Chapter 3

Description of Study Area
DESCRIPTION OF STUDY AREA

The area of this study is Wadi Zabid basin. The wadi basin lies in western Yemen and drains into the Red Sea (Fig. 3.1). The wadi basin extends from the mountain ranges (Yemen Highlands) in the east to the Tihama coastal plain in the west. It lies between longitude 43° 5’ and 44° 20’ east and latitude 13° 45’ and 14° 30’ north. The wadi originates in the Dhamar district of Dhamar governorate, where it starts as a small stream at an elevation of 2520 m ASL. With a total length of 212 km, Wadi Zabid and its major tributaries drain a catchment area of 5257 km². The source region of Wadi Zabid and its major southern tributary, Wadi al Sahwal, are located on the Yemen Plateau. In the middle reaches, the other major tributaries of Wadi Zabid namely, Al Fanaj, Annah, Aqaqah, Wajis, and Kahalan, join the main wadi and have their sources either in the western escarpments of the Yemen Plateau or in the high rise hills of central zone.

Wadi Zabid is one of the largest systems in the Red Sea catchments. (Fig.3.2). It is second only to Wadi Mawr, which is located in the northern part. The wadi carries water during and shortly after rainstorms from the catchment area in the east where higher rainfall occurs. The Tihama Plain’s contribution to the runoff is thought to be insignificant. Losses of runoff resulting from infiltration into the alluvial aquifer and irrigation usage are predominant. During high flow the wadi may travel for long distances in the Tihama coastal plain. Hardly ever does the wadi flow reach the Red Sea, as indicated by the people in the coastal areas of the wadi. In the Tihama Plain, the regime of the wadis is described as extremely variable. DHV report (1990) indicates that within 24 hours the discharge in the major wadis at times may increase from less than 1m³/ second to as much as 500 or even 1000 m³/ second.
Physiographical Divisions of Yemen

Fig. 3.1

Source: Based on Steffen [1979] and Van Der Gun et al. [1995]
The Major Catchment Areas and the Drainage Basin

Saudia Arabia

Oman

Red Sea

Gulf of Aden

Arabian Sea

Source: Based on Van der Gun et al. [1995]

Fig. 3.2
In Wadi Zabid basin, surface waters are fully utilized for irrigation purposes. Traditional system "Spate Irrigation" has been used for centuries to divert the wadi flow into the cultivated lands. In the Tihama part of the basin, five modern diversions were constructed on the wadi bed in order to reduce the dangers of the floods and to manage the wadi flow. In the upper catchment areas, traditional spate irrigation is widely used. Farmers construct barriers of stones, sand, and branches of trees and bushes across the wadi bed so that the wadi flow can be diverted into the fields.

The study area, the Tihama zone in particular, is one of the most promising areas for the recent and future agricultural development in Yemen. The study area is also considered to be one of the agricultural heartlands of the country. The importance of this area is due to its agricultural potential and the richness of the water resources comparing to elsewhere in Yemen. However water resources have not been properly managed; hence the development and management of water resources are crucial.

Most people in the Wadi Zabid basin, like the majority of Yemeni, are involved in the agricultural sector. Agriculture in the Tihama zone depends mainly on ground water and the surface water, represented by Wadi flow. Rainfall is insufficient. Due to the scarcity of water, the use of ground water has increased in recent past. However, the uncontrolled pumping of ground water results in declining water table and increasing salinity in the downstream areas in particular. In the catchment area, to the east of Tihama, agriculture mainly depends on rainfall. Other sources of irrigation are wadi flow, base flow, springs and groundwater.

**Physiography**

Topography is the main factor influencing the wadi basin climate, while land use and runoff characteristics in the basin are
mainly governed by climate. The topography of the basin is linked to
the geological processes of the past. Topographically, the basin land
surface varies from low relief of coastal areas in the west to the
escarpment in the east. Based on altitudes, the study area has been
divided into three physiographical zones (Fig. 3.3). From east to west,
these zones are: (1) highlands; (2) mid-lands (central); and (3) Tihama
lowlands. The following is a brief description of these zones, however,
these physiographical zones will be analyzed in details in later chapters.

1. Highlands (eastern) Zone

These highlands are part of the Yemen Highlands. This zone
represents the main catchment area of Wadi Zabid. Elevations in this
area are more than 2000 m. The origins of some of the wadis, however,
lie at an elevation of more than 3000 m. The landscape of the area is
characterized by its rugged and complex topography. The area is
dissected by the drainage systems. The deep eroded valleys are
occupied by the drainage systems of Wadi Zabid. Mountain massifs are
surrounding the wadi basin.

2. Mid-lands (central) Zone

This zone extends between the highlands in the east and the
Tihama lowlands in the west. Elevations range from 400 m to 1500 m.
The numerous streams of Wadi Zabid and its major tributaries dissect
the area.

The landscape features include steep slopes, rugged topography,
and series of ridges, mountains peaks, and flood plains. In this area, all
the major tributaries of Wadi Zabid join together and generate the main
Wadi Zabid, which enters the Tihama coastal plain. The western part of
this zone represents the extension of the mountains towards the Tihama
Plain. The landscape of this part was affected by the tectonic activities
that created this transition zone.
3. The Tihama Lowlands (western) Zone

This zone extends between the foothills in the east and the Red Sea in the west. It forms part of the Tihama Plain. The Tihama Plain is the general name of the Red Sea Coastal Plain in the western part of Yemen. It formed as a result of many factors. These factors are: (1) the final opening of the Red Sea rift; (2) the frequent raising of the fault-blocks at the eastern side of the plain; and (3) the different climate regime of the past, as compared with the present one (Abdu, 1993). The climate that prevailed during Quaternary times produced huge quantities of clastic material carried towards the Red Sea by what were most probably perennial rivers, aided by the huge differences in relief (ITALCONSULT, 1973). Following that wet period a dry spell in which the wind started to play a major role that gave the Tihama plain its recent topographical features. Topographically, the plain is open to the west, where on topographical features separate the area from the Red Sea shoreline.

Geological Setting

Geology of the basin is a very significant factor affecting stream runoff. The physical character of both the underlying rocks and the weathered material is important in determining the rate of movement of water through the upper soil and rock layers. It is also useful in determining storage characteristics and yield of particular strata (Mather, 1984). The present physiography of the study area is the result of several phases of geological evolution. In other words, there is a strong link between the topographic features of the area and the geologic processes that took place in the past. This section briefly describes the geological set up of the area, covering mainly the geological structure and the stratigraphy.
Geological Structure

The catchment area of Wadi Zabid lies on the Yemen Plateau that had strongly been uplifted and tilted roughly westward. The vertical movement of the plateau created the escapements that face the Red Sea valley on the west of the country. The Red Sea Rift occurred during the separation of the African and Arabian plates from the late Oligocene into the Miocene (Young et al., 2000). The other major effect of the tectonic movements included the regional faults (Fig. 3.4), most of them running parallel to the Red Sea rift, and the widespread volcanic activities. The rising of the magma led to the formation of extensive volcanic extrusions in Yemen including the upper catchment area of Wadi Zabid. Moreover, the Tihama plain was down-faulted several thousand meters (UN, 1981). The plain is situated inside the Red Sea Rift Valley. According to Tesco (1973) the faults are oriented generally N-S and the regional down throw is to the west into the major graben.

Stratigraphy

The outcropping formations range from Precambrian to Quaternary of the geological time scale. Yemen Volcanics (Tertiary) are dominant in the upper catchments of Wadi Zabid and Quaternary deposits are dominant in the Tihama coastal plain. However, old formations tectonically elevated, are also found in the outcrop of the transition Zone (Foothills) between the Tihama Plain and the mountainous region of the basin. These formations include Precambrian igneous rocks (granite, and gneiss), Jurassic sedimentary rocks (Amran Group – Limestone, Marl and Shale), and Cretaceous sedimentary rocks (Tawilah Group – Sandstone).
The Tihama Plain, as mentioned above, is characterized by Quaternary deposits (alluvial and aeolian deposits). According to Van Enk and Van der Gun (1984) the Tihama coastal plain has been built up mainly by unconsolidated or slightly connected, clastic sediments, deposited in the Red Sea depression on top of a down faulted surface of consolidated rocks. These sediments have been divided into two parts: a Quaternary upper part and a lower part, which is probably of Tertiary age. Figure 3.4 shows the general geological features of the study area. In addition, the stratigraphy and lithology of the mapped unit are presented in Table 3.1.

In conclusion, the morphological features of the study area are largely formed as the results of the tectonic movement, volcanic activities during the Tertiary and Quaternary periods, the major fault systems, the drainage patterns, the terrace system; the alluvial fans, and the coastal aeolian deposits. As far as, ground water potentials are concerned, the geological map (1: 500,000) by Grolier and Overstreet (1978) shows enormous systems of joints, faults and dikes in the upper catchments of Wadi Zabid. These might help in water percolation. However, the uplift of the area generates quick runoff from the catchments. Therefore, there is less chance of recharging the regional aquifer system in this area. On the other hand, the Tihama Plain is composed of a gently sloping area. It receives a great amount of surface runoff from the upper catchments. Also the Tihama plain, as previously mentioned, contains a significant aquifer system. In addition, the geological structures and the morphological characteristics of the catchments have significant impact on the sediment transportation, which affect the downstream area. Tesco (1971) indicated that the suspended sediment ranges from 40 to 85 g/lit during flood waves to not more than 0.01 - 2 g/lit during periods of low water. The suspended mater is silt, composed of relatively homogenous particles of a grain.
## Litho-Stratigraphy of Wadi Zabid Basin

<table>
<thead>
<tr>
<th>Geological Age</th>
<th>Symbol</th>
<th>Formation</th>
<th>Location</th>
<th>Lithology (I)</th>
<th>Hydrogeological Characteristics (II)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary to Recent</td>
<td></td>
<td>Alluvial and Aeolian Deposites</td>
<td>Tihama Coastal Plain Zone</td>
<td>River terrace deposits, alluvial fans, gravels, sands, silts and conglomerate</td>
<td>The Quaternary alluvial deposits are grouped under the highly aquifers in which the intergranular flow is dominant. These aquifers formed the widely exploited aquifers in Yemen and ground water development is widespread.</td>
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<tr>
<td>Tertiary</td>
<td>Intrusive Rock (+)</td>
<td>Yemen Volcanics (V)</td>
<td>Eastern &amp; Central Zone</td>
<td>Alkali granite diorite and Gabbro</td>
<td>The tertiary intrusive rocks are grouped under the regions without significant groundwater resources. They are specifically put under the strata with essentially no groundwater resources. In the Tertiary intrusive primary permeability is likely to be negligible because of the close crystalline structure of the rock, but limited ground water flow may occur in shallow cracks and joints opened by weathering. However, it is not likely to be generally sufficient to sustain flow.</td>
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<tr>
<td>Cretaceous</td>
<td>Tawilah Group</td>
<td>Foot hill Zone</td>
<td>Sandstone with conglomerates</td>
<td>Sandstone with conglomerates</td>
<td>The Tawilah sandstone rocks are generally grouped under the aquifers in which fissure flow is dominant. They are also sub grouped under the highly productive aquifers. The rock is mostly friable but occasionally well cemented. Fissure flow is thought to dominate in most areas but where it is poorly cemented intergranular flow may be important.</td>
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<tr>
<td>Upper Jurassic</td>
<td>Amran Group</td>
<td>Foot hill Zone</td>
<td>Limestone with marls and shale</td>
<td>Limestone with marls and shale</td>
<td>Amran Limestone rocks are grouped under aquifers in which fissure flow is dominant and are sub grouped under moderately or poor productive aquifers. Intergranular permeability is thought to be very low and groundwater flow is mostly restricted to fractured zones in the rock and bedding plane discontinuities.</td>
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<tr>
<td>Precambrian</td>
<td>Basement Complex</td>
<td>Foot hill Zone</td>
<td>Granite and gneiss</td>
<td>Granite and gneiss</td>
<td>The basement complex is grouped under the regions without significant groundwater resources. It is also sub grouped under strata with local and limited groundwater resources.</td>
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Table 3.1

I: Based on the geographical map - Grible and Overstreet (1978)
II: Hydrogeological map - (western part) by Robertson (1980)
size 0.002 – 0.05 mm. The bed load forms about 10 percent of the total transported load and the proportion decreases downstream. It consists mainly of andesite granite and basalt. Tesco (1971) also found that part of the suspended load was carried to the irrigated area through the diversions and lateral canals.

Soils

Soil is the portion of the land surface in which plants can grow. It is a dynamic natural body composed of fine materials and contains both mineral and organic matter (Christopherson, 1994). Soil characteristics have great effects on the infiltration and runoff process in the drainage basin. The soil types in the wadi basin are result of the climate, geomorphological process as well the lithology of the bedrocks on the basin. King et al. (1985) indicate that most soils in the northern governorates of Yemen are either subject to constant erosion processes or are the product of recent deposition. The general geological map of the wadi basin shows that the rock formations are dominant by volcanic rocks (Tertiary) and Quaternary deposits. Old formations are also found particularly in the transition zone. Quaternary alluvial and aeolian deposits are predominant on the surface of the Tihama plain.

Soil map at scale 1:500,000 (King et al, 1985) was used to generate a general soil map of the basin and to determine the soil distribution in the Wadi Zabid basin (Fig. 3.5). The description of the soil types is based on the works of Tesco (1971), Al Hubaishi and Müller-Hohinstein (1984) and King et al (1985) (Table 3.5).

According to Al Hubaishi and Müller-Hohinstein (1984) in the Tihama lowlands, due to water deficiency, mechanical weathering predominates over chemical reactions in the soils. Thus no ‘true soils’ in the pedogenetic sense are developed. Sand dunes are predominant feature of the Tihama plain. Sand loess from the wadi beds are moved by wind. Barchans and longitudinal dunes are frequently observed in
the areas between wadis (King et al, 1985). According to Tesco (1971), soils formed on the delta cone of Wadi Zabid cover gravel detritus in a thin layer (10-15 cm) at the foot of the mountains and increasingly thickening layers (6-8 m) further from the mountain. These soils mostly belong to the silt group; the extension of loamy areas is less than 10%. Approaching the sea the silt-soils are intermingled with aeolian sand.

According to Al Hubaishi and Müller-Hohinstein, in the highland isolated mountain peaks, cliffs and rocky outcrops, with extremely soil erosion; bear neither soil, nor vegetation. On the steep slopes and on the non-arable lands of the escarpment area there is no much of the natural soil cover left. Therefore, very stony, shallow and skeletal soils with a dwarf-shrub community dominate. However, in few sites, a well-developed medium textured brown soil appears. Very important soils develop on the alluvial deposits in the mountain basins of the highlands as well as the Tihama Plain.

Terracing system represent the old traditional ways of soil conservations. These terraces retain and collect soil parent material along the mountain slope. According to King et al (1985) two kinds of terraces are recognized in Yemen volcanic zone: colluvial terraces and loess terraces. The colluvial terraces consist of colluvium from volcanic rocks mixed with some loess. The soil material in colluvial terraces is quite erodible. The colluvium itself is gravely and or stony and has a lower water holding capacity than the loess material. The loess terraces have no constructed retaining wall, because loess erodes less easily than colluvial soil parent material.

In Wadi Zabid basin, in a north-south cross-section, King et al. (1985) observed several levels of natural alluvial terraces, each with distinct textural compositions. The older, more extensive terraces contain less sorted, coarser materials (gravel and small boulders) while younger, less extensive terraces are typically better sorted and finer in texture. In an east-west cross section along the wadi from the catchment
WADI ZABID BASIN
SOIL MAP

Source: Based on King et al. (1985)

Index

I. Soils Predominantly Aridisols
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   ASF

II. Soils Predominantly Entisols
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   EHU
   EOC
   EST
   ETO
   ETT
   EUB
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   EUR
   EUU

III. Soils Predominantly Inceptisols
    EUC

IV. Soils Predominantly Rock Outcrops
    RTT
Table 3.2: Index for Soil Map (fig. 3.5)

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<th>Map Units</th>
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area to the Red Sea, another sequence of sediments is observed. The materials become finer westwards from the mountains until to a zone of recent sedimentary marine deposits near the Red Sea.

In general, based on the soil map of the basin, the major soil types are grouped into four predominant soil orders and each into subgroups. These major soil groups are: (1) Aridisols, (2) Entisols, (3) Inceptisols, and (4) rock Outcrops. Aridisols are found along the Red Sea coast and in small portions in the Transition zone. Entisols are the predominant soil order in the basin. They cover large areas in the catchment zone as well as the Tihama plain. In the transition zone these soil types appear in small areas. According to King et al (1985), most Entisols in the northern governorates of Yemen are strongly influenced by alluvial or loessal calcareous silt parent materials but where the parent rocks are sandstone or on the plains where sand has accumulated in dunes, Psamments are common.

Inceptisols are very limited in the basin. They occur in small portions in the northeastern part of the wadi basin. The rock outcrops areas occur on the middle, transition zone as well as on the pediment area in the eastern Tihama part of the wadi basin.

Natural Vegetation

The infiltration and runoff process in a drainage basin are strongly controlled by a set of variable such as vegetation cover, soil characteristics, slope and lithology of the basin surface. According to Venugopal et al (1996) vegetation cover plays a curial role in the evolution of a drainage basin to its current hydrological and geomorphologic status as it strongly influences the input and out put of matter and energy. While dense vegetation slows down the surface runoff and promotes infiltration, it influences the development of the stream networks and in turn the drainage density or the total length of the drainage channels maintained by unit area of the basin surface. On
the other hand ground surface with sparse or scanty vegetation cover will increase the erosion activity and considerable loss of soil layers.

Rainfall and temperatures are the most important climatic factors for plant life. In Wadi Zabid basin, rainfall and temperature are strongly correlated with the altitude. The Tihama plain is dominated by arid conditions. Rainfall is low and evaporation is high associated with the high temperatures. Therefore, plants are well adapted to these conditions. Desert plants grow in this region. The central zone is dominated by the semi-arid conditions. Rainfall is much higher than the Tihama and temperatures are low. In the eastern highlands, the climate is moderate and the region receives high amount of rainfall especially around Ibb area. Thus high density of vegetation is found in this region. In general, the vegetation landscape of Wadi Zabid basin is the result of factors such as topographical features, climate particularly rainfall and temperature, and soils. The great diversity of climate, altitude, and relief has led to the existence of various natural environments throughout the wadi basin.

Based on the works of Al Hubaishi and Muller-Hohenstein (1984) and Scholte et al. (1991), five major vegetation landscape zones have been identified in Wadi Zabid basin. These zones have been divided based on altitudes. The zones are shown in figure (3.6 a-e). The profiles were adopted from Al Hubaishi and Muller-Hohenstein (1984). The details descriptions of vegetation in each profile are based on the same sources mentioned above. The following is the description of vegetation in each major zone.

1. The Tihama Lowlands (0-300 m)

Due to environmental conditions, the Tihama part of the study area is generally covered by desert vegetation which is adapted to the sand soil and salty water, especially along the coastline of the Red Sea. Four types of natural environments can be distinguished in the Tihama
Along the coast zone large areas are scarce in vegetation because of the increasing salty water and movement of the sand. Thus only halophytes survive. Vegetative cover consists of hylophytic dwarf shrubs as *Sowyah* (*Suaeda fruticosa*), and *Molyh-Fdhadan-Waqid* (*Salsola spinescens*), and short grasses as *Regl al Harba'a-Karzy-Adbab* (*Dactyloctenium scindicum*) and *Najil Balady-Molyh* (*aeluropus massauensis*). At the downstream areas close to the shoreline, where ground water found in very shallow depth, date palm trees and other plants exist. To the east due to lack of sufficient rain, the vegetation is much less. The vegetation is sparse and dominated by shrub and grassland. The Tihama Development Authority, under environmental protection program, has been actively involved in planting trees and shrubs in order to prevent the sand dunes extension and reduce threat of desert extension into agricultural fields as well as the settlements. In the areas of the alluvial deposits, lands were cleaned for cultivation, therefore, very little natural vegetation remains. Acacia trees are found along with other trees in the area. In the eastern part of the Tihama Plain, there is bare gravel area formed by deposits that are brought from the foothills. Scattered trees are found in the area with some dense vegetation along the Wadi Zabid courses.

2. **Foot hill zone (300-1000 m)**

In foothill areas (Fig.3.7 b), where rain is insufficient and the vast rocky outcrops exist, the natural vegetation is scare or almost absent. Wadi bed vegetation is found as well as some scattered vegetation. Towards the east, where altitude is about 1000 meters, a considerable range of vegetation type can be found. As seen from figure 3.7b, along the lower high hillsides and on the pediment and steep slopes the vegetation covers include annual and perennial herbs, short grasses, dwarf shrubs, succulents, and trees such as bottle- tress, umbrella- shaped trees, and drought- deciduous trees. Where the silty
and sandy basins occur, the natural vegetation includes evergreen woodland. The dominant trees are evergreen sclerophyllous trees, drought-deciduous trees as well as evergreen shrubs. While in the wadi system, the dominant trees are microphyllous trees Athl-Abl-Tarfa'a-Tarfah (Tamarix nilotica). Other vegetation includes rod-shaooed shrubs and tall grasses.

3. Lower Escarpment (1000-1600 m)

This zone represents the gradual transition from the low altitude to the medium altitude western mountains, which have their upper boundary at about 1800m. In this medium altitude (1000 – 1600 m) there are trees, shrubs, and annual grasses (Scholte et al., 1991). Figure 3.7c shows the vegetation landscape in this zone. On the dry slopes drought deciduous trees are dominant. Other vegetation includes bottle – trees, dwarf shrubs and grasses. On the wadi system of the lower escarpment area a tropical evergreen seasonal forest with broad-leaved evergreen trees prevails and closed, sometimes very dense, are found. Along the wet slopes the plant communities consist of dwarf shrubs, drought-deciduous shrubs, drought-deciduous trees, evergreen shrubs and evergreen broad-leaved trees.

4. Higher Escarpment (1600-2200 m)

In the high altitude (above 1600 m) especially around Ibb, which receives high rainfall in the Wadi Zabid basin, the area is covered year round with green vegetation. Dense woodlands can be found in some zone of this area. Figure 3.7d shows the natural vegetation landscape in this zone. On the dry slopes the dominant trees are the drought-deciduous trees. Other vegetation includes geophytes plants, grasses, perennial herbs, and dwarf shrubs. Moreover, evergreen broad-leaved trees are found on the V-shaped valley areas. On the wadi system evergreen broad-leaved trees are dominant. On the wet steep slopes and
cliffs large varieties of plants are found. The dominant trees are evergreen broad-leaved Taloq-Tulq (*Ficus vasta*), Tanb (*Cordia abyssinica*) and Athum-Attm sclerophyllous (*Olea chrysophylla*). The area represents an intensively cultivated part of the Wadi Zabid basin. The landscape of the area is characterized by the magnificent terraces systems on the mountain slopes.

5. Highlands and High Mountains Zone (2200-3000 m)

In this zone vegetation covers consist of perennial herbs, short grasses, ferns Ayfajan (*Ceterach officinarum*), Kylansh (*Cheilanthes pteridioides*), evergreen shrubs, drought-deciduous trees, evergreen sclerophyllous trees, and Alpine pasture.

Generally, the natural vegetation has been subject to such activities like grazing of livestock, cutting / collecting firewood, and cleaning for cultivation. These have led to land degradation problems.
Ecosystem and Natural Vegetation

A: Tihama

- Mangrove
- Saltswamp (Coastal)
- Drought-DECIDUOUS (DUNES AND BUNES VALLEY)
- Evergreen (WADI SYSTEM)
- Drought-DECIDUOUS (FOOTFLAT)

B: Tihama-foothills

- Drought-DECIDUOUS (FOOTHILLS)
- Evergreen woodland (INERMOUNTAIN BASIN)
- Evergreen (WADI SYSTEM)
- Drought-DECIDUOUS (PEDIMENT)

C: Lower Escarpment

- Drought-DECIDUOUS SUBMONTANE (DRY SLOPE)
- Evergreen (WADI SYSTEM)
- Drought-DECIDUOUS SUBMONTANE (WET SLOPE)

Annual herbs as Zygophyllum simplex, Bysphoria indica
Woody perennials as Tephrosia purpurea, dipyrgyrum glaucum
Short grasses as Dactyloctenium scindicum, Astragalus massaenensis
Tall grasses as Desmostachya bipinnata
Rod-shaped shrubs as Leptadenia pyrocica
Bunch grasses as Panicum turgidum, Lusitana hirtanu
Dwarf shrubs as Indigofera spinosa
Halophytic dwarf shrubs as Avicenna fruticosa, Salcura spinosa
Evergreen shrubs as Cadaba rotundifolia, Cassia sesan
Palm trees as Hyphaene thebaica
Drought-deciduous shrubs as Abrus bettor, Ormocarpum yemenense
Succulents as Bysphoria insculptula, Coralluma quadrangular
Bottle-trees as Adenanther obusum
Umbrella-shaped trees as Acazia tortilis, A Migambiana
Stem-building drought-deciduous trees as Zitrophus spinos-christi, Acacia asak, A. Meliffere
Evergreen sclerophyllous trees as Debera glabra, Balanites aegyptiaca
Drought-deciduous trees as Commiphora myrrha, Copalsamum
Evergreen microphyllous trees as Tamarix nilotica
Evergreen broad-leaved trees as Ficus salicifolia, Cordia abyssinica
Mangrove trees as Avicenna marina

Fig. 3.6

Ecosystem and Natural Vegetation

**D: Higher Escarpment**

- **Drought-Deciduous Mountain (Dry Slopes)**
- **Evergreen Forest (Wadi System)**
- **Evergreen Broadleaved (Wet Slopes and Cliffs)**

**E: Higher and the High Mountains**

- **Drought-Deciduous Evergreen and Alpine Pastures (High Mountains)**
- **Drought-Deciduous Submontane (Piedmont and Wadi System)**
- **Drought-Deciduous Mountain Shrubland (Volcanic Plains and Dry Slopes)**

- perennial herbs as *Achyranthes aspera, Flavens trinxema*
- annual herbs as *Achnatherum commutatum, Festuca transvaala, Salvia schimpfii, Campanula edulis*
- short grasses as *Andropogon distachyus, Hyparrhenia hirta*
- tall grasses as *Typha elephantina*
- geophytic plants as *crimyemense, scadaxus multiflorus, Ceterach offlorna, Chilanthus pyriformis, Indigofera spinosa, polygala irregularis*

- drought-deciduous shrubs as *Lycium showii, Rosa abyssinica*
- evergreen shrubs as *Carissa edulis, Myrsine africana*
- succulents as *Euphorbia ineruculata, Corallium quadrangula*
- palm trees as *Phoenix reclinata*
- stem-building drought-deciduous trees as *Ziziphus spina-christi, Acacia gerardii*
- evergreen sclerophyllous trees as *Olea chrysophylla, Buddleja polyactyla*
- evergreen microphyllous trees as *Tamarix martina*
- evergreen broad-leaved trees as *Ficus vallata, Cordia abyssinica*
- alpine pastures with *Cichorium botanum, Duallia uniflora*