63.01	78.13		3.25
Forest , woodland/ Water erosion	1.48	7.88	3.07	12.43		0.52
Forest, woodland/ Wind erosion	0.00	9.44	0.00	9.44		0.39
Subtotal	**1.48**	**32.45**	**66.07**	**100.00**	**Subtotal**	**4.17**
Rangeland & meadow/ Vegetation degradation	20.59	33.14	14.98	68.72		55.72
Rangeland & meadow / Water erosion	1.08	4.05	0.00	5.13		4.16
Rangeland & meadow / Wind erosion	2.40	12.92	10.84	26.15		21.21
Rangeland & meadow / Waterlogging	0.09	0.34	0.15	0.59		0.48
Subtotal	**24.16**	**50.45**	**25.98**	**100.00**	**Subtotal**	**81.56**
Dry agriculture/ Water erosion	4.80	37.16	2.40	44.36		3.05
Dry agriculture/ Wind erosion	32.03	22.96	0.66	55.64		3.84
Subtotal	**36.82**	**60.11**	**3.06**	**100.00**	**Subtotal**	**6.89**
Irrigation agriculture/ Salinization	27.22	47.90	24.88	100.00		**7.18**
Dried up sea floor/ Salinization	0.00	52.62	47.38	100.00		**0.20**
Percentage of total	**24.14**	**49.95**	**25.91**	**100.00**		**100.00**

Table 7.2

Desertification assessment by degrees and types of land degradation (km^2)

Land degradation type	Degree of land Degradation				Percentage of total
	Slight (1) (km^2)	Moderate (2) (km^2)	Severe and very severe(3) (km^2)	Total (km^2)	
Vegetation degradation (V)	1,636,595	2,696,680	1,448,557	5,781,832	58.97
Water erosion (W)	124,467	605,107	28,753	758,327	7.73
Wind erosion (E)	407,014	1,220,638	866,105	2,493,757	25.43
Salinization of irrigated soil (I)	191,697	337,378	175,240	704,315	7.18
Waterlogging of rangeland (L)	7,363	27,206	12,258	46,827	0.48
Salinization of dried up sea floor (S)	0	10,335	9,307	19,642	0.20
Total	2,367,136	4,897,344	2,540,220	9,804,700	100.00

Table 7.3

Distribution of vegetation degradation, water erosion and soil erosion in function of land use types

Land use class	**Vegetation degradation**		**Water erosion**		**Wind erosion**		**Waterlog ging**	**Salinization / irrigation**	**Salinization/ dried up sea**
	(km²)	**%**	**(km²)**	**%**	**(km²)**	**%**	**(km²)**	**agriculture(km²)**	**floor (km²)**
Forest/ woodland	319,098	5.52	50,760	6.69	38,563	1.55	-	-	-
Rangeland & meadow	5,462,734	94.48	407,816	53.78	2,079,155	83.37	46,827	-	-
Dry agriculture	-	-	299,751	39.53	376,039	15.08	-	-	-
Irrigation agriculture	-		-	-	-	-	-	704,315	-
Dried up sea floor	-	-	-	-	-	-	-	-	19,642
Total	5,781,832	100.00	758,327	100.00	2,493,757	100.00	46,827	704,315	19,642

Appendix A Explanation of the legend for "Desertification Map of the Drylands of Asia"

Table A.1 Desertification classes

Number	Desertification Class	Data values in the file of desertification map	Area (km^2)	Area in %
1	FV1	11	-	-
2	FV2	12	61,765	0.63
3	FV3	13	257,333	2.62
4	FW1	21	6,041	0.06
5	FW2	22	32,198	0.33
6	FW3	23	12,521	0.13
7	FE1	31	-	-
8	FE2	32	38,563	0.39
9	FE3	33	-	-
10	RV1	41	1,636,595	16.69
11	RV2	42	2,634,915	26.87
12	RV3	43	1,191,224	12.15
13	RW1	51	86,021	0.88
14	RW2	52	321,795	3.28
15	RW3	53	-	-
16	RE1	61	190,582	1.94
17	RE2	62	1,026,945	10.47
18	RE3	63	861,628	8.79
19	RL1	71	7,363	0.08
20	RL2	72	27,206	0.28
21	RL3	73	12,258	0.13
25	DW1	91	32,405	0.33
26	DW2	92	251,114	2.56
27	DW3	93	16,232	0.17
28	DE1	103	216,432	2.21
29	DE2	102	155,130	1.58
30	DE3	103	4,477	0.05
31	AI1	111	191,697	1.96
32	AI2	112	337,378	3.44
33	AI3	113	175,240	1.79
34	SS1	121	-	-
35	SS2	122	10,335	0.11
36	SS3	123	9,307	0.09
Total			9,804,700	100.00

Note: The following classes do not exist in the desertification map of the drylands of Asia: FV1, FE1, FE3, RW3 and SS1.

Table A.2 Classes excluded from assessment

Number	Class name	Data values in the file of desertification map	Area km^2	Area in %
1	Bogs	1	514	0.02
2	Solonchak	2	121,568	5.72
3	Bare land	3	113,091	5.32
4	Stone surface	4	4,249	0.20
5	Mountains	5	401,148	18.87
6	Moving sands	6	290,286	13.66
7	Extra-arid land	7	1,194,563	56.20
Total			2,125,419	100.00

Explanation of desertification classes:

The desertification classes are named using three characters, the first character symbolizes the land use type under assessment as shown in **Table A.3**, the second and the third characters symbolize the type of land degradation as shown in **Table A. 4**.

Table A.3 Symbolization of land use types

Land use type	Symbol used for desertification classes
Forest/woodland	F
Rangeland and meadow	R
Dry agriculture	D
Irrigation agriculture	A
Dried up sea floor	S

Table A.4 Land degradation types

Land degradation type	Slight	Moderate	Severe and very severe
Degradation of vegetation cover	V1	V2	V3
Water erosion	W1	W2	W3
Wind erosion	E1	E2	E3
Salinization of irrigated soil	I1	I2	I3
Waterlogging of rangeland	L1	L2	L3
Salinization of dried up sea floor	S1	S2	S3

Table A.5 Legend for Regional map of the drylands of Asia

Class name	Data values in the file of Dryland map	Area km^2	Percentage
Semi-arid land	201	3,040,189	25.49
Arid land	203	7,294,219	61.14
Extra-arid land	206	1,194,563	10.01
Mountains	209	401,148	3.36
Total		11,930,119	100.00

Note: The classes "Extra-arid land and Mountains in this legend represent the same areas of the same classes given by **Table A.2**.

Map scale:

A map scale of "desertification map of the drylands of Asia" when we output in a way that the horizontal size of the map will be 81 cm:

Map projection: Plate Carrée
Nominal scale 1: 10,000,000

Actual scale varies at different locations as follows due to the map projection:

The horizontal scale on the 50 degree N latitude line: 1: 8,390,996
The horizontal scale on the 40 degree N latitude line: 1: 10,000,000
The horizontal scale on the 20 degree N latitude line: 1: 12,266,816
The vertical scale on longitude lines: 1: 13,010,304