ICARDA International Center for Agricultural Research in the Dry Areas

AREA

OASIS Country Report 4

Combating Land Degradation in Yemen— A National Report

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A Review of Available Knowledge on Land Degradation in Yemen
OASIS — Combating Dryland Degradation

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EXECUTIVE SUMMARY

The purpose of this document is to review the current land characteristics and use status in Yemen as well as agricultural policies and institutional efforts to combat land degradation in the country. Despite agriculture's relatively low contribution to GDP (18 percent), the sector remains the most important element of the effort to combat poverty and provide employment to the majority of the poor in Yemen`s rural areas.

It is intended as a guideline for all those involved in organizing the next stages of Oasis and similar project implementation in Yemen– Government officials, international funders and agencies, national research stations, farmers and rural communities.

In Yemen's rural areas, desertification covers around 30 million hectares of the land accounting for over 50 percent of total area. The potential for even more desertification is high. The main driving forces for desertification have been water and wind erosion, overgrazing and depletion of tree cover, abandonment of terraces and changes in socio-economic factors and farming practices. Yet, there are significant processes of land degradation in Yemen that are not being captured adequately by current mapping methods. A fine-tuning of mapping accuracy and resolution is needed to reveal more accurate current stages of land degradation, particularly in lands used for small ruminant grazing and for other agricultural purposes. Such improved precision will allow for new policy measures addressed to rehabilitating degraded lands.

The most effective means to combat land degradation in Yemen have proven to be measures to prevent water erosion, controlling pasture grazing, promoting good farming practices, encouraging fodder production, rehabilitation of degraded lands by using local species (such as Jatropha curcus) and declaration of protected areas. In Yemen's experience with land resource conservation,the use of conservation-based farming practices and soil and water conservation techniques have been effective in controlling land desertification.

Conservation farming has been effective (though not of widespread use) for reducing water losses from agricultural fields, and for decreasing soil erodibility while increasing its filterability and water holding capacity. Good farming practices to keep soil fertile have been zero tillage, crop selection and rotation, timeliness of cultural practices, manuring, and mulching. The use of indigenous technical knowledge has also been a valuable tool, but remains a highly underestimated resource used for land conservation. Policies oriented to initiating participation and rural community partnerships for land conservation have also been positive.

Such policies, however, have not been always successful. Yemen has for many years been suffering from persistent weak institutions and a high risk of internal conflict. The international community has labeled Yemen as a "fragile state", underscoring its difficulties in initiating and sustaining sound economic and social policies. These difficulties underscore the need for Yemen's development partners to take a more selective, nuanced and holistic approach to implement policies to combat land degradation in the country.

LIST OF ACRONYMS

a.s.l.	above sea level
AAAI	Arab Agency for Agricultural Investment
ACSAD	Arab Center for Studies in Arid and Dry Areas
ARA	Agricultural Research Authority
AREA	Agricultural Research and Extension Authority
BC	Before Christ
CBOs	Community Based Organizations
CLASOD	Global Land Assessment of Degradation
COCA	Central Office of Control and Audit
Cs	Chemical soil degradation caused by salinity
DAIC	Dhamar Agriculture Improvement Center
E	Soil degradation caused by wind
EPA	Environment Protection Authority
EPC	Environment Protection Council
GDASD	General Department of Agricultural Statistics and Documentation
GDFDC	General Directorate of Forestry and Desertification Control
GDP	Gross Domestic Product
GAREWS	General Agricultural Rural Environment and Water Societies
GIS	Geographical Information System
GoY	Government of Yemen
HWC	High Water Council
IMO	International Marine Organization
IUCN	Information Unit of Conservation of Nature
LCCD	Local Council for Cooperative Development
ITK	Indigenous Technical Knowledge
MAI	Ministry of Agriculture and Irrigation
MAWR	Ministry of Agriculture and Water Resources
MDG	Millennium Development Goals
NEAP	National Environment Action Plan
NGOs	Non-Government Organizations
NORADEP	Northern Regional Agricultural Development Project
NSES	National Strategy of Environmental Safety
NWFPs	National World Food Program
Pa	Physical soil aridification
Pc	Physical soil compaction
PLa	Physical soil degradation caused by crusting and sealing
PRSP	Poverty Reduction Strategy Paper
Ps	Physical structure deterioration
RNRRC	Renewable Natural Resources Research Center
RS	Remote sensing
SHc	Stabilized human conservation of land
SN	Stabilized Naturally land
SPSEM	Sub-Program of Sustainable Environment Management
SRRS	Southern Uplands Regional Research Station
SSHAEDA	Sana'a, Sadda'h and Hajjah agricultural and rural development authority
UNDP-SPSEM	United Nations Development Program/Sub-program of Sustainable Environment Management
UNEP	United Nations Development Program
UN ESCWA	United Nation's Education, Science, and Culture for West Asia
UK-DfID	United Kingdom Department for International Development
WHS	Water Harvesting System
WUAs	Water Users Associations
WUE	Water Use Efficiency

CHAPTER 1:

Yemeni Agriculture

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Agriculture is an essential part of life in Yemen. Terraces, old irrigation systems such as dams and canals, local traditional knowledge and indigenous practices are some of the elements that confirm the position of agriculture in Yemen's civilization. At present, the agricultural sector continues to absorb more than 50 percent of the labor force in the country. In addition, it continues to serve as the main source of living for about two thirds of the population.

Despite its relatively low contribution to Gross Domestic Product (GDP), due to the high revenues of the fast growing extracting and industry sector, agriculture remains one of the main sectors contributing to the economic development of the country. Its share in GDP is about 18 percent. In fact, this sector is the major arm in the country's effort to combat poverty in the rural areas where it is growing at an average rate of no less than 20 percent.

Additionally, farm and other related products form a considerable percentage of national exports and represent a key source of foreign currency especially in view of the expanding trade relations that are constantly growing with neighboring countries and other regional and world markets. However, the growth rate of the agricultural sector—including Qat[1]—has fluctuated between 12.2 percent in 2001 and 4.8 percent in 2006 (Muharam, 2007).

The main challenges to Yemen's growth are the impending rapid decline in oil revenues, the weak capacity of government institutions, the pressure of high population growth, and the scarcity of freshwater. With the latest change in government, in the frame of the "Arab Spring", the new Government is concerned about governance problems and is recently attempting to speed up reforms. The last two challenges-high population growth and water crisis-are long recognized by the government, but reforms have been slow.

Yemen's population growth, at three percent annually, is high by regional standards and in comparison with countries with similar levels of per capita income. Yemen's fertility rate began to slow down in early 1990s, as economic and social development brought conditions that have created a "demographic transition" to lower birthrates in many countries. However, this transition appears to have stalled in Yemen.

Generally there is lack of quantitative and qualitative data on the status of the environment in Yemen, but reports on the Status of Environment in 1995 and 2000 provide broad indicators on the trends associated with natural resources and the wider status of the environment. Legislation concerning environmental and natural resources management issues faces several problems during preparation and enforcement. There has been little coordination to the extent that personal interpretation, overlap of responsibilities and tasks among various agencies subverted progress.

Over decades, a lack of attention to the environment has led to over-exploitation of natural resources beyond a sustainable capacity. The main environmental issues then relate to water resources (water depletion, pollution and supply), including land degradation; loss of biodiversity, marine and coastal zone management, natural heritage; habitat degradation and waste management.

In rural areas, women and children are burdened with traditional methods of fetching water for domestic purposes and with other traditional agricultural land use activities. Most men choose to migrate to urban areas to look for better income sources. Groundwater is the main water source for different water uses and the water level in most critical aquifers is declining due to over extraction. In some cases, water is being extracted at twice the rate of water recharge. Less than 10 percent of

[1]Qat is a flowering plant native to the Horn of Africa. In Yemen qat chewing has a long history as a social custom dating back thousands of years.

extracted water is used for domestic and industrial purposes. Fresh water per capita is decreasing, falling from 1,100 cubic meters in 1990 to 500 cubic meters in 1995 and more recently to around 137 cubic meters. Considering the present pattern of water utilization and the rate of population growth, it is expected that water per capita will fall to 150 cubic meters in the coming 25 – 30 years. In the urban areas waste and sewage problems pose a threat to ground water pollution. Water-borne diseases are one of the main causes of infant mortality in the country.

The ecological systems and biodiversity are endangered due to multiple interacting socio-economic factors causing loss of biota due to degradation of natural habitats and ecosystems. Main threats are due to land resources degradation in various forms, over hunting and over exploitation. Socotra Island is a good example of rich biological diversity. The island has more than 850 species of plants of which 30 percent are endemic and eight species have been listed by Information Unit of Conservation of Nature (IUCN) as endangered species. 120 bird species have been recorded in the island of which 30 species breed on the island and seven bird species are endemic.

Urban centers are expanding at a high rate and pose real pressure on available resources and services to meet the growing demand of the new inhabitants. Main problems relate to water supply, sanitation, and air pollution and liquid and solid waste management. Statistical evidence shows that only 60 percent of domestic waste generated is collected and that, in 2000, around 86 percent and 19 percent of urban and rural settlement, respectively, had access to the sewage network. Main hazardous wastes include waste oil, hospital waste and old stocks of pesticides (Yemen – MDG's Report, 2005).

The Poverty Reduction Strategy Paper (PRSP) 2003–2005 acknowledges the relationship and linkages between poverty issues and degradation of natural resources, hence, environment protection. The poor are one of the key population groups reliant on the natural environment for their livelihood. As the same time they are the most affected group by environmental problems and are impacted by the way natural resources are exploited. Conversely, poverty increases pressure on natural resources.

1.2 INSTITUTIONAL AND POLICY CONCERNS

Yemen continues to suffer from weak institutions and a high risk of internal conflict. Although the World Bank ranks Yemen barely above the categorization of low-income countries under stress, the UK Department for International Development (UK-DID), an important bilateral donor for Yemen, has labeled Yemen as a "fragile state" since January 2005. The index of failed states compiled by Foreign Policy magazine and the Fund for Peace ranks Yemen eighth in a global list of 60 countries rated for risk-of-state-failure, ahead of Afghanistan.

The categorization of Yemen as a fragile state underscores its difficulties in initiating and sustaining sound economic and social policies. This difficult operating environment calls for Yemen's development partners to take a more selective, nuanced approach to reforms. Yemen's traditional institutions, especially its tribal structure, have evolved with the development of modern state institutions and technology (Carapico, 1998) which continue to survive as mechanisms that coordinated individuals within small groups to provide security and support for each other, at the cost of broader interests and impersonal exchange.

Such structures may impede governance reforms because they can add to the costs of forming broad coalitions representing nationwide interests. If these are indeed the forces that have kept Yemen underdeveloped, they may have far-reaching implications for the development of the country. Again, however, the theoretical explanation needs to be consistent with evidence of the government's macroeconomic stabilization and trade liberalization, as well as the pattern of corruption and economic stagnation. Yemen's current political culture is a blend of ancient tribal cultures and modern political institutions, including informal parties and formal institutions of government.

Despite an impressive record in creating a modern administration from virtually nothing over the last thirty years, Yemen faces an enormous set of problems in its public services. Competencies, management, and motivation are all low and, as a result, performance is frequently negligible or

perverse. This contributes to a very weak governance environment; the more complex or innovative activities are a particular problem - for example, the promotion of conjunctive use of surface water and groundwater, or wastewater reuse, or watershed management all require energy and coordination skills lacking in the public sector.

1.3 OBJECTIVES OF THE REVIEW AND METHODOLOGY

The report is a product of teamwork formed by the Agricultural Research and Extension Authority (AREA) as a focal agency for the "Combating Land Degradation"—OASIS. Various parts of the report relied mainly on reviewing available secondary information sources and to a lesser extent on members own personal knowledge and experience. This document has the following main objectives:

- Furnishing adequate information about the various aspects relating to agriculture in Yemen, particularly land degradation issues;
- Reviewing available information concerning land degradation situation and causes;
- Providing some information on local and improved/modern technologies as well as their current situation in relation to adoption and impact;
- Shedding light on strategies, policies, institutions and programs/projects relating to land use and conservation;
- Drawing up some conclusions and formulating preliminary recommendations and proposed actions with regard to possible interventions that would contribute towards combating land degradation.

The report starts with an introductory chapter that provides summarized information on agricultural land, prevailing crops grown and existing production systems in the country.

The second chapter is dedicated to Yemen's various aspects such as topography, geology, ecology, soil resources, water resources and vegetative cover. It also sheds some light on the importance of agriculture in Yemen and highlights most important challenges facing it at present.

The third chapter discusses the issue of land degradation and provides a detailed description of different types of degradation and some information related to important factors causing each type. It also assesses the changes in land degradation and highlights the relative importance of each land degradation type.

The fourth chapter describes technological options related to land degradation including local knowledge and indigenous technologies as well as improved and modern technologies that are directly and/or indirectly linked to land use and conservation. This chapter also reviews available information about the extent of adoption and impact of selected technologies and lists different constraints hindering adoption.

The fifth chapter is devoted to institutional aspects of relevance to land degradation. It presents adequate information on government and non-government agencies involved in agriculture production and environment protection mainly at present.

Chapter six is dedicated to existing national, sectoral and environmental policies that affect land degradation and reviews some experiences and a number of relevant programs/ projects. Lastly, some short conclusions were drawn and primary recommendations were formulated for possible future action. The report includes some tables, graphs, maps and satellite imageries and concludes with a comprehensive list of references used by all team members while preparing their contributions.

CHAPTER 2:

Background Information about Yemen

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The Republic of Yemen is located in the southwestern corner of the Arabian Peninsula, between 12° to 19° N latitude and 42° to 53° E longitudes. Apart from the mainland, it includes many islands; the largest of these are Socotra in the Arabian Sea and Kamaran in the Red Sea. The country is bordered by Saudi Arabia from the north and northeast, Sultanate of Oman from the southeast, the Arabian Sea and the Gulf of Aden from the south and the Red Sea from the west (Figure 1).

The country is administratively divided into 21 governorates (provinces), with a total area of 455,000 Km^2 (approximately 45.5 million hectares), that consists largely of mountains and desert terrain. Yemeni total population is about 20 million people, living mostly in northern governorates, with a three percent annual population growth rate.

The topographic characteristics of the country reveal a large contrast in elevation, especially in the western part of Yemen. Broad and flat coastal plains border the Red Sea (Tihama) and the Gulf of Aden. They frame the strongly dissected mountain massif of western Yemen, where elevations range from few hundred meters to about 3760 meters above sea level. The eastern slopes are more gradual than the steep western and southern slopes; they range gradually into the depression of Ramlat As – Sabatayn desert in the Empty Quarter. The topographic appearance of the eastern part of the country is somewhat less pronounced, but noteworthy are the topographically elevated belt parallel to Wadi Hadramaout (northern and southern Hadramaout Arcs), the broad and steep-side Wadi Hadramaout canyon and the topographic depression of Al – Ghaydah of Almahra province. Only principal wadis are

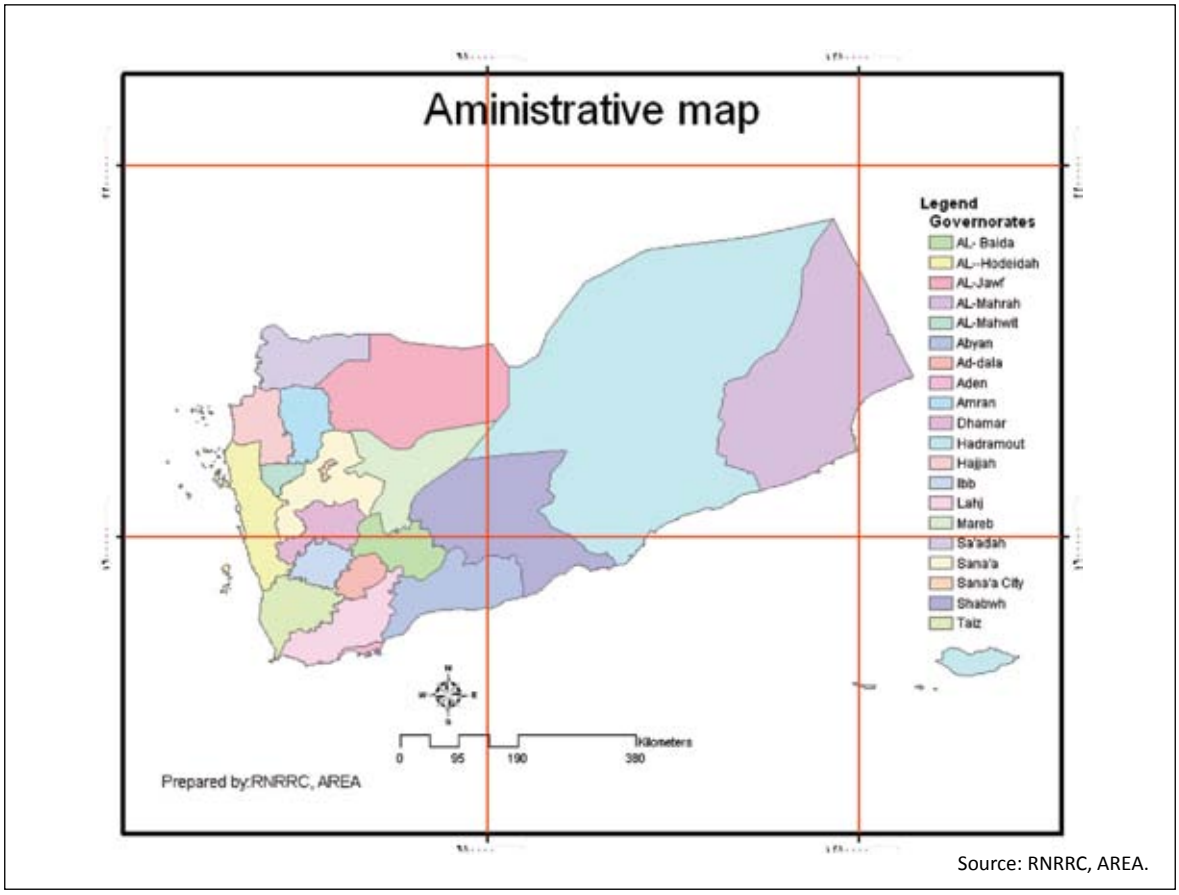


Figure 1: Administrative map of Yemen

shown (in North Africa and the Middle East wadi means valley that remains dry except during rainy season).

2.2 PHYSIOGRAPHIC REGIONS

A description of Yemen's physiographical regions has been presented in several sources (Van der Gun and Abdul Aziz, 1995; King, Forbes and Abu Ghanem, 1983; Al-Hubaishi and Mular, 1994; and El-Abbas Doca, 1996). They characterize Yemen as a diverse country with physical and topographical lands composed of mountain chains, plateaus, plains and wadis. This diversity has resulted in wide differences in climatic conditions and consequently formation of different agro-climatic zones (Al-Mashreki, 2005).

Van der Gun and Abdul Aziz (1995) and Robertson (1991) have divided the country into five main physiographical regions: 1) the Coastal Plains, 2) the Yemen Mountain Massif, 3) the Eastern Plateau Region, 4) the Desert and 5) the island Socotra (Table 2 and Figure 3). Based on these geographical regions, highland region can be located in the Yemen Mountain Massif under southern slopes subdivision. The Yemen Mountain Massif can be associated with the Arabian shields shown in Table 1 and Figure 2.

Precambrian rocks outcrop widely in the eastern part of the zone; elsewhere they are covered by Palaeozoic and Mesozoic Sediments which, in turn, in the central west and the southern sub zone are topped by thick blankets of Tertiary and Quaternary Volcanic rocks. The Yemen Massif constitutes an uplifted zone of very irregular and dissected topography, with elevations ranging from a few hundred meters (foothills) to 3760 meters above sea level (Jabal Nabi Shuayb near Sana'a). Accordingly, the climate varies from warm temperatures at lower elevations to cool temperatures at high altitudes.

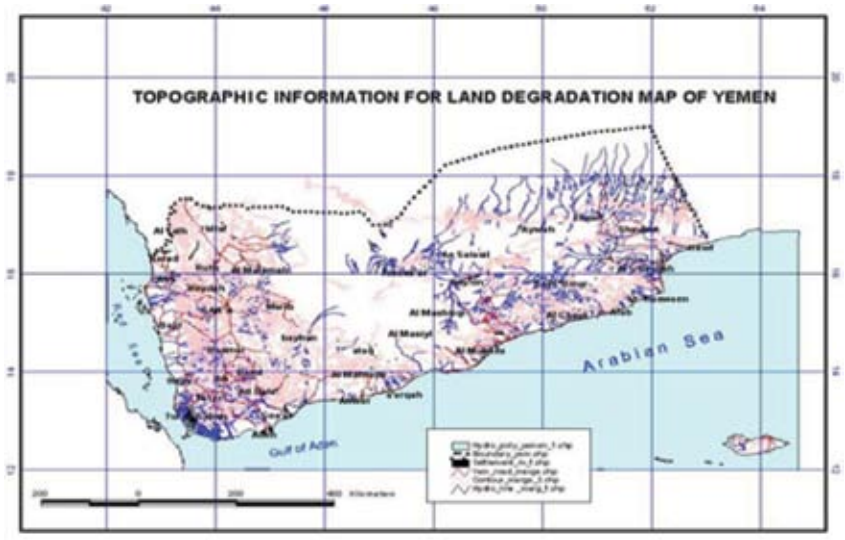
The western and southern slopes are steepest; they enjoy moderate to rather high rainfall because they are favorably oriented in relation to the movement of moist air masses. Rainfall in these slopes is on average between 300 and 500 mm/year, and in some areas can be more than 1000 mm/year.

Table 1: Physiographical regions of Yemen

K a wi	**fl a**
(1) The Coastal Plains	(a) Tihama (b) Tuban-Abyan plains (c) Ahwar-Meifa'ah plains (d) Eastern Coastal plains
(2) The Yemen Mountain Massif	(a) Western Slopes (b) Southern Slopes (c) Eastern Slopes (d) Highland Plains zone
(3) The Eastern Plateau Region	(a) Northern Plateau zone (b) Southern plateau zone (c) Wadia Hadramawt (d) Al Ghaydah basin
(4) The Deserts	(a) Ramlat as Sabatayn (b) Rub al Khali
(5) Yemen islands	(a) Soqatra - Kamaran (b) Other small islands

Source: Van der Gun and Abdul Aziz (1995) and Robertson (1991).

2Terraces are built by Yemenis in various mountainous highland areas through construction of land protection walls either using stones (Highlands) or clay (Hadhramout) at a height of 1 – 1.5 meters.



Source: Human induced soil degradation (Yemen-ACSAD, 2002).

Figure 2: Topographic map of Yemen

Rainfed agriculture is practiced widely on numerous terraced[2] mountain slopes, supporting rather high population densities. The morphological features of the whole country as well as the highland region, formed largely because of the tectonic and volcanic activities during the Tertiary, were then modified to some extent during the Quaternary period. The main current drainage systems were developed and river terraces, alluvial plains and coastal plain were formed (Van der Gun and Abdul Aziz, 1995).

Most of the highland region is of Tertiary and recent Quaternary volcanic origin. Old Cretaceous, Jurassic and Precambrian sedimentary and basic rocks might outcrop locally; recent volcanic rocks and alluvial deposits also occur (Acres, 1978). As geography changed overtime, crystalline basement rocks are now dominant in most areas of the escarpment and highlands of the country. However, Jurassic sediments, such as the sandstones of the Kuhlan-series and the still younger sandstones of the Tawilah-series are in many places just as important as volcanic rocks (basalts, andesites and trachytic tuffs) of different ages. Finally, there are alluvial deposits in the larger basins of the highlands. There is no doubt, that the different bedrocks may play an important role in the development of soils. More importantly, however, are the relief structures for soil development as well as for the climatic differentiation on a small or larger scale (Al-Hubaishi and Muller-Hohenstein, 1984).

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Yemen has a predominantly semi-arid to arid climate, with rainy seasons during spring and summer, and with high temperatures prevailing throughout the year in low-altitude zones. Three large bodies of water affect the climate of Yemen: the Indian Ocean (including the Gulf of Aden and Arabian Sea), the Red Sea and the Mediterranean Sea. They are the sources of moisture for the passing air masses and they have an impact on the general atmospheric circulation (Van der Gun and Abdul Aziz, 1995).

Yemen is characterized by diverse physical and topographical features, which are composed of mountain chains, plateaus, and plains. This variation has resulted in the wide differences in climatic conditions and consequently, in formations of different agro-climatic zones. The climate ranges from hot tropical climate in the lowland region to a temperate climate in the central mountain region. The maximum temperature in the summer may rise up to 40?C in the lowland and the desert region. In the winter, the temperature may decrease below zero in the high mountain region. The mean annual temperature ranges from 11?C in the highlands to 30?C in the lowlands (Wen Ting Tiang ????, 1998).

Table 2: Main characteristics of different agro-climatic zones in Yemen

???? wi Egwi ?a	?? i ??w? ??i ??? (mm)	Temperature Range (oC)		?fwn i ?? o?f w?? (days)	Altitude Range (m)	?f??	
		? ?d	? i			Km·	3?w?l w?v? ?f??
Central Highland	100-1200	26-35	0-20	30-240	900-2400	62,600	11.8
Zone1	700-1200	24-29	6-13	240	1500-2000	100	0.02
Zone2	600-900	20-33	0-18	170-190	1400-3000	2200	0.4
Zone3	400-700	29-35	11-18	110-240	1100-2200	12,400	2.2
Zone4	300-600	27-33	13-20	70-80	1000-2000	2100	0.4
Zone5	200-450	20-35	8-20	80-90	900-2000	28,900	5.2
Zone6	200-400	22-30	0-14	100	2200-2400	1300	0.2
Zone7	100-200	23-30	3.-16	30-40	1800-2200	5000	0.9
Zone10	157-400	26-35	16-25	30-90	600-2150	13,600	2.45
Tihama Region	100-500	32-40	18-27	20-70	70-300	10,100	1.8
Zone8	200-500	32-40	18-27	20-70	250-300	5300	0.95
Zone9	100-250	30-38	19-27	20-50	70-140	4800	0.86
Coastal Zone 12	10-200	30-35	20-28	-	10-130	40,000	7.2
Eastern Plateau Zone 11	50-125	28-41	10-24	-	700-1150	186,000	33.5
Eastern Desert Zone 13	0-100	28-40	11-25	-	1000-1100	108,000	19.5
Socotra Island Zone 14	50-200	29-36	26-33	20-60	-	3,700	0.7

Source: Bruggeman, 1997.

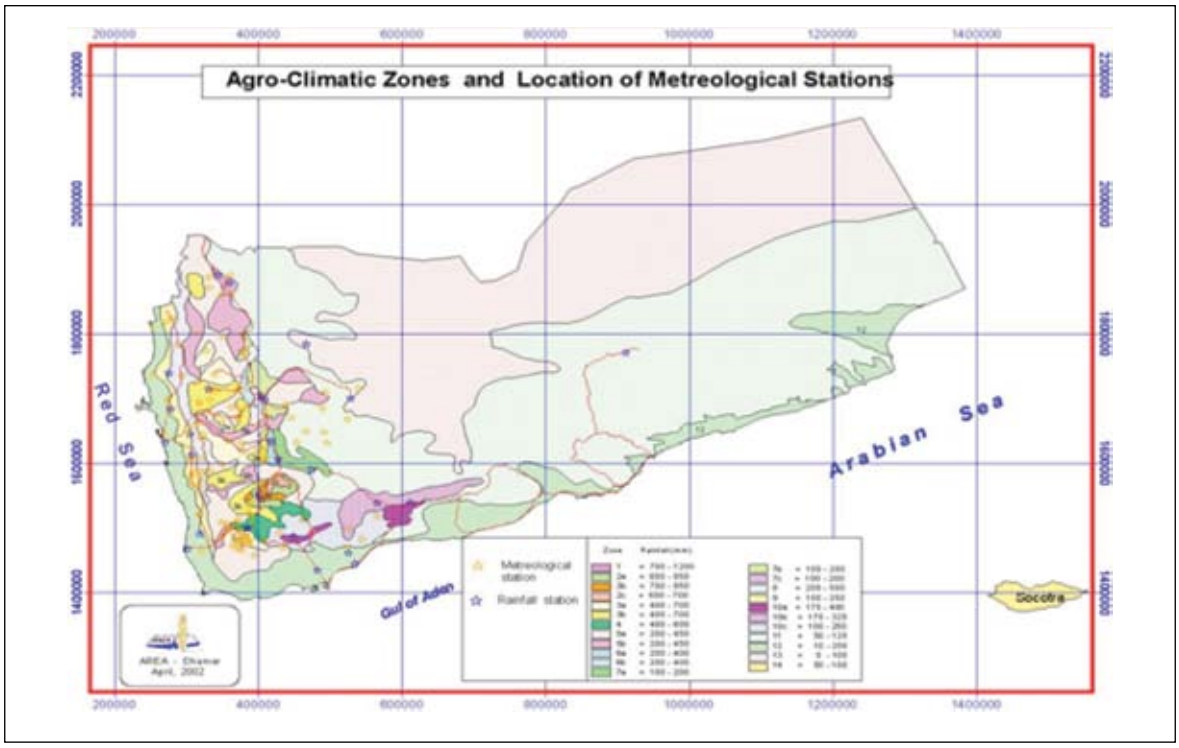

Figure 3: Map of Agro-climatic zones of Yemen

Detailed records, summaries and analysis of climatic data for the whole country is presented in Field Document no. (11) titled “Agro-climatic Resources of Yemen part (1): Agro-climatic Inventory” (Bruggeman, 1997). This recent study divides the country into 14 agro-climatic zones (Figure 3) based mainly on climatic characteristics (Table 2).

The range and natural forestland is distributed in western and southern mountain slopes. The density of the vegetative cover in these range lands vary with the variation of rainfall and with distances from heavy populated area. The vegetation of Yemen has been reduced by centuries of woodcutting, overgrazing and other factors to a sparse dwarf and shrub-grassland. A more luxuriant plant cover is found only in wetter sites or where trees have been specifically protected. Vegetation is generally sparse. Site differences are relatively small, though grass cover is marginally higher on foot slopes and more obviously higher on slopes inaccessible to grazing animals. Only on these slopes do grasses flower regularly; on most other sites, high grazing pressure restricts seeding to wet years. Only a small proportion of the recorded grass cover consisted of annuals.

2.4 PLANT SPECIES OF YEMEN

Al-Khulaidi (2000) identified a large number of plant species in the Yemeni Flora. He estimated the total plant species at about 2810 belong to 1006 genera and 173 families (2559 naturalized, 121 cultivated and 111 introduced). A high percentage of Yemen plants belong to tropical African plants of Sudanian regions. Yemen is rich in endemic plants, estimated to be 415 plant species (236 in Island Soqotra); constituting some 15 percent of the flora, which does not occur elsewhere.

The flora of Yemen is a mixture of the tropical African, Sudanian plant geographical region and the Sahara-Arabian region. The Sudanian element dominates the western mountains and parts of the highland plains, which is characterized by relatively high rainfall. The Sahara-Arabian element dominates in the coastal plains, the eastern mountain and the eastern and northern desert plains.

Examples of the Sudanian element species are: *Ficus spp., Acacia mellifera, Grewia villosa, Commiphora spp.,Rosa abyssinica, Cadaba farinosa* and others. Among the Sahara- Arabian species, the following are important: *Panicum turgidum, Aerva javanica, Zygophyllum simplex, Fagonia indica, Salsola app., Acacia tortilis, A. hamulosa, A. ehrenbergiana, Phoenix dactylifera, Hyphaene thebaica, Capparis decidua, Salvadora persica, Balanites aegyptiaca* and many others.The characteristic genera of the Irano-Turanian, which occur in the eastern and north-eastern parts of the country are: *Calligonum spp., Cymbopogon jwarancusa* and *Tamarix spp.,* and of the Mediterranean regions are: *Teucrium, Lavandula, Juniperus, Brassica and Diplotaxis.* Important families and number of plant species are shown in (Tables 3 and 4).

Table 3: The most important families and number of plant species

[illegible]	Most important plant families
322	1. Poaceae (gramineae)
223	2. Asteraceae (compositae)
203	3. Fabaceae (papilionaceae)
106	4. Euphorbiaceae
104	5. Asclepiadaceae

Source: Al-Khulaidi (2000).

Table 4: Most important families and numbers of endemic plants

No. of endemic	Families
71	1. Asteraceae (Compositae)
49	2. Euphorbiaceae
47	3. Acanthaceae
43	4. Asclepiadaeae
38	5. Boraginaceae
32	6. Fabaceae (Papilionaceae)
31	7. Lamiaceae (Labiatae)
24	8. Caryophyllaceae
24	9. Rubiaceae
18	10. Poaceae (Graminea)
18	11. Burseraceae
16	12. Scrophulariaceae

Source: Al-Khulaidi (2000).

According to Al-Hubaishi and Muller-Hohenstein (1984), the following main ecosystems and vegetation cover wide areas in the highlands and the high mountains of Yemen: 1) the more or less level plains and basins with rather deep loamy soils which receive run-off water, including the wadi systems, 2) the gently undulated pediments and lower isolated hills with shallow stony soils, 3) the plains of sub-recent volcanic deposits and still no soil development and 4) the stony and rocky high mountain slopes and peaks with a water supply below average.

During a long period, the highland has been even more intensively cultivated than the escarpment area. Therefore, it is very difficult to reconstruct the natural plant cover of the highlands. It can only be described as a 'savannah', open woodland with a large number of spiny and thorny species. Leaf-reduction and succulent life forms are again very common. The main plant formation is Drought-deciduous Mountain woodland. However, only a few woodland relics are still to be found and these very often are not natural. Only in the north of Yemen, between Huth and Sa'dah, due to the smaller population, some nearly natural woodland communities have been preserved.

The dominant species are again *Acacia* such as *Acacia origena* and *Acacia gerrardii.* Occasionally, other species may be found such as: *Buddleja polystachya, Cordia africana, Olea europaea, Ficus palmata and Juniperus procera.* Among the shrubs: *Grewia mollis, Carissa edulis, Ehretia abyssinica, Myrsine africana and Rosa abyssinica* are the most common. Usually the mountain plains are cleared and cultivated, and the bordering rocky slopes and lava fields are overgrazed. In the sparse vegetation cover, nevertheless, a large number of different small shrubs, herbs and grasses show that the Highland communities were once floristically very rich. The most important species are *Lycium shawii, Euphorbia fruticosa, E. schimperi, E. schimperiana, Kleinia semperviva, Fagonia indica, Commicarpus sinuatus, Helichrysum fruticosum, Salvia schimperi, S. merjami, Lavandula pubescens, L. coronopifolia, Echium longifolium, Reichardia tingitana, Hyparrhenia hirta and Aristida adscensionis*. Near well-watered places the plant cover can be very dense with *Flaveria trinerva, Mentha longifolia and Xanthium spinosum* as the most characteristic species.

At higher altitudes but still below the timberline, which lies between 2800 and 3000m, the plant cover is usually denser and there are many endemic plants such as *Macowania ericifolia, Delosperma harazianum, Cichoriumbottae, Teucrium yemense, Crinum yemense,* as well as some other plants that can also be found in the highlands of Ethiopia, such as *Campanula edulis, Pterocephalus frutescens, Felicia abyssinica and Crassula alba*. Some ferns such as *Ceterach officinarum, Cheilanthes pteridioides and Adiantum capillus-veneris* and the attractive *Primula verticillata* are grown on wet places below shady rocks*; Centaurothamnus maximus* is rather common on the otherwise bare cliffs.

In the highest mountains above the timberline, the dominant plant formations are alpine pastures and meadows, rich in forbs and grasses. On several occasions during the winter season they may be covered with snow for a few hours or days. In these natural grasslands *Eleusine floccifolia and Pennisetum setaceum* are important grasses and *Dianthus uniflorus, Micromeria biflora* and *Craterostigma pumilum* frequently form small patches. In the riverine plant formations and wadi communities, there are some small remnants of an evergreen tropical highland forest with only one tree species forming dense thickets: *Tamarixnilotica*, which is accompanied by Typha angustata when water is regularly flowing. On higher altitudes another riverine tree has probably been introduced: *Salix alba*. The herbs in this community are the same as those mentioned above. The small gorges and valleys of the dissected hills and slopes have a visibly denser plant cover.

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2.5.1 Previous soil surveys

Since the early seventies, numerous soil surveys and classification studies have been carried out in different parts of Yemen. These studies were conducted by various foreign agencies, often through bilateral aid, while other studies were carried out by national researchers and experts during the last ten years (Al-Mashreki, 2005).

The main purpose of these soil surveys was to provide the necessary required information for assessing the land potential for crop production as well as to characterize soils for land evaluation. Several hundreds of profiles have been described within these soil survey studies and have either been classified according under one or both of the two most common soil classification systems (i.e. USDA Soil Taxonomy or FAO-UNESCO Soil Map of the World Legend).

2.5.2 Soil parent material

Previous studies indicate that most soil parent materials in Yemeni Highlands are unconsolidated materials as a result of all three processes of soil parent material formations: alternating layers of colluviums, alluvium formations and loess in any sequence or combination of both of them. Colluvial pediments in the high rainfall areas are deeper. Parent materials of highland regions consist of the following:

- **Colluvial deposition**: In both high and medium rainfed areas, the extensive colluvial deposits are distinct. They occur as moderately sloping pediments at the base of mountain terraces. These kinds of deposits also occur in the foot slope terraces. The stones, gravel and boulders in this colluvium are usually sharp and rough-edged. Most gently sloping pediments surrounding the outcrops are basaltic. The soils on these pediments are stony and limited in depth. The weathering of basalt produces a considerable amount of calcium carbonate and clay. Consequently, soils often have a calcic horizon and are fine textured.
- **Alluvium deposition:** Alluvium is the most important parent material for soil formation. The alluvial wadi deposits comprise a major part of the highland areas. The alluvial system formed by the wadis. The wadis show a contrasting range of sediments ranging from coars to fine textured, depending on the original valleys' gradient and position. The sediments, however, are generally finer in texture than these in the active wadi beds and are spread over a much larger area. The source of the sediments is the weathering debris from the highlands mixed with reworked alluvial loess. Consequently, the present wadi deposits rise above the surrounding older alluvial plain. The sub-recent terraces are higher and generally separated from the wadi beds by the levees. Sedimentation on these sub-recent terraces is clearly influenced by parent material and consists of well-sorted silts.
- In situ weathered volcanic material can sometimes be found close to the surface. It is very rich in carbonates and has silty clay to silty clay loam texture. Different types of bedrock are presented, such as a) pinkish sedimentary soft rock (limestone), b) metamorphic harder rock

type with platy structure, rich in gypsum and calcium carbonate, and c) basic igneous basalt rock, which is also rich in calcium carbonate. In some parts, deeply weathered basalt seen as red or dark red material at some depth in the profile.

2.5.3 Soil properties

In general, soils in the highland areas are deep (> 100 cm) or moderately deep (50-100 cm) and shallow in some places (<50 cm) and they are well drained. All soils are alkaline with pH values between 7.5 and 8.5. Texture is broadly related to parent material, which is of coarser texture associated with metamorphic rocks and more clayey soils with basaltic rocks and also closely related to processes of erosion and deposition. The majority of soils have moderately fine textures, including sandy loam, loam, silt loam, sandy clay loam, silty clay loam and clay loam.

The soils are generally having well-developed structures and occasionally weak or very weak structure grades and hence often massifs are encountered. Organic matter at the surface ranges from 0.7-1.5 percent, generally decreasing with depth. Total nitrogen is usually very low, around 0.1 percent and available phosphorus is invariably very low, less than five ppm with occasional values of 5-15 ppm at the surface. Most soils have high content of exchangeable potassium and magnesium. Cation exchange capacity is mostly 15-25meq, but higher values have been recorded, coinciding with high organic matter and high clay content.

2.5.4 Soil forming factors

Soil forming factors show a great variability in Yemen (Yemen-ACSAD, 2002); they include the following:

- The surface and near-surface geological deposits (and parent materials) vary widely in origin, mineral and chemical composition, particle size and weathering resistance.
- The weathering of the soils under the combined and changing influence of India Ocean (including the Gulf of Aden and the Arabian Sea). The Red Sea and the Mediterranean Sea climates show significant spatial and time variability.
- Human interference plays an important role in soil formation processes through deforestation, flood control measures, intensive land use, irrigation and drainage, reclamation, erosion control, mechanization of agricultural production, and so on. In addition to these factors, relief and hydrological conditions also influence soil formation. The soil map of Yemen shows a mosaic pattern of great variability.
- The vegetation as determined by climatic factors, relief and wetting conditions have had various influences on soil formation processes.

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Rain is the only source of all water in the country. The mountains play great role in attracting rainfall and the amount and distribution of rainfall varies with altitude, latitude, and distance from the Red Sea and Gulf of Aden. The highest amount of rain is intercepted by the western mountain chain, reaching 1200 mm around Ibb province. The rainfall decreases with increasing distance from the sea.

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The origin of surface water is the runoff on the mountain slopes. The highland region is characterized as a runoff-producing zone with more or less permeable surface. Surface water is therefore, mainly the runoff from steep mountain slopes forming immediately after heavy rainstorms. Numerous river systems and related catchment areas cover the territory of Yemen. For conceptual and descriptive

purposes, it is useful to group them into larger zones in such a way that the river systems within each zone have their final base level in common. Such zones are indicated here as drainage basins.

Assuming natural flow conditions, the base level of a drainage basin is either the sea or a topographic depression where massive evaporation takes place as the main natural discharge mechanism. It is common practice to name the drainage basin after its particular base level, just as—at lower aggregation level—a catchment area is named after the river towards which it drains. Accordingly, the territory of Yemen can be subdivided into over four drainage basins: a) Red Sea basin, b) Gulf of Aden basin, c) Arabian Sea basin and d) Rub Al-Khali basin.

The boundary between the Gulf of Aden basin and the Arabian Sea basin is somewhat arbitrary, because the limit of the Gulf of Aden has not been accurately defined. It has been opted for in order to optimally highlight hydrological contrasts. The main wadis in Yemen have been selected from Ropertson's topographic map (1991c). Simplifications were made to match the scale of the map, and topography or names were adjusted if it seemed plausible that they were incorrect. Names are shown as far as deemed useful for this summary (78 named wadis); unnamed wadis and tributaries are mainly added to provide a better picture of drainage patterns and catchments areas.

A large number of factors control the runoff process, including, .: a) the size and shape of the catchments; b) the rainfall characteristics (total depth and distribution in space and time); c) the rates of potential evaporation and evapo-transpiration; d) the terrain characteristics of the catchments area (slope; occurrence and properties of soils, rock outcrops and vegetation); e) the presence and properties of regional groundwater systems; and f) the land use and other human interference. Clearly, all other factors remaining constant, larger catchment areas and higher rainfall amounts will result in more runoff (Van der Gun and Abdul Aziz, 1995).

Commonly, total runoff from a given drainage basin or catchment is expressed as a percentage of the average annual rainfall received by that basin or catchment. A coefficient, called 'runoff coefficient', is used for this purpose. In general, runoff coefficient is affected by numerous physical factors, which are distinguished into two groups:factors related to the characteristics of the surface receiving the rainfall; such as topography (slope), composition (rock, soil, etc.), infiltration capacity, density of vegetal coverage, land use patterns, etc., and factors related to the characteristics of rainfall in the area; namely: the time and special distribution of rainfall as well as the intensity and duration of individual rainstorms.

In Yemen, the runoff coefficient is additionally affected by at least two man-induced factors, 1) the extensive terracing of the mountain slopes, and 2) the widespread use of rainfall harvesting techniques which are widely practiced on mountain slopes to meet either domestic or irrigation water needs. Actually, these two factors are inter-related since terracing by itself may be considered a technique of rainfall harvesting.

As a result of the two above factors (i.e., terracing and rainfall harvesting), runoff from water catchments in Yemen is commonly lower (percentage-wide) than that from catchments in other countries which, except for terracing and rainfall harvesting, are otherwise under similar climatic and topographic conditions. Hence, the runoff coefficient for Yemen's catchments is generally in the range of (two to eight percent) compared with around (12 percent) in other countries (Bamatraf and Al-Eriani, 1993).

2.5.2 Groundwater

The hydrological studies, which have been conducted by international and bilateral donor agencies, indicate that the groundwater reservoirs in the highlands are very limited and only several local aquifer basins were found. The aquifers in the highlands are said to be over exploited and the runoff water from the surrounding mountain slopes and return flows from irrigation are the main source of their recharge. The study "Water resources of Yemen" carried out by Van der Gun and Abdul Aziz (1995) contains useful information about the situation of groundwater. According to this study:

"*The occurrence of groundwater, the amount of groundwater stored the flow rates underground, the groundwater levels and their fluctuations, groundwater quality, and the type and location of groundwater discharge phenomena are controlled by a large number of factors. The most important ones are: the type of rock present below the surface, geometry of the different rock units (geological formations), the topography of the land surface, the climatic and hydraulic regimes in the area, vegetation and human activities*."

On the uplifted shield in the west, only the Yemen Volcanics and the Amran group constitute aquifers of considerable lateral extension, but their productivity is generally moderate to low. The best aquifers in the Yemen Mountain Massif regions are the sediments in the basins of highland plains (tectonic features have contributed to the development of these basins). They combine relatively high transmissivities with favorable recharge conditions.

CHAPTER 3:

Agricultural Land Use in Yemen

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Current land use of Yemen very closely reflect the environment factors, while management practices have enveloped to mitigate the harshness of the environment and to maximize the returns from the land at the time conserving resources. It should be noted that Yemen's land Use map has not been produced yet. The land use patterns figures, shown in Table (5) are still estimated and by any mean not evident. Therefore, a land use study has been conducted for the northern part of the country, (King *et.* [illegible], 1984) (Al-Mashreki, 2002).

Land use structure presented in Table 5 illustrates that the country has 1.930 million ha as arable land. King *et. al*. (1984) showed in his study the soiland land use of Yemen for north west of Yemen in a land use map with a scale of 1:50 000 land use map while in southern parts of Yemen there is only a limited scattered data about land use. The country total area of 45.5 million hectares is composed mainly of 30 million hectares of bare rocks, desert and urban land, 21.4 million hectares arid and semi-arid natural rangelands and range forest, two million hectares as marginal land which is cultivated once every three-four years. The range and natural forestland are distributed in western and southern coastal plains high mountain areas and the Eastern region.

The density of the vegetative cover in these rangelands varies with varieties rainfall and with distance from the heavy populated area. The rangelands provide forage and grazing for livestock, catchments for rainwater harvesting, and fire wood and timber source for household (Wen Ting Tiange *et. al.*, 1998). However, more updated data of the total area and its distribution are stated in the next chapter.

3.2 ARABLE VERSUS NON-ARABLE LAND

Cultivated land in Yemen fluctuates from one year to another according to level of precipitation that is unstable in nature. For example, it was about 1.142.000 ha in the year 2000, but rose to 1.200.000 hectares in the year 2001, and lowered to 1.078.000 hectares in 2003. However, this figure varied again according to the latest available sources (GDAS, 2007) and reached 1.452.437 ha.

Table 5: Land use in Yemen

Category	Area (l000ha)	Area (%) of [illegible]	3[illegible]
Total area	55,500	100	–
Range and forest land	21,000	37,9	–
Marginal land	20000	3,0	–
Desert, bare rocks and urban land	30,000	56,1	–
Arable land	1.930	3,5	100
Rainfed cultivated land	1,130	–	58.5
Irrigated land	400	–	20.7
Wells irrigated land	230	–	12
Flood irrigated land	150	–	7.8
Spring irrigated land	20	–	1.0

Source: Compiled from statistical year book, (MAWR, 1997) and League of Arab States and UNEP, ACSAD 1996 and Wen Ting Tiang, *et.* [illegible], (1998).

3.3 PRODUCTION SYSTEMS

Agricultural production systems in Yemen are defined on bases of water resources availability. Accordingly, there exist two production systems in Yemen as follows:

3.3.1 Rainfed farm production system

This is the most important production system in the country as it provides working opportunities and livelihood for more than 50 percent of the population. It covers more than 50 percent of the total cultivated lands (GDAS, 2007). This system include a number of farming sub-system such as the faming sub-system prevailing in low rainfall areas with a cropping pattern composed of Sorghum, Millet and some fodder crops.

On the other hand, this farming sub-system includes plain areas where another number of crops are grown such as barely, wheat and lentil. However, there exists another farming sub-system in medium rainfall areas with a cropping pattern composed of Sorghum and fodder crops. While, the areas of higher rainfall level in the highlands and mountainous terraced areas the cropping pattern is composed of sorghum, maize wheat, barley, Legumes, fruit trees, coffee and qat.

3.3.2 Irrigated farm production system

There are numerous sub-systems under this system described by Al-Kadasi (2004) as follows:

- **Tube-well irrigation sub-system:** This sub-system covers 31percent of the total cultivated land. The cropping pattern prevailing under this sub-system varies according to differences of agro-climatic conditions. In the coastal plans, crops grown include cotton, tobacco, sorghum (kaira'a), vegetables and perennial fruits, coffee, maize, wheat, grape, alfalfa and qat. However, the cropping pattern of the Eastern Plateau is mainly composed of wheat, sorghum, maize, date palm, sesame, fruits, vegetables and alfalfa.
- **Spate irrigation sub-system:** This system covers 10 percent of the total cultivated land. It prevails in the Western Coastal Plan (Tihama), Tuban Delta and Abyan Delta and Ahwar of the southern coastal areas. Cropping pattern of this sub-system includes sorghum, maize, cotton, and sesame, legumes, fodder crops and cucumber.
- **Springs/streams irrigation sub-system:** This sub-system covers two percent of the total cultivated land with a cropping pattern composed of date palm, alfalfa, citrus, few vegetables and coffee.

3.4 AREA, PRODUCTION, AND YIELDS OF MAJOR CROPS

Cereal crops occupy about 56 percent of the total annually cultivated area. As most cereal crops rely on rainfall, areas under these crops vary from one year to another according to rate of rainfall. This area was estimated at about 532 thousand hectares in 2003, reaching 658 thousand hectares in 2001 but jumped to about 891 thousand hectares in 2007 (GDAS, 2007). However, the overall situation of cereal crops in the country is as rightly stated by Muharram (2008) that the average growth rate of area under these crops was 6.13 percent while its production rate does not exceed 1.4 percent (Table 6).

With respect to all vegetable crops, the average area occupied during the same period (2003-2007) was about 72.3 thousand hectares. As these crops rely mainly on irrigation, persistent demand of wider local and regional markets (neighboring states), data in Table 7 reveals a steady though slight gradual increase in vegetables growing.

Table 6: Area (ha) and production (Tonne) of cereal crops (2003 – 2007)

fwo	Item	Year				
		. FFG	. FFU	. FFh	. FFp	. FFt
Sorghum	Area (ha)	295409	428883	429986	453011	520963
	Prod. (tonne)	212780	263428	263691	401843	502304
	Yield (tonne/ha)	72.	61.	61.	89.	96.
Maize	Area (ha)	29982	38468	38504	43301	51961
	Prod. (tonne)	32841	32410	31108	69174	86596
	Yield (tonne/ha)	1.1	84.	81.	1.6	1.7
Millet	Area (ha)	82627	99341	99737	112955	133287
	Prod. (tonne)	40587	66383	66640	82276	98731
	Yield (tonne/ha)	49.	67.	67.	73.	74.
Wheat	Area (ha)	86520	83801	86010	110709	141519
	Prod. (tonne)	103794	103265	112963	149173	218520
	Yield (tonne/ha)	1.2	1.2	1.3	1.4	1.5
Barely	Area (ha)	37755	34998	34515	36985	42903
	Prod. (tonne)	27935	24791	21189	27745	34681
	Yield (tonne/ha)	74.	71.	61.	75.	81.
Total	Area (ha)	532293	685491	688752	756961	890633
	Prod. (tonne)	417937	490277	495591	730211	940822
	Yield (tonne/ha)	79.	72.	72.	97.	1.1

Source: Compiled from statistical year book, (MAI, 2007).

The total area under these crops was 65 thousand hectare in the year 2000, but rose to 72 thousand hectares in the year 2004 and reached 82 thousand hectares in the year 2007 with an average growth rate of 3.4 percent. Table 7 shows area, production and yield of most important vegetable crops in Yemen.

The area under fruit crops was 98 thousand hectare in the year 2003 and lowered to 81 thousand hectares in 2004. But, it rose again to 88 thousand hectares in 2007. However, the total production for fruit crops was constantly growing during the period 2000 – 2007. It has increased from 591 thousand tons in the year 2000 to 923 thousand tons in 2007 with a negative average growth rate in terms of area and about four percent in terms of production (Muharram, 2008). Table 8 shows area, production and yield data of selected important fruit crops in Yemen for the period 2003 – 2007.

The coffee crop was occupying about 33 thousand hectares in 2003 which slightly rose to 34 thousand hectares by the year 2007 with a negligible annual growth rate. Area under sesame and cotton fluctuated during the same period but realized no increase despite a noticeable increase in production and yield/ha which reached about 50 percent in Sesame. However, area, production and yield of some other cash crops such as tobacco and qat have constantly increased over the years during the same period (Table 9).

Table 7: Area (ha) and production (Tonne) of important vegetable crops (2003 – 2007)

?fwo	Item	Year				
		. FFG	. FFU	. FFh	. FFp	. FFt
Tomato	Area (ha)	19078	14909	15059	15610	16934
	Prod. (tonne)	272696	200438	204446	211734	232910
	Yield (tonne/ha)	14.3	13.4	13.6	13.6	13.8
Potato	Area (ha)	17834	16870	17155	17831	19343
	Prod. (tonne)	213324	197958	217759	226366	249005
	Yield (tonne/ha)	12	11.7	12.7	12.7	12.9
Onion	Area (ha)	5652	11909	12284	12354	13402
	Prod. (tonne)	82025	154140	173112	173893	191284
	Yield (tonne/ha)	14.5	13	14.1	14.1	14.3
Cucumber	Area (ha)	995	470	770	817	886
	Prod. (tonne)	15704	7811	10324	13108	14419
	Yield (tonne/ha)	15.8	16.6	13.4	16	16.3
Chili	Area (ha)	2351	3523	2997	3033	3290
	Prod. (tonne)	12998	19143	16810	17088	18789
	Yield (tonne/ha)	5.5	5.4	5.6	5.6	5.7
Okra	Area (ha)	3819	3015	3067	3203	3475
	Prod. (tonne)	22463	17470	17904	18818	20700
	Yield (tonne/ha)	5.9	5.8	5.8	5.9	6
Total	Area (ha)	49729	50696	51332	52848	57330
	Prod. (tonne)	619210	596960	773745	652400	727107
	Yield (tonne/ha)	12.5	11.8	15.1	12.4	12.7

Source: Compiled from statistical year book, (MAI, 2007).

Table 8: Area (ha) and production (Tonne) of important fruit crops (2003 – 2007)

?fwo	Item	Year				
		. FFG	. FFU	. FFh	. FFp	. FFt
Grape	Area (ha)	22870	12016	12424	12544	12920
	Prod. (tonne)	168824	104062	107753	117580	125811
	Yield (tonne/ha)	7.4	8.7	8.7	9.4	9.7
Date Palm	Area (ha)	23601	13739	13773	13774	14181
	Prod. (tonne)	33312	28576	29990	50090	53596
	Yield (tonne/ha)	1.4	2.1	2.2	3.6	3.8
Banana	Area (ha)	11280	8837	9075	9252	9529
	Prod. (tonne)	99010	85555	89905	112495	120370
	Yield (tonne/ha)	8.8	9.7	9.9	12.2	12.6
Mango	Area (ha)	7631	23226	23240	23436	24130
	Prod. (tonne)	116346	348651	341838	345265	369434
	Yield (tonne/ha)	15.3	15	14.7	14.7	15.3
Citrus	Area (ha)	14427	6137	6579	7606	7830
	Prod. (tonne)	166093	70641	83979	101049	108122
	Yield (tonne/ha)	11.5	11.5	12.8	13.3	13.8
Apple	Area (ha)	558	1873	1940	2129	2193
	Prod. (tonne)	3220	10833	11275	18728	20039
	Yield (tonne/ha)	5.8	5.8	5.8	8.8	9.1
Total	Area (ha)	80367	65807	67031	68741	70783
	Prod. (tonne)	586810	648318	664740	745207	797372
	Yield (tonne/ha)	7.3	9.9	9.9	10.8	11.3

Source: Compiled from statistical year book, (MAI, 2007)

Table 9: Area (ha) and production (Tonne) of important cash crops (2003 – 2007)

?fwo	Item	Year				
		. FFG	. FFU	. FFh	. FFp	. FFt
Coffee	Area (ha)	33662	28354	28821	32260	33451
	Prod. (tonne)	11608	10260	11331	17292	18330
	Yield (tonne/ha)	35.	36.	39.	54.	55.
Sesame	Area (ha)	32515	18050	18794	21001	21776
	Prod. (tonne)	18729	19181	19363	21992	23312
	Yield (tonne/ha)	58.	1.1	1	1.1	1.1
Cotton	Area (ha)	28287	17246	17609	17845	18504
	Prod. (tonne)	29091	19536	20573	22002	23322
	Yield (tonne/ha)	1	1.1	1.2	1.2	1.3
Tobacco	Area (ha)	5515	7935	8116	9299	9642
	Prod. (tonne)	11861	17001	17694	20200	21412
	Yield (tonne/ha)	2.2	2.1	2.2	2.2	2.2
Qat	Area (ha)	110873	122844	123933	136138	141163
	Prod. (tonne)	103610	118207	121399	147444	156290
	Yield (tonne/ha)	94.	96.	98.	1.1	1.1
Total	Area (ha)	210852	194429	197273	216543	224536
	Prod. (tonne)	174899	184185	190360	228930	242666
	Yield (tonne/ha)	83.	95.	97.	1.1	1.1

CHAPTER 4:

Land Degradation in Yemen

4.1 MAJOR TYPES OF LAND DEGRADATION IN YEMEN

Desertification covers around 30 million hectares of the land accounting for over 50 percent of total land. The potential for greater desertification is high. The main driving forces for desertification are water erosion, overgrazing and depletion of tree cover, abandonment of terraces and changes in socio-economic factors and farming practices that determine unsustainable practices for land cultivation.

It should be noted that GLASOD methodology was used to prepare the land degradation map of Yemen after making the necessary modifications there so as to make it compatible with the local conditions of the Republic of Yemen. Table 10 shows the pattern of land degradation and the types of land in Yemen at present while land degradation map is presented in Figure 4. However, the following data were extracted from Yemen/AREA– ACSAD (2002).

UN [illegible]

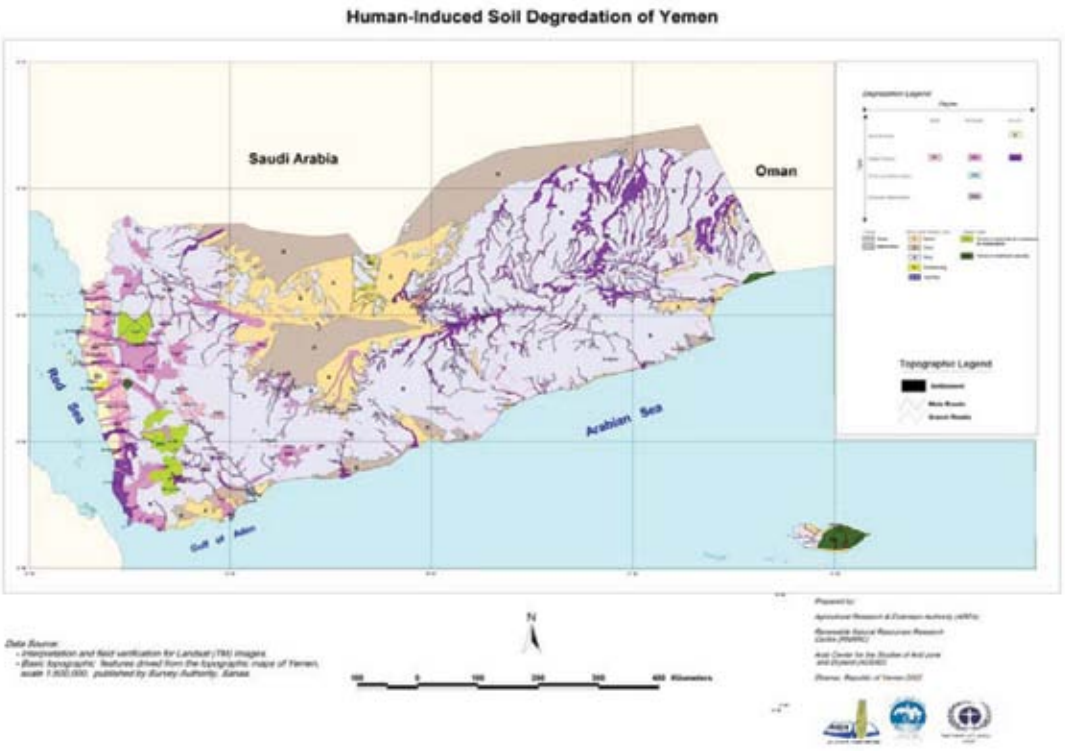
Soil degradation map of Yemen has been prepared following the GLASOD guideline. Preparation of the soil degradation map was based on scale and refinement of the mapping units of land system and soil map of Yemen, together with the correspondence of topographic sheet 1:500,000 scale and processing 16 RS images covering all Yemen

The mapping units were characterized by a great degree of homogeneity of topography, geology, soil, climate, vegetation and land use. All elements of the human-induced soil degradation status were evaluated for each mapping unit by using available information gleaned largely from existing soil survey reports. However, the field survey was carried out in order to confirm the mapping units' degradations (Yemen/AREA – ACSAD, 2002). The legend of the map follows the procedures of the word GLASOD map. However, some modifications have been introduced for Yemen case. It should be noted that four main types of soil degradation can be distinguished including three degradation severity as briefly described below.

Table 10: Different Types of Land Degradation in Yemen

Type of Land Degradation	Area (sq km)	Area (ha)
Desert Land	48,569	4,856,897
Chemical Degradation of land (Saline agriculture land)	371	37,090
Sand dunes	58,159	5,815,937
Land degraded by heavy winds erosion	4,752	475,246
Land degraded by light winds erosion	1,029	102,943
Physically degraded lands	127	12,717
Rocky Land	281,968	28,196,804
Mountainous Terraces	6,615	661,504
Naturally Stable Land (Forests and trees)	2,722	272,154
Land affected by water light erosion	6,440	643,960
Land affected by water medium erosion	18,468	1,846,813
Land degraded by water heavy erosion	25,798	2,579,835
Wet lands (Sabkha)	483	48,346

Source: Yemen/AREA– ACSAD (2002).



Source: Yemen-ACSAD, 2002.

Figure 4: Land degradation map of Yemen (Human-InducedSoil degradation)

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The western and southern parts of Yemen are exposed to considerable water erosion due to the geo-morphological conditions. Most parts of the mountainous and hilly and coastal plain wadis, regions of the country have been suffering from this process. Soil degradation map (Figure 4) shows the water erosion and its severity in different areas of Yemen. The parent material of soil is closely related to soil erodability. In different soils of certain parent material, different forms and types of erosion may occur.

The above mentioned part of Yemen is most vulnerable to water erosion due to its naturally steep and long slopes, high rainfall average (500 - > 1200 mm) and frequent rain storms. Nevertheless, in these regions, degradation has recently become more pronounced and the decline of the vegetation will undoubtedly lead to accelerated soil erosion. Damages to agricultural productivity are not only caused by degrading soil properties but also by direct impact of runoff. Roots and seeds are washed out of the soil. Seeds and seedlings on foot-slopes are buried by the deposited sediment. Rills and gullies tamper access to the fields and impede operations and transport. Deep rills and gullies form drainage system, which drain the adjacent areas and lead to considerable loss of water. Only few small isolated forests and scattered trees still exists. Consequently, soil has been eroded by water action leaving rock outcrops in considerable parts of these mountains.

The alluvial landscape within the coastal plain and desert regions contain numerous wadis, which comprise a major part of the country area. This alluvial system is formed by a complex of slightly convex fans with an overall slope of—four – eight percent downwards. Elevation ranges from 150 m a.s.l. at the upper part of the fans to 40 m a.s.l in the downwards direction. Most of these wadis are affected seasonally by flood damages. Higher alluvial terraces of most wadis, two – three m above present Wadi beds. Erosion level terraces are found in the foot slope/pediment areas and also along the wadis, because they are flooded regularly. It can be concluded that gullies, rills and sheets are the main types of water erosion over these wadies.

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Most of the areas covered by sandy deposits are exposed to wind erosion which is particularly dangerous for cultivated areas (young seedling, crops, tree-nurseries, etc.). The reworked Aeolian sands, especially adjacent to sand plains, also remnant of eroded longitudinal dune are still recognizable. The most striking aspect of Aeolian landscape is the occurrence of longitudinal dunes running along the coastal plains region (west, south and southeast of the country) as well as in the desert areas (east northern and northern parts).

The main natural factors caused wind erosion in Yemen are Strong wind, lack of permanent dense vegetative cover and dry and loose (non-stable) soil surface. The loess of Yemen probably originated in the Rub AL-Khali to the north-east, the direction of the prevailing winds. Many of the loess deposits, particularly in the inter-mountain plains, have been reworked by alluvial processes. This loess deposit occurs also in Tihama coastal plain.

Dunes are found primarily to the northwest, northeast, southeast and along the coastal plain to the west and south of Yemen. Broken and longitudinal dunes occupied these regions, indicating that sand supply is the limiting factor of dune formation. Although mostly bare of vegetation, the lower dunes are partially stabilized by a sparse ground cover. Higher dunes are mostly active and mobile. The dune areas are both depository and a source of wind-blow sand. The areas covered by these dunes are not suitable foragriculture. Some kind of shrubs and dwarf shrubs grows in the inter-dune depression. The intensive sand blowing process leads to the encroaching onto urban areas and their infrastructure. These dunes are elongated sand hills. Further on these bars become incoherent and forma vast dune field. The large number of these shifting dunes has restricted agricultural development. Figure 4 shows land degradation legend types and severity in Yemen.

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The topographic and geological diversity, in addition to the sharp variation in altitude, provides an important diversification in terms of ecosystems and ecological sectors and habitats “ecological niches”. These arm the country with a substantial and huge biological and physical resources wealth. Concerning the natural vegetation cover, various species of trees, shrubs, grasses, forbes and annual plants (many of them are endemic to Yemen) are encountered and constitute a relevant means of flexibility towards climatic fluctuations and, if properly managed, can provide sustainable forage resources during the whole year around.

Unfortunately, misuse, and abuse of all resources is steadily leading to a dramatic situation in terms of physical and biological erosion of most useful resources. However, though this diversity, many negative factors hamper the overall production in country. Most determination factors are:

- A largely deficient water balance resulting from low rainfall (below 100 mm/ year) characterizing over 60 percent of the country’s surface. In the areas where the rainfall averages high amounts (up to 1200 mm), the nature of rainfall (strong storms), the topography and the low quality of capacity soils result into high run-off. Millions of cubic meters run, indeed, during the rainy seasons through narrow wadis. Only part of these huge quantities are more or less domesticated and the majority is lost whether in the sea or in saline depression.
- Throughout the centuries, Yemeni farmers have developed appropriate technologies to domesticate part of run-off water, but limited resources of arable land do not allow the optimal utilization of water resources. In addition, any quantity of captured water increases hydric deficit the rangeland are supposed to receive. Thus, what is gained on one side is lost on the other.
- Poor soil quantity and high temperatures, when added to the scarce vegetation cover, expose the soils to extremely important evaporation.

- High pressure of utilization and misuse induced all kind of biological and physical erosion of all resources. This results into the regression of many species and the expansion of most aggressive invaders usually of low interest to human and animals. Thus, even when appearing dense and green, many of the vegetation groups have in fact limited contribution to the extensive livestock systems industry.
- Due to the apparent forest cutting, there is not a single plantation in the whole country. The only tree growing activities in the country are those done by projects for the purposes of research and wind break. There is also small scale individual tree planting often for shade and amenity.

Now, by observing the markets where such products as firewood, charcoal and poles are sold, one can easily notice that it must take a huge number of trees to supply such demand. Land clearing for agricultural purposes is also claiming huge areas of natural vegetation, sometimes unnecessarily. On the other hand, despite the limited yield mainly caused by the brittle environmental conditions and the harsh climate, the natural vegetation is particularly diversified in species (more than 2800 plants are recorded) and in phenology forms as trees, shrubs, annual forbs and grasses are represented (UNDP — SPSEM, 1998).

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Soil in Yemen is generally low in soil nutrients as well as low in organic matter due to the soil forming factors. Problems of salinization and alkalization are considered as one of soil chemical degradation in Yemen.

4.4.1 Salinization

The studies of salt-affected soils, including their formation and salinization processes, have a long tradition in Yemen. The Yemeni coastal plains by all standards—geological, geomorphological, hydrological and hydrogeological are the lowest part of the Yemeni basins. The annual potential evaporation (> 2400m) exceeds annual precipitation (50 mm). There is a considerable deficit in the water balance during the dry summer months. Under such extreme climatic conditions, the main reasons for extending areas of salt-affected soils include the following factors:

- The closed character of the basin;
- Thick, salty tertiary and quaternary layers in the geological profiles;
- Stagnant and salty groundwater, which can rise rapidly to the surface during;
- Rainy periods.

4.4.2 Secondary salinization and Alkalization

These processes usually occur because of inappropriate irrigation practices. According to surveys carried out in many pilot areas of both highland areas (intermountain plains at elevation ranging between 1600 and 2500 m a.s.l) and wadi deltas at elevation ranging between 50 and 500 m a.s.l., are affected by secondary salinization and alkalization. These areas are considered as high potential irrigated areas. The main causes are not related to the poor quality of irrigation water (it tends to be rather good), but to the following factors:

- The water quality in unlined irrigation canals deteriorates from time to time;
- Seepage from unlined canals and water reservoirs and filtration loss from irrigated fields cause the water table to rise, bringing saline groundwater to the surface.

On these areas, traditional lead drain technology is not applicable for salinity control. The reclamation of soils affected by secondary salinization /alkalization processes is only possible by employing very expensive and complex amelioration techniques. Therefore, the most cost-effective solution for proper salinity-alkalinity control is prevention.

4.4.3 Physical deterioration

The distribution of physical deterioration is quite varied partly due to different perceptions of this type of degradation. Only one subtype (Pk2 crusting and sealing) has been recognized to be mapped on this scale. Other subtypes of physical deterioration were observed in different areas (i.e. Compaction (Pc), soil structure deterioration (Ps) and aridification (Pa) but due to their localized occurrence and scale of study cannot be mapped. In addition, other kinds of land degradation were more important in general.

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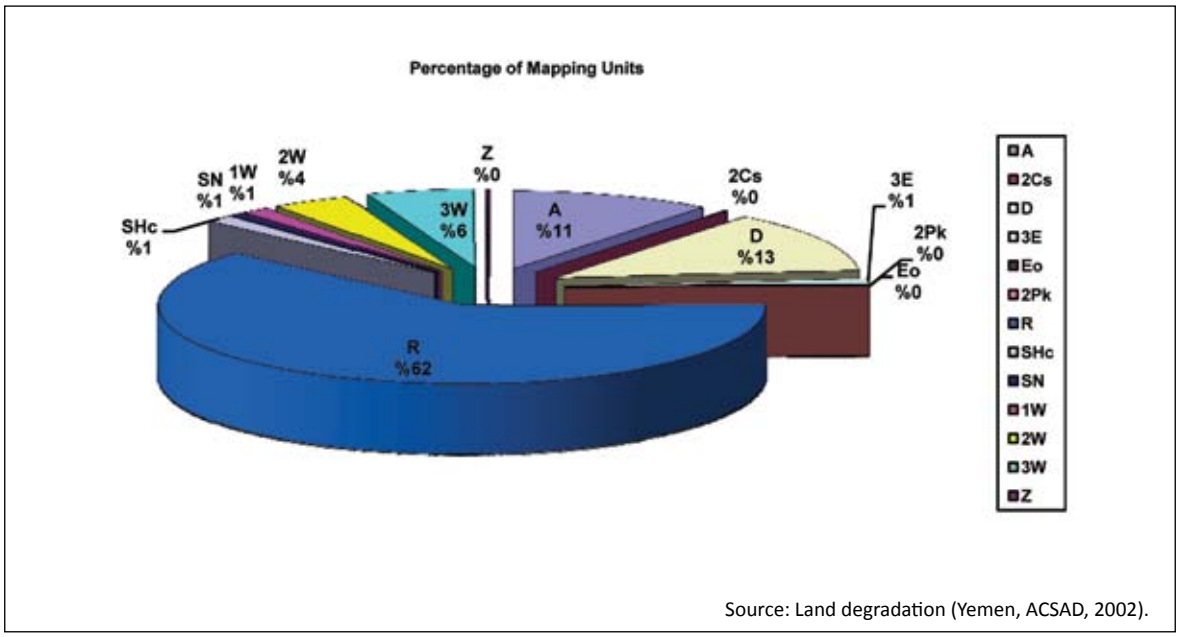
This category includes desert, sand dune, rock out crops and salt flats; it occupies a large part of the country. The different types of this category are shown as separate mapping units on the land degradation map of Yemen (Figure 4). In addition, the estimated area for each one, as well as for the different types of soil degradation, is given in Table 10.

4.5 DESCRIPTION OF THE TYPE OF DEGRADATION MAPPING UNITS

From Figures 4 and 5 and Table 10, the following degradation type mapping units are presented in the human-induced soil degradation type of Yemen.



Source: Land degradation (Yemen, ACSAD, 2002).

Figure 5: Comparison between different degradation types of soils in Yemen

4.5.1 Water erosion

The dominant soil degradation type in Yemen is water erosion. In the degradation map, there are degrees of water erosion(s) referred to as Wl, W2 and W3.

W1: refers to land with slight degradation caused by water erosion. The shallow rills are the major indicators of this degradation; they include deep and shallow soils. In deep soils, the rills are about 20 - 50 m apart, while in shallow soils, the rills are about 50 - 60 m apart. Sheet erosion is also combined with this degradation when it is slight sheet erosion;

W2: Refers to moderate soil degradation by water erosion. It can be noticed that the top layer of the deep soils is a removed rill, but present gullies. The deep moderately gullies 20 - 50 m apart in shallow soils rills are 20 - 50 m apart;

W3: Refers to soil, severely degraded by water erosion; mainly along and nearby the valleys banks. In deep soil, all the topsoils are removed. In areas with shallow soils, bare rocks appear are appeared in the area with shallow soils. Deep gullies are less than 20 m apart.

The total soil degradation by water erosion is 50706.090 km^2. This constitutes about 89.18 percent of the total degraded soil in Yemen.

4.5.2 Wind erosion

The second dominant degradation type of soil of Yemen is wind erosion presented on the map by the symbol (E):

EO: Refers to slight degradation of soils by wind erosion. In deep soils, part of its top was removed, with shallow hollows covering about 10 - 40 percent of the area. In shallow soils, very few shallow hollows (zero - five cm) cover about 10 percent of the affected area.

E3: Over-blowing of sand. It can be noticed as sand encroachment on roads, buildings and sand blasting on vegetation.

The total area degraded by wind erosion is 5781.89 km^2 of total degraded soil in Yemen. This constitutes about 10 percent of the degraded soils.

4.5.3 Chemical degradation:

CS2: Moderate soil degradation is caused by salinity. This symbol was assigned to the soil degradation map of Yemen. It covers an area of 370.896 km^2, which constitutes 0.65 percent of the total degraded soil in Yemen.

4.5.4 Physical degradation

It is mainly a moderately degraded soil by crusting and sealing. Its symbol on the map is ‘PIa’; it covers an area of 127.00 km^2.

4.5.5 Stable terrain

Stable terrain is referred to in mapping units with no sign of present human-induced type of soil degradation; e.g. water or wind erosion, chemical, physical or biological deterioration. All original biotic functions are intact. The land degradation map of Yemen includes two type of stable terrain:

- **Terrain is stabilized as a sequence of conservation (SHc)**: Man has, over centuries, artificially extended the soil cover by construction of terraces. Stonewalls have been constructed on the cultivable slopes between 5 - >30 percent. On slopes less than four percent earth bunds have been made. Land on the terraces is valued more highly by the farmers since each field will normally have water-harvesting rights and even in a year of low rainfall it will normally be possible to obtain a crop. The intensity of terraces depends on the topography and rainfall. The high rainfall areas in the western mountain slopes are very intensively terraced. While in the low rainfed eastern areas, the terraces are built only on the runoff of rain water and wadi banks, with the rest of slopes to be used for rainwater harvesting. Due to the rainfall water harvesting, a given rainfed crops yield more on the terraces than on the plains (AI-Mashreki, 2002). The area of this type is 6615.042 km^2.
- **Terrain is stabilized naturally (SN)**: This terrain is stable under natural conditions; i.e. (near) absence of human influence on soil stability, and largely undisturbed vegetation.

In Yemen, there are no forests in the usual sense of the word, but there are woodlands and scattered trees throughout the country varying in size and density. The majority of the forests in Yemen is composed of—and type of—vegetation such as acacia and euphorbia species with the exception of few species, which grow in the valleys (wadis), and intermountain water ways. This type of vegetation varies with the ecological zones of the country. The significant areas of natural forests are Jabal Bura'a, Houf, Jabal Iraf and Socotra. These unique forests are constantly utilized by the surrounding villages and those which are located inside the forests as a source of firewood and grazing area for goats, sheep and, to a lesser extent, camels.

On top of those domestic animals, the forests are a habitat for a variety of wild animals including insects, amphibians, reptiles, birds and Yemeni mammals who took refuge in these forests after having been forced out of other areas due to human pressure. The forests also ensure orderly water supply for many people who live near or far away from them *(*FAO, 1996). The area of this type is 2721.542 km^2. The total area of the stable terrain is 9336.584 km^2.

Unstable Land

This term refers to the mapping units of terrain, which have reached the status of degradation under natural conditions. This terrain has either lost its vegetative cover, or became non-used wastelands.

- **O** Refers to deserts with different colors and types, its area is 48568.970 km^2;
- **O** Symbolizes active dunes mainly on the coastal areas of Yemen. Its area is about 58159.369 km^2.
- **O** Refers to rock outcrops and mountains and its area is about 281968.036 km^2;

O Refers to the salt flats (Sebkhas) mainly along the coastal area of Yemen and its area is 483.467 km^2. The total area of the non-used lands is 389179.84 km^2 which constitutes 85 percent of the stable area of Yemen.

Table 10 shows the data of each sheet and the degradation area, stable lands and waste land. The map of land degradation is shown in Figure 4 containing all the databases of soil degradation layers (contour, road and settlement).

Unstable Land (LAND DEGRADATION DYNAMICS)

It is essential to assess the effect of time on land degradation because this sheds light on the relation between land and man, and the natural interaction between them; land being a factor of production and man being an individual of the social section that deals with this important natural resource.

The relation between the land and the socio-economic conditions is a closed, circular one which cannot be interrupted. Man, through tampering with land's specific chemical characterization, is inadvertently causing land degradation, and ultimately decreased agricultural productivity.

Continuous exploitation of agricultural land depletes its productive capacity and reduces yield profit. Enriching the land with fertilizers, and using pesticides for pest control, may preserve the quantity and quality of the expected yield or output and therefore increase farmers' income, and ultimately their social conditions.If the previous patterns are projected on the state of land degradation in Yemen, and if the reciprocal effect between the land and the society is studied, some of the negative effects on natural resources, population, economy and environment can emerge as follows:

a) The population pressure on the natural resources, due to population increase at an annual growth rate of three percent;

b) Increased use of the marginal regions in agriculture;

c) Land degradation due to planting slopes and failure to follow scientific bases for planting and preserving the slopes, and due to deforestation;

d) Degradation of pasturelands due to the disequilibria between the grazing capacity and the number of grazing animals;

e) Deterioration of the quality and the quantity of ground water, due to over-exploitation;

f) Recurrent drought cycles during the past three decades, the effects of which concentrated on the land degradation, especially pasturelands and rain-fed lands;

g) Socio-economic studies conducted in Yemen indicate that there is a connection between increased land degradation and planting of traditional crops (DHV, 1985; Aloudi 1996; Al-Hemiary, 1999; Al-Hakimi, 1996 and FAO, 1996). It was noticed that the change from low-income traditional crops to high-economic yield crops has increased the farmer's income and raised his interest in conserving the soil and water and their non-degradation, especially when using modern technologies suitable for the environment;

h) Failure to take into consideration the socio-economic aspects when implementing natural resources conservation programs decreases the success rate of the program's activities. Between 60 and 70 percent of the agricultural holdings are less than five hectares, and 25-40 percent of them are less than 2.5 hectares (DHV, 1985 and MacDonald, 1993). The natural result of this degradation is the ecological degradation in general and the socio-economic regression of the local community leading to higher level of poverty.

- The considerable rural emigration to urban areas in Yemen has further increased. This phenomenon has negative mutual effects on the land and society. Land degradation played a negative role in increasing this phenomenon, which, in turn, had negative repercussions on the natural resources summarized as follows:
  a) Neglecting the lands for many seasons exposed them to over-grazing and tree-cutting, or led to their salinization or deterioration of fertility;
  b) Using the capital obtained from emigrants abroad for building houses on agricultural lands, or for the expanding urban centers as a result of the population pressure has led to the encroachment of buildings on the limited available agricultural lands.
- Much of the mountainous agricultural land in Yemen is terraces which represents a traditional agricultural method in Yemen since 2000 B.C. Such terraces played an important role in the Yemeni agricultural economy and consequently, in the national economy. At present, however, these terraces are not given enough attention.

This gradual transformation took place over the last two decades as a result of the significant increase of labor costs and decrease of the price of traditional crops, which resulted in neglecting the maintenance of terraces and the provision of required services and necessary care. This added to the lands' constant degradation after being abandoned by their owners who immigrated to improve their living conditions. It must be noted that agriculture in Yemen depends basically on the use of labor at the rate of 70 percent and the use of animals at the rate of 24 percent, while the use of agricultural machinery is only at about six percent, (GTZ, 1996).

It is noticed that most social categories which were economically affected by this process are these of poor men and women farmers who live under the poverty line that is increasingly widening in most rural areas throughout the country. Prolonged human activities have had a strong negative impact on the land surface. For example, the main Wadi beds—once covered with dense vegetation of *Salvadora Persica*, *Tamarix spp*, *Typha* sp*,* and *Pluchea - arabica with Palm trees,* have now become seasonal semi-deserts or river beds - filling up only after rainy seasons and remain dry during the rest of the year. The vegetation cover has dramatically changed to the sparse or savanna-likepoor habitatandto arid habitats.

Extreme floods and human activities have also turned the vegetation in many parts into sparse cover with scattered *Acacia spp,* and spiny, or succulant cover, or to sparse dwarf shrubland dominated by halophytic species - such as *Zygophyllum album* or to sand dune shrubland habitat dominated by *Acacia ehrenbergiana* and *Dipterygium glaucum*. Generally, several undegraded wadis with *Salvadora persica,* and *Tamarix aphylla* also give an impression of what the previous climax vegetation might have been like when the climate was wet, before it was replaced by a vegetation association dominated by *Acacia spp., Calotropis procers, Fagonia indica, Tephrosia apollinea, Cymbopogon schoenanthus, Rhazya stricta, Ochradenus baccatus* and others that can survive the present arid climate*.*

Figure 6 represents satellite imageries of Wadi Adem (Hadhramaout) showing Off-road effect from oilwork activities that have generated a high impact on soil and vegetation cover on the plateau of Hadhramaut (Al Khulaidi, 2006) over time. These satellite imageries demonstrated an insignificant off-road impact in 1984 to a very high impact in 2001. Soil cover and the sparse vegetation on the plateau surfaces have been altered by extensive off-road travel. Some damage will remain obvious for decades. The current oil exploration survey methods which incur a high density of trails and cover extensive areas are readily visible from the air. The potential for further damage still exists because of the large number of vehicles and facilities used for exploration.

The degradation processes on mountain slopes or wadis of several areas in Yemen can be noticed. The climax vegetation which may represent the past vegetation was probably dominated by tropical forests dominated by Ficus spp., *Tamarendus indica*, *Trichelia emetica*, (on wadis) or by *Acacia sp., Grewia spp., Commiphora spp. (on slopes).*

Due to human activities and climate change however, the vegetation cover of these slopes and wadis has degraded to a sparse cover with fewscattered species that adapted to the current climate, such as *Jatropha spinosa, Indigofera spinosa, Blepharis ciliaris* andother unpalatable and spiny vegetationtype*.* With continuing human activities and climate change, these habitats will be degraded again to sparse grassland with few plant species, such as*Zygophyllum spp, Depterigium glaucum and Calotropis procera* or to very poor sand dune habitats. A summary of the process of vegetation degradation on mountain slopes is depicted in Figure 7.

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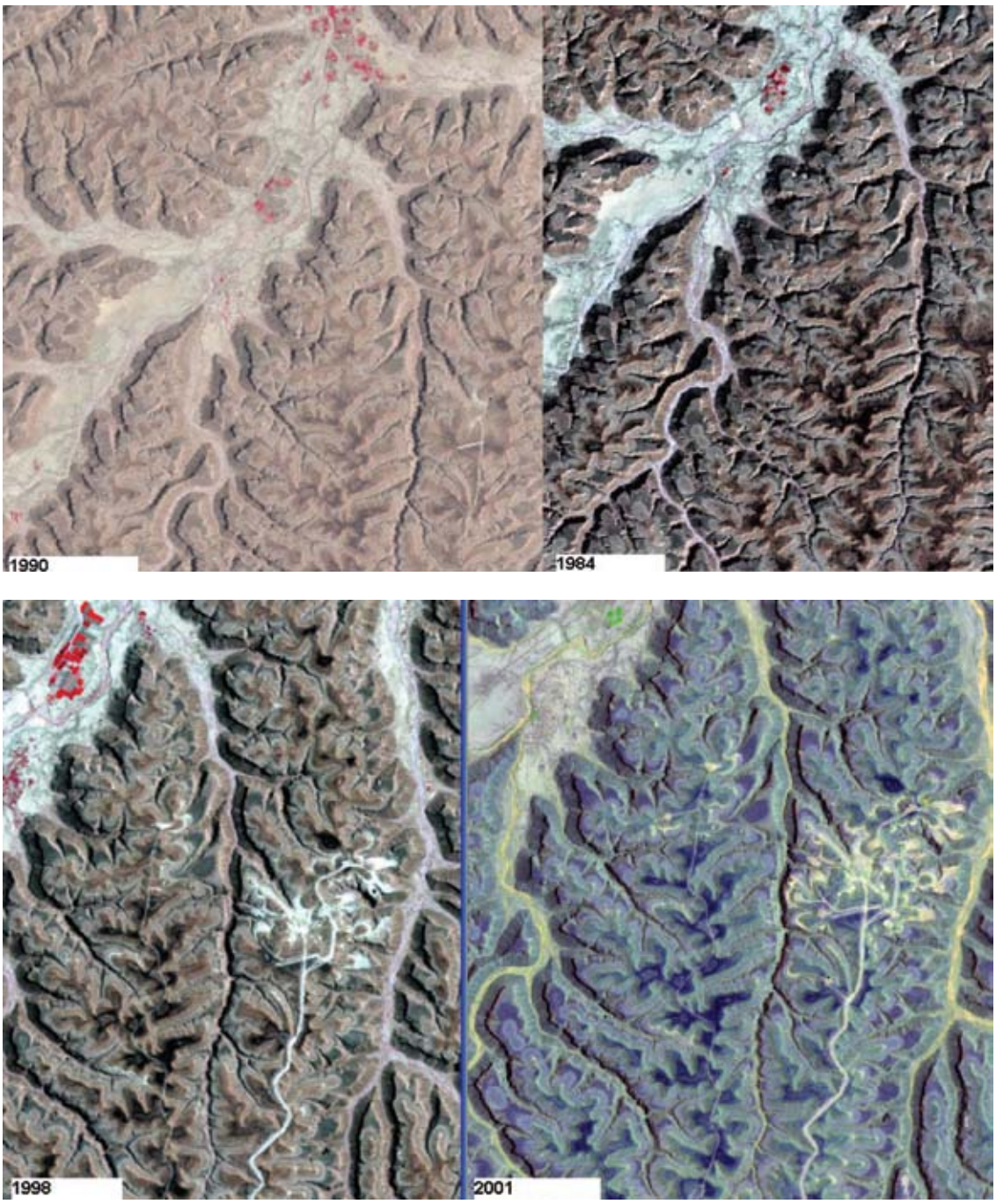
Many of the factors responsible for the loss of vegetation and land degradation in Yemen are related to population growth. Population increase brings further pressure on the land due to increased agricultural production and urban development. For example, many rich vegetation areas near the main cities have been affected by expanding unplanned settlement and urbanization activities; accompanied by soil and watershed degradation, these are considered major threats.



Source: Al Khulaidi, 2006.

Figure 6: Satellite imageries of Wadi Adam (Hadhramout) showing off-road effect of oil activities on soil and vegetation cover overtime (1984, 1990, 1998 and 2001).

Generally, important watersheds with a high hydroelectric value that supply drinking water to cities like Taiz and Ibb, and supply water for agriculture and animal husbandry are under severe threat. Clearing very rich woodlands is another major factor that has led to severe land degraded.

The movement of rural population to urban areas and the disappearance of traditional protected systems of grazing lands have caused major pressure on plant biodiversity. After the Gulf War, more than one million Yemenis working in Saudi Arabia and the other Gulf states were forced to return to Yemen. This created more pressure on the natural vegetation cover and caused major problems. It resulted in intensive cutting and gathering of wood for fuel and charcoal, or in clearing the woodlands

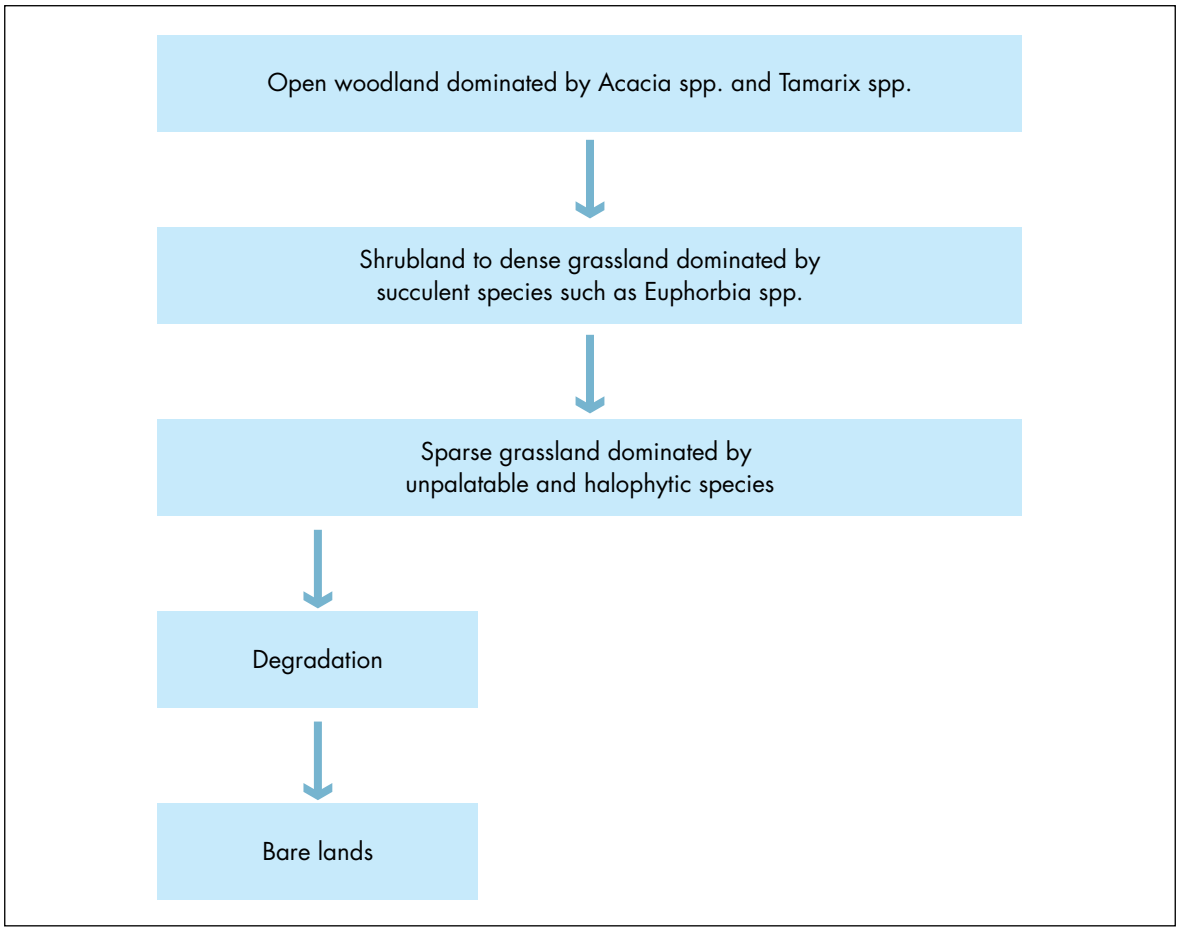


Figure 7: The process of vegetation degradation on mountain slopes

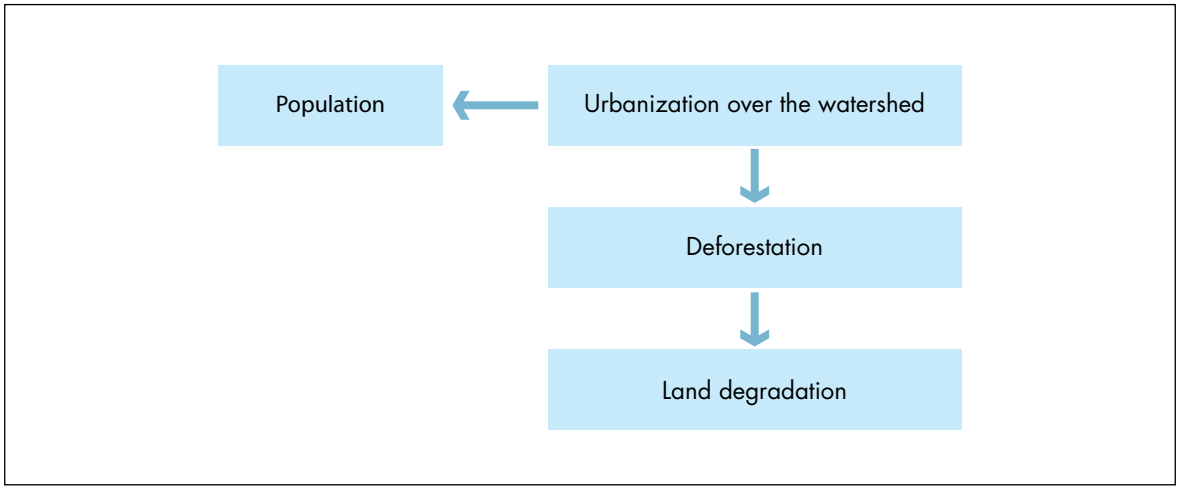


Figure 8: Effect of population increase on land degradation

for agricultural and other similar activities. Generally, the demand for lands, particularly for houses, by urban populations has led to rapid devastation and degradation of the natural vegetation around main cities and other urban centers. Land degradation due to increase population in cities is shown in Figure 8.

Prosopis juliflora (Mesquite) is an invasive species that was observed in many parts of the country such as coastal areas and Hadhramaut region, as well as *Opuntia ficus-indica* which was observed on

mountain slopes of high and moderate altitude areas such as Disufal, J. Sumara and Amran. These species have recently invaded neglected agricultural land, natural vegetation lands and wadi beds in many parts of the country. This can be a result of the increase in modern agricultural activities in recent years. In some locations, these species form a pure stand of woodland and shrubland. Both species are invaders that compete with native species in many parts of the world. As a result, the natural habitats of shrubland or grassland have been transformed to uncultivabledegraded lands dominated by *Prosopis juliflora* or *Opuntia ficus-indica*.

In Wadi Hadhramaut and coastal areas, pseudo-savanna-like vegetation in wadi beds and runnels in several locations has been transformed to Prosopis woodlands due to the encroachment of the invasive tree *Prosopis juliflora*. Pure stands of *Prosopis juliflora* woodlands are common now in the river beds of several wadi beds. For example, many fields are invaded by this tree which forms thickets on marginal lands, sandy, fallow lands and along road sides in many locations along the main wadi Hadhramaut

4.7.1 Overgrazing

Overgrazing by goats, sheep, cattle and camels is one of the principal causes of degradation in the region. Intensive grazing in many areas has led to serious plant damage and soil erosion. The abandonment of traditional rangeland management in such temporarilyprotected areas is leading to serious overgrazing. Overgrazingplays an important role in decreasing wild palatable species.

Several plant species are becoming rare or endangered in their habitats, some of these species are endemic to Yemen. Example species are: *Hyparrhenia papiilipes, Hyparrhenia quarrei, Hyparrhenia variabilis, Taverniera lappacea, Seddera fastigiata, Seddera semhahensis, Neuracanthus aculeatus, Metaporana obtuse, Marsdenia robusta, Justicia takhinensis, Helichrysum nimmoanum, Heliotropium kuriense, Festuca obturbans, Eragrostis curvula, Eragrostis aspera, Croton sulcifructus, Clerodendrum galeatum, Chrysopogon aucheri, Chloris roxburghiana, Chapmannia gracilis, Chapmannia reghidensis, Chapmannia sericea, Chapmannia tinireana, Cephalocroton socotranus, Brachiaria ovalis, Brachiaria brizantha, Brachiaria chusqueoides, Brachiaria comata, Arthraxon micans, Aristida migiurtina* and *Aristida funiculate*.

Overgrazing has also participated in changing the structure of the vegetation from grassland to succulent shrubland dominated by *Euphorbia spp*. (Miller and. Morris, 2004 and Cope, 2007).

4.7.2 Agriculture

The increase of the area under cultivation, mainly qat (Catha edulis) fields, along with the effects of the increasing use of herbicides, pesticides and fertilisers, is becoming a serious problem in many areas, particularly in Ibb and Dhamar governorates. In the past, the migration of rural workers to the rich gulf countries has led to the abandonment of the agricultural terraces in mountain areas, resulting in destruction of these terraces and, as a result, to serious soil erosion on mountain slopes. Clearing of vegetation for palm plantations and other cultivation are obvious in many parts of Yemen (Miller and Morris, 2004, Herzog, 1998).

4.7.3 Fuel wood collecting

Wood and charcoal are the main energy sources in large parts of the country. is The present shortage in bottled gas in many places, particularly in rural areas, may lead to the destruction of the woodland areas. To meet the fuel requirements in many places, the recent Acacia woodland protected areas will soon be destroyed.

4.7.4 Tourism

Tourist development, particularly in Soqotra island, is having an increasingly serious effect on the natural vegetation cover. Most of the associated development was uncontrolled and had little consideration for the environment. For example, roads and hotels were built in most fertile or high biodiversity areas, which has become a major threat for the biodiversity of Soqotra Island. Establishing roads along the very fertile valley forest in Jabal Bura' protected area has caused habitat destruction followed by habitat degradation and fragmentation.

Modifying the springs' habitats in Soqotra Island could lead to the extinction of very restricted endemic species such as *Scaevola socotraensis* and *Erythroxylon socotranum* (Miller and Morris, 2004). The largest local threat to the persistence of the rare species found in the valley forest is the construction of a new road in Wadi Rijaf. All the rare species in the valley forest are either regionally, or critically endangered. The removal of a large area of their habitat for the construction of a new road poses a massive threat to their persistence. Critically endangered species due to this road can include *Stereospermum kunthianum* and *Piliostigma thonningi*i (Hall, 2005)

4.7.5 Other factors

Floods also play an important factor in the destruction of lands. Extreme floods have been recorded in the main wadis of the Hadhramaut governorate (Lewcock, 1987; MacDonald and INTERCONSULT, 1993 and SOGREAH, 1979). Other contributing factors to degradation have been:

Erosion, particulary caused by flooding, plays an important role in the destruction of fertile cultivated fields, especially date palm fields and terraces, and also in changing or destroying the vegetation structure in many areas. It can even cause the disappearance of some individual species that cannot stand the extreme flood characteristic of the main wadis (Al Khulaidi, 2006). This type of degradation is concentrated in productive wadis such as Hadhramaut. Floods also contribute to raising the number of plant species especially the exotic, which may be brought in by floods from other areas, like the example of *Prosopis juliflora.* As a result of severe floods, the woody vegetation dominated by *Ziziphus leucodermis, Acacia ehrenbergiana, Acacia hamulosa, Tamarix nilotica T. aphylla, Salvadora persica* and date palm trees has disappeared or shrunk in coverage and has been replaced by communities more resistant to the severe-floods and disturbances.

Industrial and urban pollution also play an important role in land degradation, but not extnsively. The impact of waste water and contaminated water from small industerial factories and oil companies on vegetation resulted in the disappearence of some specis or created bare lands due to concentration of chemicals.

Oil works: most recently, large parts of eastern Yemen (Hadhramaut region) were affected by oil work activities. These activities have changed the vegetation structure and resulted in pollution and compaction of the soil surface preventing roots from penetrating the soil (Al Khulaidi, 2006). Due to these activities, large areas of the southern plateau of Hadhramaout were eroded and degraded. The roads created by oil work activities have resulted in compaction of the soil surface preventing, thus, plants' roots from penetrating the soil and consequently, increased wind and water erosion.

CHAPTER 5:

Technological options to combat water erosion

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Water erosion has become a major problem throughout Yemen. It is integrally linked with catchment land use and the gradual collapse of the upland terrace systems which represent 455,000 ha in area. This leads to further land development incursions upstream which reduce the vegetative cover and accentuate the consequences on the terraced agriculture and further downstream. This is probably the most dangerous aspect of this form of erosion because it not only affects the areas victim of mismanagement (catchment areas) but also initiates a “domino effect” of aggravated wadi flash floods. This causes destruction of economically and ecologically viable lower terraces and wadi agriculture downstream, ultimately affecting the whole production system and the environment.

Therefore, in order to understand the ecology of Yemen, it is necessary to study the highland terrace system and related wadi spate network. The productive base of this wadi region,a highly populated area, has for centuries been in a delicate and vulnerable state of imbalance. Without maintenance of the terraces, farming systems and water management regimes, virtually all the productive land would naturally revert to a rocky and barren landscape.

Water erosion leads to lowland watercourse erosion due to peak flows. Erosion is integrally linked with catchment land use. Further, land development incursions into upstream sections of escarpment valleys are also occurring. They are subject to erosion due to up slope landslides associated with road cuts and fills and in-efficient man-made drains. Such erosion can have severe consequences not only to resident land holders, but also downstream, through erosion of valley terraces and flood plain lands. The effects on the downstream area lie in the destruction of lower, economically-viable terraces and wadi-bottom land.

In the southern uplands, de-vegetation and abandonment of marginal agricultural lands are resulting in serious watershed degradation. All major wadi systems are much affected by flood erosion, but in the central highland plains, the erosion phenomena can exist along the banks of the wadis entering the plain giving rise to serious branch gullies, which through backward erosion, result in deep gullies rendering the area unfit for cultivation.

The ecosystems of Yemen are deteriorating rapidly due to multiple interacting factors mostly due to socio-economic changes which result in excessive grazing, felling, soil erosion, land degradation and declining biological diversity. As agricultural land use is totally dependent on water availability, the country has limited arable land with fluctuating cultivated land area that ranges from one year to another between 1-1.5 million ha at a cropping intensity of 64 percent. Nearly 60 percent of the labor force is working in agriculture, 40 percent of which are female workers.

Rain-fed farming is practiced on 60 percent of mostly terraced land, which varies between seasons. Arid and semi-arid rangelands and rang forests cover about 43 percent of the country’s land area, comprising the western highlands and eastern rangelands. The productivity and biological diversity of these rangelands is closely correlated with rainfall. This land use class provides catchments area for wadis, forage and grazing for livestock, as well as firewood.

Generally, heavy rain leads to increased flooding on arable land downstream of degraded wood and grassland. Irrigated land is degraded through sedimentation and erosion during occasional flooding. Land under rain-fed cultivation is degraded through soil erosion, deterioration of the physical, chemical and biological properties of the soil, loss of natural vegetation and sand encroachment. Terraces are in many places badly maintained and formerly terraced soil is lost by erosion. Due to the extreme physiographic diversity, typographic variations, differences in slope, and location relative to the Gulf of Aden and the Red Sea, rainfall varies considerably with annual averages ranging from less than 300 mm to more than 1000 mm.

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Farm resources in Yemen are limited and susceptible to severe degradation mainly through soil erosion, desertification, water losses, and pollution of both soil and water resources. In addition to many other underlying reasons, the shift from subsistence to commercial agriculture accelerates the pace at which degradation is taking-place and may prove environmentally devastating. Over the years, awareness among farmers of resource sustainability has noticeably decreased.

Key factors contributing to degradation of land and water resources have been recently analyzed and grouped into three categories, physical, technical, socio-economic and institutional. Although the physical factors cannot be directly modified, they need to be fully understood. They include drought conditions, the rugged terrain of the country and unfavorable hydro-geologic conditions. Technically, resource degradation could be accelerated by:

1. Inappropriate cropping patterns and cultural practices;
2. Vulnerability of many terrace lands to deterioration;
3. Inadequate waste-disposal practices;
4. Inefficient water control and delivery techniques;
5. Poor land-use planning.

Population growth, with its consequent increasing needs and pressures, seems to be the overwhelming social problem that limits resource sustainability. At present, available cultivable land is approximately 0.1 ha per capita. By the second decade of the next century, the population of the country will have doubled, with a consequent increase in pressure on land. Additional constraints on resource sustainability include:

1. Inequitable resource allocation due to inflexible water rights and inappropriate land tenure;
2. Fragmentation of farm holdings;
3. Social influences and/or tribal conflicts in rural areas, in addition to the country's overall economic situation (e.g. inflation, high costs, shortage of funds etc.) which further aggravate the problem.

Weaknesses in institutions dealing with land and water resources exacerbate these problems. The main adverse institutional factors include:

1. Lack of national resource policy;
2. Weak legal framework;
3. Inadequate resource data;
4. Poor, resource-related educational programs;
5. Lack of capability in determining or monitoring proper usage norms.

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Indigenous Technical Knowledge (ITK) is a valuable, but highly underestimated and little-known asset. ITK should constitute a valuable supplement to new technology. Like science, it is based on careful and continuous observation which allows it to provide information not accessible to orthodox researchers. ITK is also based on local field-testing, but it lacks facilities for systematic experimentation. Any innovation that is to serve individual or community development should, whenever feasible, be first based on existing knowledge available locally. In this respect, it is essential to capture farmers' knowledge, experience and proven managerial skills. It is also necessary to conciliate farmers' innovation capacity with scientific on-farm research and experimentation as well as with modern technology. Therefore, the present ITK gaps need to be filled up by research institutions as well as extension and technical services.

5.4 INITIATING PARTICIPATION AND RURAL COMMUNITY PARTNERSHIPS IN LOCAL [illegible]

The importance of participation in effective delivery of local public goods is well recognized, and it is central to community provision of services. While this is increasingly being acknowledged, there remains a major gap in the knowledge of how to bring from the initial stage (identification/ formulation), various donors with different but complementary sector-oriented interests and, together with beneficiaries and grass-root organizations, to combine efforts within a specific zone to satisfy the complementary short, medium and long-term needs of a given group of beneficiaries within a sustainable approach to local development.

[illegible] INFORMATION SYSTEMS

While several institutions are attempting to establish environmental information systems for natural resources conservation and use, they all suffer from lack of expertise and from their inability to combine efforts in establishing a decentralized environmental information system network. Furthermore, the vital ground data which is essential in any information system is not available as most institutions have not developed the capacity to undertake inventories, collect and analyze field data. The General Directorate of Forestry and Deforestation Control (GDFDC) for instance, cannot monitor the changes occurring in its forest resources without being able to assess regularly, through the analysis of field data, the available woody biomass.

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There is a lack of qualitative and quantitative data on the status of natural resources in the country. Consequently, public awareness of environmental degradation and its implications is fragmentary (deficient) and not founded on complete information on ecosystems and land use systems. While people in the primary sector may clearly see the effects of land on the production of crops, animals, etc., neither the gravity of the problems, nor the causes and the processes involved are always well understood. There is still a lack of understanding of the value of biodiversity, even when it is admitted that the situation was better in the past, in terms of biomass production and in terms of number of species present. There is a lack of understanding of how over-exploitation of one species can affect the wellbeing and the productivity of the ecosystem as a whole.

Nevertheless, environmental awareness is growing among the public, thanks, in good part, to the important extension efforts carried out within forestry projects, which target large and specific related groups (mainly rural). This helps farmers to better recognize the negative impact of growing populations and of increased pressure on land and natural resources. They also acknowledge the role of bad management decisions and form a better perception of the limited availability of the resource.

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Yemen's experience with farm resources conservation entails two domains: conservation-based farming practices and soil and water conservation techniques (Bamatraf and Agbary, 1989; AI-Eryani and Bamatraf, 1993). Conservation farming aims at:

1. Reducing water losses from agricultural fields;
2. Decreasing soil erodibility while increasing its in filterability and water holding capacity.

In order to achieve these management objectives, common practices should include: zero tillage, crop selection and rotation, timeliness of cultural practices, manuring, and mulching. In conservation farming, cultural practices have been developed on the basis that water is the main factor limiting

production and aim to reduce water requirements. In this respect, conservation activities could be categorized as being related to crop selection, soil micro-climate control and soil conditioning.

Selecting low-water-demanding crops, in areas of limited water supplies, is a well recognized concept. In the dry land farming of Yemen, crops like sorghum, millet, barley and lentil have been the farmers' choice. Consequently, well defined calendars have been developed for each crop, in conformity with changes in environmental conditions, especially rainfall, to meet crop needs.

The importance of fallowing after cropping has not been clearly realized by farmers. Crop residues, when left to shade the soil surface, reduce soil-water evaporation and increase infiltration to replenish soil moisture. Although very few farmers appear to practice organic mulching to prevent their fields from drying-out, stone mulching in coffee plantations in particular, seems to be common practice.

Minimum tillage is practiced in some rain-fed areas. For instance, sand dune cultivation is a particular soil conservation method aimed at desertification control. An undisturbed, dry-surfaced sand layer serves as mulch within which vapor transfer becomes slow, conserving moisture in subsurface layers. It should be noted, however, that successful sand dune cultivation is totally dependent on both amount and distribution of rainfall. Resource conservation techniques aim at:

1. Maximizing rainfall effectiveness;
2. Diverting and utilizing runoff;
3. Collecting and storing rainwater;
4. Protecting flood endangered land along wadi courses;
5. Providing for water delivery from source to points of utilization.

Common techniques which achieve these management goals include: terracing, spate irrigation, water harvesting, flood breaking, and water distributing and associated organizational aspects. These techniques have been the main task of the Yemeni farmer for many centuries. It was only because of the application of these practices that agriculture (and even human life in some remote areas) still exists under the adverse environmental conditions in almost all regions of Yemen. Evidently, if the mountain slopes were not terraced, farming would have been impossible on these rugged areas.

Centuries ago, even steep mountain slopes were extensively terraced.Terrace-agriculture comprises a considerable portion of the country's agricultural land. Most terraces are of the level or bench type. They effectively protect soil from erosion in steep slopes, where other techniques are difficult, and they increase effective rainfall by reducing runoff.

In order to utilize surface runoff, landscaping and flow control techniques were developed and practiced for many centuries. These techniques are water harvesting and spate diversion. The collection of rain water from fallow land to supplement rain in adjacent cultivated fields is the common rainwater harvesting technique. Land from which water is collected is left uncultivated to reduce the soil intake capacity and increase runoff volume. In a broader sense, spate-irrigated highland-terraces and spate basins in lowland plains could also be considered as water harvesting techniques, as water is collected on one location and allocated for utilization in another.

Traditionally, in flood plains, farmers build earth barrages in the middle of the wadi beds to control and direct flood water through diversion systems onto cultivated land. Modern water diversion in the Tihama region comprises diversion weirs, siphons and networks of distribution canals that convey spate water for irrigation.

Achievement of maximum conservation of water, as it is transported from storage to utilization sites, requires efficient conveyance structures. Apparently, most traditional water control and storage structures have been modified over time but some are assumed to have survived, with only minor modifications, since first constructed. High efficiency irrigation systems were introduced during the last two decades, and many farmers are adopting improved irrigation systems which utilize pipe systems

Table 11: Conceptualization of some conservation objectives & measures

▯ ▯l▯f▯▯wbf▯▯	Objectives	Common techniques
Rainfall	1. To increase rainfall effectiveness	Terraces
	2. To conserve water (and soil)	
Local Runoff	1. To collect water (and soil)	Micro-catchment Muraheq) Cisterns
	2. To store limited quantities of harvested water (also used for domestic use)	
Wadi flow (flood and base-flow)	1. To divert water for irrigation	Earth dykes (spate irrigation and small-head pumps & earth canals (base-flow irrigation)
	2. To protect land against floods (soil erosion control)	Wadi-bank enforcement (not common)
Spring water	1. To deliver water to participants within water rights limits	Earth canals
	2. To store limited quantities of water for short periods (also used for domestic supply)	Cisterns
Ground- water	1. To abstract water from shallow aquifers (also used for domestic supply)	Shallow dug wells and pits

Source: Bamatraf and Aleryani (1993).

for conveying water. Conceptualization of some conservation practices and techniques is given in Table 11.

Most parts of the valleys, mountainous, hilly and coastal plains in western and southern parts of Yemen are subject to a considerable amount of water erosion due to the geomorphologic conditions. Therefore, these valleys are seasonally affected by the damages resulting from floods, and the erosion of the upper alluvial terraces. They also cause water erosion in the terraces of the surface slopes and deposit areas, ridges and sheets according to the prevalent type of water erosion.

The ruins of dams and reservoirs, and the operational ancient water storage and delivery structures as well as the unique mountain terraces, confirm the early history of a wide variety of water harvesting systems in the various agro-ecological zones of the country. Traditional methods of water resources control, storage and delivery include soil erosion prevention, rainwater harvesting, and irrigation and drinking water- delivery structures, some of which have survived for many centuries.

The durability of these structures indicates that advanced procedures had been followed in their design and construction. With their traditional knowledge, the farmers of ancient Yemen must have understood and analyzed data relating to rainfall, runoff, soils and climatic conditions associated with land and water resources management. This indigenous knowledge has neither been well documented nor scientifically analyzed in order to be further utilized for supporting the sustainable development of rain-fed, runoff and spate-irrigated farming. Terraces function as soil and water conservation techniques on sloping land. The process of soil erosion down slope is greatly slowed due to retention and collection of runoff on terraces.

Cisterns and tanks (for runoff storage) of different names, shapes, size and uses are found in all agro-ecological zones. Although most types are still built, there is a lack of records on when or who started them. A case study is the utilization of historical water control structures, such as cisterns in the spring irrigation farming system. About one fifth of interviewed farmers indicated that their water techniques had been functional for several centuries, but half of them were not able to remember the age of the system (Bamatraf, 1994).

According to Abdul Malik (2000) there is a considerable amount of local experiences and knowledge that can be traced in the ancient Yemeni agriculture in relation to conservation of natural resources such as land and water. Some of these local knowledge and experiences include the following:

- **Water Harvesting**: Yemeni farmers possess vast knowledge and experience related to securing their water requirements either through building constructions for the protection of their land from powerful flood flow or through water storage for various use purposes. Yemenis were among the first innovators of water collection, harvesting and water flow reduction techniques and water storage and directing methods for irrigation especially during seasons with little or no rainfall. Some of these methods and techniques include dams, earth dig, tanks, blockades, bands and the like. They gave these structures and techniques, which still exist in many parts of Yemen, different names that differ from one area to another.
- **Land Terracing**: Terraces are built by Yemenis in various mountainous highland areas through construction of land protection walls either using stones (Highlands) or clay (Hadhramout) at a height of 1 – 1.5 meters.
- **Irrigation structures**: There are numerous ancient irrigation systems existing today that vary according to the conditions of different regions where terraces built at tops of mounts to block rainfall water for irrigation and to preserve soil fertility.
- **Flood irrigation structures**: Flood irrigation is one of the oldest irrigation methods used by old Yemenis. It is the process through which flood water is added to agricultural lands. Yemeni farmers introduced innovative methods for irrigation,such Okum consisting of surface tunnel (Ubar in singular or A'abar in plural) using canals.This method is considered as one of the major land irrigation systems in Yemen, especially for lands of moderate slope Valleys. This method enhances the natural features of land, washes the soil and fosters its chemical contents. In general, the traditional water harvesting and storage systems have many positive aspects that enable them to play an essential role in preserving natural resources including soil, water and biodiversity. Some of the positive aspects of these water traditional systems are as follows:
  - Realizing the optimum benefits during the irrigation season based on clear customary norms and traditions (e.g. irrigation priority is granted to certain selected crops to avoid water depletion).
  - Preserving water from loss into the sea and utilizing it according to resources available and capabilities accessible to the people.
  - Ruling norms of irrigation do not allow frequent irrigation of the same land before ensuring that all neighboring land/fields have already been given their share of irrigation.
  - When flowing water quantity is limited, irrigation is given to land less frequently and at a greater period span instead of frequent and closer time span.
  - Allocating available stored water for specific purposes with priority to human consumption followed by animal watering and then other less important purposes to ensure that available water lasts for the longest period possible till the advent of the next rainy season.

- **Protected areas:** Protected areas are those systematically managed and administered to ensure the balance between exploitation and rehabilitation of resources and their further conservation. Protected areas have always played a certain role in preventing land degradation. Protected areas have different classifications, one of which is locally called Mahajer, and mainly used for grazing. This type of protected areas can be divided into the following categories (Kessler, 1988a):
  - **Areas with temporary protection:** These small areas are located around or adjacent to cultivated fields. Most of these areas are located on steep hill slopes, and remain under protection for as long asplanted crops last. There are two reasons for land owners to set up such protected areas:to protect the crop from being grazed, and to reserve forage for animals.

- **Areas with permanent protection:** These privately owned areas consist of hilly or mountainous slopes of variable sizes, closed mainly for common grazing. They are established to: a) avoid serious conflicts between two rival villages which might lead to declaring the area between them as no-man's land; b)the land might have already been declared as no man's land as a result of a dispute over the ownership of the area, c) to be used as personal grazing land and fuelwood reserve; d) to collect the rain from the slope and direct it to fields down the slope (water harvesting).
- **Village areas with temporary protection**: A large part of mountain slopes of villages can be declared a protected areas for a certain period, mostly for about five months (from the start until the end of summer rain period). These areas are mainly used for grazing by the animals of the villages. The former protected areas are mainly common in the Montane plains of Dhamar and surrounding areas. In the north-eastern areas of the country (al Bayd'a governorate), large mountains are used to be declared as protected areas. These areas are commonly owned by surrounding villages or a tribe, and yearly grazed for a limited period of time (mainly in winter). Animals not owned by the tribe are not allowed to graze.

5.8 IMPROVED TECHNOLOGY AND LAND USE OPTIONS

5.8.1 Catchment area

The component of a water harvesting system in which rainwater accumulates and runs off is the catchment area. In most zones catchment surfaces can be either natural or treated, depending on the uses of the harvested water. Traditionally, natural catchments are used to collect runoff for both agricultural and domestic uses. Under this issue, two main points are mentioned. These are: zero tillage farming, and drip irrigation systems (Irrigation Pipes). However, no other technologies could be used in this specified area.

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A storage structure is the component of the water harvesting system that stores the collected runoff for use. Water storage methods vary in shape, size, function, use of water, and even local names.

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These structures are used solely for spate irrigation and may allow for storage. They either consist of earthen barrages or concrete weirs that are built in the middle of the wadi beds to control the flood and direct water through diversion systems onto cultivated fields. Both traditional barrages and modern weirs are constructed in valley plains in all agro-ecological zones.

5.8.4 Flood control and protection options in the catchment area

Theseaim at a reduction in peak flow. They include: a) watershed management through improvement of agricultural practices, reconstruction of terraces, reduction of grazing and reforestation; b) construction of a large number of small dams and reservoirs, and c) construction of spate breakers with bottom outlets of sufficient capacity to allow the passage of small and medium floods.

5.8.5 Flood control and protection options along the wadi bed

These are mainly intended to control the outflow of water from the wadi bed. They include: a) creation of vegetated bank protection and spurs (wadi training); b) construction of earth banks to guide wadi flow; c) construction of gabions; d) construction of revetments and stone masonry walls; e)

construction of submerged vanes.Accordingly, the technical measures for the prevention or reduction of the flood damage can be summarized as follows: retaining walls, spurs, guide walls, submerged vanes, rubble protection, vegetation, watershed management, storage dams, spate breakers, and river training.

5.8.6 Effectiveness of flood protection measures

The following section describes the effectiveness of various types of protection structures, ranging from traditional to modern; with suggested improvements.

- **Traditional:**
  - Bank protection: banks can be protected by dry stone walling especially in small, steeper wadis;
  - Irrigation infrastructure: This can be done through earth ogmas[3] or random masonry protection to the head reaches of irrigation canals;
  - Small spurs: this can be done through brushwood, timber rubble protection.
- **Improved:**
  - construction of bunds;
  - concrete protection of canal intakes;
  - earth soil structures.
- **Modern:**
  - Introduction of gabion mattress;
  - Gabion revetment;
  - Protection of spur ends.

5.8.7 Other Technologies relevant to combating natural resources degradation

Although improved technologies for land use and conservation of natural resources are limited, there are some improved technologies relevant to land conservation, some of which were lately introduced into different parts of the country:

- **Protected farming**: This technology was introduced with the aim of improving farmers' income and preserving available natural resources such as land and water in addition to increasing use efficiency of land area unit. Disseminating 35 plastic greenhouses in different sites in Taiz Province, installed on marginal lands and planted with some vegetable crops "tomato and cucumber", has proven feasible and economically viable. This technology realized a significant difference in cucumber and tomato production of 4630 and 1990 kg respectively from 270 m^2 as compared to that achieved by using traditional technology (open fields) from same area unit. The economic feasibility could be assessed through the following:
  - Utilization of cultivable land throughout the year with preserving land from degradation and negligence;
  - Increase in production as compared to traditional technologies;
  - Rationalization of water use through drip irrigation system technology;
  - Realization of economic revenues with a rate of return equals to 75 percent;
  - Reduction of production cost, especially the cost of irrigation water, by 50 percent.

[3]In Yemen, local farmers traditionally build an earthen bank or "Ogma" of wadi bed material across the low flow channel of the wadi, with the object of diverting the entire low flow channel of lhewadi, with the object of diverting the entire low stage of the spate flow to their fields (Camacho, 2011).

The total cost per season, including capital investment, is 444,370 YR where capital investment reached 306.320 YR and remaining amount represents input costs (AREA-SRRS, 2000). A French assisted project promoting protected agriculture in Taiz reported that the cucumber average production increase achieved by farmers under greenhouse conditions reached 90 percent, while tomato average production realized an increase of 77.1 percent as compared to production of same crops under open fields during the 2006/07 season (ICARDA, 2008).

The same project report comparing net benefit of cucumber production under protected agriculture in different locations in Yemen indicated that it was 18.1, 9.5 and 43.9 percent in Al-mahweet, Yarim (Ibb) and Taiz respectively during the 2001/02 season. While, the same ratio of net benefit to cost reached 124 percent in Taiz during the 2006/07 season (ICARDA, 2008).

In this experience, full technology recommendation package and input were used under supervision of research and extension specialists. Additionally, farmers were trained on greenhouse installation and operation. However, there is a number of factors that might limit the adoption of this technology, most important of which are the following:

  - High prices of greenhouse materials especially house structures and other accessories;
  - High cost of inputs required (fertilizer and pesticides);
  - The destructible nature of the plastic materials used in covering plastic greenhouses (only two to three years of usability);
  - Non-availability of required materials locally;
  - Zero tillage farming;
  - Improved irrigation systems (drip irrigation).

- **Zero tillage farming:** This technology was introduced to Yemen after it was experimented in Sudan. It was funded by the Arab Agency for Agricultural Investment (AAAI). This technology was subjected to four years of field trials in different areas and locations in Taiz and Ibb provinces. It was accompanied by a technology input package (fertilizer, herbicides etc.) aiming at preserving soil fertility and moisture and reducing soil erosion (degradation) as well as lowering cost of land tillage. Results of this program, which is still under implementation, have shown a positive indication in terms of yield per unit area and farmer's acceptance of the technology. There is a number of factors that are expected to limit farmers' adoption of this technology, including:
  - The large size of the machine and its high cost (two Million YR) in addition to its need for a tractor (about eight Million YR);
  - The application of this technology requires that weeds are chemically controlled before and after planting;
  - The use of this technology is restricted to plain land (Kia'an).

- **Drip irrigation systems (Irrigation pipes):** This technology aims at controlling the depletion of reserved underground water used irrationally for irregular and sporadic irrigation purposes (submerging fields). The technology has proven economically feasible with a production difference of 15 – 20 percent as compared to traditional farmers' irrigation practices. It also reduces cost of irrigation by 15 – 30 percent. The application of this technology in the fields of farmers who own tube-well and are provided with improved irrigation system (Plastic Pipes) at a prepaid reduced price, has reduced the irrigation cost by 40 percent, and this percentage would increase by 70 percent with the increase of the size of irrigated land. There is a noticeable acceptance and adoption of these technologies by farmers due to the reduction (incentives/subsidy) in the cost of inputs required for their application.

Table 12: Percentages of water saving resulting from irrigation of some crops using improved irrigation technologies in different areas in Taiz & Ibb provinces

wN	Crop (s)	l	Irrigation lAw	wwvff S tions	Water Qty., Traditional method (m3)	lf Qty., Improved method	Time span ln i irrigations (days)	3n lf a Ki
1	Tomato	Albarakani, Taiz	Surface improved plastic pipes irrigation	31	6120	4622	4	24
2	Chili	Alkhiami, Taiz	Surface improved plastic pipes irrigation	18	3903	3346	7	14
3	Potato	Alkalaebah, Taiz	Drip irrigation	41	5473	3648	3	33
4	Tomato	Alkalaebah, Taiz	Drip irrigation	61	6120	3515	2	43
5	Cucumber	Alazaiz, Taiz	Drip irrigation	30	3900	2664	3	32
6	Wheat	Dhamran, Ibb	Surface improved plastic pipes irrigation	18	6591	5492	6	17
7	Melon	Alsafiah, Taiz	Surface improved plastic pipes irrigation	30	6067	5056	4	17
8	Sorghum	Almakha, Taiz	Surface improved plastic pipes irrigation	17	6489	5408	7	17
9	Onion	Alsafiah, Taiz	Surface improved plastic pipes irrigation	23	6560	5623	5	14
10	Mango	Albarakani, Taiz	Surface improved plastic pipes irrigation	40	18797	15239	9	19
11	Potato	Yarim, Ibb	Drip irrigation	24	6002	3926	5	35

Note: Cost is 17 US$ per meter.
Source: UWSCP (2008).

The factors limiting adoption of these technologies include:

- The high cost per meter (17 US$);
- The water scarcity in some tub-wells;
- Non-availability of low interest loans for farmers;
- The limited farmers' knowledge in irrigation systems management;
- Restricting the selection of farmers only to those who own tube-wells.

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5.9.1 Relative costs of flood protection in wadi bank erosion

Flood protection will involve substantial lengths of bank protection works, capable of withstanding flow velocities of up to five or six meters/second. Recent practice tends to use gabions, but alternatives are also considered below. Although gabions are considered to be an expensive option, they remain

cheaper than other alternatives, unless labor cost has to be absorbed by the farmers themselves. For the purposes of comparison, the cost of the gabion mattress has been taken as 100 percent.

5.9.2 Gabion Mattress

Flexible, embankment-supported; relative cost 100 percent. A gabion mattress laid on a 1:2 slope and provided with a falling apron for scour protection is an effective method of bank protection at a reasonable cost. The price is for a 0.3 m thick mattress.

5.9.3 Gabion wall with falling apron

Flexible, free-standing; relative cost 127 percent. Where it is difficult to excavate a deep foundation the falling apron provides an alternative means of scour protection.

5.9.4 Gabion wall with deep foundation:

Flexible, free-standing; relative cost 145 percent. A free standing wall is safer where there is a possibility of material being scoured out behind a revetment.

5.9.5 Stone pitching

Semi-flexible, embankment-supported; relative cost 121 percent. Stone pitching is the traditional form of bank protection in Yemen, but it has become largely disused. However, competent modern work was observed by experts, and it remains an appropriate method where the skills are available on unpaid basis, since most of the cost is for labor.

5.9.6 Soil Cement Facing:

Rigid, embankment-supported; relative cost 121 percent. Soil cement is a mixture of soil with 10- 15 percent cement, placed in layers, and has been used for wave protection on earth dams. Bags of cement are distributed over a two m wide strip of loose soil then mixed into the soil with a rotovator. After adding water, the mixing is completed, and then the material is compacted to obtain a 150 mm thickness of compacted soil cement. A soil cement facing would be impracticable in a cobble bed, because of the limitations imposed by the rotovating operation, but could be appropriate in a sand bed wadi where stones for filling gabions are not available nearby. A reasonably long length of protection is necessary to achieve efficient use of construction plants.This technique is deemed impracticable as it is only applicable in sand wadi beds. But, if the wadi bed materials is cobble, it is good for filling the gabion to support and protect the embanks of the wadis.

5.9.7 Adoption of available technological options

Results of field experiments on soil and water resources conservation are meager and almost no field research had been carried out prior to 1980. This lack of quantitative data of on-farm rainwater harvesting was an important motivation for the initiation (during 1981-1984) of a study centered on the analysis and evaluation of runoff.

Agriculture in the Amran region, the northern highlands sub-zones, has two major irrigation methods that are rainfall irrigation and sewage (runoff) supplemental irrigation(Eger, 1987). Eight water harvesting systems were differentiated and evaluated by characterizing their components and quantifying collected runoff amounts which could be used for crop production. The study

identified and described five runoff agricultural systems and recommended further activities for the improvement of this unique farming system. No follow-up work has been conducted.

In the central highlands sub-zone, field observations on water harvesting and soil moisture conservation were briefly documented by Berry (1985) of the former Dhamar Agricultural Improvement Center (DAIC). At the experimental farm of the Center, a series of water harvesting fieldtrials were carried out in 1985 with the general aim of developing techniques to improve water use efficiency by the collection and redistribution of rainfall falling within the boundaries of a field (Berry, 1986). The results of these trials showed that there are possibilities for increasing crop (barley) production under dry land conditions by careful water harvesting practices.

This one-season work identified a need for considerable further research especially with regard to: (i) establishing the effect of water harvesting on various dry land crops, (ii) testing different runoff-to-runon area ratios, and (iii) investigating the potential for growing fodder crops on the runoff area and the likely reduction in runoff amount.

Continuity in related research activities has not been sustained until recently, when the national irrigation research program was re-organized by the Agricultural Research Authority (ARA, 1987). Actual research work commenced during 1991-92 in the southern upland subzone (Ghaleb, 1993). The work aimed at utilizing rainwater runoff for sorghum production and concentrated on testing three different runoff-to-runon area ratios. Significant yield variations under the different treatments were not obtained, due to the exceptionally high rainfall during the sorghum growing season in 1992.

Tests on utilizing residual soil moisture and non-atmospheric water (fog and dew) for winter wheat are needed to be researched. Similar experimental work is needed in other agro-ecological zones of the country. For reasons related to crop needs and soil water retention, previous results of experimental work clearly showed that the timing of application of supplemental water is more important than the total diverted amounts. Thus, developing and utilizing stored harvested water for later use (when needed) has important implications on the ability to achieve better results from water harvesting and remains to be investigated.

In this context, work on supplemental irrigation of coffee in the Bani Ismail area of the western highland escarpment sub-zone introduced a cost-effective method of storing runoff for utilization at critical periods of crop water needs (Neuvy, 1993). The on-farm water harvesting system comprises a catchment area and a small-capacity (10–20 m^3) storage facility, from which water can be released by gravity to adjacent plots.

The storage facility is a shallow excavation in the ground with earth embankments, covered and lined by plastic films to control evaporation and seepage losses. The system has been installed at several coffee farms and at the instructional farm of the College of Agriculture, Sana'a University. Preparations are under way for investigating the system's efficacy in improving dry land crop production in the Sana'a Basin and other areas of the western escarpment.

As mentioned earlier, the field of studying adoption and assessing the impact of various modern agricultural technologies and interventions is a relatively new to Yemen. With regard to farm management technologies, some work has been done so far. Those available studies were mainly carried out by Yemeni fellows in the course of fulfilling academic requirements while pursuing their higher education programs in Arab and Foreign universities. However, other adoption and impact assessment studies were part of Agricultural Research and Extension Authority (AREA) research program that were occasionally implemented especially during the near past.

Examples of these studies is Alsharjabi (1990) who studies the information flow and adoption of modern farm technologies—especially high yielding crop varieties with emphasis on wheat varieties – in the Yemeni central highland. The study concluded that 78 percent of interviewed farmers were familiar with new improved varieties and admitted using some of them. But, 82 percent of the interviewed farmers reported to have continued using seeds of the new improved varieties.

The results of the same study indicated that most new technologies took about five years to reach farmers while few, other technologies, particularly those closer to main roads, reached farmers knowledge within shorter time of about 2.5 years. However, only few interviewed farmers were able to state the names of the new improved varieties they were using; instead, the majority of farmers just gave them the Arabic name “Mohassan” which means “Improved” (Alsharjabi, 1990).

Another adoption study was conducted by Aljeraidi (1997) who used the survey method to investigate the adoption of different improved production technologies in Wadi Hadhramout and assessed the adoption level of different technology components. He also aimed at identifying factors leading to higher or lower farmers’ adoption of improved technologies.

The study found discrepancies in the adoption rate of different improved technologies among farmers with noticeable lower adoption of technologies requiring additional expenses on their part. Additionally, the study identified a number of constraints to adoption, as stated by farmers, such as non-availability of required inputs and the higher cost involved with technology use and the unsuitability of some technologies.

For example, some farmer non-adopters have attributed causes of non- adoption of some recommended improved varieties to poor performance of the varieties under conditions of high salinity field soil and its poor competition capability to weeds as compared to locally prevailing varieties. Similarly, with respect to non-adoption of recommenced chemical fertilizer doses and herbicides, farmers stated several reasons such as high prices and the difficulties they are facing in timely securing required inputs for technology application.

In his study, Aljeraidi (1997) found other factors that affect the level of technology adoption by some farmers, including their age and level of education, as well as the effect of land tenure and sharing arrangements on their decision making. He explained that younger farmers, with higher education seem to better accept new technologies, and that farmers who owned their land were more enthusiastic about promoting improved technologies than those who shared land/crops.

Another study (Alwan, 2003) conducted in Wadi Hadhramout revealed that the partial adoption of research recommendations (Technology Package) relating to onion farming has led to an average increase of 13.9 tonne/ha (92 percent) compared to that realized by following farmers own ordinary practices. However, farmers who fully adhered to those recommendations were able to achieve an average increase of 35.2 tonne/ha (216 percent) more than that realized by conventional practices.

In other words, the application of the full improved technology package has led to the realization of a net return higher than that achieved by using traditional practices with a profitability of 86 percent compared to farmers’ practices (the rate of return to cost was 1.8 Yemeni Rials in the case of improved technologies while it was only 0.92 Yemeni Rials in the case of traditional practices).

While the same study (Alwan, 2003) indicated that when farmers partially adopted wheat research production recommendations, the average wheat yield per hectare scored an increase of 47 percent (equals to 0.8 tonne/ha), the average production has jumped to 107 percent (1.9 tonne/ha) as compared to the farmer’s own traditional practices when the farmer adopted the full research technical recommendation package.

In this connection, Alsharjabi and Taha (2000) stated in their study on “Assessing the impact of research technology application at farmers’ fields level” that the increase in yield and an economic net return realized through the use of a number of improved research technologies pertaining to several field crops and other farm management technologies ranged between 30 – 330 percent.

5.10.1 Constraints concerning adoption of flood erosion technologies

- Lack of clear plans for construction and management of dams. At present, dams are constructed on bases of claims made by individual local social personalities as being the case in most areas of existing dams;
- Lack of participation of all beneficiaries of each dam in al1 stages of dam construction (i.e. planning, follow-up and implementation). This creates the feeling of responsibility diffusion especially in relation to the operation and maintenance of the dam following its construction;
- Inappropriate site selection of some dams that causes a number of technical, environmental, social and economic problems;
- Existence of some social problems in some dam areas such as the control over dam management by some influential persons and disputes over water distribution;
- Lack of suitable sites and the cost of construction, compared with the small areas commanded, will prevent the implementation of any such schemes;
- High cost of the flood construction systems that farmers cannot cover;
- Efficiency of dam water transportation and distribution to farmers' fields is low because of using soil canals in most dams studied;
- Lack of data concerning geological and hydrological aspects needed before deciding on the site for dam construction;
- Lack of clear systems for dam management and maintenance after completion of construction;
- Lack of Water Users Associations (WUAs) to ensure optimum operation and periodical maintenance and cleaning of the dams.

5.10.2 Constraints concerning conservation measures by rill and gully erosions

- High prices of conventional construction materials;
- Availability and apporpriate skill level of labor force is lacking;
- Techniques developed are relatively expensive, because they require considerable effort to install and require periodic maintenance;
- Water Harvesting Systems (WHSs) are sometimes not technically sound, properly designed or well-maintained;
- Lack of available funds for constructions with no obligation on the user;
- Limited funds to carry out more research activities on water harvesting techniques;
- Lack of follow up work has been conducted for new WHS by research institutions (AREA);
- Lack of better data base useful in providing valuable information for proper research planning;
- Lack of conservation based farming which introduces and promotes stable systems of land and water use and management;
- Improper cultural and completed socio-economic relations that causes low productivity and inefficient utilization of resources;
- Significant measures in terms of adaptation of innovations have not materialized;
- Introduction of techniques that were too expensive or unfamiliar to the farmers provide discouraging results to beneficiaries;

- Un-completed integrated study prepared prior to project implementation resulted in numerous technical errors in design and installation;
- Size and cost of the WHS were not always within the reach of farmers especially for maintenance;
- Land tenure issues and land fragmentation have often constituted a hindrance to the success of WHS;
- Inappropriate land use planning.

5.10.3 Other constraints to the adoption of soil erosion technologies

- Dissemination activities of most soil erosion technologies are carried out in areas that have not been targeted by research activities previously. Increased research work on these technologies in different areas should be made prior to their dissemination so as to enable farmers to choose among the different technology options or packages that suit their varying conditions;
- Scarcity of hydrological information relating to soil characteristics and classification of land use especially for the purpose of economic investment;
- Limited information about optimum production opportunities through using modern methods and technologies;
- Problems relating to migration from rural areas due to low income associated with agricultural production conditions.

5.11 RESEARCH STRATEGY TO COMBAT WATER EROSION

Research topics of AREA are briefly discussed below. The priorities outlined below are just few examples of the vast field research and methodology development actions that await exploitation because of the magnitude of the soil and environmental degradation problem. These issues need to be researched immediately and in a cost-effective manner. Further, the problem of soil and environmental degradation cut across disciplinary boundaries, and are better addressed by interdisciplinary teams. Therefore, soil scientists should work in close cooperation with agronomists, hydrologists, ecologists, biochemists, GIS socialists, economists, sociologists, and political scientists in developing appropriate methods.

Standardization of methods is very important to assess because of the limited resources available and the urgency with which this information is needed. Cooperation and teamwork approach among disciplines and institutions are needed to address this enormous problem of soil erosion. Priority researchable issues in relation to assessment of soil degradation are those dealing with methods to quantify:

1. Economic impact and sustainability;
2. Environmental quality especially with regards to Carbon dynamics and gaseous, emissions;
3. Critical limits to soil properties in relation to soil quality;
4. Watershed process and ecological approach;
5. Soil restoration by understanding and quantifying soil resilience.

Standardization should be applied to:

1. Productivity and sustainability:Soil degradation severity cannot be evaluated in isolation without relating it to productivity under different land uses and management scenarios;
2. Environmental quality: Effect of soil degradation processes on water and air quality is not known and needs to be quantified. High priority needs to be given to the study of carbon

dynamics and gaseous emissions to soil erosion. The effects of erosion on soil organic carbon (SOC) content at different scales are not known;

3. Soil quality: There is a need to develop and standardize methods of soil quality assessment. The impact of soil degradation on soil quality especially in terms of interactive effects with soil erosion, soil structural decline, and nutrients imbalance etc should be assessed;
4. Critical limits of soil properties and process;
5. Watershed processes;
6. Soil restoration and bioremediation;
7. Ecological approach to soil degradation;
8. Scaling out;
9. Modeling.

In addition, the following points should be considered during the identification of research topics to combat soil degradation:

a) Improving water use efficiency, which could be achieved through the following: 1) Improving and maintaining the existing water conservation systems including terrace and water harvesting techniques; 2) crop improvement including selection for drought resistant and less water requirement; 3) soil management for increasing water holding capacity and soil moisture conservation techniques including mulching, tillage systems and manure application; 4) designing appropriate crop rotations for certain climate conditions; and 5) surveys and inventory of the existing crop rotation systems and studying their effect on WUE;

b) Genetic improvement (drought, pest resistance, yield, quality, earliness);

c) Concentrating on post-harvest technology and crop interaction management, and studying the economic effect on technology packages on reducing production cost;

d) Improving water harvesting techniques to prevent small rocks and sediment from entering the mountain terrace;

e) Increasing the water distribution uniformity and soil moisture management in the terrace;

f) Assisting the farmers with the design and construction of small reservoirs to collect rain water for irrigation during the dry periods;

g) Improving the storage and use of existing reservoirs to prevent water losses;

h) Improving the irrigation conveyance system and drainage channels to avoid water losses, damage of terrace walls and soil degradation;

i) Improving the water application at the terraces by using standard methods of surface irrigation;

j) Assist the farmers with the implementation of modern irrigation system to improve water use efficiency;

k) Adopting farming systems approach especially in the rain-fed agriculture;

l) Improving land management through the development and adaptation of viable land and natural resources management options for sustainable water development.

CHAPTER 6:

Institutional Role and Environment

pNB [illegible]

Numerous institutions in Yemen play an active role in the management of the nation's resources. These include the different line ministries and their specialized agencies and departments, local administrations, universities, NGOs, and the communications media. The system is characterized by the centralization of the management of natural resources at the national level, under the responsibility of the line ministries.

The provision of many environmental services, such as urban water supply, wastewater collection and disposal, and solid waste management is also centralized at the national level. In addition, the Universities of Sana'a and Aden have developed some research and training in the environmental field, even though both institutions are under-staffed and under-equipped. A few recently created environmental NGOs (e.g., Yemeni Society for Environmental Conservation, Yemen Omithological Society among others) contribute to the expansion of public awareness and education on environmental issues.

pN [illegible]

The Ministry of Water and Environment (MWE) was established by the Government in 2003. The Ministry is responsible for Water Resources Management and serves as the focal point for environmental management. The Ministry's mission is to address environmental issues and ensure the sustainable use of Yemen's natural resources by monitoring the implementation of Government policy pertaining to environmental protection and conservation of natural resources. Specifically, the Ministry is responsible for initiating and implementing policies pertaining to environmental protection, pollution control and conservation and sustainable exploitation of natural resources.

The Environmental Protection Authority (EPA) is a body "to do all such things as are necessary to protect, the environment, control pollution and to ensure the health and welfare of persons, animals and the environment in general". The primary function of EPA is to advise the Government through the Minister of Water and Environment, on the formulation of policies relating to good management of environmental resources and development of appropriate environmental legislation.

The Ministry of Planning and International Cooperation (MPIC) is responsible for planning and coordination of all development activities and for resource mobilization. MPIC works in conjunction with the Ministry of Finance. MPIC mobilizes external aid in form of grants and provides the main link between the macro and micro-economic frameworks by ensuring that planned investment programs of the Government are in line with stated national objectives. In addition, it coordinates the preparation of the Public Investment Program and monitors its implementation in line with stated goals for sustainable humandevelopment.

The Ministry of Agriculture and Irrigation is responsible for food security, land and soil conservation, land use planning and irrigation water management and Water Resources Management in conjunction with the MWE.

Ministry of Public Works and Highway is responsible for human settlements, road constructions and urban and peri-urban development.

The Ministry of Tourism is responsible for Wildlife Management and development of tourist infrastructure.

The Ministry of Oil and Minerals is responsible for the oil & gas and mining sectors.

Other Government institutions with responsibilities in the environment sector include: The General Authority of Meteorology for climate analysis; The Agricultural Research and Extension Authority (AREA) for Scientific Researches; Renewable Natural Resources Research Center (RNRRC) for natural resources studies and research (especially in soil and land resources inventories and mapping); National Water Resources Authority for water management; National Water and Sanitation Authority have responsibility for the urban sector; and The General Authority of Rural Water Projects and certain municipalities have responsibility for the rural sector.

Non-Governmental Organizations also play an important role in the management of natural resources and in environmental protection and are expected to participate in the various activities of the sub-programs.

pNG [illegible]

In 1990, immediately after the unification, the Government of Yemen constituted the Environment Protection Council (EPC) by Decree of the Prime Minister 94/1990. The EPC replaced two separate institutions for environmental management that existed in both the former People's Democratic Republic of Yemen (PDRY) and the former Yemen Arab Republic (YAR). A National Council for Environmental Protection of the PDRY was organized in 1984 under the Ministry of Health. A Technical Committee was set up under the Ministry of Fisheries. An Environmental Protection Council was established in YAR in 1987, by decree of the Chairman of the Council of Ministers. In 1992, EPC was expanded with a Technical Secretariat. The tasks and functions of the Secretariat were determined by Decree of the Prime Minister 34/1992. Three Directorates were set up to implement the Secretariat's functions.

Numerous other institutions in Yemen play an active role in the management of the nation's resources. These include the Ministry of Planning and Development, the different line ministries and their specialized agencies and departments, local administration, universities, NGOs, and the communications media. The system is characterized by the centralization of the management of natural resources at the national level, under the responsibility of the line ministries. The provision of many environmental services, such as urban water supply, wastewater collection and disposal, and solid waste management is also centralized at the national level. In addition, the Universities of Sana'a and Aden have developed some research and training in the environmental field, even though both institutions are understaffed and under-equipped. A few recently created environmental NGOs (e.g., Yemeni Society for Environmental Conservation, Yemen Ornithological Society) contribute to the expansion of public awareness and education on environmental issues.

In 2000, EPC was replaced by the Environmental Protection Authority to be the focal point for Environmental Protection, which established its regional offices in some Governorates. Despite the contributions of EPA, line ministries, and other organizations, in the management of Yemen's environment, significant institutional problems remain. Below is an overview of the main issues:

- **Coordination of national efforts:** Among the many agencies with natural resource management responsibilities at the national level, there is fragmentation and lack of coordination. For example, at least four ministries and a number of government agencies share responsibility for water management but do not coordinate their operations. This leads to overlap and duplication of functions. In addition, conflicting sectoral interests undermine the establishment of overall objectives and formulation of policies and strategies for resource management;
- **Coordination of international efforts:** Coordination of the efforts of various international donors in Yemen is another important issue in environmental management. Although donors occasionally meet to coordinate activities, there has been little coordination among the donors and the government of Yemen on joint environmental projects. The Ministry of Planning is initiating efforts to improve government-donor coordination on environmental projects;

- **Management:** Some gaps in management have been identified and certain environmental concerns have never been addressed. For example, there is no agency designated to coastal zone management. There is no Department in the Ministry of Tourism to deal with Eco-tourism. There is no central authority to deal with oil spills. Although spills within the confinement of harbors are the responsibility of the port authorities, there is no budget allocated to control oil pollution;
- **Local administration:** The increasing demands for environmental services associated with the rapid urban growth have not been met by line ministries, due to their limited managerial, institutional, and financial capacities. The role of local administrations in the provision of these services is limited, even though the allocation of key natural resources, such as water, is mostly regulated at the local level through customary law. At present, most municipalities do not have the mandate or resources to provide even basic services such as waste collection and disposal. Recognizing the need for decentralization, the Government is creating greater administrative and financial autonomy for local governments. The proposed Municipality Law is the first step toward achieving this objective. According to this law, local authorities will be able to expand their services through central government transfers and increased local taxation. These reforms are expected to have an immediate impact on the management of the urban environment;
- **Enforcement of existing legislation:** The institutional capacity in Yemen to enforce environmental regulations and ensure compliance with national and international laws lags behind what is anticipated by legislators. In particular, the capacity to implement international treaty obligations is missing. E.g. inability to comply with the Convention on International Trade in Endangered Species (CITES), toxic dumping reporting and port facilities that comply with the International Convention for the Prevention of Pollution from Ships (MARPOL);
- **□ i □i □ □Vf□awbf□□aO** Despite its initial efforts in institutional strengthening and capacity building, the EPC Secretariat still has insufficient resources to fulfill its present mandate. Critical issues include the shortage of professional and managerial staff, the absence of skills in some environmental fields, and insufficient equipment and information resources. Moreover, its limited budget has forced EPC to rely heavily on external technical assistance;
- **Scientific support:** The weakness of scientific capabilities in the domain of environmental sciences is an additional constraint to the work of the environmental administration. Due to the shortage of qualified staff, equipment, and financial support at the Universities of Sana'a and Aden, only little academic research has taken place. Some applied research has been developed by specialized departments in sector ministries, but its findings have not been widely disseminated. Insufficient resource data and the capacity to collect, analyze, store, disseminate, and update those data place additional constraints to effective environmental management.

1n 1997, Renewable Natural Resources Research Centre (RNRRC) was established under the umbrella of AREA. This center is the responsible government agency for all the aspects of soil and land resource inventories and mapping. This center has trained the scientific staff needed for addressing agriculture services, and specifically emphasizing on land resources and environmental aspects. Its present activities and responsibilities in the area of soils/land are to sustain soils/land and water management, monitor soil fertility of agricultural land, make environmental assessments, and create the national soil database. To foster these activities within the RNRRC, the National Information Database of Soil and Water Resources was established in 1997. This centre is now digitizing available soil maps at different scale and is setting up the national database for soil, land and water resources.

6.4 CIVIL SOCIETY ORGANIZATIONS (CSO)

Civil society and the private sector have a vital role to play in conserving the environment as well as degrading the environmental resources. NGOs are among the civil society organizations that play a major role in the Yemeni society. As for the labor unions and syndicates, it is crucial to strengthen

Table 13: A profile of the Yemeni civil society

Item (s)	Yemen	[illegible]
Number of international non-governmental organizations (NGOs), 2000	318	20 519
NGOs per million population, 2000	18	49
Number of formally committed municipalities to Local Agenda 21, 2001	2	98

Source: World Resources Institute (WRI), 2005, "Environmental Institutions and Governance-- Yemen," Earth trends: Environmental Information Portal, http://earthtrends.wri.org.

the role of workers and labor unions through training, enhanced information flow and exchange, and increased participation to realize improved environmental management and sustainability in Yemen. Research institutes play a vital role in addressing environmental and development issues. Their role effectively depends upon a suitable set of technical and legal standards (Table 13).

[illegible]

1. Yemen was associated to two regional projects; The Dune Stabilization and Afforestation Project (DP/RAB/89/034) - 1991 to 1993, aimed to set-up regional sand encroachment control cooperation machinery, based upon a network of national institutions; and The Development of Forest Resources for Environmental Protection and Food Security Project (GCP/REM/052/JPN) -1991 to 1994 aimed to review and evaluate the contribution of forestry to food security and environmental protection. This project was to generate a continuing program of information exchange through the establishment of an appropriate network that would help increase public awareness and manpower capabilities;
2. Strengthening Environmental Planning and Management Capabilities Project (YEM/91/004/G/01/99). This project, implemented by EPC in two phases from 1992 to 1997 was to integrate economic and ecological considerations into development planning through strengthening the environmental planning/management capacities of the Republic of Yemen and implementing some NEAP recommendations;
3. Forestry Development Project (GCP/YEM/015/SWI). Implemented in four phases (1985-1997). This Swiss financed and FAO executed (FDP) Project has been the major forestry Project in Yemen. FDP played a key role in supporting institutional capacity building and in upgrading the Forestry Department of the (GDFDC) and in strengthening and promoting forestry programs as well as establishing pilot areas. These pilot areas were established to promote better techniques/methods involving afforestation, desertification control, agro-forestry, and natural forest management. FDP was successful in establishing a forestry extension department and introducing the participatory approach in Yemen. The project was finally instrumental in setting-up an information and data collection system to assist the GDFDC in contributing to policy development and to the formulation of plans, techniques and approaches in natural resources conservation and management;
4. Land and Water Conservation Project (UTF/YEM/022-023-024). Meant to implement between 1993 and 2000 a national program for natural resource conservation, the (LWCP) addresses the issues of land and water conservation by improving irrigation management, setting standards for water and soil conservation, and developing a program for sustainable watershed and natural forest management as well as for fuel-wood production. Organized into three main components (training, forestry and water), the project supports the on-going water resources planning and monitoring activities, including the control and regulation of water exploitation in the agricultural sector. Its forestry component is meant to support agricultural production, protect land from erosion (pilot watershed management sites), and strengthen the capacities of the GDFDC;

5. Environment Resources Assessment for Rural Land Use Planning (GCP/YEM/021/NET). Funded by the Netherlands and implemented from 1994 to 1999 with the technical assistance of FAO, this project supported MAI/AREA in carrying out proper land resource studies and land use planning for agricultural development. FAO is providing technical assistance in the field, computer operations, and soil laboratory and cartographic facility operations;

6. Urban and Peri-Urban Forestry in Yemen (TCP/YEM/4554). This FAO-TCP executed between 1995-1997, aimed at the reuse of treated wastewater for forest/fodder tree planting in four cities (Sana›a, Dhamar, Hodeidah, and Aden). It established demonstration plots, for watershed management, wastewater irrigated peri-urban tree planting, schoolyard tree planting, farm windbreaks, forest nursery establishment, in addition to, training provided to forestry staff;

7. Environment Protection Project in Tihama (1996-2002). Funded by IFAD and implemented by the Tihama Development Authority (TDA), this project aims at achieving a sustainable increase in agricultural production, introducing land conservation measures to control sand dune movement and encroachment, improving irrigation efficiency, supporting women's basic education needs, improving household incomes, and strengthening of TDA;

8. Sustainable Environmental Management Program. This UNDP-government cost-sharing program (1997-2000) aims at building the capacity of government and research institutions, NGOs local communities etc. in the fields of environmental protection, land degradation and desertification control, habitat and biodiversity to ensure the sustainable use of Yemen's natural resources. The program consists of seven sub-programs among which those relative to the National Action Plan to Combat Desertification and the National Environmental Protection Action Plan bear high priority;

9. Sustainable Water Resources Management Program (1997-2001). To overcome the confusion that prevailed in the water resources sector prior to 1996, the National Water Resources Authority (NWRA) was created, through a merger of four governmental departments, to be the sole national institution responsible of water resources planning, policy making, development, and management. Upon its creation, NWRA was lacking the capacity to achieve its mandate; hence the private sector developmenton Sustainable Water Resources Management, whose primary aim is institutional building and capacity strengthening of NWRA and, to a certain extent, NWSA, MAI and GAREWS (General Authority for Water Supply Projects) as end users of water resources. The Ministry of Agriculture and Irrigation is responsible for the implementation of the sub-program «Agriculture Water Use and Conservation». The components of the sub-program and its objectives are to develop the capacities of the General Directorate of Irrigation (GDI), the Agricultural Research and Extension Authority (AREA) and the General Directorate of Forestry and Desertification Control (GDFDC). Achievements to date consist of the following: i) development of a National Water Strategy (passed in the council of government); ii) elaboration of a Water Irrigation Policy; iii) elaboration of the Taiz Water Resources Master Plan; iv) training a large number of staff; v) establishment of Taiz and Aden branches of NWRA; vi) establishment of an hydrometric monitoring system; vii) establishment of a hydrological database in NWRA; viii) production of reports on technical issues and of public awareness materials;

10. Support to Yemen National Poverty Alleviation Program 41 (YEM/97/300). Building on its first Five-Year Development Plan, the Government Of Yemen has decided to launch an ambitious five-year National Program Framework for Poverty Alleviation articulated around initiatives in social development, agricultural development, social infrastructure development, and industrial development. The main objectives of UNDP's support of the above mentioned program framework, to be pursued through sector development are to: i) assist in formulating a national policy framework on poverty alleviation and also establishing a national entity to manage it. ii) enhance efforts to streamline the government›s institutional network and reinforce its capacity in the areas of labor policy formulation and data management; iii) promote the socio-economic integration of the poor, especially rural women; and iv) support the Government to redirect development activities to the regions by assisting Regional Authorities in developing their planning and implementing capacity;

11. Watershed Management and Wastewater Reuse in Pre-Urban Areas in Yemen-WWPU (GCP/YEM/026/NET). Funded by the Government of the Netherlands and the Government of Yemen and implemented with the assistance of FAO, the WWPU project (1998-2002) aims at assisting the Yemeni government and people in their search for grassroots sustainable development. The intended watershed management, wastewater re-uses as well as the agro-sylvo-pastoral management and development packages/interventions provided for optimal natural resources use, income generation and environmental stability. The project had a positive impact on food security because various mini-projects that have been, or are in the process of being initiated, resulting in income generation for the beneficiaries. In the long run, the benefits accrued from afforestation, watershed management, wastewater re-use, and rangeland management helped in improving the food security situation, environmental and ecological balance, and community organization;
12. Afforestation and erosion control projects in Manakha/Haraz. In May 1981 a pilot project was initiated jointly funded by the government of the federal Republic of Germany and the YAR concerning erosion control in the Haraz region. This project culminated in a comprehensive four year program. The project pursued three main objectives:
    - Preparation of data for sustained and practicable erosion prevention measurements in the Haraz region;
    - Reduction of progressive erosion in unused terraces through erosion prevention measures particularly by means of afforestation and agro-forestry activities of the rural population;
    - Establishment and operation of a nursery for forest and fruit trees.
13. British-Yemen Forestry Research and Development Program: started in the early 1980s, and was carried out from the Dhamar and Taiz offices of the agriculture research authority (ARA). Two British forestry experts have been seconded to the ARA. Agricultural and forestry research in the YAR commenced in the 1970›s with FAO supporting three agricultural projects. In 1973, a research station and training projects was established for Taiz and Ibb provinces. In 1983, the government established the agricultural research authority as a semi-autonomous organization within the former Ministry of Agriculture and Fisheries. ARA›s third five year plan for agricultural research identified a number of research programs focusing on soil and water conservation to protect soil from erosion and desertification; these identified research priorities have been implemented under the British-Yemen forestry research and development project and consist of five main areas of activities:
    - Ecosystems studies;
    - Genetic resources studies;
    - Species and provenance evaluation studies;
    - Farm forestry studies;
    - Watershed protection and sand dune stabilization studies.

    A number of these sub-programs are executed in close cooperation with FAO.
14. Introduction of appropriate irrigation systems and technology in the Sana'a governorate: This UNDP=funded project (YEM/87/001) focuses on effective use of rainwater through five model state farms and 45 private farms. No serious erosion problems, however, are encountered in the Sana'a governorate;
15. Assistance to the technical secretariat of the High Water Council Project (HWC). Since 1988 the UNDP has been supporting the technical secretariat (TS) of the HWC in order to facilitate their role in the coordination, monitoring and control of all water-related activities on the national level. The TS is mandated to initiate studies concerning water resources and their management requirement. The data compilation facilitated the preparation of a water resources master plan. The following studies have been completed or are in progress which bears relevance to erosion control measures:
    - Inventory of all existing hydrological surface monitoring networks;

- Inventory of surface water resources and structures;
- The final report examined existing trends of water use, rain-fed agriculture and culminated in regional water management strategies.

16. Central Highlands Agricultural Development Project. The key objective of the project was to increase income level of farmers through production and productivity increase. The project consists of the establishment of an extension service; construction of 15 rural water supply schemes and studies for a second phase. The project covers an area of 816400 ha. It benefited 45000 people.The project area covers parts of the government of Dhamar and Sana'a in a region collectively known as the Central Highlands. It covers five western districts of the Sana'a governorate and the four southwestern district of Dhamar and the upper part of the catchment areas of the wadis Surdud, Siham and Rima. These districts comprise the inter-mountain areas (above 2000 m); the intermediate region or escarpments constituting the upper catchments of the rivers systems draining to the west (elevation range 1300 to 2000 m); and the wadis on the floors of the intermediate zone valleys with an elevation decreasing from 1300 to 1000 m.

    The project carried out research programs in the districts where severe soil erosion problems are suffered the most. It was hoped that during phase II of the project these districts will be included. As part of phase I, research project on land and water resources was carried out, the results of which were published in September 1989. The scope of the reconnaissance study on land and water resources were among others to evaluate the present status of agriculture in the areas of operation of the Central Highlands Agricultural Development Project. This component of the project generated detailed land-use maps (1:50000) for the entries region. In addition, the study presented recommendations for the development of this sector, which could be incorporated in phase II of the program. The study identified watershed development for improving rainfed farming as a priority. A watershed development plan was called for to:

    - Identify and delineate various watersheds;
    - Prepare a detailed resource inventory;
    - Identify watershed problems;
    - Assess available technology to solve the problems identified;
    - Prepare a master plan for mapping out land and water management practices, crop-plans, and animal husbandry practices for different land utilization types found in the watershed.

17. Water resources assessment project. The Yemen Ministry of Oil And Mineral Resources is co-operating since 1982 with the Dutch Resources Institute TNO (Institute of Applied Geo-science) in the Project Water Resources Assessment in Yemen Arab Republic. During the first phase of the project, funded through Dutch aid, all available hydrological and hydro-geological information on the former YAR were compiled and regional water resources assessment studies were carried out for Sadda'h and Wadi Surdud. During phases II and III, a hydrological monitoring network was established in Sadda'h and Wadi Surdud. Investigations into erosion problems were not part of these studies, even though during the phase III of the Wadi Dana / Marib dam sedimentation transport was measured. During phase III a pilot study on water resources management for the Wadi Surdud region was carried out. The objectives of the pilot study were:

    - To provide and evaluate promising strategies for water resources development, use and management in the Wadi Surdud area, as a significant contribution to a regional water resources management plan;
    - To develop methodologies that may enable a comprehensive rate resources management plan for the entire Tihama region.

A number of phases are identified in the project execution:

- Inception phase with elements that include: review of water resources information; preliminary analysis of problems and measures; defining water resources management issues to be considered; identification of planning objectives, constrains and criteria; and specification of the analytical approach;
- Data compilation phase, with the following elements: analysis of the macro-economic and institutional setting; analysis of water use and other water-related activities; analysis of the natural and man-made elements of the water resources;
- Systems analyses phase in which all results generated during the previous phases are integrated.

During the present phase IV, a pilot study on water resources management was executed for the Wadi Dana and Marib Lake. This comprehensive study entailed socio-economic studies, analyses of the institutional setting, remote sensing study as well as research into the sediment load;

18. Rada Integrated Rural Development Project (RIRDP). Since 1987, as part of the road section activities, the land and water conservation subsection has been operateing as a small unit within RIRDP to advice on land and water conservation works. All 16 Local Councils for Co-Operative Development (LCCD) within the province could submit appropriate land and water schemes for implementations. Work of this project was funded through Dutch Aid; it focuses mainly on construction of weirs, temporary cross-dams; guide bunds and bank protection; and medium-sized land conservation dams. In addition, some support has been given to the construction and maintenance of terraces in view of their capacities to control erosion;
19. Range and Livestock Improvement Project. As part of this program, in 1985 an ecological rangeland inventory has been carried out as a first step for a comprehensive land evaluation program. The program funded through Dutch Aid has terminated;
20. Al-Mahwet Integrated Rural Development Project. This project, funded by the federal Republic of Germany, covers the entire Al-Mahwet governorate. The project started in 1985 and focuses on supporting agricultural and extension services and water supply projects. Another component of the program is the establishment of a regional water resources master plan. The project aims, among others, to halt further fragmentation of land building; a process which could ultimately lead to the abandonment of the land and deterioration and collapse of terraces with subsequent erosion problems. Fragmentation of holdings is often caused by traditional inheritance processes; therefore the Al-Mahwet project seeks to identify alternative job opportunities for family members claiming land as beneficiaries of inheritance. Due to road construction works in the Al-Mahwet governorate some erosion is taking place on steep unprotected road-banks, as a result of regressive erosion processes. The project is assisting a number of farmers with reconstructing terraces affected by road construction development. Funds from both the Yemeni and German side are made available to individual farmers. At a minor scale, the project is financing soil and water conservation measures through afforestation, construction of gabions and rehabilitation of water storage tanks on steep slopes;
21. Terrace Control Project. In 1967 and 1968 a project was executed with funding from USAID which sought to halt terrace degradation. The mission was unable to obtain further details concerning the location, scale of environmental problems and objectives for the project from both the USAID office and the DG planning of the MAW;
22. National Plan of Action to combat desertification. In 1987, a joint mission by the United Nations Economic and Social Commission for West Asia (UNESCWA) and United Nations Environment Program (UNEP), studied desertification problems in Yemen and formulated a national plan of actions to combat desertification (UNESCWA and FAO 1988). The nation-wide plan identified twenty priority programs for the short-term. The majority of these programs comprise sand-dune institutional strengthening projects. The document lists one program focusing on resources conservation and watershed management. A pilot study, the

Wadi Manashiyah watershed management project, could ultimately lead to a nation-wide program to control resources degradation. The objectives of this US 6.15 million project, among others, were to:

- Initiate an afforestation program of the denuded rangelands;
- Increase cereal and forage production through appropriate agronomic measures to halt further abandonment of marginal terraced lands owing to the out-migration of farmers. From the discussion held with FAO official, it was not clear why the project was shelved.

23. Wdi Sharis highlands pilot watershed rehabilitation. As part of the activities of the Sana'a, Sadda'h and Hajjah agricultural and rural development authority, a project has been proposed by the United Nations Development Program (UNDP) for the Hajjah governorate aiming at integrated watershed management and leading to the protection and conservation of mountainous watersheds. Within this project, which is scheduled to last for four years, an action plan for watershed rehabilitation was elaborated for two sub-catchments (Wadi Masraf and Wadi Ashugah).The proposed pilot watershed rehabilitation project seeks to adopt an overall strategy that addresses the various ecological and socio-economic elements of watershed conservation as an integrated, multi-sectoral package, and fully recognizing the interactions on the various resources. The areas were selected on basis of the reported considerable damage to the arable land during the 1988 floods. Since 1970s, the river bed of wadi Sharis has extended as a result of torrential floods. These floods also washed away the gallery forest and the affordable credit the bank in Sana'a used to provide to farmers for building protection banks along the river bed.Both wadis feature a number of ecological problems such as high surface run-off, severe erosion, terrace degradation and low overall agricultural productivity. The project has good demonstration opportunities, not only for the district and region, but also for national level decision makers as the areas chosen was easily accessible from Sana'a. Projected interventions for watershed rehabilitation are:
    - Afforestation on unused or abandoned terraced land;
    - Afforestation of land not suitable for cultivation;
    - Rock-wall stream bank terrace construction;
    - Gully control.

24. NORADEP (Northern Regional Agricultural Development Project). In its effort to support agricultural development, the government, with external support from the World Bank and UNDP, has initiated the Northern Regional Development Project(YEM/87/015). The main objective of this technical assistance program was the establishment of a water development plan for this region through input-intensive engineering technologies. Such a plan should be produced for each catchment area and should address erosion problems. During the inception phase, a review of previous studies dealing with soil erosion and identify affected areas within the NORADEP area of operation was made;
25. The High Water Council. As part of the tasks assigned to the HWC's technical secretariat the preparation of a water resources master plan addressed water resources allocation and management issues. It also detailed the water requirements for each governorate and sector and focus on water management needs for terraced agricultural practices. In preparation for this water master plan, a two month environmental study was implemented to identify and prioritize the environmental protection issues which the HWC should directly deal with. The consultants looked into sedimentation problems and required to suggest mitigating action including basic legislation needs;
26. Central Highlands Agricultural Development Project. The project included among others, devising a watershed development plan for watersheds facing criteria erosion problems;
27. National Agricultural Sectors Management Project. This project, which started in July 1991, as a three-year program providing support for institutional strengthening of MAW. The program addressed soil erosion problems as the project focused on improving and developing forestry and land use;

28. Community-based environmental program to reverse the processes of deforestation, terrace collapse, wadi flood and desertification. In 1990, a UNDP grant program was executed by the arid lands initiative. The program was a follow-u activity to the documentary the hanging gardens of Arabia, produced by the arid lands initiative. The main purpose of the program was to identify and plan a community-based environmental initiative to arrest or reverse the related processes of deforestation, terrace degradation, abandonment of small-holdings, wadi flood damage and desertification. The main output was a detailed proposal for halting further environmental degradation.

pNb [illegible]

Yemen has international environmental law obligations that are directly related to its national environmental planning activities; they concern both the marine and terrestrial habitats. By themselves, international conventions have little direct impact on environmental conditions in any given country. In most cases international law is implemented through domestic legislation and environmental actions.

Different scenarios may occur depending on each particular case. Firstly, the international agreement may already be covered by similar national laws, and no particular action is required to comply with the international agreement. Secondly, the implementation of international law may be in line with national legislation but may call for additional monitoring or regular reporting to an international agency. Thirdly, international agreements may require new or substantially changed national laws and new compliance measures. All conventions are listed in Table 14.

It appears that, in Yemen, the capacities of national agencies to deal with the technical complexities and reporting requirements of international agreements are underestimated.

pNl [illegible]

There are a number of public agencies and development projects that are concerned with combating land degradation. The most important ones are:

a) The Environmental Protection Authority (EPA) which was founded in 2005 as a substitution to the former Environmental Protection Council (EPC) to develop and propose general policies to protect the environment, formulate national legislations and regulations, set-up national environmental standards, coordinate and monitor national, regional and international efforts in environmental protection and promote environmental education and public awareness of environmental issues;

b) The General Directorate of Forestry and Desertification Control (GDFDC), a public institution of the Ministry of Agriculture and Irrigation (MAI), has a responsibility of maintenance and protection of forests, woodlands and range resources and combating desertification;

c) The Agricultural Research and Extension Authority (AREA) is a national institution in charge of agricultural research and extension in Yemen;

d) Yemeni various relating CSOs some of which are mainly concerned with environmental and development issues.

Table 14: Global Conventions for Protecting the Environment Ratified by Yemen

Major International Conventions	Ratification Year
Framework Convention on Climate Change (New York, 1992)	3.12.1995
Convention on Biological Diversity (Rio de Janeiro, 1992)	3.12.1995
Convention on the Control of Trans boundary Movements of Hazardous Wastes and their Disposal (Basel, 1989)	1992
Protocol on Substances that Deplete the Ozone Layer (Montreal, 1987)	Approved by Parliament
Convention for the Protection of the Ozone Layer (Vienna, 1985)	3.12.1995
Protocol concerning Regional Cooperation of the Red Sea and the Gulf of Aden Environment	20.8.1985
Regional Convention for the Conservation of the Red Sea and the Gulf of Aden (PERSGA) (Jeddah, 1982)	20.8.1985
UN Convention on the Law of the Sea (Montego Bay, 1982) [UNCLOS]	10.12.1982
Agreement on Banning the Use of Technologies that Change the Environment for Military Purposes & for Any Other Aggression (Geneva, 1977)	5.10.1978
Protocol on Interference on High Seas in case of Marine Pollution with Substances other than Oil (London, 1973)	30.3.1983
Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London, etc., 1972)	6.3.1979
Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons, and on their destruction (London, etc. 1972)	1.6.1979
Convention Concerning the Protection of World Cultural and Natural Heritage (Paris, 1972)	7.1.1981
Agreement on Civil Responsibility of Marine Transport of Nuclear Materials (Brussels, 1971)	4.6.1979
Convention on Interference on High Seas in case of Catastrophes of Oil Pollution with Substances other than Oil (Brussels, 1969)	4.6.1979
Agreement on civil responsibility concerning Damage from Oil Pollution (Brussels, 1969). Amended (London 1981)	4.6.1979
Agreement for Combating Desert Locust (FAO, Rome, 1965)	20.3.1969
Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Underwater (Moscow, 1963)	1.6.1979
Convention for the Safety of Life at Sea (1960)	1969
Convention for the Prevention of Pollution of the Sea by Oil (1954)	6.6.1969

Source: Ministry of water and environment-Environment Protection Authority. 2006. A National strategy for environment sustainability 2005-2015 and national environmental action plan 2005-2010.

6.7.1 Public Sustenance Program

Desertification is almost impossible to check and control without public involvement. Recommendation 3 in the UN Plan of Action to Combat Desertification lists the various kinds of public activities required. There are several sub-programs and projects that come within the scope of land degradation corrective measures. Some of these were either bilateral or multilateral projects planned by the government and regional and international funding agencies as well as friendly governments. Additionally, a number of projects have been implemented for few years and have come to an end. Other interventions were conceptualized as part of certain policies, strategies and national plans, but remained only on paper due to the fact that they are still waiting for funding especially that combating land degradation needs relatively costly intervention that the Yemeni government could not afford to grant from local budget.

In this regard, below is a brief description of some of these programs, sub-programs and projects. However, it should be noted that lack or inadequacy of funds is among the factors that prevented their execution completely or partially. But, their concepts, scope, objectives, and methodologies and assigned command or operation area(s) might be of interest and quite revealing for perceiving directions for any new interventions.

6.7.2 Moving Sand Stabilization Sub-Program

This sub-program includes projects in Tihama, Al Jauf and Ma'reb, and a number of affected areas in the plains, along the southern coast (in Maifa'a and the Bana estuary for example), and in the Wadi Hadramawt. The number of such projects should be enough to protect agricultural areas from the onslaught of sand dunes by the year 2010 or beyond.

The Ma'reb Shifting Sand Stabilization Project provides for the protection of some 850 hectares of fertile agricultural land over a three year period. The major objectives of the project are to prepare studies and collect data for use in the preparation of other projects within the scope of the program.

6.7.3 Degradation Control Sub-Program

This sub-program is concerned with problems of soil fertility deterioration, water and wind erosion, soil salinization and alkalinization and soil waterlogging. It is also concerned with all other manifestations of desertification and natural environmental degradation. All projects proposed under this sub-program for the reclamation of vegetation cover, and the management of water basins and rangelands, must be integrated, multi-purpose, and include a variety of elements.

6.7.4 Re-evaluation Program

This sub-program aims at the readjustment of ongoing projects in order to prevent their collapse. Minor changes involving the addition or alteration of simple components of the program helps alleviate major desertification-related threats. Examples are the planting of trees to combat wind and water erosion and the improvement of drainage to prevent soil salinization.

6.7.5 Socioeconomic Aspects Program

This program concerns itself with two questions: The impact of desertification processes on people's welfare and social condition; andthe behavior of socioeconomic systems as a primary factor in the desertification process.

The program's concern with the impact of desertification on people is translated into projects that can be grouped under the heading of integrated rural development projects. They aim generally at improving the living conditions, and raising the income of farmers, shepherds, and under- privileged people through the adoption of improved management and advanced technology methods.

The program's concern with the livelihoods of farmers makes it focus on the various attitudes and traditions that have turned people into victims of subsistence level economies and led them to engage in overgrazing and cultivation of marginal areas and logging, that strip the soil of its natural vegetation cover and bring about desertification.Projects concerned with either of these two issues should seek to eliminate discrepancies in resources available for development within any one area or among provinces. Such discrepancies tend to have severe effects on the life of the poorest people who strive to extract a living out of cultivating arid and semi-arid lands in marginal areas. Projects in this program would have to presume the availability of easy credit for small farmers along with support for necessary production inputs.

Such projects would also have to work in collaboration with other relevant field activities concerned with people's perceptions, concepts and inclinations. It is therefore, important to mount educational projects, particularly in the ecological domain, together with adult literacy campaigns aiming at increasing awareness of the environmental aspects of development and of the national use of arid lands. Equally important was the provision of support to meet the basic needs of the poor. This would be done through collaboration with projects that have similar objectives.

Planners of projects within this program should focus on the benefits to be gained from educating farmers, shepherds, and other rural workers and offering them attractive incentives. Easy credit remains one of the best means of bringing about changes in the way of life of poor farmers, land tenants, shepherds and the like. In this respect, the agricultural and collective banking sectors can play a major role.

6.7.6 Insurance against risks and effects of drought program

This program aims at safeguarding against drought by assisting people exposed to drought disasters in desertification-prone areas. People in such areas are known to pursue a variety of strategies to protect themselves against the effects of drought. Official emergency relief work, as well as all related projects, should take account of these strategies and reinforce them, rather than ignore or damage them. In fact, the Yemen Republic has a rich heritage in this respect, which includes the famous "Hima" system, which, for one reason or another, has disappeared throughout the country.

It would, however, be possible to work out projects along the lines of this extinct system. Other directions to be followed include the creation of credit mechanisms and the establishment of well-equipped relief centers that would help people come out of disaster with the least losses possible.

6.7.7 Workforce, science and technology program

This program undertakes research and training with the objective of reinforcing the scientific and technological capabilities needed for the success of desertification control programs. In fact, three of the recommendations of the UN Action Plan to Combat Desertification deal with this objective, particularly with regard to planning and management, and to directing research towards seeking alternative or non-conventional sources of energy. Research and training have to be linked to the requirements of development and should be directed towards solving various problems faced by the population, particularly those connected with the ever-diminishing supply of water for irrigation.

At present, the workforce engaged in desertification control is almost negligible. There is very few qualified and knowledgeable staff in the field and they normally have other responsibilities. The planning, preparation and implementation of projects for this plan would require hundreds of professionals and technicians. The training of such numbers is an immense task that requires prompt action.

6.7.8 Institutional Requirements Program

The United Nations Plan of Action to Combat Desertification adopted in 1977 calls for the establishment of strong national bodies to immediately undertake tasks relevant to desertification control.

6.7.9 International Collaboration Control Program

This program covers all anti-desertification regional projects requiring more than national efforts. An example of such projects is the monitoring of desertification factors by means of advanced satellite

technology as well as climate monitoring equipment. Preventive measures include transnational green belts and inter-country joint water management. There is finally the area of training and exchange of information, an area which, by its very nature, requires considerable regional and international collaboration. Since most developing countries continue to find difficulty in securing funding for their desertification control projects, the very implementation of this program requires commitment to explore all possibilities of bilateral and multilateral assistance.

6.8 REQUIRED FAVORABLE POLICY ENVIRONMENT:

The required favorable policy environment should allow for further consolidation and coordination of different national strategies and policies and of complementary programs within the overall national planning and budgeting. At the local level, it has been proven that people did not divide themselves sectorally, and that they found participatory approaches easier to use to provide integrated outcomes. However, at higher levels of governance, areas of overlapping need to be identified, along with recognition of strategies, an understanding of institutional capacity and with respect to desertification, mainstreaming of dryland development into national development agendas.

A coordinated global and cross-sectoral effort should also be undertaken. This global vision would certainly increase the knowledge-base and consolidate the data available in compatible form, and helps obtain an improved base of information for a better understanding of the desertification issues and consequently for better planning and action. Finally, there is an urgent need to establish a national organization to be in charge of approving, coordinating, facilitating and monitoring all desertification control programs, projects, activities, efforts, etc., from various institutions and organizations concerned at national level. This forum is an opportunity to coordinate, integrate, and harmonize different development actions relating to desertification control.

CHAPTER 7:

Existing Policies and Strategies Related to Soil Degradation

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Environmental legislation in Yemen is relatively recent. The government has recognized the importance of integrating environmental issues in the developmental plans. Provisions have been made in the Environment Protection Law to enable incorporation of environmental aspects and concerns at all stages of the development plans. The National Environment Action Plan of 1996 (NEAP) acknowledged the inter-relationship between socio-economic developments and sound environmental developments. The NEAP formed a basis for inputs into the Development Plan for the period 1996-2000 and the National Population Strategy and Action Plan for the same period. These provisions and documents reflect the commitments and efforts to integrate environmental concerns into developmental plans.

This commitment is also evident in the government's initiative for the development of the Socotra Island, through assistance from the Global Environment Fund (GEF) and other donors. The development of the Socotra Island is strongly linked with environmental protection and biodiversity conservation of the island and its archipelago.

Priority environmental issues identified in NEAP are as follows:

- Water depletion, pollution and supply
- Over extraction of ground water
- Lack of water allocation and conservation systems
- Water pollution
- Inadequate water supply services
- Land degradation
- Soil erosion
- Deforestation
- Agricultural and range land deterioration
- Loss of farm land due to urban encroachment
- Habitat degradation
- Degradation of natural habitats (forests, wetlands, coastal habitats)
- Loss of biodiversity (extinction of endemic, rare and endangered species)
- Lack of management of ecotourism
    - Waste management
    - Solid waste management
    - Hazardous waste management
    - Pesticide management

7.2 STRATEGY OBJECTIVES TO COMBAT LAND DEGRADATION.

The major objectives of the strategy were to end desertification in the near future. The most important ones to combat land degradation were:

a) To ensure a definite end to desertification;

b) To effect a change in people's attitude towards the problem of desertification. The new attitude must view desertification as the greatest danger to the basic requirements of food production and subsequently to all food security and self-sufficiency pre-requisites;

c) To confirm that desertification control is a fundamental precondition for any increase in agricultural and animal production, for environmental improvement, and for the provision of better living condition;

d) To ensure that desertification control becomes a major cornerstone in the development process and that the basic elements in the desertification control plan embody constituents which are essential and necessary for comprehensive rural development.

[illegible]

a) Proposed long-term and short-term programs, including projects, should be the subject of periodic reviews in order to incorporate the changes required by the dynamic nature of desertification;

b) Recent oil discoveries will, in the long-run, solve strategic problems and overcome obstacles created by lack of financial resources;

c) There should be coordination and mutual support among all national projects regardless of their geographical location, as well as between national and regional projects;

d) Future economic and social development encourages people to be better aware of the desertification problem;

e) The adequacy of desertification control projects should not be measured by the usual financial and economic feasibility criteria;

f) Desertification control requires long-term commitment. Therefore, the political will of the government, and the priority it gives to desertification control, must be maintained at a constant level and for a long time.

7.4 DESERTIFICATION LONG-TERM ASSESSMENT AND LAND MANAGEMENT
[illegible]

This program covers all activities connected with the assessment and monitoring of desertification. These activities should be pursued actively until the very end of the program and beyond, with a view to detecting any indications of relapse. It should also determine areas affected or threatened by desertification. It should also include land management improvement schemes in affected or vulnerable areas. The following are the proposed activities under this program:

1. The production of a desertification map using a provisional methodology for assessment and mapping;
2. The production of a land use map;

3. Evaluation and follow-up of desertification and its causes in selected areas such as Al Jawf, Ma'reb, in mountain areas near southern coast, the Abyan estuary, Lahj, and Wadi Hadramawt.

This work requires comprehensive measures in the social, economic, institutional, legislative and technical fields. It also requires special case management in the light of complete and sound data. However, initiation of work should not be dependent on the total completion of all site studies.

[illegible]

Public involvement is necessary to combat desertification. Recommendation 3 in the UN Plan of Action to Combat Desertification lists the various kinds of public activities required. In the past, people in Yemen, drawing on their long and vast experience in agriculture, discovered and devised ways of dealing with land degradation and desertification. Testifying to this are their methods of water harvesting and conservation, land terracing, and surface dam and water diversion network building. Public awareness sub-programs would enhance people's knowledge about desertification. Public debate on the phenomenon of desertification and on the substance and implementation of the various projects should be encouraged. The success of these sub-programs can be ensured by drawing upon the following positive factors:

1. The prevailing collective work spirit manifested regularly by voluntary organizations, youth and women's organizations and local collective development councils;
2. The fact that television transmission covers the entire country and can be used for guidance and information purposes with regard to desertification.

[illegible]

7.6.1 Areas of Corrective Measures

This part has received the greatest attention in the UN Plan of Action to Combat Desertification. In fact, out of the 22 national and regional action recommendations, seven deal with corrective measures. These recommendations are:

a) That efficient planning, development, and management of water resources be introduced as part of measures to combat desertification;

b) That measures be taken to ameliorate the condition of degraded rangelands, to introduce suitable systems of rangeland livestock and wildlife management, to develop diversified and integrated systems of production and to improve the living conditions of the inhabitants of these areas;

c) That comprehensive measures be adopted for the conservation of water and the conservation and improvement of soil in rain-fed agricultural areas;

d) That measures be taken to prevent and control water logging, salinization and alkalinization;

e) That existing vegetation be maintained and protected, and that special measures be taken to revegetate denuded areas and later maintain and protect them to promote soil conservation and to stabilize moving sands;

f) That all necessary steps be taken to ensure the conservation of flora and fauna in areas subject or likely to be subject to desertification;

g) That national or intra-regional systems for monitoring climatic, hydrological or pedological conditions and the ecological conditions of land, water, plants, and animals to be established or strengthened in areas affected or likely to be affected by desertification.

The UN plan, recognizing that these measures would remedy current desertification-caused damage and prevent future deterioration, devotes considerable attention to this section and provides extensive details. Once put into effect, these measures yield tangible economic effects that bring benefit to the population. Yet, a 1984 general assessment showed that actual measures taken in the field over a period of seven years had been rather ineffective, and that most desertification control activities were in the category of support activities such as training and research. Such support activities are indeed essential in the end, but there is some more urgent need for work in the field.

7.6.2 Examples of Required Field Work

The strategy, for the reasons stated above, focuses on the following field activities:

- The development, improvement, and maintenance of public, private, and communal rangelands and forests;
- The establishment of more nurseries to produce the appropriate local and imported, forest and rangeland tree and bush varieties;
- The forestation of slopes, marginal production areas, abandoned terraces, and uncultivated lands;
- The improvement of available fodder plants and the intensification of rangeland cultivation;
- The implementation in rangeland areas of the improved reserve, “Hima”, system which would ensure the rationalization of grazing through tribal or communal arrangements;
- The implementation of the necessary legislations for the conservation of rangeland and forest resources.

7.6.3 Measures related to soil conservation in mountain areas

- The cultivation of slopes along contour lines in order to prevent landslides by reducing the volume and velocity of water flow;
- The construction of water breakers at suitable distances in the course of strong water currents in order to prevent furrowing, soil erosion and floods;
- the discontinuation of logging in exhausted forests and rangelands with a view to protecting the soil from water and wind erosion.

7.6.4 Measures related to soil conservation in marginal areas

- The prohibition of over-grazing;
- Control of logging and firewood collecting.

7.6.5 Measures related to soil conservation in cultivated areas

- Repair of corroded terraces;
- Employment of feasible reclamation methods in the cultivation of slopes;
- Application of appropriate agricultural rotation in order to keep the soil constantly covered by crop vegetation;
- Revitalization of soils by the periodic application of natural and chemical fertilizers.

7.6.6 Water conservation measures

- Construction of small dams and water reservoirs in appropriate areas in order to store enough water to recharge underground aquifers and to employ supplementary irrigation when necessary;
- The implementation of rainwater harvesting techniques in order to save irrigation water for rain fed crops;
- The use of water-saving irrigation methods such as drip irrigation and sprinkler irrigation;
- Avoidance of over irrigation, which causes water logging and soil salinity;
- Rationalization of well digging and monitoring of underground water use.

[illegible]

[illegible]

The first Five-Year Development Plan (1996-2000) states that environmental considerations have to be made in all phases and at all stages of development planning. Regarding the agriculture sector to achieve the following strategic objectives:

a) Raising the GDP from agriculture at the rate of six percent per annum through achieving increases in yields and better allocation of resources;

b) Controlling the deficit in the balance of trade for agricultural commodities through increased production and exports of commodities in which Yemen has a comparative advantage;

c) Conserving natural resources including soil, water, forests, and rangelands, and taking the necessary measures to halt their degradation;

d) Integrated development of the rural areas to provide these areas with the necessary pull factors capable of inducing reverse migration from urban to rural centers and causing an increase in investment and trained manpower, which will contribute to the required increases in agricultural production in rural areas;

e) Enhancing the role of the private sector in agricultural investment.

The above strategic objectives can be accomplished through reforming agricultural policies, taking the necessary organizational measures, implementing the public sector agricultural investment program, and allowing the private sector to assume a basic role in agricultural production, marketing, processing, and supply of inputs.

7.7.2 Water Irrigation Policy and Law

The Yemeni Cabinet adopted the Water Irrigation Policy in March 1999. The policy is aiming, in general, at:

a) “Optimization of the use of the limited water resources allocated for irrigation. Economic and sound use of water to be practiced to reach the highest yield and income from the unit of water and land in irrigated agriculture;

b) Gradual and practical increase of the very low overall irrigation efficiency (30-40 percent) should be achieved through the mid-term plans;

c) Establishment of strong institution to form the central body fully responsible for Irrigation in the country. It should be supported with clear mandate, which will be, in the mid-term, limited to planning, control, supervision, awareness, and transfer of technology. In the short-term, this institution should be structured to achieve the decentralization role by delegating the execution activities to the regional authorities, project units, agriculture and irrigation offices in the governorates. Accordingly, and in order to implement the Water Strategy and the Water Irrigation Policy, a Water Irrigation Law was drafted and waiting for debate and approval in the parliament. The draft law recognizes the need for:

    1. re-arrangements of irrigation institutions to work with clear mandate, which defines the duties and responsibilities of the central and regional entities;
    2. cooperation and coordination among the inter-related agencies to replace the scattered efforts, avoid duplication, overlapping, and competition;
    3. establishment and enforcement of water irrigation standards to avoid pollution;
    4. ensure water rights and irrigated areas tenure in order to solve problems related to water and land disputes;
    5. collection and assessment of data; and information on water irrigation activities including water irrigation charges;
    6. improvement of water irrigation efficiency as well as productivity of irrigated lands;
    7. enforcement of the role and involvement of farmers and private sector;
    8. Preparation and elaboration of public and farmer awareness campaigns and programs dealing with water conservation and environment protection.

7.7.3 National Watershed Management Policy and Action Plans

Integrated watershed management approach is newly introduced in Yemen. This integrated approach considers the socioeconomic aspects and acts as a means to sustain natural resources utilization. Watershed management is considered among the top priorities of the Ministry of Agriculture and Irrigation (MAI). The National Watershed Management Policy aims to achieve the following objectives:

a) Protection and development of natural resources as they represent the basic element for economic and social development;

b) Implementation of an Integrated Watershed Management. This concept consists of a comprehensive planning, which takes into consideration the techno-socio-economic aspects that ensure natural resources protection and development aiming at improving the socio-economic conditions of the communities;

c) Enhancement of institutional and legislative measures through the establishment of adequate institutions able to implement the plans and programs resulting from the developed policies and the development and elaboration of appropriate legislation that organizes the use and exploitation of the natural resources.

Accordingly, and in order to implement the approved policy, Action Plans have been elaborated and presented to the MAI for further action.

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The first stage aimed at assessing environmental issues and incentivizing stakeholders gaining commitment towards the National Strategy for Environmental Safety (NSES). Environmental profiles of Yemen were contained in a report that brought together valuable relevant information on the state of environment problems and opportunities. The document identified the interaction between resources and development needs. It also examined the institutional framework for the environmental management and actions needed for it.

In Yemen, that was a bottleneck causing the emergence of the environmental problems. The information in the report was used as major resources for facilitating the participatory and decision-making process. A key event in the first stage was the national consultation held in December 2005. The objective of this national consultation was to: “Raise awareness and reach common understanding of environmental issues”.

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State indicators show the current condition of the environment, such as the concentration of lead in urban areas, the noise level near main roads, the global mean temperature.

Section one attempts to portray the state of the environmental systems of Yemen based on national and international information.

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These are the underplaying factors influencing a variety of relevant variables, such as the number of cars per capita, total industrial production and the GDP.

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Describe the variables which directly cause environmental problems. Examples include, toxic emissions, CO_2 emissions, noise pollution, etc., that are caused by road traffic, required parking spaces, the amount of waste produced by scrap cars, and other causes and consequences of economic activities and social and institutional frameworks for the sustainability of the Yemeni environment.

7.8.4 Impact indicators

Describe effects of certain factors on the people and their environment, such as the percentage of children suffering from poisoned food (uncontrolled use of pesticides), mortality due to noise-induced health injuries, and the number of people suffering from crop failure due to climate change.

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Responses indicators demonstrate the societal effort (i.e. politicizations, decision makers) to solve environmental/health problems. Examples include the percentage of cars with catalytic convectors, maximum allowed noise levels for cars, the price level of gasoline, the revenue coming from production levies, the budget spent for solar energy resources.

As a result of the consultation process, the National Environment Report (NER) was further elaborated and carefully prepared to bring together the widest possible spectrum of existing and potential participants and partners including donors, representatives of investors and Government bodies.

7.9 LEGAL AND REGULATORY INSTRUMENTS

The Yemeni legal system is based on Islamic law, Turkish law, English common law, and local customary law. Statutory law was introduced by the British in former South Yemen. According to the Unification Declaration, the existing laws and provisions of both the former YAR and PDRY remain valid and applicable to Yemen as a whole, until consolidated or replaced by new legislation.

In 1995, the Parliament enacted a comprehensive **Environment Protection Law**. The law is designed to safeguard sustained use of the national resource base and provides a comprehensive framework for environmental management and the establishment of sectoral legislation. It outlines the basic objectives and the roles of concerned authorities in the protection of air, water and soil; and establishes controls on pesticide use, environmentally damaging activities, transportation and disposal of hazardous materials and wastes, environmental monitoring, and marine pollution. The law also proposes broadening the role of the Environment Protection Council to include statutory planning, licensing, monitoring and auditing functions. It outlines the procedures for developing, adopting, monitoring environmental standards, and project licensing. It also establishes the principle of environmental assessment.

There is no comprehensive regulatory framework for environmental management to support the Environment Protection Law. Such regulations and standards should be formulated and implemented in accordance with available technical, financial, and enforcement capacity. Priority procedures and regulations should be developed in line with the existing codes. Islamic legal provisions address many aspects of the relationship between society and the environment, and they have a strong role in the definition of land and water rights as well as the management of natural resources at the local level. Other existing legislations deal with the management of specific natural resources (for example, fisheries, and water supply) and public health and safety aspects. Some environmental provisions are scattered in legislation primarily concerned with other subjects, such as the penal code, the labor law, municipal laws, and the PDRY Constitution. The protection of the coastal environment is a notable exception. The PDRY government passed comprehensive national maritime legislation that covers activities at sea (transportation of goods, navigation, and shipping), and the protection of the marine environment.

In addition to the Environment Protection Law, several new laws related to the environment are in various stages of development. The Land Use Law will address the environmental effects of automobiles and roads. Also, a new Forest law and new Water and Sewage Law are in preparation. It could be concluded that Environment Protection legislation was rarely applied in reality due to political reasons, as well as uncoordinated actions by the government agencies. This caused the mismatch between land quality (LQ) and land use (LU) resulting in land resource consumption, and increasing land degradation in the country. The following are some examples of land degradation resulting from the mismatch between land quality and land use.

a) Urbanization and industrialization seem to take place at the expense of agricultural development due to inappropriate land use activities;

b) The coastal areas, western and southern Yemen have undergone major and significant expansion in the last three decades. Almost all of the surrounding fertile arable lands were used for urban buildings. The urban and semi-urban areas (metropolitan areas) increased approximately four times from 1990 to 2005;

c) The industries, as well as the urbanization in main cities have consumed high quality agricultural lands throughout the provinces. Almost all the changes in 1990-2005 resulted in the reduction of surface areas of Land Capability Classes (LCC) I, II and III.

Similar other examples of misuse could be given for other areas throughout the country. They all indicate the deficiency in the application of legislation and lack of co-ordination.

Legal Problems: There is much duplication and overlap in legislation related to the environment. The first step towards solving this issue is through conducting a study of international experiences and success stories related to the coordination and rationalization of environmental legislation.

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Environmental policy often generates contentious policy questions. These conflicts manifest through the property contradiction of environmental assets i.e. the contradiction between the use value of the resource, which the society appreciates, and the market value of the natural resource. The market value is often the basis for evaluating alternative policy, strategic, planning and project options.

7.10.1 Policy Options Considered in the National Environmental Action Plan (NEAP)

The NEAP promotes sustainable use of natural resources through a set of policy options addressing priority issues. These policy options deal with legislative, institutional, economic and financial measures in addition to information and community involvement. The fundamental strategy used to address priority issues lies in the selection and application of appropriate policy options. Following are the outlines of measures selected:

- Legislative measures include development and redrafting of laws, regulations and standards for environmental quality;
- Institutional measures include capacity building of government institutions, universities, NGOs, community and private sector;
- Economic instruments include policies for licensing, incentives, pricing, import restrictions, user charges, subsidies, penalties and taxation which favor sound resource use;
- Financial measures include investments in environmental infrastructure and technology. The private sector and local communities are encouraged to gradually increase their involvement;
- Information instruments involve environmental information management, awareness, research and monitoring. Public institutions, universities, NGOs and the public are encouraged to play active roles in the collection, analysis and dissemination of data.

7.10.2 Policy options considered in the National Strategy for Environmental Sustainability (NSES), 2005

- The strategy aims to (a) Prevent and/or reduce land degradation; (b) Rehabilitate partly degraded land; and (c) Reclaim desert land. According to the convention, a National Action Plan (NAP) should identify the factors contributing to desertification and prescribe practical measures to combat it. This implies the adoption of an integrated approach that offers the proper identification, assessment and monitoring of factors and processes of desertification and their adverse impacts on the nation's resource base and socio-economic aspects, as well as describing present feasible and environmentally sound measures to combat factors and processes of desertification;
- Environmentally sound management of agricultural and rural development. Major adjustments in agricultural, environmental and economic policies are required for Yemeni agricultural and rural development to be sustainable. These requirements include cooperation involving rural people, the central and local governments, private sector, and of course the international community.

7.10.3 Policy Options Considered in the Second Five-Year Developmental Plan

Environmental protection strategy in the Second Five-Year Developmental Plan was based on preserving the sustainability of the nation's natural resources and maintenance of the ecological system through maintaining a balance between socio-economic growth and available resources. The environmental strategy and policies are based on the following principles:

- Environment protection and maintenance of ecological balance;
- Controlling pollution sources rather than problems;
- Promotion of sustainable use of natural resources, use of renewable resources and recycled items;
- Consideration of environmental aspects at all levels of planning and decision-making;
- Preservation of the nation's cultural and historical heritage;
- Polluters pay for damages caused and bears mitigation, removal and compensation costs;
- Enhancement of environmental awareness and education and encouragement of civil and local community participation in environmental work;
- National commitment to address environmental issues having regional and global implications within available resources.

7.10.4 Policy options considered in the Poverty Reduction Strategy Paper 2003–2005

Poverty Reduction Strategy Paper (PRSP) indicated four major developmental challenges of which two issues, water resources and population problems have direct linkages with natural resources management practices and relate to carrying capacities of natural recourses. The other two challenges have indirect linkages as they deal with having the right to use natural resources for the benefit of current population without undermining the ability of the future population and of improving institutional structure and efficiencies for sound environmental management.

PRSP aims to reinforce sustainable management of natural resources, mobilize beneficiaries, involve the poor and support the role of women and youth in environmental conservation. This Paper proposed a number of measures to strengthen environmental policies and actions such as:

- Enhancement of technical capacities of relevant institutions to develop comprehensive environment and development programs based on community participation;
- Enhancement of legal framework;
- Empowerment of local organizations;
- Assessment of environmental conditions;
- Enhancement of environmental awareness;
- Provision of job opportunities through environmental projects;
- Environmental impact assessment of developmental projects;
- Financial support to projects providing soft loans to the poor;
- Reinforcement of water resources institutions;
- Enactment of laws and regulations relating to water rights and exploitation, development and protection of water resources;
- Improvement of water uses efficiency;
- Expansion of sanitation and waste treatment facilities;
- Suitable use of treated waste water;
- Improvement of water harvesting.

7.10.5 Policy options considered in Vision 2025

Vision 2025 supports environmental and poverty reduction actions. The Vision notes that environmental degradation affects the poor and development. It reviews major environmental problems such as water resources depletion and pollution, degradation of land resources, natural habitat and biodiversity, waste management, over exploitation of natural resources such as fisheries, and urban expansion over agricultural land. In terms of environmental interventions, the following measures have been proposed:

- Development and implementation of sustainable management and monitoring programs for water and land resources, agriculture, coastal zone, biodiversity and waste management;
- Development of desertification control program;
- Provision of energy substitutions;
- Application of environment-friendly technologies and enhancement of renewable energy resources;
- Application of environmental impact assessment for developmental projects;
- Enhancement of environmental awareness.

7.10.6 Policy options considered in the Environment and Sustainable Development Investment Program 2003 – 2008

The plan presents an outline strategy and priority interventions aimed at controlling and gradually reversing environmental impacts. It also aims at supporting sustainable human development for the people of Yemen. Six main areas of interventions were identified in the plan as follows:

- Habitat and biodiversity conservation;
- Sustainable land management;
- Sustainable water resources management;
- Sustainable waste management;
- Sustainable climate change and energy management.

7.10.7 Policy options considered in the National Biodiversity Strategy and Action Plans

The Government of Yemen has recognized the necessity to protect natural resources and biological diversity as reflected by the ratification of the Convention on Biological Diversity. A draft of “National Biodiversity Strategy and Action Plans for Yemen” was prepared by EPC at the end 1999. The main objectives of the Strategy are defined as follow:

- Conservation of biological diversity in Yemen;
- Sustainable use of biological diversity and related natural resources;
- Development and enforcement of policies and legislations relating to biological diversity;
- Community participation in the revival of traditional techniques and knowledge in natural resources management;
- Participation equity and fairness in biological diversity in the country;
- Development of human resources and institutions in the field of biological diversity.

7.10.8 Policy options considered in the National Wastewater Strategy

The high population growth, expansion of urban population, and the increasing coverage of domestic water supplies and sewage networks will give rise to greater quantities of municipal wastewater, which can become a new source of water irrigation. The reuse of such marginal quantity of water can be significant in terms of national water budgets, particularly in Yemen where water of good quality is limited. In this context, the MAI/GDFDC, supported by the FAO Project on "Watershed Management and Wastewater Reuse in Peri-Urban Areas of Yemen – GCP/YEM/026/NET", prepared in March 2000 a draft "National Wastewater Strategy" in close collaboration with all concerned institutions. The proposed strategy would:

- Contribute in strengthening sustainable agriculture;
- Assist in better management of water resources;
- Support complementary actions to ongoing water resources planning activities;
- Assist in setting-up mechanisms for the implementation of legislative and other measures to regulate and control wastewater reuse;
- Improve on-farm wastewater reuse.

7.10.9 Main strategies, policies, and laws approved or awaiting approval

The Forest Policy and Forest Law: A concise statement for Forest Policy had been officially declared in the Third National Plan (1987-1991) whose principles are embodied within the present Five Year Plan (1996-2000). A corresponding Bill of Forest Law has been drafted and updated in 1999 and submitted to the Ministry of Legal Affairs for further action. The objectives of the Draft Forest Law are defined as follows:

a) Forest protection and preservation;

b) Forest development;

c) Management and regulation of forest formations;

d) Erosion and desertification control;

e) Contribution to the national economy.

In addition, six items constitute specific harmful actions that are prohibited by the Draft Forest Law, i.e. (i) forest fires; (ii) forest land cultivation, leveling and reformation; (iii) river dam construction and river course modification; (iv) settlements and constructions on forest land; (v) harvesting, transporting forest products and grazing; and (vi) modification of forest boundaries and signs of public infrastructures.

The Water Strategy and Law:While its traditional water rights and customs deal mainly with surface water, with no or very limited concern for groundwater, Yemen does not yet have an operational water law that regulates the overall development and management of water resources nationwide. A Water Strategy was prepared and adopted by the Cabinet during 1998. The Water Strategy aims, in general, at:

a) Protection of water resources from over-exploitation;

b) Sustainable use of water resources;

c) Responding to the needs of community and different sectors for water resources.

A Water Law was developed in 1999; it was cleared by the Cabinet of Ministers and is awaiting debate in Parliament. The Water Law focuses more on conservation and sustainability than on the

development of water resources. It recognizes existing rights and makes future exploitation subject to a previous license, particularly for groundwater. The anticipated law puts the National Water Resources Authority (NWRA) as the sole national institution in charge of planning and elaborating national strategies and of supervising their implementation. It also gives NWRA the power to license and regulate both the development and use of water.

The law bears a significant limitation, however as it does not build on communities' local rules and hence may prove to be difficult to enforce in the present context. The positive aspect of interest related to drought mitigation and desertification control is that it encourages the creation of associations of beneficiaries and of councils/committees/groups of stakeholders at various levels, particularly that of basins and watersheds. It also gives NWRA the ability to delegate its powers to such groups as well as to decentralized management institutions to self-regulate water use.

Water Irrigation Policy and Law: The Water Irrigation Policy was adopted by the Cabinet on March 1999. The policy45 is aiming, in general, at:

- Optimization of the use of the limited water resources allocated for irrigation, and economic and sound use of water to be practiced to reach the highest yield and income from the unit of water and land in irrigated agriculture;
- Gradual and practical increase of the very low overall irrigation efficiency (30-40 percent) should be achieved through the mid-term plans;
- Establishment of strong institution to form the central body fully responsible for irrigation in the country. It should be supported with clear mandate, which will be, in the mid-term, limited to planning, control, supervision, awareness, and transfer of technology. In the short-term, this institution should be structured to achieve the decentralization role by delegating the execution activities to the regional authorities, project units, and agriculture and irrigation offices in the governorates.

Accordingly, and in order to implement the Water Strategy and the Water Irrigation Policy, a Water Irrigation Law was drafted and waiting for debate and approval. The draft law recognizes the need for:

1. Re-arrangements of irrigation institutions to work with clear mandate, which defines the duties and responsibilities of the central and regional entities;
2. Cooperation and coordination among the inter-related agencies to replace the scattered efforts, avoid duplication, overlapping, and competition;
3. Establishment and enforcement of water irrigation standards to avoid pollution;
4. Ensure water rights and irrigated areas tenure in order to solve problems related to water and land disputes;
5. Collection and assessment of data and information on water irrigation activities including water irrigation charges;
6. Improvement of water irrigation efficiency as well as the productivity of irrigated lands;
7. Enforcement of the role and involvement of farmers and private sector;
8. Preparation and elaboration of public and farmers awareness campaigns and programs dealing with water conservation and environment protection.

7.10.10 National Watershed Management Policy and Action Plans

Integrated watershed management approach is newly introduced in Yemen. This integrated approach, not only considers the socioeconomic aspects, but helps sustain natural resources utilization. Watershed management is considered among the top priorities of the Ministry of Agriculture and Irrigation (MAI). A National Watershed Management Policy was jointly prepared by MAI/GDFDC and Natural Water Resources Authority (NWRA). The Cabinet endorsed this Policy in May 2000. The National Watershed Management Policy aims to achieve the followings objectives:

a) Protection and development of natural resources as they represent the basic element for economic and social development;

b) Implementation of an Integrated Watershed Management. This concept consists of a comprehensive planning, which takes into consideration the techno-socio-economic aspects that ensure natural resources protection and development aiming at improving the socio-economic conditions of the communities;

c) Enhancement of institutional and legislative measures through the establishment of adequate institutions able to implement the plans and programs resulting from the developed policies and the development and elaboration of appropriate legislation that organizes the use and exploitation of the natural resources.

Accordingly, and in order to implement the approved policy, Action Plans have been elaborated and presented to the MAI for further action.

7.10.11 Decentralization and Local Governance Law

The concept of decentralization or local governance is not new in Yemen as it has been the subject of numerous debates, particularly in the last years. It was in fact included to some degree in the constitution, through its articles 142 and 144, which stipulated respectively that: i) administrative units enjoy juridical personality, provided that they have freely elected councils at governorate and directorate levels; and ii) administrative units and local councils are integral parts of the State's authority. There is in any case, a wide consensus in Yemen to consider decentralization as a vital demand. The Law on decentralization – local administration - was accordingly passed on February 2000.

Decentralization assumes the necessary support from central government to poorer regions. It may increase the economic participation of local people through employment, implementation of local projects and the decrease of the concentration of people in urban areas, but may lack the necessary measures and criteria to implement and sustain them. The measures to implement them are political and institutional. They consist in the empowerment of local communities, particularly women, local institutions, and aid organizations. The means and criteria to sustain them lie in creating conditions for local substantial investments and funding capacities, which in turn require direct external assistance.

7.10.12 Policy options considered in the National Wastewater Strategy

The high population growth, expansion of urban population, and an increasing coverage of domestic water supplies and sewage networks will give rise to greater quantities of municipal wastewater, which can become a new source of water irrigation. The reuse of such marginal quantity of water can be significant in terms of national water budgets, particularly in Yemen where water of good quality is limited. In this context, the MAI/GDFDC, supported by the FAO Project on "Watershed Management and Wastewater Reuse in Peri-Urban Areas of Yemen – GCP/YEM/026/NET", prepared in March, 2000 a draft "National Wastewater Strategy" in close collaboration with all concerned institutions. The proposed strategy would:

- Contribute in strengthening sustainable agriculture;
- Assist in better managing water resources;
- Support complementary actions to ongoing water resources planning activities;
- Assist in setting-up mechanisms for the implementation of legislative and other measures to regulate and control wastewater reuse;
- Improve on-farm wastewater reuse.

CHAPTER 8:

Conclusion and General Recommendations

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The application of a clear scientific methodology has to be made possible to adopt a method as a reference to define the areas affected by the various soil degradation factors, most important of which are water and wind erosions which are the most widespread factors in Yemen. By reverting to the national land degradation map, it was possible to define the locations of those processes and the extent of their prevalence. An initial digital database was set up for the previous work by using the Geographic Information System (GIS).

It is worth noting that some types of degradation did not appear clearly on the available national map due to the map scale of 1:500000. Therefore, maps should be prepared at larger scales (1:20000 - 1:50000) for the hot areas highlighted by the current map, as well as for the areas being agriculturally exploited, in order to take measures that ensure the maintenance of those areas and the rehabilitation of degraded lands.

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- Carry out detailed studies of the degraded lands at the level of each governorate, and determine precisely the slight and moderate degraded lands;
- Carry out studies on the economic loss due to land degradation, and on the costs of rehabilitating the slightly and moderately degraded lands, and start rehabilitating them at the level of each governorate in the areas to improve economic feasibility;
- Define the economic and social impact of land degradation on those concerned (the local inhabitant);
- Define the lands exposed to special natural disasters due to water flow and take measures to protect them;
- Prepare a reference study on the connection of the irrational land use and land productivity and its role in the drop of the income of the local communities;
- Carry out field measures to prevent some lands of good production from degradation;
- Integrate the work of the different parties engaged in the rehabilitation of the degraded lands, the Ministries of Agriculture, Environment, Planning, and Finance, and farmers' unions dedicated for rehabilitating the decertified lands, with the Agriculture, Research and Extension Authority (AREA) being the focal point;
- Implement measures to combat desertification to water erosion, which is the basic degradation factor in Yemen, such measures include the following:
  - Protective measures to prevent land degradation such as organizing pasture grazing;
  - Give support for producing fodder to prevent the degradation of pasturelands;
  - Construct drainage systems in the irrigated land to prevent dry ploughing and degradation due to salinization and raise adequate funds for combating land degradation. Some countries in the world have set up such funding establishments and received financial assistance from institutional associations, organizations and periodic campaigns. - Build on local knowledge to develop new suitable technologies and experiment on introducing them in different communities suffering from land degradation.

- Monitor the spread / diffusion of relevant improved local and modern technologies and assess the level of their adoption and their impact on the socio-economic, environmental, health and equity levels.The following are possible future needs and priorities to be taken into consideration:
    - Biodiesel plantation for rehabilitation degraded lands by selecting plants such as Jatropha curcus;
    - Increasing government involvement in the management of traditional protected areas;
    - Implementing local tree and shrub planting projects in degraded areas, involving local school childern and villagers.

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About ICARDA and the CGIAR

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is one of 15 centers supported by the CGIAR. ICARDA's mission is to contribute to the improvement of livelihoods of the resource-poor in dry areas by enhancing food security and alleviating poverty through research and partnerships to achieve sustainable increases in agricultural productivity and income, while ensuring the efficient and more equitable use and conservation of natural resources.

ICARDA has a global mandate for the improvement of barley, lentil and faba bean, and serves the non-tropical dry areas for the improvement of on-farm water use efficiency, rangeland and small-ruminant production. In the Central and West Asia and North Africa (CWANA) region, ICARDA contributes to the improvement of bread and durum wheats, kabuli chickpea, pasture and forage legumes, and associated farming systems. It also works on improved land management, diversification of production systems, and value-added crop and livestock products. Social, economic and policy research is an integral component of ICARDA's research to better target poverty and to enhance the uptake and maximize impact of research outputs.

The Consultative Group on International Agricultural Research (CGIAR) is a strategic alliance of countries, international and regional organizations, and private foundations supporting 15 international agricultural Centers that work with national agricultural research systems and civil society organizations including the private sector. The alliance mobilizes agricultural science to reduce poverty, foster human well being, promote agricultural growth and protect the environment. The CGIAR generates global public goods that are available to all.

The World Bank, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), and the International Fund for Agricultural Development (IFAD) are cosponsors of the CGIAR. The World Bank provides the CGIAR with a System Office in Washington, DC. A Science Council, with its Secretariat at FAO in Rome, assists the System in the development of its research program.