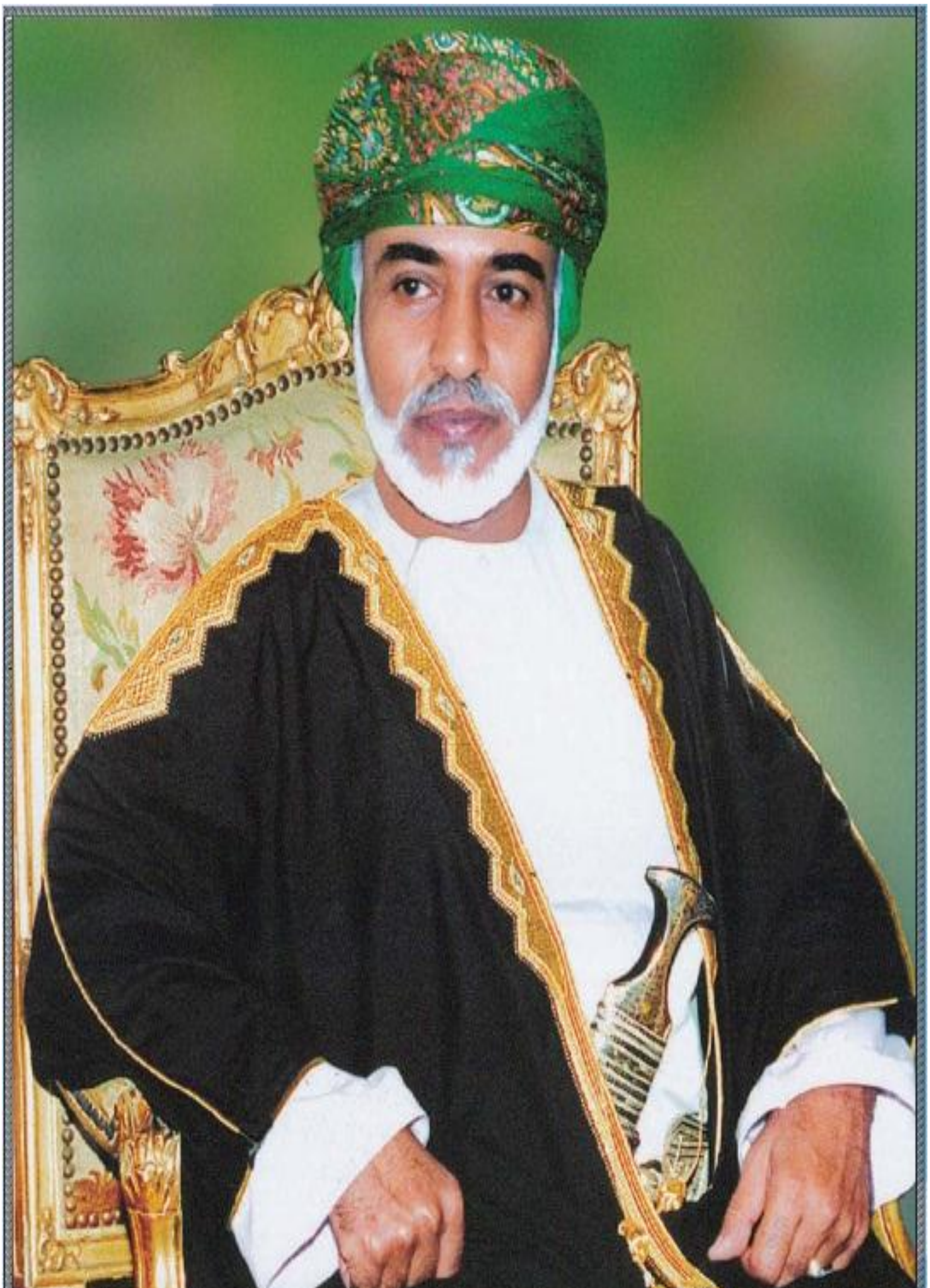



Sultanate of Oman

Initial National Communication under The United Nations Framework Convention on Climate Change

Ministry of Environment & Climate Affairs

October 2013



His Majesty Sultan Qaboos Bin Said

FOREWORD

On behalf of the government of the Sultanate of Oman, I am delighted to present the ''Initial National Communication'' to the Conference of the Parties through the UNFCCC Secretariat in fulfillment of Obligations under the United Nations Framework Convention on Climate Change.

The Sultanate of Oman is vulnerable to climate change. During the last few years the country witnessed two severs tropical cyclones. Intensity of tropical cyclones and severity of their impact may increase in future warmer climate. Climate change is predicted to have numerous impacts on the Sultanate of Oman. These include, but not limited to the following; livestock's and fish resources losses, severe water scarcity due to droughts and increased temperatures, biodiversity loss and ecosystem degradation. Along the coastal areas, sea level rise will affect the coastal infrastructures and fragile ecosystems.

Climate change impacts predicted for the Sultanate of Oman will adversely affect the extent and the speed at which long-term, medium and even short-term national development goals can be achieved. It is clear that the cost of addressing impacts of climate change will far outweigh the cost of no action. Action on climate change is required across all sectors. A national strategy for climate change adaptation - is a necessary course of actions.

I would like to thank all the experts, the national and international organizations who participated in the preparation of this report, and in particular, Sultan Qaboos University, UNDP and UNEP for their synergies and active role in the compilation and preparation of the Initial National Communication.

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ACKNOWLEDGEMENTS

The Ministry of Environment & Climate Affairs (MECA) and Sultan Qaboos University (SQU) jointly prepared Sultanate of Oman's Initial National Communication. Financial support is gratefully acknowledged from the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP). Technical support is gratefully acknowledged from the United Nations Environment Programme/Regional Office of West Asia (UNEP/ROWA). SQU coordinated all technical inputs from national experts and other contributors.

The Project Team would like to acknowledge the support of the GEF, UNDP, UNEP and MECA during the implementation of this project. In particular, special thanks go to members of the research team for their valuable contributions in data collection, analyses and capacity building workshops. The research team came from many different institutions in Sultanate of Oman, including:

- Ministry of Environment & Climate Affairs
- Ministry of Oil & Gas
- Ministry of Commerce & Industry
- Ministry of Transport & Communication/Directorate General of Meteorology & Air Navigation
- Ministry of Agriculture & Fisheries
- Public Authority for Electricity and Water
- Petroleum Development Oman
- Muscat Municipality

Words of thanks are expressed to all local and international experts who have trained, supported, guided and advised the project team during the implementation of this project. We would like also to express our gratefulness to the National Authority Survey, for their technical support.

Finally, a debt of gratitude is due to the following people from Sultan Qaboos University who have worked tirelessly to ensure that this report reflects the perspectives and inputs of the range of stakeholders in the Sultanate of Oman: Prof. Adel Gastli, Dr. Yassine Charabi, Prof. Sabah Al-Sulaiman, Dr. Slim Zekri, Dr. Rashid Al-Maamari, Dr. Adnan Al-Azri, and Dr. Ghazi Al-Rawas.

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List of Acronyms

Bcm	Billion cubic meters (m^3)
°C	degrees Centigrade
CDM	Clean Development Mechanism
CoP	Conference of Parties
DEM	Digital Elevation Model
DNA	Designated National Authority
FAO	Food and Agriculture Organization of the United Nations
GCC	Gulf Cooperation Council
GCM	Global Circulation Model
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GIS	Geographic Information System
GPG	Good Practice Guidelines
GWP	Global Warming Potential
ha	hectare
HFCs	Hydrofluorocarbons
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWRM	integrated water resource management
LUCF	Land-use change and Forestry
m^3	cubic meters
Mm^3	Million cubic meters
MDG	Millennium Development Goal
MECA	Ministry of Environment & Climate Affairs
MHT	Mean High Tide
NCDC	National Climatic Data Center
RNO	Royal Navy of Oman
SF_6	Sulfur hexafluoride
SoO	Sultanate of Oman
SQU	Sultan Qaboos University
UAE	United Arab Emirates
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

Executive Summary

National Circumstances

The Sultanate of Oman occupies the southeastern corner of the Arabian Peninsula. The country encompasses an area of about 309,500 km^2, and is characterized by a diverse range of topography including mountain ranges, arid deserts and fertile plains.

The Basic Statute of the State is the cornerstone of the Omani legal system and operates as a constitution for the country. The Basic Statute was issued in the year 1996 and stipulates a Sultani hereditary governance system through the male descendants of Sayyid Turki bin Said bin Sultan.

The Sultanate of Oman is an arid region. Nevertheless, due to its complex topography, the country has a number of microclimates ranging from hyper-arid conditions in the Empty Quarter and along coasts and plains, to arid conditions in foothills and highlands, to semi-arid conditions along the slopes and summits of the Al Hajar Mountains in the north.

The Sultanate of Oman is a fast-growing country in terms of its population, economic progress, and education. In 2010, the year of the last national census, the population reached nearly 2.8 million people, with growth of about 2.5% per year over 2003-2010. It is on track to achieve all health-related Millennium Development Goals.

Over the years, there have been many legislative actions and institutional developments to protect the environment and natural resources, as well as to address all forms and sources of pollution. The Five Year Development Plans, implemented since 1975, include the basic principles that link development with environmental considerations.

The Sultanate of Oman's environment is home to a rich and unique biodiversity. In the northern regions, biodiversity shows a strong affinity with neighboring Iran and Pakistan, while flora and fauna in the far southern regions are more characterized by the influence of African biodiversity. Overall, over four thousand flora and fauna species and subspecies can be found.

The Sultanate of Oman is one of most water-stressed countries in the world. Keeping water supply and demand in equilibrium in a pressing development challenge facing Sultanate of Oman in the years ahead.

Table ES-0-1: Total GHG emissions in Sultanate of Oman, 1994 (Gg)

GHG Sources & Sinks	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1 Energy	12,445	10,596	87.7	0.0	0	0	2	3
2 Industrial Processes	592	589	0.2	0.0	0	0	0	0
3 Solvent & Other Product Use	0	0	0.0	0.0	0	0	0	0
4 Agriculture	7,469	0	18.5	22.8	0	0	0	0
5 Land-Use Change & Forestry	0	0	0.0	0.0	0	0	0	0
6 Waste	372	0	17.7	0.0	0	0	0	0
Total National Emissions	20,879	11,184	124.2	22.9	0	0	2	3
Net National Emissions	**20,879**	**11,184**	**124.2**	**22.9**	**0**	**0**	**2**	**3**

Agricultural production is wholly dependent on irrigation. Hence, water rather than the availability of arable land and/or suitable soils are the critical constraints. Cultivated area grew rapidly between 1970 and 1997, averaging about 3.7% per year.

The Sultanate of Oman has the fifth largest economy in the Gulf Cooperation Council (GCC) region. The oil and gas sector continues to be the largest sector. Nevertheless, there has been steady progress in moving away an oil-based economy to one that is more diversified. Particular attention has been devoted to transportation activities due to its importance in socioeconomic development. This is evidenced by the sharp growth in the length of asphalt roads over the 1970 - 2010 period and increased air traffic through the international airport in Muscat.

Greenhouse Gas Emission Inventory

Table ES-0-1 presents total GHG emissions and sinks for the year 1994. Total GHG emissions were 20,879 GgCO_2-equivalent, which includes 12,445Gg from energy; 592Gg from industrial processes; 7,469Gg from agriculture, and 372Gg from waste. With CO_2 sink by the forestry and land use sector amounting to zero Gg, net GHG emissions are equal to total emissions. Emissions from hydrofluorocarbons (HFCs) are considered negligible, as the products containing these gases are not produced in the country.

Vulnerability and Adaptation

Coastal zones, water resources, and the marine environment are considered the most vulnerable sectors in Sultanate of Oman.

For coastal zones, nearly 400 km^2 of total land area is projected to be inundated under the lowest sea level rise scenario. Under the highest sea level rise scenario, over 900 km^2 is potentially inundated. At the Governorate scale, the Al Wusta Governorate is most vulnerable under high sea level rise scenarios, with potentially up to roughly 280 km^2 of total land inundated.

For water resources, climate change is expected to aggravate an already serious challenge of balancing water supply and demand. Going forward, it will be important to implement an integrated water resource management planning framework in Sultanate of Oman. Such framework should be the basis by which adaptation strategies and policies can be identified and pursued.

Regarding the marine environment, rising water temperatures from climate change is expected to cause declines in the health of phytoplankton communities, the abundance of fish populations, and changes in the physiology and behavior of marine species. Such changes will adversely impact commercial fishery production in the Sultanate of Oman.

Roadmap in Response to Climate Change

Sultanate of Oman recognizes the need to develop a national strategy for climate change adaptation and mitigation. This is driven by the inherent threat of climate change, the depletion of oil and natural gas, and the Sultanate of Oman's vision for sustainable socioeconomic growth. Recognizing that the impacts of climate change will adversely affect the extent and the speed at which long-term, medium and even short-term national development goals can be achieved in the Sultanate of Oman, the national strategy focuses on plans for institutional coordination, network development, and capacity strengthening.

1. NATIONAL CIRCUMSTANCES

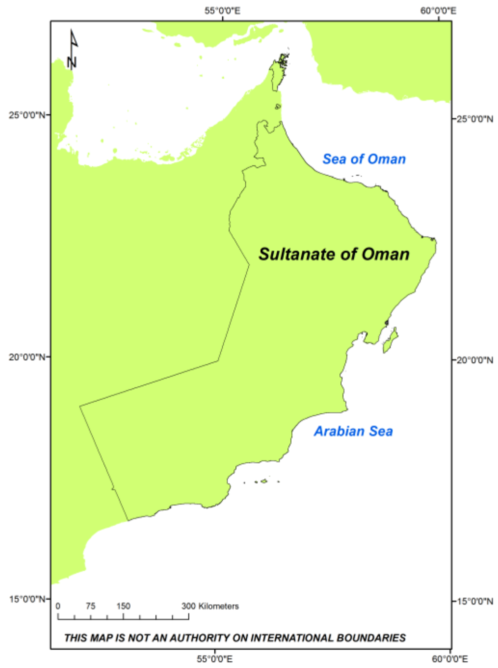
1.1 Introduction

This chapter provides an overview of the Sultanate of Oman's national circumstances, including its geography, government structure, climate, population, and other characteristics. In addition, the chapter devotes several sections to describe its environmental setting such as the regulatory framework, biodiversity, and natural resources.

1.2 Geography

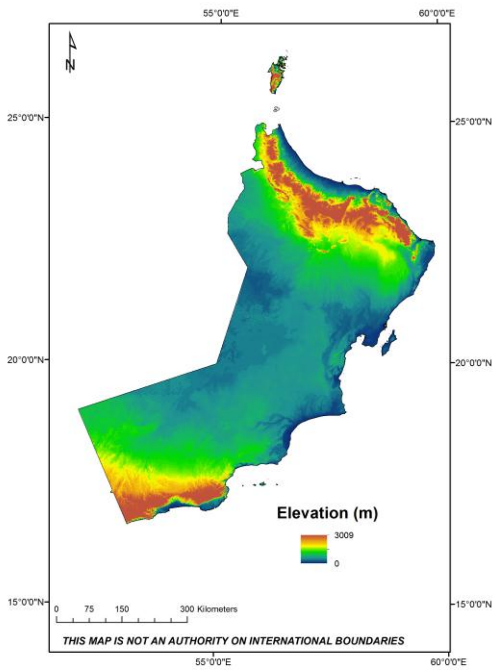
The Sultanate of Oman (SoO) occupies the southeastern corner of the Arabian Peninsula and is located between the latitudes 16°40´ and 26°20´ North and the longitudes 51°50´ East (see Figure 1-1). It is bordered to the West by the Kingdom of Saudi Arabia, the United Arab Emirates and the Republic of Yemen; to the east by the Sea of Sultanate of Oman up through the Strait of Hormuz at its northern end, and the Arabian Sea in the South.

Figure 1-1: Location of the Sultanate of Oman in the Arabian Peninsula (Source: DIVA-GIS)



The country encompasses an area of about 309,500 km^2, and is characterized by a diverse range of topography including mountain ranges, arid deserts and fertile plains (see Figure 1-2). There are three major regions, as briefly described in the bullets below.

Figure 1-2: Topography of Oman (Source: The National Survey Authority)



- *Mountains:* These areas occupy about 15% of the country. In the north, the Al Hajar Mountains extend in an arc form for 700 km from Musandam in the north and curve eastward towards the coast to Ras Al Had, the easternmost part of country. The highest point is at Jabal Shams, 3,009 meters above mean sea level. In the south, the Dhofar Mountains Chain are located in southwestern Sultanate of Oman and have peaks from 1,000 to 2,000 m above mean sea level.
- *Coastal plains:* These areas occupy about 3% of the country. They extend from the Al Batinah North and Al Batinah South Governorates to the Salalah Plain in the south. These plains, which serve as Sultanate of Oman's main agricultural areas, have elevations ranging from 0 to 500 m. The coastline extends 3,165 km, from the Strait of

Hormuz in the north to the borders of the Republic of Yemen, with a number of islands offshore, the largest being Masirah to the East of Central Sultanate of Oman.

- *Interior:* These areas occupy the largest share of the country, about 82%. The interior region occupies the total area between the Al Hajar Mountains in the north and the Dhofar Mountains Chain in the south. This region consists of sandy, wasteland desert with elevations typically reaching no higher than 500 meters above sea level.

The physical features of the coastline vary considerably, from precipitous cliffs falling to depths of over 40 meters near the shore of Musandam in the far north, to shallow sandy beaches with scattered inlets and lagoons (some of which support mangroves) along the Al Batinah coast. The coast of Central Sultanate of Oman is characterized by sandy beaches with areas of salt flats, especially in the Bar Al Hikman, which joins the Rimal Ash Sharqiyyah (Sands) opposite Masirah. Extensive high cliffs with some sandy beaches and tidal inlets characterize the coast of Dhofar in the southwest.

1.3 Government

The Basic Statute of the State is the cornerstone of the Omani legal system and operates as a constitution for the country. The Basic Statute was issued in the year 1996 and stipulates a Sultani hereditary governance system through the male descendants of Sayyid Turki bin Said bin Sultan. The Basic Statute further stipulates that the Sultan is the Head of the State and the Supreme Commander of Armed Forces, that he is to preside over the Council of Ministers, and that he is responsible for promulgating laws and appointing judges.

The Council of Ministers is the body responsible for implementing the general policies of the State. The Council of Sultanate of Oman is responsible for reviewing legislation and submitting it to the Sultan for Royal Assent. It is made up of the State Council, an appointed body, and the Shura Council, an elected body. The judiciary is guaranteed independence.

The Sultanate of Oman is divided into eleven Governorates (Ad Dakhliyyah, Adh Dhahirah, Al Batinah North, Al Batinah South, Al Buraymi, Al Wusta, Ash Sharqiyyah North, Ash Sharqiyyah South, Dhofar, Muscat, and Musandam). Each of these is subdivided into smaller districts called *wilayats*, which are governed by the *wali*, the person responsible for the area who reports to the Ministry of the Interior. Formal decentralization of government exists with the division of the nation into municipalities. Sultanate of Oman has a total of 44 municipalities, which are overseen by the Ministry of Regional Municipalities and Water Resources.

1.4 Climate

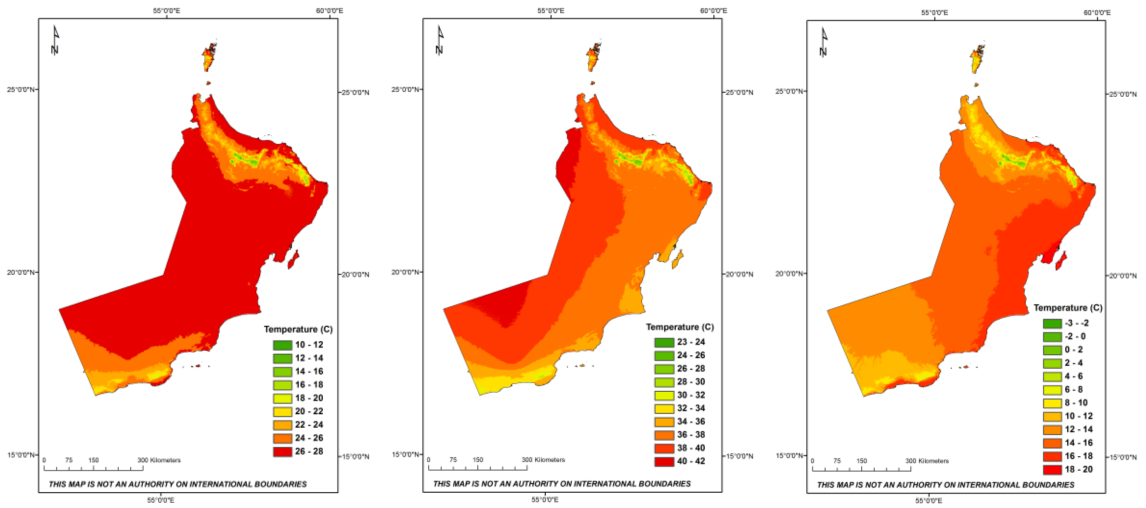
By virtue of its position astride the Tropic of Cancer, and according to the Köppen and Geiger classification system (Köppen and Geiger, 1928), the Sultanate of Oman is classified as an arid region. Nevertheless, due to its large latitudinal extent and complex topography, Sultanate of Oman has a number of microclimates across its territory. These microclimates range from hyper-arid conditions (< 100 mm/year of rainfall) in the Empty Quarter *(Ar Rub Al Khali)* and along coasts and plains, to arid conditions (100–250 mm/year of rainfall) in foothills and highlands, to semi-arid conditions (250– 500 mm/year of rainfall) along the slopes and summits of the Al Hajar Mountains in northern Sultanate of Oman. Scarce and erratic rainfall and varying temperatures have combined to shape the distribution and abundance of vegetation (Ghaznafar and Fisher, 1998).

Temperature is affected by major air masses that occur in the Arabian Peninsula. Specifically, the Polar Continental air mass occurs in winter from December to February and brings cold temperatures and high pressure. The Tropical Continental air mass occurs in summer from June to September and brings hot and very dry air. Both systems are affected by minor incursions of Polar Maritime and Tropical Maritime. The simulated temperature profile in Sultanate of Oman due to these air masses is briefly described below based on the 1961-1990 period.

- *Average annual temperature:* Overall, these temperatures fluctuate between 10°C to 28°C (see Figure 1-3a). The lowest average annual temperatures are found at peaks in the Al Hajar Mountains. Most of the rest of the country experiences average annual temperatures within a narrow range between 26°C and 28°C.
- *Average maximum temperature:* The hottest month of the year in Sultanate of Oman is June. During this month, average maximum temperatures are between 23°C and 42°C (see Figure 1-3b). In the interior plains, high temperatures in summer can exceed 42°C.
- *Average minimum temperature:* The coldest month of the year in Sultanate of Oman is January. During this month, average minimum temperatures are between -3°C and 20°C (see Figure 1-3c). Coldest temperatures are encountered in highland and mountain areas in the northern and southern part of the country.

Figure 1-3: Temperature patterns in Sultanate of Oman, 1961-1990 (Source: Charabi and Al-Yahyai, 2013)

a) Average annual b) Average maximum (June) c) Average minimum (January)

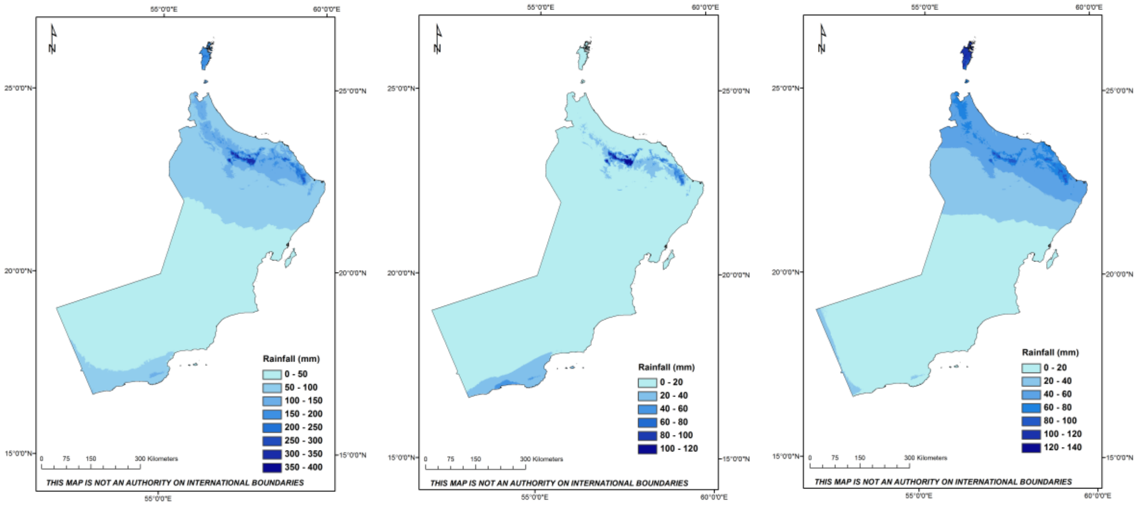


Rainfall is caused by four principal mechanisms - convection, cold frontal troughs, monsoons, and tropical storms/cyclones - and their interactions with local topography and other meteorological conditions (Charabi, 2009; Kwarteng et al, 2008). Historical rainfall patterns in Sultanate of Oman are briefly described below based on the 1961-1990 period.

- *Average annual rainfall:* Overall, rainfall fluctuates between 27 and 400 mm/year (see Figure 1-4a). The lowest average annual rainfall is found in the interior plains and coastal areas along the Arabia Sea. The highest average annual rainfall is found around peaks in the Al Hajar Mountains. Most of the highland areas of the country experience average annual rainfall within a narrow range between 50 and 100 mm/year.

Figure 1-4: Rainfall patterns in Sultanate of Oman, 1961-1990 (Charabi and Al-Yahyai, 2013.)

a) Annual average b) Summer average c) Winter average



- *Average summer rainfall:* During the summer months of June through September, average rainfall is between zero and 20 mm for the overwhelming majority of the country (see Figure 1-4b). Summer brings the monsoon rains *(khareef)* along the Dhofar coast and bordering mountain areas with between 20 and 60 mm during the summary months (between 100 and 400 mm per year). Occasionally, monsoon conditions penetrate further inland to produce convective storms in the southwest. During the khareef season, parts of Dhofar region are transformed into lush landscapes of green field and verdant vegetation.
- *Average winter rainfall:* During the winter months of November through April, average rainfall is between 20 and 60 mm for northern parts of the country, and between zero and 20 mm for the rest (see Figure 1-4c). Cold frontal troughs originating in the North Atlantic or Mediterranean Sea are common during this period and are responsible for the rain in north Sultanate of Oman. Physiographic conditions significantly affect average winter rainfall, with Muscat along the coast receiving about 75 mm as opposed to high elevation areas in the Al Hajar Mountains between 400 and 3,009 meters above mean sea level receiving between 80 and 120 mm in the winter months (between 250 and 400 mm per year).

Extreme weather events are not uncommon in the Sultanate of Oman. They are associated with tropical cyclones in the north Indian Ocean and Arabian Sea. While most of the tropical depressions, tropical cyclonic storms and severe cyclonic storms affect the west coast of India and Pakistan; there are many storms that track toward the Sultanate of Oman (see Figure 1-5). Such storms are usually confined to two cyclone seasons, namely the pre-monsoonal period (May-June) and the post-monsoonal period (October-November).

Since 1889, there have been a total of 15 extreme weather events that have caused loss of life and substantial damage throughout the coastal areas of Sultanate of Oman (see Table 1-

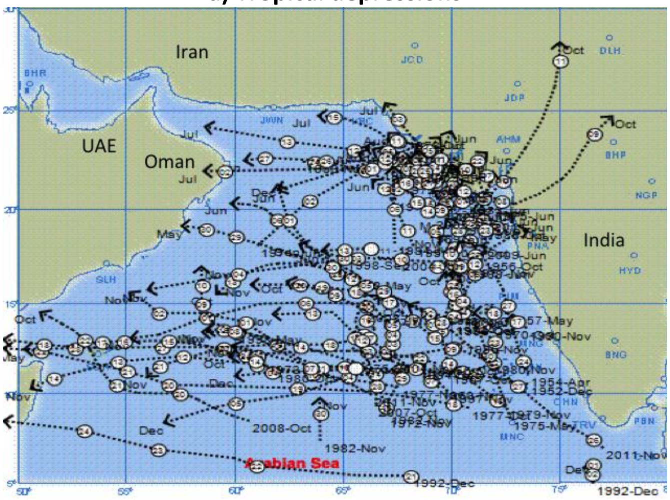
1). Most recently, in June 2007, the super cyclone Gonu tracked into the Sea of Sultanate of Oman (Al-Maskari, 2010). This cyclone is the strongest on record in the Arabian Sea, with 900 mm of rain falling on a single day (5 June 2007) and average wind speeds reaching about 130 km/h. A total of 50 people were killed as a result of Gonu in Sultanate of Oman, with damages of about $4.2 billion. Three years later, on 4 June 2010, the cyclone Phet made landfall in Sultanate of Oman, dropping 450 mm over northeastern Sultanate of Oman. In Sultanate of Oman, 24 people died with damages of about $0.8 billion (Reuters, 2010).

The seasonal frequency of extreme weather events varies greatly across the entire Arabian Sea area. Given the right set of enabling meteorological conditions, tropical depressions in this large region can develop into tropical cyclonic storms, which can then intensity into severe tropical cyclonic storms. The historical seasonal probability of storm intensification in the Arabian Sea is summarized in the bullets below, based on an analysis of data for a 61-year period, 1950 through 2011.

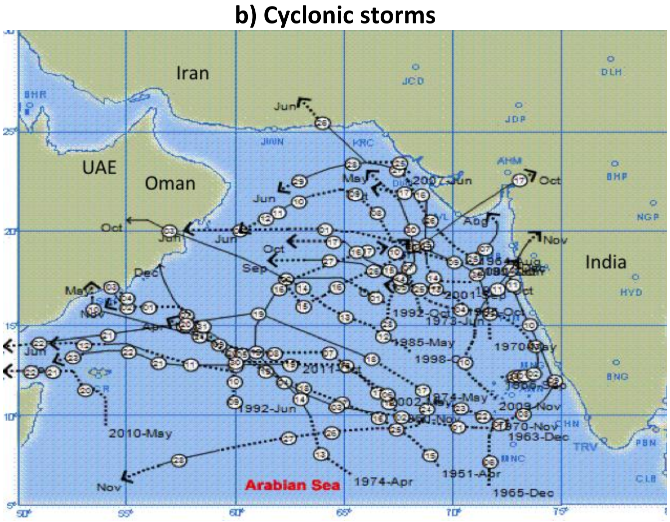
- *All extreme weather events:* The seasonal frequency of depressions, cyclonic storms and severe cyclonic storms over the Arabian Sea during (1950-2011) is shown in Figure 1-6a. The October-November-December (OND) season has the highest frequency of storm events, with the March-April-May (MAM) season showing the lowest frequency. No tropical cyclonic activities have been recorded

Figure 1-5: Storm tracks over the North Indian Ocean and Arabian Sea, 1950-2011 (Source: India Meteorological Department, 2012)

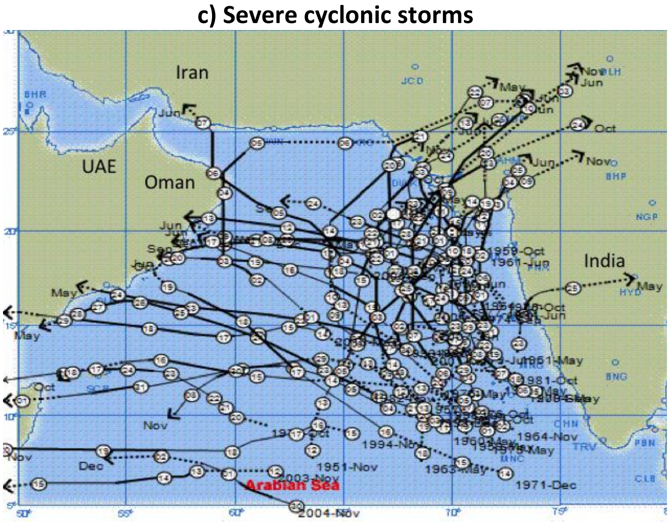
a) Tropical depressions



b) Cyclonic storms



c) Severe cyclonic storms



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during January-February (JF) season.

- *Development of tropical depressions into cyclonic storms:* The seasonal probability of tropical depressions intensifying into severe cyclonic storms over the Arabian Sea is shown in Figure 1-6b. The March-April-May (MAM) season has the highest probability of intensification events (about 40%), with the July through December period (JJAS and OND) showing roughly half the probability (about 40%). Negative values during January-February (JF) season indicate an indeterminate probability.
- *Development of cyclonic storms into severe cyclonic storms:* The seasonal probability of cyclones intensifying into severe cyclonic storms over the Arabian Sea is shown in Figure 1-6c. Between March and December (MAM, JJAS, and OND), the probability of intensification events is consistently about 60%. Negative values during January-February (JF) season indicate an indeterminate probability.

1.5 Demography and human development

The Sultanate of Oman is a fast-growing country in terms of its overall human development. The 2010 UNDP Human Development Report indicated that Sultanate of Oman is classified in the "high human development" category. The Report also distinguished Sultanate of Oman as the country with the fastest increase in the Human Development Index globally over the past 40 years (Human Development Report, 2011).

The Sultanate of Oman is also a fast-growing country in terms of its population, economic progress, and education (see Table 1-2). In 2010, the year of the last national census, Sultanate of Oman's population reached nearly 2.8 million people, or about 2.5% per year over 2003-2010.

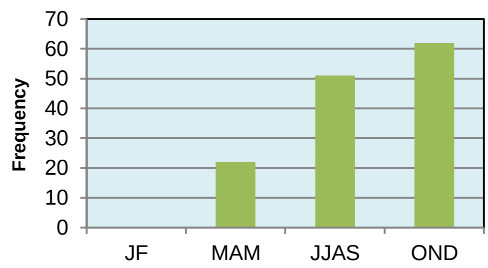
Over this same period, per capita annual income grew from $16.9 thousand to about $25.4 thousand, equivalent to a nominal growth rate of about 6% per year. While most of the jobs continue to be in the government sector, the

Table 1-1: Tropical depressions, cyclones and severe cyclones that have impacted coastal areas of Sultanate of Oman, 1889-2010 (Source: Al-Maskari, 2010)

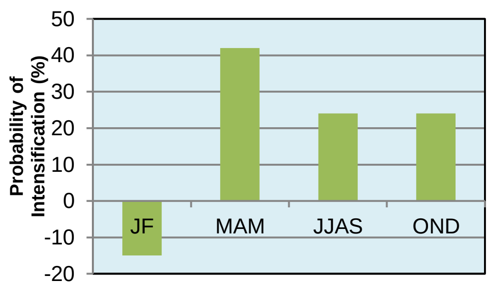
#	Year	Month	Cyclone/Storm
1	1889	-	Storm
2	1890	June	Cyclone
3	1948	October	Cyclone
4	1959	May	Cyclone
5	1963	May	Cyclone
6	1966	November	Cyclone
7	1977	June	Cyclone
8	1983	November	Storm
9	1993	October	Storm
10	1992	November	Storm
11	1996	June	Storm
12	1998	December	Storm
13	2002	May	Storm
14	2007	June	Cyclone
15	2010	June	Cyclone

Figure 1-6: Seasonal characteristics of tropical depressions, cyclonic storms and severe cyclonic storms over the Arabian Sea, 1950-2011 (Source: India Meteorological Department, 2012)

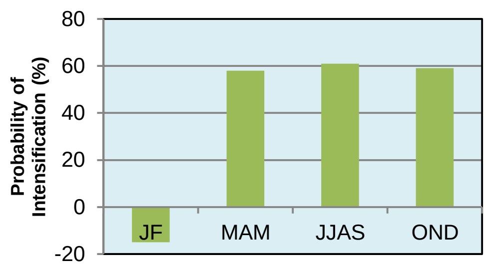
a) Overall frequency of all extreme storms



b) Probability, tropical depressions→cyclones



c) Probability, cyclones→severe cyclones

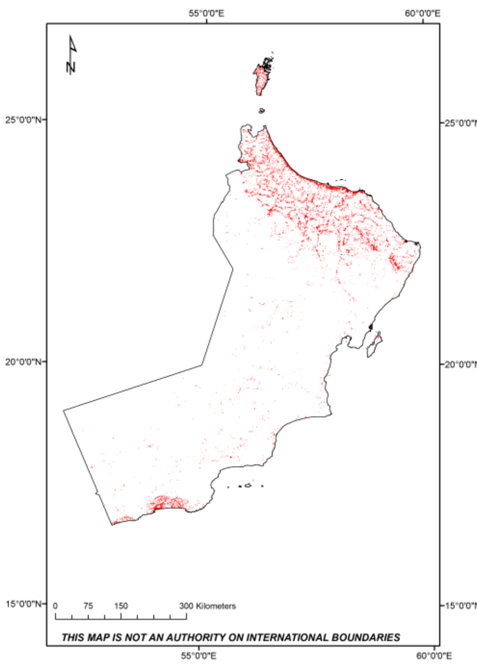


share of private sector jobs has climbed to nearly 40% of total jobs in 2010, compared to less than 30% in 2003. Education has steadily reached more and more households in Sultanate of Oman. Illiteracy rates have fallen precipitously from over 30% of the population in 1993 to under 12% in 2010.

Table 1-2: Key demographic Indicators for Sultanate of Oman (2010 Census)

Indicator		1993	2003	2010
Total Population	Thousand people	2,018,074	2,340,815	2,773,479
Per Capita Income	PPP, US$	12,671.54	16,895.39	25,438.71
Urban Population	% of total	71.7	71.5	75.0
Population by gender	Gender Ratio	140.2	127.8	138.8
Population less than 15 years old	%	41.0	33.8	27.8
Population between 15-64 years old	%	56.7	63.6	69.5
Population 65 and older	%	2.3	2.6	2.7
Illiteracy	% of total population	30.5	15.9	11.7
Total labor force	Thousand people	704,798	873,466	1,245,573
Employed Omanis, Public Sector	%	NA	62.6	53.3
Employed Omanis, Private Sector	%	NA	27.4	39.7

Figure 1-7: Built-up population areas in Sultanate of Oman, 2007 (Supreme Committee for Town Planning, SCTP)



Most of the population (about 56%) is concentrated along the Sea of Oman coast in the Muscat and the Al Batinah North and Al Batinah South Governorates. Other major population centers include the Adh Dhahirah Governorate, Ad Dakhliyyah Governorate, and Ash Sharqiyyah north and Ash Sharqiyyah south. Together these areas accounted for about 30% of the population in 2010. Most of the remaining population resides in the Dhofar Governorate near the southwestern part of the country. The distribution of major population centers is illustrated in red-shaded areas on Figure 1-7.

1.6 Public health

The Sultanate of Oman is on track to achieve all health-related Millennium Development Goals (MDGs). Progress toward the MDGs is evaluated relative to a number of key public health indicators (see Table 1-3). Notable achievements include a steep reduction in the mortality rate for children younger than 5 years of age, declining from 32 deaths per 1,000 live births in 1990 to just 9 deaths per 1,000 live births by 2010. Another significant achievement are reduced maternal mortality rates which reached a low of 32 per 100,000 live births in 2010, which is more than 80% below the global average in 2010 (WHO, 2012a).

Steady progress has also been experienced on other major health indicators. Life expectancy at birth has continued to rise; 72 years for men and 77 years for women. These life expectancies exceed global averages and are roughly on par with those in European countries (WHO, 2012b). Total health care expenditure (i.e., public and private expenditures) as a percentage of GDP has averaged about 3% over the 1995-2010 period, or roughly a third of the world average over this same period.

Table 1-3: Key public health indicators for Sultanate of Oman, 2010 (Ministry of Health, 2011)

Indicator	Units	Value
Life expectancy at birth (males)	years	72
Life expectancy at birth (females)	years	77
Mortality rate – all children under 5 years of age	per 1,000 live births	9
Male mortality rate (15-60 years of age)	Per 1,000 population	157
Female mortality rate (15-60 years of age)	Per 100,000 births	85
Maternal mortality rate	Per 100,000 births	32
Per capita health care expenditure	International $/capita	598
Total health care expenditure	% of GDP	2.8

1.7 Environmental protection framework

The Five Year Development Plans, implemented since 1975, include the basic principles that link development with environmental considerations. The Sultanate of Oman Economic Vision, which represents the developments strategy up to 2020, is also a major basis for preserving non-renewable natural resources (Ministry of Regional Municipalities, 2005; Ministry of Environment and Climate Affaires, 2012).

Several legislative initiatives and institutional arrangements underlie all efforts to achieve sustainable development goals and ensure the right of future generations to benefit from Sultanate of Oman's rich natural resource heritage. The Marine Pollution Control Law (Royal Decree No. 34/74) is the core piece of national environmental legislation. Royal Decree No. 68/79 established the Board of Environmental Protection and Pollution Control under the chairmanship of His Majesty the Sultan and his Council of Ministers. These decrees are considered the cornerstones of the institutional environment in the Sultanate.

There have also been two recent ministerial decisions regarding climate change. The Ministerial Decision No. 18/2012 issuing regulations for the Climate Affairs Management and the Ministerial Decision No. 30/2010 issuing the Regulations for the approval of Clean Development Mechanism (CDM) Projects under the Kyoto Protocol and establishment of the Designated National Authority (CDM-DNA) to promote the CDM projects in the Sultanate of Oman.

Over the years, there have been many other actions and institutional developments in Sultanate of Oman to protect the environment and conserve the natural resources, as well as to address all forms and sources of pollution. Some of the more prominent developments are briefly described in the bullets below.

1974 Establishment of the "Office of the Advisor of Environmental Protection at the Diwan of Royal Court".

1979 Establishment of the "Board of Environmental Protection and Pollution Control" under the Royal Decree No. 68/79.

1985 Modification of the Ministry of Environment to become "The Ministry of Environment and Water Resources" under the Royal Decree No. 104/85.

1985 Modification of the Council of environmental protection and pollution control to the "Council for the Protection of the environment and water resources" under the Royal Decree No. 105/85.

1986 Development of the terms of reference of the Ministry of Environment and Water Resources and Environmental Protection Council and water resources under the Royal Decrees No. 91 and 92/86.

1989 Establishment of the Ministry of Water Resources and determine its terms of reference under the Royal Decree No. 100/89.

1990 Modification of organizational structure of the Ministry of Environment and terms of reference after the establishment of a "Public Authority of Water Resources" under the Royal Decree No. 11/90.

1991 Integration of the Ministry of Environment and the Environmental Protection Council and the Ministry of Regional Municipalities to become "The Ministry of Regional Municipalities and Environment" under the Royal Decree No. 117/91.

1999 Development of the terms of references of the Ministry of Regional Municipalities and Environment under the Royal Decree No. 18/99).

2001 Integration of the Ministry of Regional Municipalities, Environment and Ministry of Water Resources in one ministry called "The Ministry of Regional Municipalities, Environment and Water Resources" under the Royal Decree No. 47/2001.

2007 Establishment of the Ministry of Environment & Climate Affairs by the Royal Decree No. 91/2007.

2008 Issuing the Royal decree No. (18/2008) specifying the Ministry of Environment & Climate affairs mandate and approving its organizational chart including setting up a new Directorate General of Climate Affairs.

Box 1-1: Royal decrees on environment

- *Marine pollution:* Sanctioning the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other matter (Royal Decree No. 26/81)
- *Industrial development:* Sanctioning the UN Industrial Development Organization Charter (Royal Decree No. 40/81)
- *Maritime law:* Authentication of UN Convention on the Law of the Sea Law (Royal Decree No. 67/89)
- *Hazardous waste:* Authentication of Basel Convention on the Control of Trans boundary Movements of Hazardous Wastes and their Disposal (Royal Decree No. 119/94)
- *Climate Change:* Authentication of the UN Framework Convention on Climate Change (Royal Decree No. 119/94)
- *Biodiversity:* Authentication of the UN Convention on Biological Diversity (Royal Decree No. 119/94)
- *Ozone:* Accession to Vienna Convention on Ozone Layer protection and the Montreal Protocol on Ozone depleting substances (Royal Decree No. 73/98)
- *Kyoto Protocol:* Ratification of the Kyoto Protocol on Climate Change by Royal Decree No. 107/2004.

In addition, the Council of Ministers adopted the National Strategy for Environmental Protection and Conservation in 1995. The most important elements of this strategy are summarized in the bullets below. Box 1-1 summarizes royal decrees confirming Omani endorsement of multilateral environmental conventions and protocols.

- *Renewable energy:* Established a national priority on the exploitation of local renewable resources.
- *Integrated resource management:* Confirmed the importance of sectorial integration and collaborative approaches in national resource management.
- *Monitoring and evaluation:* Developed a system to monitor achievements regarding nature conservation and environmental protection.
- *Community-focused:* Confirmed the role and place of the human as the goal for Development.
- *Sustainability:* Proposed policy frameworks for linking development activities and environmental protection initiatives.
- *Environmental accounting:* Recommended the introduction of natural resource accounting and environmental costs in national income ledgers.

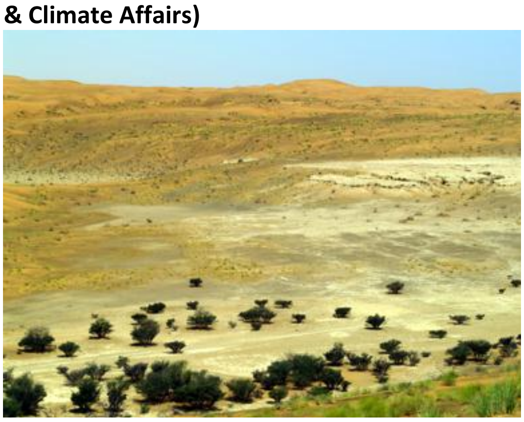
Table 1-4: Sultanate of Oman's biodiversity count (source: Fourth National Report to the Convention on Biological Diversity, 2010)

Group	Species & subspecies
Plants	1,295
Fish	991
Birds	546
Mammals	99
Sea grass	4
Macro algae	323
Phytoplankton	182
Arthropods	399
Mollusks	58
Corals	253
Echinoderms	56
Amphibians & Reptiles	93

1.8 Biodiversity

The Sultanate of Oman's terrestrial environments are home to a rich and unique biodiversity (see Table 1-4). In the northern regions, biodiversity shows a strong affinity with neighboring Iran and Pakistan, while flora and fauna in the far southern regions are more characterized by the influence of African biodiversity. Overall, over four thousand flora and fauna species and subspecies can be found today in Sultanate of Oman.

Figure 1-8: Typical desert landscape in Sultanate of Oman (Ministry of Environment & Climate Affairs)



The terrestrial environment is characterized by desert, mountain, and wetland ecosystems. Desert ecosystems, consisting of both sandy and gravel areas, cover a large share of the land surface of Sultanate of Oman. What little vegetation exists in these areas is confined to depressions, stream beds *(wadis)*, and rocky pavements (see Figure 1-8). Key desert biodiversity is summarized in the bullets below (SoO, 2010).

- *Trees:* Tree species include *Acacia-Prosopis-Ziziphus, Prosopis cineraria* and *Bosellia sacra.*

- *Shrubs:* Shrub species include *Lyciumshawii*, *Ochradenusarabicus, Zygophyllum qatarense, and Acacia etbaica*.
- *Annual vegetation:* Common annual vegetation includes *Zygophyllum simplex*, *Plantago ovata*, *Aizooncana riense* and *Asphodelus fistulosus*.
- *Plants:* Basic plant communities include *Calligonium critinum arabicum and Cyperus eremecius,* as well as *Heliotropium, Panicum, Euphorbia and Indigofera.*
- *Reptiles:* The central desert plains and hinterlands are the only locations in Sultanate of Oman where *Pristurus minimus, Uromasty xthomasi* and *Acanthodactylus masirae* are found.

Mountain ecosystems consisting of arid and monsoon-affected mountains also cover a significant portion of the land surface of Sultanate of Oman. Arid mountains are located in northern areas, including the Musandam peninsula and display bare rock outcrops, varied/shallow soils on slopes and gravelly soils in the valleys. These areas also contain many oasis where date palms, limes, alfalfa and vegetables are supported by traditional irrigation systems *(falaj)* that tap local springs (see Figures 1-9a and 1-9b).

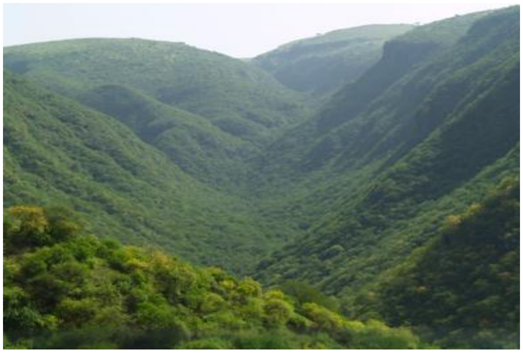
Monsoon-affected mountains are located in the Dhofar Region in the southwest along the Salalah and Rakhyout coast. These areas are moisture-rich and display lush woody vegetation on steep slopes and gullies, with grasses and bushes at lower elevations (see Figure 1-9c). Some of the key biodiversity in mountainous areas is summarized in the bullets below (SoO, 2010).

Figure 1-9: Typical mountain landscapes in Sultanate of Oman (Ministry of Environment & Climate Affairs)

a) Arid mountains – Al Hajar Ash Sharqi (Western Al Hajar Mountains)

b) Arid mountains Al Jabal Al Akhdar in central Al Hajar Ash Sharqi (Al Hajar Mountains)

c) Monsoon-affected mountains – Jabal Samhan in Dhofar Governorate



- *Central range:* In the central range of the Al Hajar Ash Sharqi (Western Al Hajar Mountains), isolated trees *(Juniperusex celsapolycarpos)* form open woodland, often dominant with *Oleaeuropaea* at elevations from 2100 to 3000 meters. Sultanate of Oman's juniper woodlands are unique to the Arabian Peninsula, likely the result of plant migration from southeastern Iran. They are generally in a poor state with minimal regeneration.
- *Northern range:* The northern range of the Hajar Mountains is a center of reptile and amphibian endemism. Three nationally endemic species can be found, namely *Asaccus montanus*, *Asaccus platyrhynchus* and *Pristurus gallagheri.* In addition, five regionally

endemic species can be found: *Asaccus caudivolvulus*, *Asaccus gallagheri*, *Pristurus celerrimus*, *Lacerta jayakari* and *Lacerta cyanura*.

- *Southwest range:* The Dhofar Mountains Chain running through the border with Yemen contain a number of endemic reptile species *(Hemidactylus lemurinus, Meslaina ayunensis)* and snake species *(Colubert homasi)*.
- *Foothills and valleys:* The alluvial wadi fans and foothills of the mountains are dominated by open, drought-deciduous woodlands and shrublands, often intermixed with xeromorphic grasslands *(Panicum turgidum)* dominated by *Acacia ehrenbergiana*, A. *tortilis, Prosopis cinerea* and *Ziziphus spina-christi*.

Figure 1-10:Typical wetland landscapes in Oman (Ministry of Environment & Climate Affairs)

a) Coastal lagoon: Khawr Al Qurm As Saghir in Dhofar Governorate

b) Natural mangrove forest: Jazirat Muhut (Island in Al Wusta Governorate)

Wetland ecosystems cover the remaining land surface of Sultanate of Oman. Four major ecosystems are found in Sultanate of Oman, as briefly described in the bullets below.

- *Coastal lagoons:* These areas contain fish-breeding and nursery sites *(khwars)*,which support dense masses of plant species such as *Enteromorpha*, crab species such as *Scylla serrata,* and a wide variety of mullet fish (see Figure 1-10a). Plant species such as *Sporobolus virginicus, Sporobolus iocladus and Paspalum vaginatum* border the lagoon areas, with *Phragmites australis* and *Typha spp* forming bordering reeds.
- *Mangroves:* Natural mangrove forests are found sporadically along coastal areas. Good stands, covering a total of 1,100 hectares (ha) still exist in Al Batinah North, Muscat, Ash Sarqiyyah North, Jazirat Muhut (Island) and Salalah. These areas likely have less than a third of the size of past stands due to destruction for fuel wood, grazing, and coastal development. Only one natural mangrove species, *Avicennia Marina*, is endemic to Sultanate of Oman's harsh climatic conditions (see Figure 1-10b).
- *Salt flats:* Known locally as *sabkhas*, salt flats are found the coastline. In the mainly sandy soils of the north, vegetation is dominated by the *Limonium stocksii- Zygophylum quatarense* community. Along rocky shores with narrow beach areas, vegetation is dominated by the *Limonium cf. stocksii-Suaedaa egyptica* community. On islands and flat sandy beaches, the *Atriplex-Sueda* vegetation community is found.
- *Streams:* Seasonal water flows, or *wadis*, are one of the most common and important landscape elements in draining rainwater from wide catchment areas and high mountains. Terraces along wadi banks are intensively farmed. Vegetation along wadis includes *Tamarix*, *Saccharum sp.*, *Nerium mascatense*, *Ficus cordata* and *Acacia nilotica*. Alluvial plains support growth of *Acacia*, *Ziziphus*, *Moringa* and *Ficus salicifolia*.

A range of development and other causes threatens some of Sultanate of Oman's unique biodiversity. Table 1-5 summarizes the current conservation status of endangered species based on IUCN criteria for a subset of Sultanate of Oman's biodiversity, namely mammals, amphibians & reptiles, birds, and plants. The bullets below briefly describe the threat status of individual species within each of these categories.

Table 1-5: Protected species in Sultanate of Oman (Fourth National Report to the Convention on Biological Diversity, 2010)

	IUCN designation			
Group	Critically endangered (CR)	Endangered (EN)	Near threatened (NT)	Vulnerable (VU)
Mammals	2	2	2	0
Amphibians & Reptiles	2	2	0	1
Birds	2	6	1	0
Plants	0	3	0	6

Note : 6 vulnerable plant species as per GCC 2002 Convention Appendix 1

- *Mammals:* The Arabian leopard and Dhofar white-toothed shrew are critically endangered. The Arabian Oryx and Arabian Jird are endangered; the Blasius horseshoe bat and sand cat have near-threatened status. These mammals are protected in Sultanate of Oman and are shown on Figure 1-11.

Figure 1-11: Protected mammals in Sultanate of Oman (source: Ministry of Environment & Climate Affairs)

a) Arabian leopard

b) Dhofar white-toothed shrew

c) Arabian Oryx

d) Arabian jird

e) Blasius horeshoe bat

f) Sand cat

- *Reptiles and amphibians:* All the species in this category are sea turtles. The Hawksbill and Leatherback turtles are critically endangered. The Loggerhead and Green turtles are endangered. The Olive Ridley turtle is vulnerable. These turtles are protected in Sultanate of Oman and are shown on Figure 1-12.

Figure 1-12: Protected turtles in Sultanate of Oman (source: Ministry of Environment & Climate Affairs)

a) Hawskbill

b) Leatherback

c) Loggerhead

d) Green

e) Olive Ridley

- *Birds:* There are eight endangered bird species that can be found in Sultanate of Oman. The Northern Bald Ibis and Slender-billed Curlew are critically endangered. The

Ferruginous Duck, Eastern Imperial Eagle, Golden-winged Grosbeak, White-eyed Gull, Sociable Lapwing, and Lesser Kestrel are endangered. In addition, Ruppel's Vulture is near-threatened. These birds are protected in Sultanate of Oman, a sampling of which is shown on Figure 1-13.

Figure 1-13: Protected birds in Sultanate of Oman (source: Ministry of Environment & Climate Affairs)

a) Northern Bald Ibis | **b) Slender-billed Curlew** | **c) Ferruginous Duck** | **d) Eastern Imperial Eagle** | **e) Golden-wing Grosbeak**

- *Plants:* There are three endangered plant species that can be found in Sultanate of Oman, namely Dracaena, aloe and carob tree *(Ceratonia oreothauma somalensis)*. In addition, there are several other plants that have threatened or near threatened category in CITES/GCC Appendices. These plants are protected in Sultanate of Oman, a sampling of which is shown on Figure 1-14.

Figure 1-14: Protected plants in Sultanate of Oman (source: Ministry of Environment & Climate Affairs)

a) Dracaena | **b) Aloe** | **c) Lily** | **d) Blue Sanseviera**

With the aim of protecting the biodiversity described above, Sultanate of Oman has set aside the Ad Dimaniyyat Islands Nature Reserve launched as a conservation initiative. The Reserve encloses some 203 km^2 of sea and seabed and includes the nine islands, rocks and reefs and offshore shoals situated about 18 km off the As Seeb-Barka coast (70 km west of Muscat). These are relative unspoiled islands of great scenic beauty.

The Ad Dimaniyyat Islands Nature Reserve is an important conservation area to the nation and region. It has the highest density of nesting seabirds and the only known osprey nesting sites in the capital area. The Reserve also shelters the largest nesting population of hawksbill turtles in the country. While there is high coral diversity in the region, they are threatened by large scale, irreversible damage and continued devaluation or loss of coral reef resources. Both the islands and the reefs are important to the mainland-based fishermen and people from Muscat, for fishing, recreation and worship. There are few other islands in Sultanate of Oman that are in various stages of proposal to become protected areas. These include Masirah and Juzor Al Hallaniyyat. These areas are also important areas for mangrove restoration.

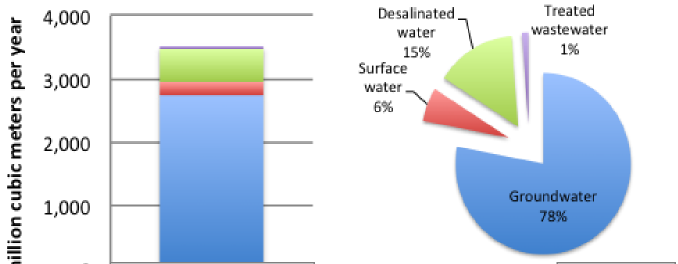
1.9 Water resources

Sultanate of Oman is one of most water-stressed countries in the World, with less than 1,000 cubic meters in freshwater availability per person per year (UNEP, 2008). In 2010, there was a water shortage of Sultanate of Oman estimated around 378 million cubic meters. Keeping water supply and demand in equilibrium in one of the most pressing challenges facing Sultanate of Oman in the years ahead (Ministry of Regional Municipalities and Water Resources, 2012).

There are two main types of water resources, conventional and non-conventional. Conventional water resources consist of surface water and groundwater. Non-conventional water resources consist of desalinated water and treated wastewater. As of 2007, total water availability was about 3,517 million cubic meters per year. A breakdown of water supply by type is illustrated in Figure 1-15. A brief overview of these major water sources is provided in the bullets below.

- *Groundwater:* Groundwater accounts for the overwhelming majority of supply, representing about 78%. Most of the groundwater extracted is renewable in nature, being recharged annually by rainfall or through surface water infiltration. Non-renewable groundwater exists in the interior regions of Sultanate of Oman in the An Najd, Al Masarrat and Rimal Ash Sharqiyyah (Sands). These are fossil water resources that are being developed and used judiciously.
- *Desalinated water:* Desalinated water accounts for the next highest share of water supply, representing about 15%. By the end of 2007, there were a total of 94 desalination plants in Sultanate of Oman. Of these, 47 plants used seawater as the feedstock and the other 47 used brackish water.
- *Surface water:* Surface water accounts for about 6% of total water supply. The annual average wadi flow is estimated at 211 million m^3. While average rainfall is estimated at 9.5 billion m^3 per year, about 80% of this precipitation evaporates (Ministry of Regional Municipalities and Water Resources, 2012).
- *Treated wastewater:* Treated wastewater accounts for the remaining 1% of total water supply. The first project was completed in 2003 for reinjection of 20,000 m^3per day in the coastal wells in Salalah plain to prevent seawater intrusion. In the Muscat Governorate, the current treatment capacity of 25 million cubic meters per year is projected to increase to 100 million cubic meters per year by 2030.

Figure 1-15: Water supply in Sultanate of Oman (source: Ministry of Regional Municipalities and Water Resources, 2012)



Type	Water supply quantity
Treated wastewater	42
Desalinated water	521
Surface water	211
Groundwater	2,743
Total:	3,517

Type	Water supply share
Conventional - *Groundwater* - *Surface water*	84%
Non-conventional - *Desalinated water* - *Treated wastewater*	16%
Total:	100%

Water consumption has been increasing sharply in Sultanate of Oman. Water use for industrial, commercial, municipal and tourism increased threefold over the 1998-2007 period, from 86 Million cubic meters (Mm^3) per year in 1998 to 399 Mm^3 in 2007. The total volume of water use in the agricultural, commercial, industrial, municipal, governmental and tourist sectors is about 1,430 Mm^3. The agricultural sector is the main consumer of water with a consumption of about 78%.

1.10 Agriculture and fisheries

In Sultanate of Oman, agricultural production is wholly dependent on irrigation. Hence, water rather than the availability of arable land and/or suitable soils are the critical constraints. Cultivated area grew rapidly between 1970 when only 27,888 hectares were under cultivation to a peak of 73,710 hectares in 1997, or an average annual growth rate of about 3.7%. Since 1997, cultivated area has decreased slightly and was down to 70,434 hectares in 2010, primarily due to pressures from salinization and urbanization. Given only about 0.02 hectares of cultivated land per person, there is a clear perception within government agricultural planning agencies that promoting food security requires continued heavy reliance on imports (see Table 1-6).

Table 1-6: Production and imports for selected agricultural commodities in Sultanate of Oman, 2010 (FAOSTAT, 2012)

Commodity	Quantity (tonnes)	
	Oman	Imported
Wheat	0	455,895
Rice	0	100,201
Maize	0	77,000
Soybeans	0	41,704
Palm oil	0	101,112
Sugar Refined	0	100,707
Cattle meat	2,835	8,000
Chicken meat	4,794	65,482
Sheep meat	6,313	6,551
Milk (fresh & dried)	69,600	74,927

Only 5.9% of Sultanate of Oman's total land area is considered suitable for agricultural production activities (FAOSTAT, 2012). About 56% of the cultivated area is located in coastal areas. The most intensely farmed areas are located along a 320 km stretch in the Al Batinah coastal region northwest of Muscat, and a 100 km long stretch in Salalah coastal plain in the Dhofar Governorate. Together these coastal areas encompass about 380 km^2, over 90% of which is located in the Al Batinah North and Al Batinah South Governorates (Ministry of Agriculture and Fisheries, 2012). Other major areas for agricultural production include the interior plains, oases, and the land adjacent to wadis. A brief overview is provided in the bullets below.

- *Al Batinah North and Al Batinah South Governorates:* This coastal region adjacent to the Sea of Oman accounts for over 50% of Sultanate of Oman's total annual agricultural production, with the main crops being dates, fruit trees, vegetables and forage crops.
- *Dhofar Mountains chain:* This is rainfed pasture land located in mountainous areas in the southwestern part of the country. The area covers about500 thousand hectares and is where two-thirds of the cattle and one third of the goat populations are found.
- *Interior plains:* These areas lie within the inner foothills of the Al Hajar Mountains rand include Al Buraymi plain, Ibri, Wadi Qurayyat, Bahla and Nizwa. The main crop is dates followed by alfalfa.
- *Al Jabal Al Akhdar:* This is rainfed land located at high elevations within the Al Hajar Mountains. The relatively mild temperatures facilitate the cultivation of a number of

temperate fruits and nut trees such as pomegranates, peaches, apricots, apples, pears, walnuts and almonds.

- *Wadi Al Batha:* Agriculture is concentrated in valley areas of the Al Hajar Mountains around Ibra, Ad Diriz, Al Ghabbi and Al Wafi. The area under crops is estimated to be 1,512 hectares in 26 oases irrigated mainly by the traditional falaj system.

In 2010, perennial forage crops covered 20,481 hectares, representing about 29% of total cropped area. These crops are used to feed the population of cows (333,000), sheep (389,000), goats (1,719,000) and camels (129,600). The production of eggs in 2010 reached 189 million units. The most common diseases observed and treated are Foot & Mouth Disease, Goats & Sheep pox, Enterotoxaemia, Rabies, and Botulism.

Pesticides are used intensively in Sultanate of Oman’s farms for crop protection. Among the major insect-pests, whiteflies *(Bemisiata baci)*, leaf miners *(Liriomyza trifolii)*, melon fruit flies *(Bactrocera ciliatus)*, aphids *(Aphis spp.)* and tobacco leaf worm *(Spodoptera litteralis)* were recorded in Omani farms. Among the plant diseases, powdery mildew *(Erysiphe spp.)*, blight *(Alternaria spp.)*, damping off *(Pythium spp.)*, leafspot *(Altenaria spp.)* and mosaic *(CMV)* were major cause of vegetable diseases. Among the most commonly used pesticides, vegetable farmers typically use 29 insecticides, 16 fungicides and 3 herbicides. Around 55% of Omani farms used routine application of pesticides, irrespective of the pest presence.

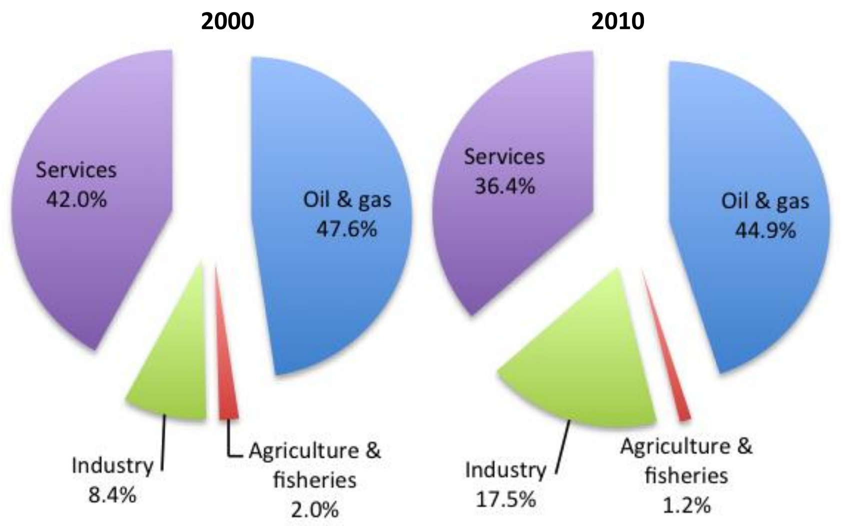
Fisheries also represent an important element of Sultanate of Oman's culture and economy. A total of 991 fish species have been identified in Sultanate of Oman’s national waters of which about 50 species are of key importance to the traditional and commercial fishing sectors. As one of the biggest fish producers in the region, fisheries are a significant national income resource after oil. In 2010, total landings from traditional fisheries were estimated to reach 146,964 tonnes with a value of US$ 259.5 million (Ministry of Agriculture and Fisheries, 2011). Surveys and special projects involving the Ministry of Agriculture and Fisheries, Sultan Qaboos University and other agencies are regularly implemented to monitor and assess the status of fisheries.

1.11 Economy

The Sultanate of Oman has the fifth largest economy in the GCC region. In 2010, GDP reached US$ 31.6 billion (in 2000$, equivalent to 12.08 billion Omani rials) compared to US$ 19.9 billion (in 2000$, equivalent to 7.4 billion Omani rials) in the year 2000 (Statistical Year Book, 2011). The average GDP annual growth rate over the period 2000 to 2010 was nearly 5%, ranging between 0.4% from 2002 to 2003 and a high of 13.1% from 2007 to 2008. Over this same period gross national income per capita grew at an average rate of 10.1% per year.

The oil and gas sector continues to be the largest sector in Sultanate of Oman's economy. Nevertheless, there has been progress in moving away an oil-based economy to one that is more diversified. This is illustrated by Figure 1-16 which shows oil and gas activities dropping from 47.6% of GDP in 2000 to 44.9% in 2010. Notably, this shift occurred in the context of increasing oil production and prices. Over this same period, the industrial share of GDP more than doubled, from 8.4% to about 17.5%. Over this period, the share of GDP of the services and agriculture/fisheries sectors decreased by about 5.6% and 0.8%, respectively.

Figure 1-16: Sectorial shares of GDP (Central Bank of Sultanate of Oman, 2012)



In 2010, there were a total of 1,298,000 formal jobs in Sultanate of Oman. The public sector employs 164,000 people, representing about 12.6 % of all employees, of which 86% are Omani. The private sector employs the remaining 1,134,000 people, of which 84% are expatriates. Overall, Omanis represent about 25% of the work force while expatriate workers represent 75 percent. Despite the small share of GDP for agriculture and fisheries, this sector continues to be a major source of informal jobs in Sultanate of Oman. In 2005 about 13% of the Sultanate of Oman's population of 2.4 million was economically active in the agricultural sector that provided permanent employment for the 226,500 people of whom almost three-quarters – 170,000 – were Omani (Central Bank of Sultanate of Oman, 2011).

Several major initiatives underlie the vision for Sultanate of Oman's future economy. With the objective of integrating into the international economy, Sultanate of Oman became a full-fledged member of the World Trade Organization in 2000. Also, as a founder-member of the GCC, Sultanate of Oman is progressing in the implementation of the Common Market launched in 2008 and is playing an active role in the Greater Arab Free Trade Area of the Arab League.

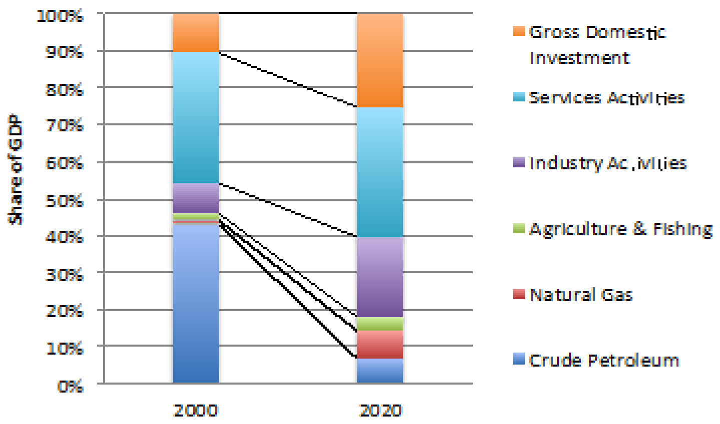
Together with ongoing efforts at economic diversification, these initiatives highlight Sultanate of Oman's commitment to achieve sustainable economic development in a private sector-led and an export-oriented economy with diversified sources of national income. The overarching policy framework for achieving a sustainable and robust future economy is summarized in the bullets below.

- Develop human resources, and upgrade Omani skills and competencies to keep abreast with the technological progress; to manage the dynamics of this progress in a highly efficient way; and to face the ever changing domestic and global conditions;
- Create a stable macroeconomic framework aimed at the development of a private sector capable of the optimal use of human and natural resources of the Sultanate in an efficient and ecologically sound way;
- Encourage the establishment of an effective and competitive private sector; and consolidate the mechanisms and institutions that will foster shared visions, strategies and policies between the private sector and the Government.

- Provide appropriate conditions for the realization of the economic diversification, and strive toward optimal use of natural resources and the geo-strategic location of the Sultanate;
- Enhance the standard of living of the Omani people; reduce inequality among regions and among various income groups; and ensure that the fruits of development are shared by all citizens; and
- Preserve the achievements accomplished during the past twenty-five-years, safe guard and develop them, along with the completion of some of the necessary basic services.

This policy framework is intended to secure important structural changes to the Omani economy by the year 2020. These projected changes in the GDP profile are illustrated in Figure 1-17 and briefly described in the bullets below.

Figure 1-17: Sectorial shares of GDP, actual in 2000 and projected in 2020 (source: Global Research-Economy Oman, 2011)



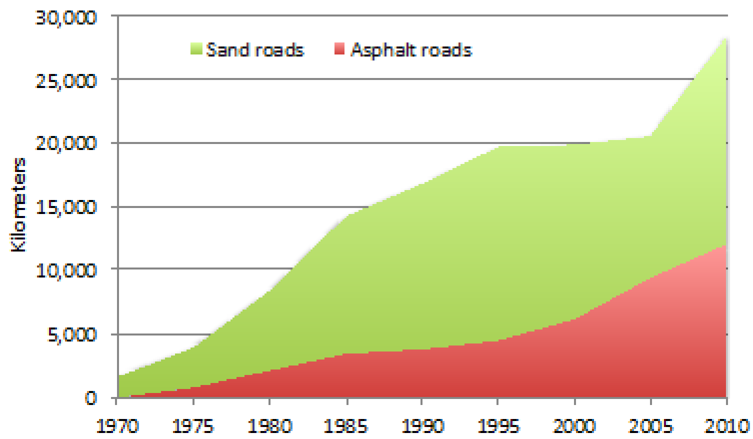
- *Oil:* The crude oil sector's share of GDP is estimated to drop significantly to around 7% in 2020, compared with about 43% in 2000.
- *Gas:* The gas sector is expected to contribute to around 8% to GDP in 2020, substantially increased from a 1% share in 2000.
- *Industry:* The Industrial sector is where major changes are expected. The non-oil industry sector's contribution to GDP is expected to rise from 8% in 2000 to 22% in 2020.
- *Services:* The various Service subsectors are expected to contribute around 35% to GDP in 2020, compared with the same level in 2000.
- *Capital Investment:* Gross domestic investment is expected to reach 25% in 2020, compared with 11% in 2000.

1.12 Transportation

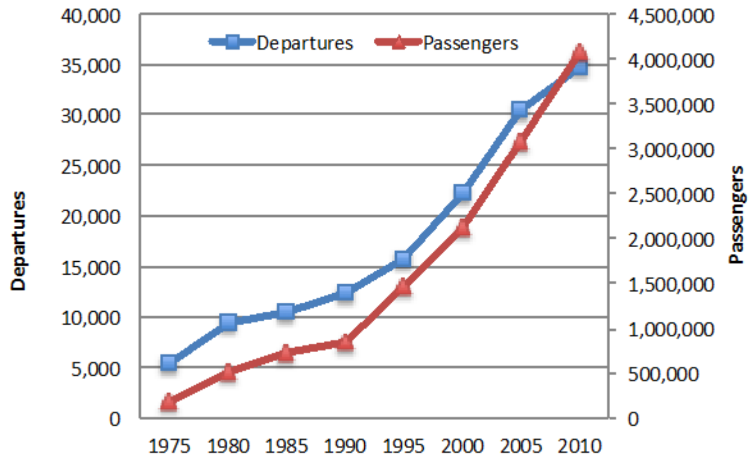
The Ministry of Transport and Communications is embarking upon the implementation of major projects related to the construction and establishment of Roads, Seaports and Airports as well as the provision of Post and Communication services. Particular attention has been being devoted to road transport due to its importance in socioeconomic development. On the one hand, this is evidenced by the sharp growth in the length of asphalt roads over the 1970 - 2010 period, from 10 kilometers in 1970 to over 12,000 kilometers in 2010, an average annual growth rate of about 19.4% (see Figure 1-18a). On the other hand, institutional arrangements have been strengthened to promote development in road transport.

Figure 1-18: Transport development in Sultanate of Oman

a) Road transport (Ministry of Transport and Communications, 2011)



b) Air transport (source: World Bank, 2012)



Starting with ministerial resolution No 77/2008 which formed the basis for the Department of Road Transport, there have been important bilateral agreements with regional and international organizations to facilitate road transport with neighboring countries. In addition, the Omani Land Transport Committee has a mandate to coordinate road transportation planning across government agencies.

Air transport has also experienced sharp growth in Sultanate of Oman. Over the 1975 - 2010 period, the number of departures grew by over 6 times, from 5,400 to 34,637. Notably, over this same period, the number of passengers grew by over 23 times, from 173,000 passengers in 1975 to nearly 407,000 in 2010 (see Figure 1-18b). Air transport activities are coordinated by the Air Transport Department of the Civil Aviation Authority. Sultanate of Oman is a member of the International Civil Aviation Organization and Arab Civil Aviation Organization.

1.13 Ambient air quality

Rapid economic development, improved living standards, and increased urban population density have led to increased air pollution from both stationary and mobile sources. This is particularly evident in coastal areas where the combination of high population/industrial concentration and unfavorable natural conditions for pollution dispersal aggravate air pollution problems (Charabi and Al-Yahyai, 2010).

The major sources of air pollution are from energy production, transportation and industry (from cement plants, chemical and petrochemical plant). Intense industrial activity in Sohar City make this area one of the most problematic in terms of air pollution, particularly sulfur dioxide from oil refineries (Charabi et al, 2012). Other prominent areas with air pollution problems include the capital Muscat where dense vehicular traffic contributes to high ambient air concentrations of nitrogen oxide (NO_x).

A major feature of air pollution in Sultanate of Oman is its topographic and climatic context. Along the northern coast where much of the population and industry is located, there is constrained land-sea breeze circulation such that air mass stagnation is a common phenomenon for about three-quarters of the year. In the southern and eastern areas of the country, stagnant air masses are evident for about one-fifth and half the year, respectively.

Currently, there are 15 air quality monitoring stations being operated by major industrial plants such as oil refineries, petrochemical factories and power stations. In 2012, 6 new air quality monitoring stations are to be installed in the Sohar Industrial Port area. Of the six units, three will be deployed inside the port area, while two will be placed in nearby residential neighborhoods. Also, two mobile stations are being set up, one for Muscat Governorate and the other for Ad Duqm Industrial Port area. The one in Muscat Governorate will also be able to monitor noise pollution.

1.14 Special Considerations under Article 4.8 of UNFCCC

Article 4.8 of the UNFCCC states that Parties shall give full consideration to actions to meet the country's specific needs and concerns of the developing signatory country arising from the adverse effects of climate change and/or the impact of the implementation of responsive measures. The sub-clauses that affect Sultanate of Oman are:

- Countries with areas prone to natural disasters;
- Countries with areas liable to drought and desertification;
- Countries with areas with fragile ecosystems, including mountainous ecosystems;
- Countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels and associated energy-intensive products; and associated energy–intensive products.

Sultanate of Oman is highly vulnerable to climate change relative to each of the above points, as briefly outlined in the bullets below.

- *Natural disasters:* During the last five years the Sultanate of Oman has experienced very severe tropical cyclones such as Gonu in June 2007 and Phet in June 2010, both have caused significant damages (estimated at US$ 5.2 billion).
- *Drought and desertification:* Sultanate of Oman receives less than 100 mm in annual rainfall on average, with 95% of land is characterized as being either as desert or more than moderately affected with desertification. Land degradation is already acute in Al Batinah North and Al Batinah South, Al Hajar Mountains, Ash Sharqiyyah North and Ash Sharqiyyah South and in Dhofar and likely to worsen with climate change.
- *Fragile ecosystems:* Al Jabal Al Akhdar is a fragile arid mountain ecosystem in the northern Sultanate of Oman. It is considered as an important terrestrial eco-region in the world. Al Jabal Al Akhdar is unique in its geography, climate, geology, biodiversity, history, culture and aesthetic value.

Fossil fuel export dependent: As stated in the previous section of this report, Oil and Gas dominates the economic landscape with an important contribution of 45.8 % to GDP in

2010. While economic diversification plans are underway, Sultanate of Oman expects fossil fuel exports to represent a significant portion of GDP in 2020.

1.15 Institutional Arrangements for the Sultanate of Oman Initial National Communication to UNFCCC

The Ministry of Environment & Climate Affairs led the preparation of the Initial National Communication (INC) to UNFCCC. The United Nations Development Programme (UNDP) and United Nations Environment Programme (UNEP) provided technical support. The Global Environment Facility (GEF) provided financial support.

The National Committee for Climate Change provided guidance, coordination, and oversight for all INC activities. The Committee was composed of representatives of 11 ministries. A technical team of national experts was formed by the Sultan Qaboos University to undertake technical studies. Within the team, three working groups were established to perform tasks for each component of the INC.

The preparation of the INC was participatory and consultative in nature. A number of workshops were organized within the duration of the project. Targeted training was provided on GHG inventory development and vulnerability assessments.

1.16 List of References

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2. Greenhouse Gas Inventory

2.1 Introduction

This chapter presents estimates of national anthropogenic greenhouse gas emissions and sinks for the year 1994. This is Sultanate of Oman's initial GHG inventory and includes five categories: energy; industrial processes; agriculture; land use, land use change and forestry (LULUCF) and waste.

2.2 Methodology

The methodology used to develop the inventory is based on the *Revised 1996 Guidelines for National Greenhouse Gas Inventories* (IPCC, 1997), as well as the *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000) prepared by the Intergovernmental Panel on Climate Change (IPCC). In the sections that follow, GHG emissions are reported both in absolute units of carbon dioxide, methane and nitrogen oxide emissions, as well as in units of CO_2-equivalent by applying 100-year global warming potentials (GWP) of 1 for CO2, 21 for CH_4, and 310 for Nitrous Oxide.

2.3 Total GHG emissions

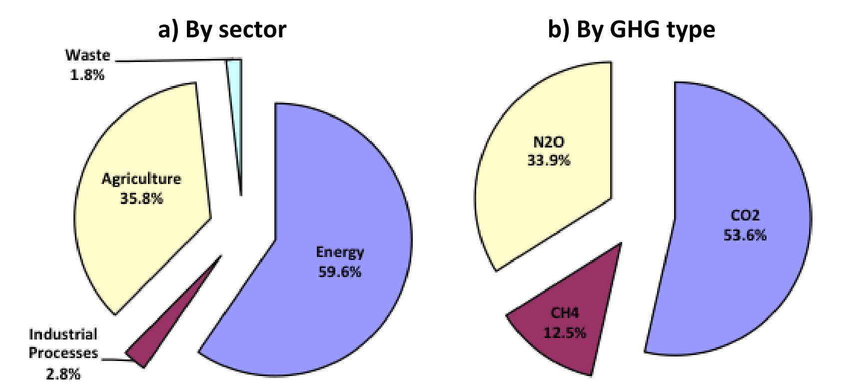
Table 2-1 presents total GHG emissions and sinks for the year 1994. Total GHG emissions were 20,879 GgCO_2-equivalent, which includes 12,445Gg from energy; 592Gg from industrial processes; 7,469Gg from agriculture, and 372Gg from waste. With CO_2 sequestration by the forestry and land use sector amounting to zero Gg, net GHG emissions are equal to total emissions. Emissions from hydrofluorocarbons (HFCs) are considered negligible, as the products containing these gases are not produced in the country. Emissions from sulfur hexafluoride (SF_6) in Sultanate of Oman could not be estimated due to a lack of data. Additional details are provided in tabular summaries in Annex 1 at the end of this chapter.

Table 2-1: Total GHG emissions in Sultanate of Oman, 1994 (Gg)

GHG Sources & Sinks	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1 Energy	12,445	10,596	87.7	0.0	0	0	2	3
2 Industrial Processes	592	589	0.2	0.0	0	0	0	0
3 Solvent & Other Product Use	0	0	0.0	0.0	0	0	0	0
4 Agriculture	7,469	0	18.5	22.8	0	0	0	0
5 Land-Use Change & Forestry	0	0	0.0	0.0	0	0	0	0
6 Waste	372	0	17.7	0.0	0	0	0	0
Total National Emissions	20,879	11,184	124.2	22.9	0	0	2	3
Net National Emissions	**20,879**	**11,184**	**124.2**	**22.9**	**0**	**0**	**2**	**3**

Figure 2-1a illustrates the shares of total GHG emissions by sector for the year 1994. Energy-related activities accounted for the dominant portion of GHG emissions in Sultanate of Oman. Approximately 60% of all GHG emissions are associated with the combustion of fossil fuels for electricity/desalinated water production and the release of fugitive emissions from oil and gas operations. Agricultural activities accounted for about 36% of all GHG emissions, followed by industrial processes with 3% and the waste with less than 2% of total emissions. Figure 2-1b illustrates the shares of total GHG emissions by GHG type for the year 1994. Carbon dioxide dominates total emissions, accounting for about 54% on a CO_2-equivalent basis. Nitrous oxide accounts for about 34% and methane less than 13% on a CO_2-equivalent basis.

Figure 2-1: Shares of total GHG emissions in Sultanate of Oman, 1994



2.4 Energy

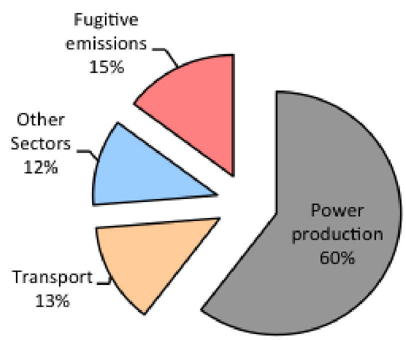
Table 2-2 summarizes GHG emissions associated with energy activity in 1994. Relative to overall emission levels, the 12,445Gg of CO_2-equivalent represented about 59.6% of total national emissions. GHG emissions from energy activities are due to fossil fuel combustion and fugitive emissions from oil and gas production activities. Fuel combustion emissions are associated with the use of a variety of petroleum products and natural gas.

Table 2-2: GHG emissions from energy activities in Sultanate of Oman, 1994 (Gg)

GHG Source Categories	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
All energy emissions	**12,445**	**10,596**	**87.7**	**0.02**	**0**	**0**	**2**	**3.0**
A Fuel Combustion Activities	10,603	10,596	0.0	0.02	0	0	0	0.0
1 Energy Industries	7,516	7,509	0.0	0.02	0	0	0	0.0
2 Manufacturing Industries & Construction	0	0	0.0	0.00	0	0	0	0.0
3 Transport	1,657	1,657	0.0	0.00	0	0	0	0.0
4 Other Sectors	1,430	1,430	0.0	0.00	0	0	0	0.0
B Fugitive Emissions from Fuels	1,842	0	87.7	0.00	0	0	2	3.0
1 Solid Fuels	0	0	0.0	0.00	0	0	0	0.0
2 Oil and Natural Gas	1,842	0	87.7	0.00	0	0	2	3.0
Memo Items	417	417	0.0	0.00	0	0	0	0.0
International Bunkers	417	417	0.0	0.00	0	0	0	0.0
CO2 Emissions from Biomass	0	0	0.0	0.00	0	0	0	0.0

Figure 2-2 illustrates the breakdown in energy-related GHG emissions in 1994 by activity. Most of the CO_2 from energy activities, about 60%, was associated with power production.

Figure 2-2: Breakdown of GHG emissions associated with energy activities in Sultanate of Oman, 1994



Notably, fugitive emissions of methane, a gas that has a high global warming potential, accounted for the second highest share of energy-related GHG emissions, about 15% on a carbon dioxide equivalent basis. This was directly associated with Sultanate of Oman's role as a major oil exporter.

Transport emissions for road transport and domestic civil aviation accounted for about 13% of total energy-related emissions in 1994. There was no specific data for the civil aviation and navigation; therefore, a 70% - 30% split was assumed for international and domestic fuel use, respectively.

2.5 Industrial processes

Table 2-3 summarizes GHG emissions associated with industrial processes in 1994. Industrial processes accounted for only 592Gg of CO_2–equivalent in 1994, or about 2.8% of national CO_2–equivalent emissions. Default IPCC emission factors were used to establish emission levels.

Table 2-3: GHG emissions from industrial activities in Sultanate of Oman, 1994 (Gg)

GHG Source Categories	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
All industry emissions	592.4	588.8	0.18	0.0	0.0	0.0	0.01	0.4
Industrial Processes	592.5	588.8	0.18	0.0	0.00	0.0	0.01	0.4
A Mineral Products	588.8	588.8				0.0	0.00	0.4
B Chemical Industry	3.7	0.0	0.18	0.0	0.00	0.0	0.00	0.0
C Metal Production	0.0	0.0	0.00	0.0	0.00	0.0	0.00	0.0
D Other Production	0.0	0.0			0.00	0.0	0.01	0.0
E Production of Halocarbons and Sulphur Hexafluoride								
F Consumption of Halocarbons and Sulphur Hexafluoride								

Mineral products (i.e., cement production and limestone production) accounted for virtually all industrial process GHG emissions in 1994, about 99%; followed by chemical production at about 1%. There was no metal production or other industrial processes in Sultanate of Oman in the 1994 inventory year.

2.6 Agriculture

Table 2-4 summarizes GHG emissions associated with agricultural activity in 1994. Relative to overall anthropogenic GHG emissions, the 7,469 Gg CO_2-equivalent represented about 35.8% of total national emissions in 1994.

Table 2-4: GHG emissions from agricultural activities in Sultanate of Oman, 1994 (Gg)

GHG Source Categories	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
All agriculture emissions	7,468.8	0.0	18.5	22.8	0.0	0.0	0.0
A Enteric Fermentation	370.3		17.6				
B Manure Management	20.0		0.9	0.0			0.0
C Rice Cultivation	0.0		0.0				0.0
D Agricultural Soils	7,078.5		0.0	22.8			0.0
E Prescribed Burning of Savannas	0.0		0.0	0.00	0.0	0.0	0.0
F Field Burning of Agricultural Residues	0.0		0.0	0.00	0.0	0.0	0.0

Agriculture is an important activity in Sultanate of Oman from a GHG emissions perspective. The overwhelming majority of emissions, about 95%, are associated with agricultural soils, specifically N_2O emissions due to the volatilization of synthetic fertilizers and animal manure. In contract, emissions from enteric fermentation among Sultanate of Oman's sizeable animal herd population accounts for only 5% of total agricultural emissions.

Emissions associated with manure management accounted for less than 1% of total agricultural emissions in 1994.

2.7 Land use change and forestry

There are no managed tree plantations Sultanate of Oman capable of sequestering measureable amounts of carbon. Therefore, for the purpose of the initial GHG inventory, carbon sequestered in sinks is considered to be negligible.

2.8 Waste

Table 2-5 summarizes GHG emissions associated with waste management activity in 1994. Relative to overall anthropogenic GHG emissions, the 372Gg CO_2-equivalent represented just 1.8% of total national emissions.

Table 2-5: GHG emissions from waste management activities in Sultanate of Oman, 1994 (Gg)

GHG Source Categories	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
All waste emissions	372	0	17.7	0.0	0.0	0.0	0.0
A Solid Waste Disposal on Land	116	0	5.5		0.0		0.0
B Wastewater Handling	256	0	12.2	0.0	0.0	0.0	0.0
C Waste Incineration	0	0			0.0	0.0	0.0
D Other (please specify)	0	0	0.0	0.0	0.0	0.0	0.0

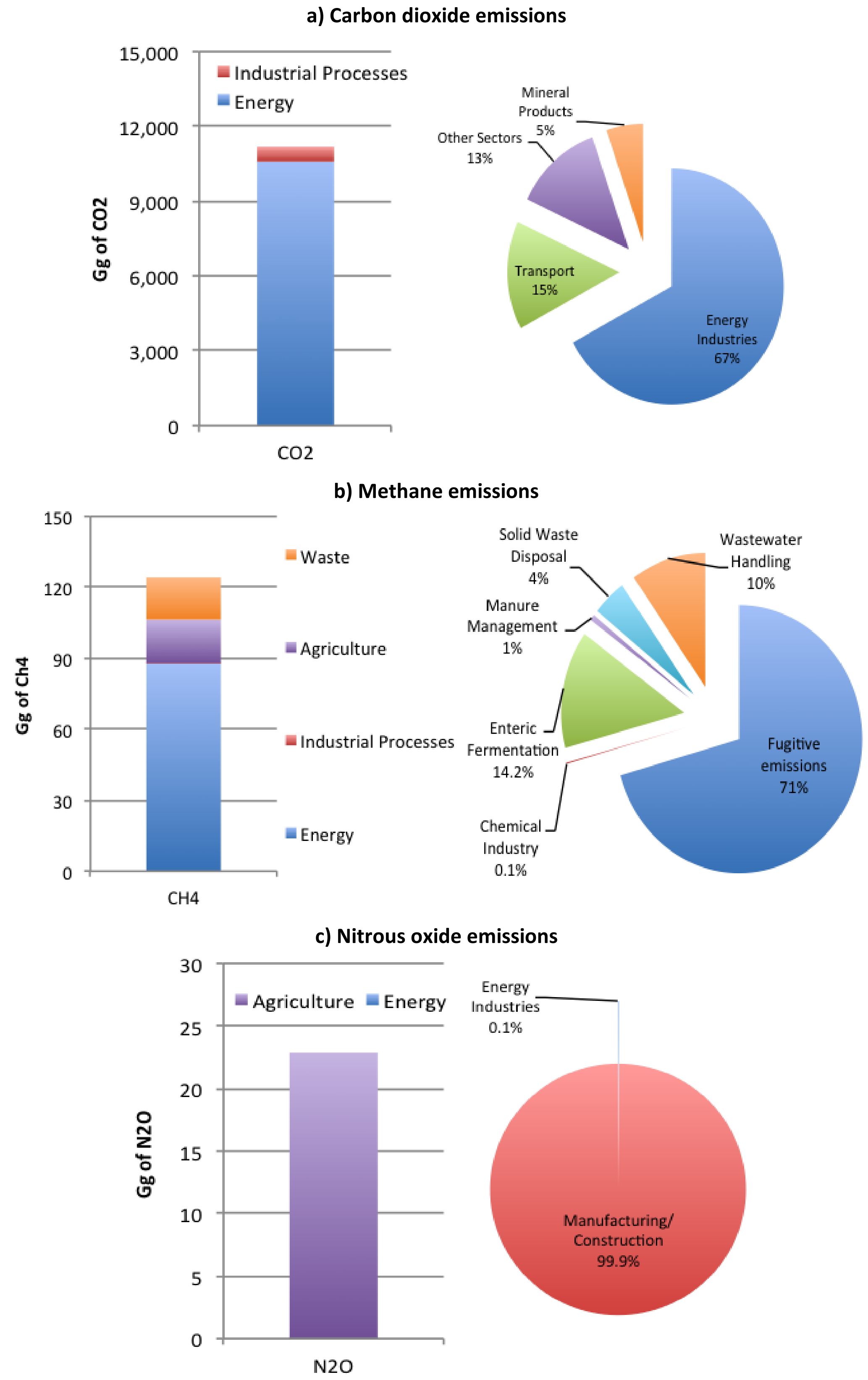
There are two main sources of greenhouse gases within the Sultanate of Oman's waste sector. It was assumed that the percentage of population that benefitted from solid waste disposal (unmanaged sites) and wastewater collection was about 10% of the total population in 1994 (estimated around 2.057 million people). Solid waste disposal on land accounted for 31% of total waste-related emissions. Domestic and commercial wastewater handling accounted for the remaining 68% of waste-related emissions.

2.9 Emissions summary by sector and type

The following bullets provide an overview of GHG emission totals by all sectors and GHG types for the year 1994.

- *CO_2:* Total CO_2 emissions were estimated to be 11,184Gg, or 53.6% of Sultanate of Oman's total greenhouse emissions in the year 1994. Figure 2-3a summarizes the contribution associated with CO_2 emissions at both the sector and activity levels.
- *CH_4:* Methane had the third largest share of greenhouse gas emissions. Total and CH_4 emissions were estimated to be about 124.2Gg, or about 12.5% of Sultanate of Oman's total greenhouse emissions on a CO_2e basis. Figure 2-3b summarizes the contribution associated with CH_4 emissions at both the sector and activity levels.
- *N_2O*. Nitrous oxide emissions had the second largest share of greenhouse gas emissions. Total N_2O emissions were estimated to be about 22.9 Gg, or about 33.9% of Sultanate of Oman's total greenhouse emissions on a CO_2e basis. Figure 2-3c summarizes the contribution associated with N_2O emissions at both the sector and activity levels.

Figure 2-3: Breakdown in GHG emissions, 1994 (Gg)



2.10 Uncertainty

The uncertainties associated with the GHG emission levels reported in the previous sections are mainly due to missing activity data and/or poor data quality. Given the importance of energy and agricultural activities in the profile of GHG emissions, these are the considered the highest priority sectors. For future updates, the most pressing recommendation is for the development and maintenance of a systematic database for these priority sectors. Such a database should include disaggregated activity levels and more appropriate local emission factors, as well as indicators of technological performance and other relevant information.

Specific recommendations for reducing uncertainty in each emitting sector are summarized in the bullets below in the order of priority.

- *Energy:* In the current inventory, several emission sources are not included namely flaring, cement production, waste, as well as indirect emissions from loading crude oil, solvent use and venting offshore. The conversion factor, emission factor and difference in activity data also lead to deviation in calculations following reference and sectorial approaches. The latter is especially important for crude oil, since the output from the reference approach method is dependent on the input values of crude oil and natural gas. In addition, some assumptions used in the current inventory (i.e., ratio between international and domestic aviation and navigation) will require evaluation and revision to reduce current high uncertainty levels.
- *Agriculture:* Nitrous oxide from soils represents the overwhelming majority of emissions from agricultural activities. However, large uncertainties exist regarding the type and quantity of nitrogen inputs to soils. In addition, some assumptions used in the current inventory (i.e., ratio between dairy and non-dairy cattle) will require evaluation and revision to reduce current high uncertainty levels.
- *Industrial processes:* While there were only two categories of industrial emissions in the initial inventory (i.e., minerals and chemicals), it will be important to account for the expansion in industrial operations to account for iron and steelmaking in future updates.
- *Waste:* For the estimation of the wastewater and sludge, the population benefiting from the solid waste disposal and wastewater collection was estimated to be about 10% of total population. In addition, it was assumed also that all waste was disposed to unmanaged sites. These assumptions will require future scrutiny and vetting. In addition, some coefficients used in the current inventory (i.e., Wastewater and sludge coefficients) will require evaluation and revision to reduce current high uncertainty levels.

2.11 List of References

IPCC, 1997. Revised 1996 Guidelines for National Greenhouse Gas Inventories.

IPCC, 2000. IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

Annex – Detailed GHG inventory tables

Table 2-6: Sultanate of Oman GHG inventory of anthropogenic emissions by source and removals by sinks of all GHGs not controlled by the Montreal Protocol and GHG precursors, 1994

	CO2 Emissions	CO2 Removals	CH4	N2O	NOx	CO	NMVOC	SO2
Total National Emissions and Removals	**11,184.36**	**0**	**124.15**	**22.86**	**0.218**	**0.316**	**2.040**	**3.375**
1 Energy	10,595.59	0	87.71	0.024	0.218	0.316	2.034	3.015
A Fuel Combustion (Sectoral Approach)	10,595.59		0	0.024	0.024	0.024	0.024	0
1 Energy Industries	7,508.51		0	0.024	0.024	0.024	0.024	0
2 Manufacturing Industries and Construction	0.00		0	0	0	0	0	0
3 Transport	1,656.62		0	0	0	0	0	0
4 Other Sectors	1,430.47		0	0	0	0	0	0
5 Other (please specify)	0.00		0	0	0	0	0	0
B Fugitive Emissions from Fuels	0.00		87.71		0.194	0.292	2.010	3.015
1 Solid Fuels			0.00		0	0	0	0
2 Oil and Natural Gas			87.71		0.194	0.292	2.010	3.015
2 Industrial Processes	588.76	0	0.18	0	0	0	0.006	0.360
A Mineral Products	588.76					0	0	0.360
B Chemical Industry	0		0.18	0	0	0	0	0
C Metal Production	0		0.00	0	0	0	0	0
D Other Production	0		0.00	0	0	0	0.006	0
E Production of Halocarbons and SF6								
F Consumption of Halocarbons and SF6								
G Other (please specify)	0		0.00	0	0	0	0	0
3 Solvent and Other Product Use	0			0			0	
4 Agriculture			18.52	22.838	0	0	0	0
A Enteric Fermentation			17.63					
B Manure Management			0.89	0.004			0	
C Rice Cultivation			0				0	
D Agricultural Soils				22.834			0	
E Prescribed Burning of Savannas			0	0	0	0	0	
F Field Burning of Agricultural Residues			0	0	0	0	0	
G Other (please specify)			0	0	0	0	0	
5 Land-Use Change & Forestry	0	0	0	0	0	0	0	0
A Changes in Forest and Other Woody Biomass Stocks	0	0						
B Forest and Grassland Conversion	0	0	0	0	0	0		
C Abandonment of Managed Lands		0						
D CO2 Emissions and Removals from Soil	0	0						
E Other (please specify)	0	0	0	0	0	0		
6 Waste		0	17.737	0	0	0	0	0
A Solid Waste Disposal on Land			5.536		0		0	
B Wastewater Handling			12.201	0	0	0	0	
C Waste Incineration					0	0	0	0
D Other (please specify)			0	0	0	0	0	0
7 Other (please specify)	0		0	0	0	0	0	0
Memo Items		0						
International Bunkers	417		0	0	0	0	0	0
Aviation	363		0	0	0	0	0	0
Marine	54		0	0	0	0	0	0
CO2 Emissions from Biomass	0							

Table 2-7: Sultanate of Oman GHG emissions summary (by sector and gas), 1994

SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)									
GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Total National Emissions and Removals		11,184.36	0	124.2	22.862	0.218	0.316	2.040	3.375
1 Energy	Reference Approach								
	Sectoral Approach	10,596.59		87.7	0.024	0.218	0.316	2.034	3.015
A Fuel Combustion		10,596.59		87.7	0.024	0.024	0.024	0.024	
B Fugitive Emissions from Fuels		0		0		0.194	0.292	2.010	3.015
2 Industrial Processes		588.76		0.2	0	0	0	0.006	0.360
3 Solvent and Other Product Use		0			0			0	
4 Agriculture				18.5	22.838	0	0		
5 Land-Use Change & Forestry		0	0	0	0	0	0		
6 Waste				17.7	0				
7 Other		0	0	0	0	0	0	0	0
Memo Items:									
International Bunkers		3,474		0	0	0	0	0	0
Aviation		1,050		0	0	0	0	0	0
Marine		2,424		0	0	0	0	0	0
CO_2 Emissions from Biomass		0							

Table 2-8: Total GHG emission in Sultanate of Oman, 1994

SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)							
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	CH4 21 CO2 eq	N_2O	N_2O 310 CO2 eq	Total CO2 eq
1 Energy							
A Fuel Combustion	10,595.59		0.000	0.00	0.0240	7.44	10,603.03
B Fugitive Emissions from Fuels	0.00		87.714	1841.99		0.00	1,841.99
Energy total							0.00
2 Industrial Processes	588.76		0.175	3.68	0.0000	0.00	592.44
3 Solvent and Other Product Use	0.00			0.00	0.0000	0.00	0.00
4 Agriculture	0.00		18.524	389.00	22.8380	7079.78	7,468.78
5 Land-Use Change & Forestry	0.00	0	0.000	0.00	0.0000	0.00	0.00
6 Waste			17.737	372.48	0.0000	0.00	372.48
7 Other	0.00	0	0.000	0.00	0.0000	0.00	0.00
Total	11,184.36	0	124.150	2607.15	22.8620	7087.22	20,878.73

3. Vulnerability & Adaptation

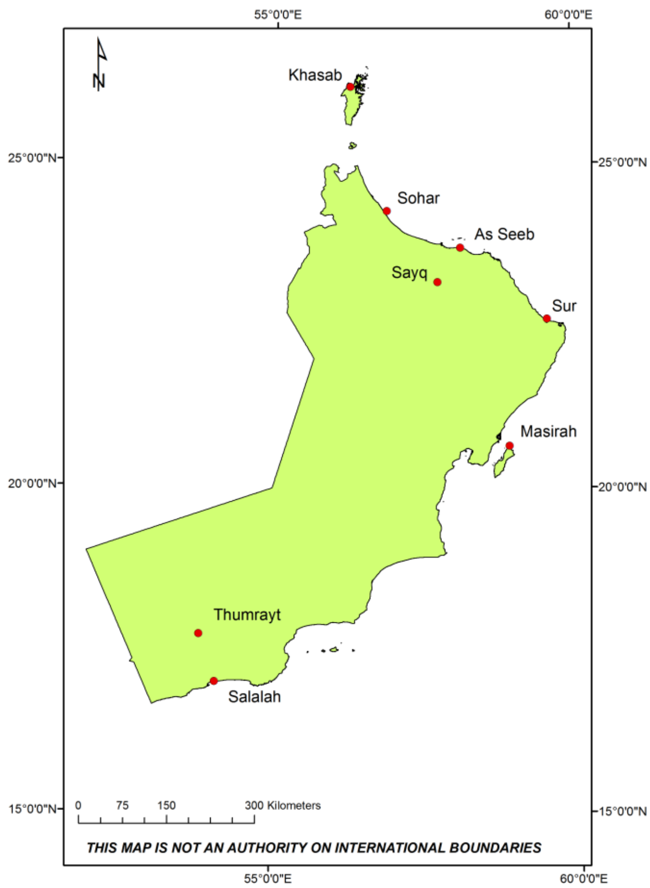
3.1 Introduction

This chapter provides an overview of the potential adverse impacts of climate change on key sectors in Sultanate of Oman, together with an overview of potential adaptation options. The chapter begins with a review of temperature and rainfall past trends and future projections. The bulk of the chapter is a summary of vulnerability and adaptation studies regarding Sultanate of Oman's coastal zones, water resources, and marine environment.

3.2 Climatic conditions

Sultanate of Oman's baseline climate was evaluated relative to temperature, rainfall and extreme event patterns. With climate change, these baseline conditions are expected to change. Projected changes in temperature and rainfall were assessed and the results of this assessment formed the basis by which the vulnerability of coastal zones, the marine environment, and water resources are understood.

Figure 3-1: Location of the 8 meteorological stations with longest data record in Sultanate of Oman



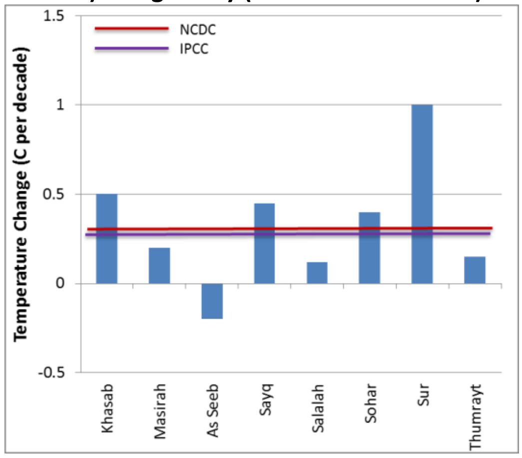
3.2.1 Baseline climate

Al-Sarmi and Washington (2011) conducted a study about recent observed climatic trends for the Arabian Peninsula. Subsets of those results focusing on Sultanate of Oman have been extracted, namely trends in mean, maximum and minimum temperatures as well as rainfall. These trends correspond to historical data over the 1980-2008 period for 8 meteorological stations distributed around the country (see Figure 3-1). Data from the stations were quality controlled in two stages:

- *Data quality:* A check was made for physically implausible data (e.g., negative rainfall or maximum temperature less than minimum temperature); and
- *Implausible data:* An analysis of outliers was conducted by means of numerical and visual checks. Suspect data were compared to data from nearest stations to assess whether flagged values were associated with real or anomalous weather events. Physically implausible were not used.

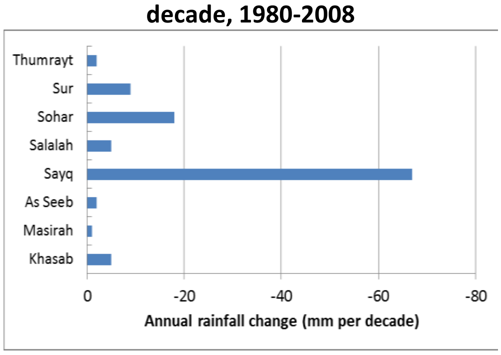
Data homogeneity was assessed using the RHtestV3 software, which uses a two-phase regression model applied to monthly data in order to check for multiple step change points that could exist in a time series. An overview of major baseline climate trends is provided in the bullets below.

Figure 3-2: Mean annual temperature trends in Sultanate of Oman during 1980-2008 (green bars) and globally (IPCC and NCDC lines)



- *Mean temperature:* Mean annual temperatures in Sultanate of Oman show a clear warming pattern (see Figure 3-2), and good consistency with the IPCC and the National Climatic Data Center (NCDC) global mean temperatures. Seven of the eight stations show statistically significant warming at a 95% confidence level, with most showing statistically significant results at a 99% confidence level. The greatest warming occurred in Sur, about 1.03°C per decade (2.98°C overall from 1980 to 2008) and Khasab, about 0.50°C per decade (1.44°C overall from 1980 to 2008). Moreover, for the month of May, temperatures in Sur show the highest statistically significant monthly mean temperature increase for the entire Arabian Peninsula (1.47°C per decade, 4.26°C overall from 1980-2008). Only As Seeb station shows cooling, though that may be due to its relocation in 1994. The lowest warming trends, showing the lowest significance were along the south Sultanate of Oman coast (Thumrayt and Salalah).

Figure 3-3: Total annual rainfall trends per decade, 1980-2008



- *Maximum temperature:* Average maximum annual temperatures in Sultanate of Oman also show a clear warming pattern. There is a broad statistically significant increase except for the As Seeb and Sohar stations. The highest increases are in Sur (0.93°C per decade, 2.7°C overall) and Khasab (0.88°C per decade, 2.6°C overall). Both Sayq and Masirah showed the lowest statistically significant trends (0.27°C per decade, 0.78°C overall).
- *Minimum temperature:* Average minimum annual temperatures in Sultanate of Oman show similar warming patterns while displaying greater statistical significance than mean and maximum temperatures, even over the south Sultanate of Oman coast. The highest trend value is observed in Sohar (1.17°C per decade, 3.4°C overall). There is only one statistically significant cooling trend observed in As Seeb with trend value of -0.32°C per decade (-0.9°C overall).
- *Rainfall:* Rainfall trends are less clear for Sultanate of Oman, though indications suggested decreasing total annual rainfall (see Figure 3-3). There is only 1 station, Sayq, with statistically significant results that shows a decrease of about 67.7 mm per decade (196.4 mm overall for 1990-2008). For all other stations, trends indicate decreasing total rainfall though not statistically significant. However, during the monsoon summer

season (June, August and September), rain over Salalah (southern of Sultanate of Oman) shows statistically significant negative trend (-3.72 mm per decade, -10.8 mm overall).

- *Climatic extremes:* There are indications that the frequency, amplitude, and persistence of climatic temperature extremes are increasing in Sultanate of Oman (see Table 3-1). Twelve indicators were developed to characterize trends in extremes that typically occur a few times every year. The linear trend of the climate extreme indices between 1980 and 2008 shows a number of statistically significant and spatially coherent trends in indicators corresponding to increasing extreme temperature events in Sultanate of Oman. Trends in the precipitation indicators are weak and are typically not statistically significant.

Table 3-1: Climatic extreme trends, 1980 to 2008 (Al-Sarmi and Washington, 2013)

Indicator	Trend	Significant?	Applicability
Consecutive dry days	-	No	Masirah
	+	No	All other stations
Consecutive wet days	-	Yes	Sayq, Sur
	-	No	All other stations
Number of days above 35mm	-	Yes	Sayq, Khasab, Thumrayt
	-	No	Sohar, Masirah, Salalah
	+	No	As Seeb and Sur
Extremely wet days	-	No	Sayq, Sohar
	+	No	All other stations
Annual Contribution from wet days	+	Yes	As Seeb, Salalah
	-	No	Sohar, Masirah, Thumrayt
	+	No	Sur, Khasab
Cold spell	+	No	As Seeb
	-	Yes	All other stations
Warm spell	+	Yes	As Seeb, Sur, Masirah
	-	Yes	All other stations
Very hot days	-	No	As Seeb, Salalah
	+	Yes	All other stations
Cool night frequency	+	Yes	As Seeb
	-	Yes	All other stations
Cool day frequency	+	Yes	Khasab, Sohar, Sur
	-	Yes	Sayq, As Seeb, Thumrayt
Warm night frequency	-	Yes	As Seeb
	+	Yes	All other stations

3.2.2 Future climate

To assess future temperature and rainfall projections, the IPCC's A1B GHG emissions scenario was chosen. This scenario provides an intermediate level of warming by the end of the century and has more Global Climate Model (GCM) output data available than any other emissions scenario. The outputs from the HadCM3 Climate Model were used to develop long-term (i.e., through 2070) climatic forecasts for Sultanate of Oman for this scenario.

A dynamic downscaling approach was used on a model grid of 0.30 seconds for rainfall and 5 degrees for temperature. The climatic baseline over 1961-1990 was used to compare and calculate projected changes in the average annual maximum temperature, average annual minimum temperature, and annual precipitation. An overview of major future climate trends is provided in the bullets below.

- *Maximum temperature change:* Figure 3-4 shows the simulated average maximum temperature change during the periods 2011-2040 (Figure 3-4a), and 2041-2070 (Figure 3-4b). As can be seen in these figures, the A1B scenario clearly shows an increase in future maximum temperature in the range of 1°C to 2°C for the entire country through 2040, with the areas showing the highest change along stretches in the open desert just east of the UAE and along portions of the coast by the Arabian Sea By 2070, average maximum temperatures are projected to increase in the range of 2°C to 3°C, with the geographic distribution of these changes following similar patterns as in the earlier period
- *Minimum temperature change:* Figure 3-5 shows the simulated mean minimum temperature changes during the periods 2011-2040 (Figure 3-5a), and 2041-2070 (Figure 3-5b). As can be seen in these figures, the A1B scenario clearly shows future minimum

temperature increases that are similar to the results shown for maximum temperature changes.

Figure 3-4: Projected average maximum temperatures changes in Sultanate of Oman

a) By the 2011-2040 period **b) By the 2041-2070 period**

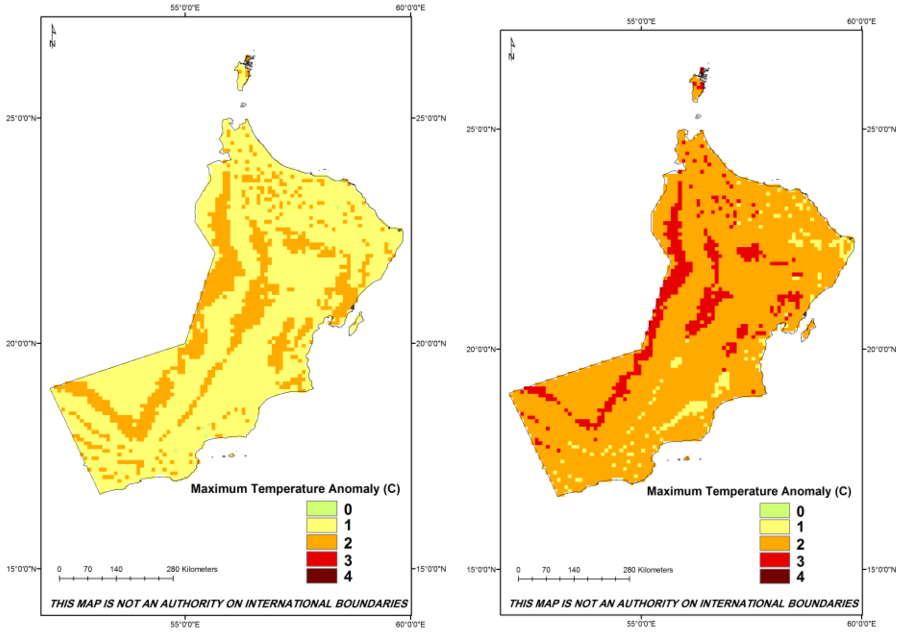
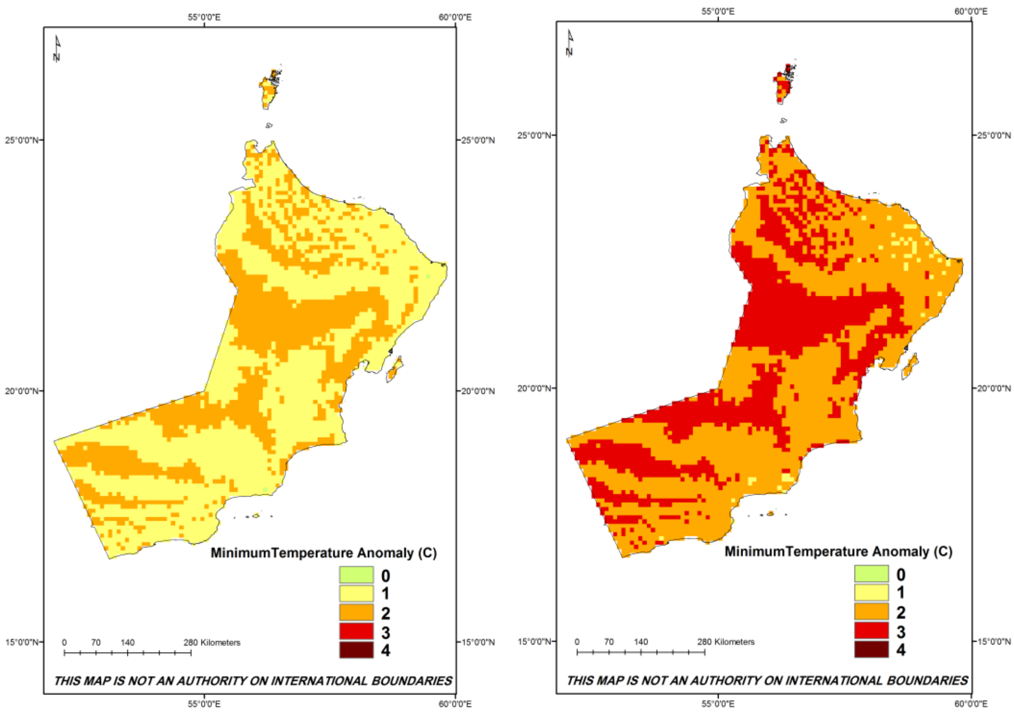


Figure 3-5: Projected future average minimum temperature changes in Sultanate of Oman

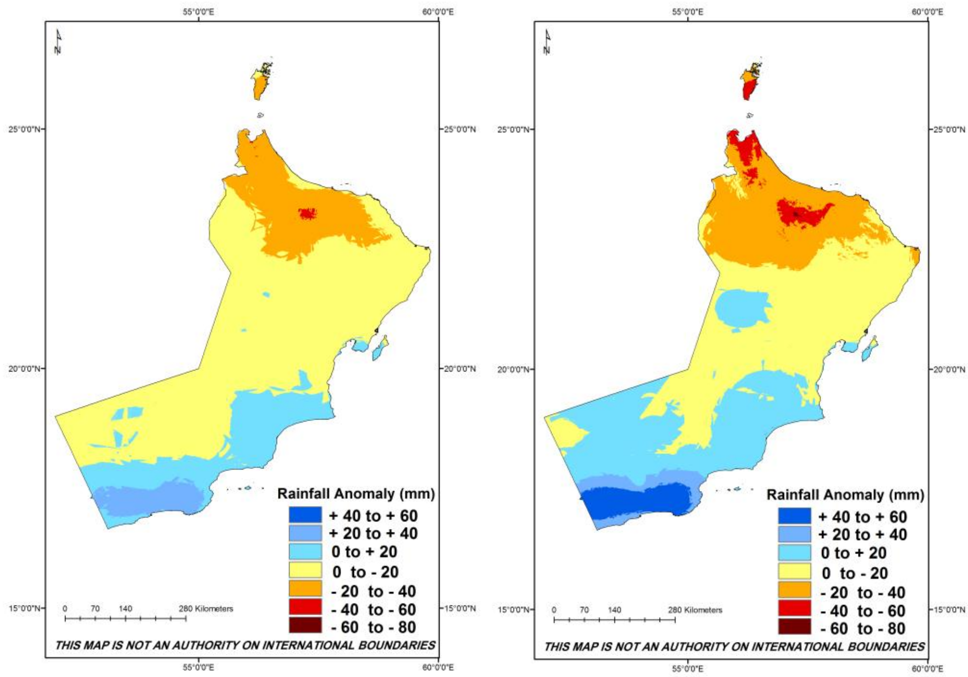
a) By the 2011-2040 period **b) By the 2041-2070 period**



- For both time periods, there is a clear expansion in the land area where the highest minimum temperature changes are projected compared to results for maximum temperature change, suggesting that minimum temperatures will experience the greatest impact from climate change. By 2070, most of the land area just south of the Hajar Mountains from the UAE border to the Arabian Sea is projected to experience an increase in average minimum temperatures by about 3°C.
- *Annual rainfall change:* Figure 3-6 shows the simulated average annual rainfall changes during the periods 2011-2040 (Figure 3-6a), and 2041-2070 (Figure 3-6b). As can be seen in these figures, the A1B scenario clearly shows that most of Sultanate of Oman will become drier, with large portions of the Al Hajar Mountains receiving up to 40 mm less in annual rainfall throughout the projection period. On the other hand, model results indicate that summer monsoons are likely to intensify, leading to increased rainfall in the southwestern parts of the country. By 2070, most of the Dhofar Governorate and a large portion of the Al Wusta Governorate are projected to receive up to 20 mm more in annual rainfall, with up to 60 mm more rainfall along coastal zones in the far southwestern parts of Sultanate of Oman.

Figure 3-6: Projected future average annual rainfall changes in Sultanate of Oman

a) By the 2011-2040 period **b) By the 2041-2070 period**



3.3 Coastal zones

Coastal erosion along several stretches of Sultanate of Oman's shoreline has long been recognized as a problem of growing magnitude. At present, coastal erosion and accretion occurs as natural processes and the continuing change of the shoreline. The problem is particularly severe for the Al Batinah North and Al Batinah South coasts along the Sea of Sultanate of Oman, which is retreating at a rate of about 60 cm/year (Al-Hatrushi et al, 2009). With future climate change-induced sea level rise, coastal erosion rates are expected to increase, posing even greater challenges to coastal settlements.

3.3.1 Methodology

The impact of sea level rise on the entire Omani coastal zone was assessed to develop estimates of inundated land area relative to a set of sea level rise scenarios. A brief overview of the major elements of the methodological approach is provided in the bullets below.

- *Modeling approach:* The impact of sea level rise was evaluated through the use of a GIS framework. Specifically, sea level rise scenarios were layered onto land elevations in the coastal zones to produce estimates of the total inundated areas in each of the six coastal Governorates.
    - *Topography:* A Digital Elevation Model (DEM) was developed with a horizontal spatial resolution of 40meters and a precise database of the elevation benchmarks of the coastal zone. The source for the DEM data was The National Survey Authority. The source for the elevation benchmark data along the shoreline was the Royal Navy of Sultanate of Oman's Hydrographic Department.
- *Sea level:* The Tidal Datum and Reference Benchmarks data based was obtained from the Sultanate of Oman National Hydrographic Office. The assumed tidal range in the Sea of Sultanate of Oman was 0.89 to 1.70 meters. Since 1990, Chart Datum has been established at over 40 sites along Sultanate of Oman's coast from observations conducted by, or under the supervision of, the Royal Navy of Sultanate of Oman's Hydrographic Department (Sultanate of Oman National Hydrographic Office, 2012).
- *Sea level rise scenarios:* A total of seven (7) sea level rise scenarios were considered: 0.2 meters, 0.5meters, 1meter, 2meters, 3meters, 4meters and 5meters. To assess the maximum inundation risk to coastal communities, these levels were added to mean high tide (MHT) levels.
- *Spatial resolution:* The sea level scenarios were overlain on land use/elevation datasets to estimate the inundation risk among all land use categories. All the grid cells that would be inundated based on a user-defined horizontal spatial resolution of 0.5meters for the entire Al Batinah North and Al Batinah South Governorates coastline.

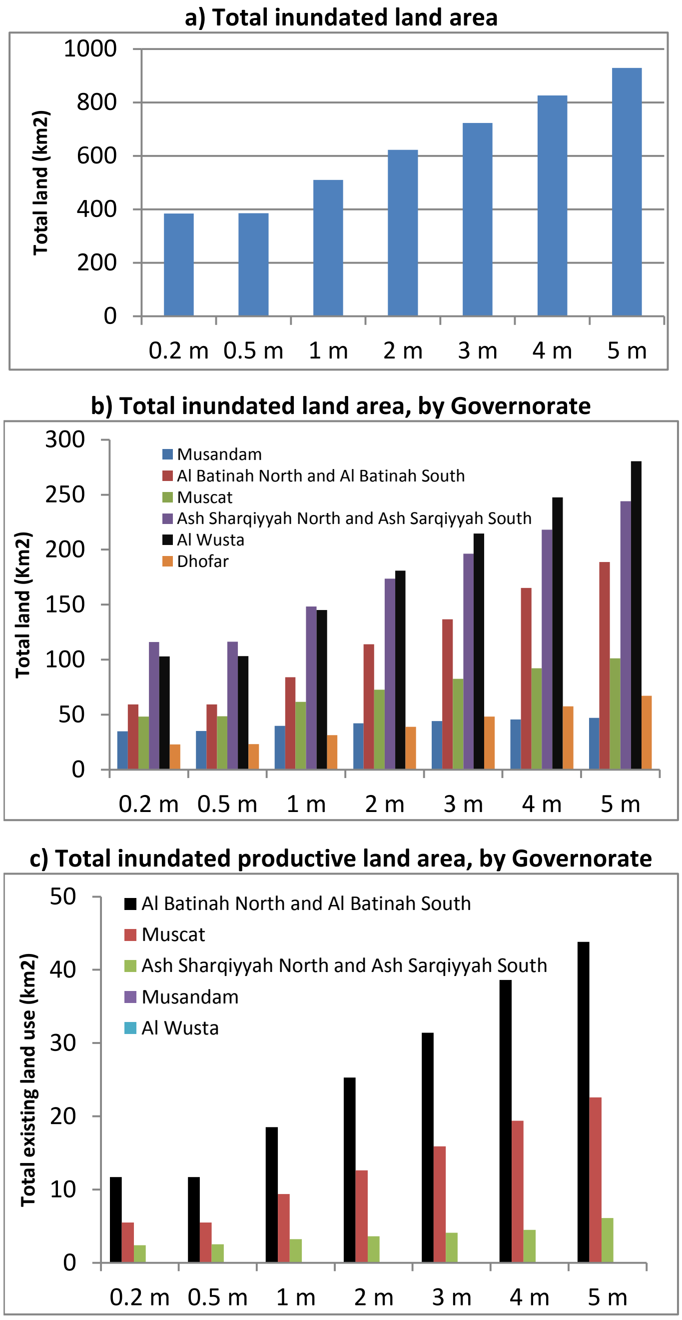
3.3.2 Vulnerability and risk

The results of the assessment show that Sultanate of Oman is highly vulnerable to climate change-induced sea level rise. At the national scale, nearly 400 km^2 of total land area is projected to be inundated under the smallest sea level rise scenario. Under the highest sea level rise scenario, over 900 $km^2$is potentially inundated (see Figure 3-7a).

At the Governorate scale, the Al Wusta Governorate in the central-south portion of the country is most vulnerable under high sea level rise scenarios (i.e., greater than 2 meters), with potentially up to roughly 280 $km^2$of total land inundated, while the Musandam Governorate is the least vulnerable under the high sea level rise scenarios, with under 50 $km^2$of total land inundated (see Figure 3-7b). Under the low sea level rise scenarios (i.e., less than 2 meters), the Dhofar Governorate shows the least vulnerability with potentially up to 40 km^{2}of total land inundated.

Currently, much of the land inundated at the Governorate level is open land that is not under any agricultural, industrial, residential, or other use. An assessment of the vulnerability of productive land use shows that the Al Batinah North, Al Batinah South Governorates and Muscat Governorate are the most vulnerable under all sea level rise scenarios (see Figure 3-7c). In the case of the Al Batinah North and Al Batinah South Governorate where much of Sultanate of Oman's agricultural production takes place, rising sea levels are projected to claim between 12 km^2 and 44 km^2 of scarce arable land. This corresponds to between 3 and 4% of such land. In the case of the Muscat Governorate, Sultanate of Oman's most densely populated, rising sea levels are projected to claim between 5 km^2 and 23 km^2 of valuable public/private property. This corresponds to between 10% and 16% of residential, commercial and government land.

Figure 3-7: Land inundation in Sultanate of Oman due to projected sea level rise



3.3.3 Adaptation

The Ministry of Environment & Climate Affairs, among other authorities, have expressed concerns about coastal erosion and the potential impacts of sea level rise on coastal communities and resources. Additionally, the Royal Navy of Sultanate of Oman (RNO) and many local authorities along the Al Batinah North and Al Batinah South Governorates share these concerns. The development of a set of potential adaptation strategies for this priority coastal region is recognized as important follow-up activity to the results described above.

3.4 Water resources

Water resources are already facing considerable threats in Sultanate of Oman. With climate change, it is expected that the prevention of groundwater degradation and balancing supply and demand will become even greater challenges. While a vulnerability assessment has not been undertaken, this section summarizes baseline conditions that will need to be factored into any future assessment of the vulnerability of water resources in Sultanate of Oman. This section also outlines the current framework for integrated water resource management in Sultanate of Oman. This framework provides a basis by which a future evaluation of adaptation strategies and policies can be built.

3.4.1 Baseline conditions

As discussed previously, northern Sultanate of Oman is expected to face decreasing rainfall in the coming decades. In a region where historic average annual rainfall levels are between 50 and 100 mm for the northern coast area (see Figure 1-4a), climate change is expected to lead to between 20 and 40 mm less rainfall by 2040 (see Figure 3-6b). This is equivalent to a reduction in average annual rainfall of about 40%.

With less future rainfall in northern areas, groundwater recharge and surface water flow are expected to also decrease. When combined with continued socioeconomic growth, current challenges in balancing water supply and demand will grow more difficult, as will the capacity to maintain water quality standards. Moreover, greater rainfall variability and longer drought episodes may adversely impact already fragile and vulnerable mountain ecosystems in the region.

Even without climate change occurring, water availability and groundwater deterioration have been identified as major development constraints, with absolute water scarcity predicted as early as 2020 (Ministry of Regional Municipalities and Water Resources, Sultanate of Oman 2012). An overview of baseline conditions for these water development constraints is provided in the bullets below.

- *Water supply and demand:* Total renewable ground water supply (i.e. annual ground recharge quantity) is about 1.3 billion m^3(bcm) per year. Notably, water demand in the north is about 1.6 bcm per year, or about 25% more than groundwater supply. In the past few years, over pumping of wells and *aflaj* sources have led lowered groundwater tables as well as seawater intrusion into aquifers. Hence, strategies and measures to balance supply and demand, already a government priority, will become critical as the climate continues to change. Desalinated water, already accounting for 15% of total water supply, is considered Sultanate of Oman's only reliable major option to confront growing water scarcity, despite its high cost.
- *Groundwater quality:* Deterioration of the groundwater quality has become evident in recent years. First, groundwater salinity is increasing in the Al Batinah North, Al Batinah South and Salalah plains because of saltwater intrusion due to over-pumping. For example, groundwater withdrawals Al Batinah South increased fivefold over the 1970-1995 period, from 34 Mm^3 to 161 Mm^3; with current withdrawal rates roughly double the recharge rate. Second, groundwater pollution is increasing in wadi areas. This is due to improper disposal of wastewater.

3.4.2 Adaptation

Integrated water resource management (IWRM) is considered a fundamental organizing framework to identify and evaluate potential adaptation strategies for water resources. The principles of IWRM are particularly applicable to Sultanate of Oman's circumstances of accelerated socioeconomic development producing increasing water demands against a backdrop of decreasing and deteriorating freshwater supply. The following objectives represent a starting point for future adaptation planning in Sultanate of Oman.

1) Ensure a balance between water use and renewable water supply in order to preserve water resources, limit pollution, and support ecosystem functions;
2) Pursue water security especially during drought periods through greater use of treated wastewater;
3) Promote sustainable resource use by balancing water consumption by industrial, commercial, tourist and agricultural activities with water resource constraints.
4) Enhance water supply by freshwater exploration/discovery, groundwater recharge initiatives, surface dam construction, rainfall harvesting techniques, and greater use of non-conventional water resources such as desalination, use of treated wastewater or brackish water.
5) Increase the efficiency of water supply by reducing losses through transmission and distribution pipes.
6) Undertake hydrologic, socioeconomic, and management studies of high priority water catchment basins in order to better understand available water supply/demand dynamics.
7) Conduct comprehensive techno-economic assessments of strategies to ensure balance in future water supply and demand in order that costs, technologies, resources, and local management systems are fully accounted for in policies and planning.
8) Conserve water and preserve water quality through new legislations and institutional reform at the national and regional levels.
9) Enhance public awareness of water scarcity through campaigns as an initial measure to reduce water use in domestic, industrial and agricultural sectors.

Table 3-2: Major water resource management projects in Sultanate of Oman

Project	Description
Al Masarrat Basin	The volume is about 19 Bcm of fresh water. (115,000) people are provided with 8 Mm^3 annually of fresh water in 2002. The quantity is expected to rise to supply 215,00 people with 26 Mm^3 annually after 30 years.
Rimal Ash Sharqiyyah (Sands)	The volume is about 12 Bcm of fresh water. The Project was designed to provide a total of 79,000 people with 3.3 Mm^3 annually of fresh water at the beginning of operation in 2003. The quantity is expected to rise to supply 196,00 people with 15.8 Mm^3 annually after 30 years.
Wadi Al Maawil	The volume is about 2 Bcm of fresh water which can be used as a strategic reserve covering the needs of Muscat Governorate of potable water.
Wadi Rawnab	The reservoir volume is about 100 Mm^3 of fresh water that can be used as a strategic reserve providing Al Jazir and the surrounding villages with freshwater.
An Najd	About 5 Mm^3 of water was discovered in An Najd
South Al Wusta	About 1 Bcm of water, which can be utilized in agricultural development, was discovered in Al Hashman and Mitan in Al Wusta governorate.
Falajs Inventory	Development of data base about Aflaj.
Emergency urban water supply	Assessment of expected reserves of the potable resources and recommendation to provide potable water reserves in 11 cities.
Emergency non potable water supply	The non-potable water in Al Ansab and Bawshar was assessed in order to be used as a water resource in case of sea pollution.
Reserve water storages	Consultancy study was prepared to establish water reserve storages for Muscat.
Storage Dams	32 groundwater recharge dams was constructed to hold about 1064 Mm^3 of flood waters till 2009. 11 groundwater recharge dams are being constructed and the number of surface storage dams in mountain areas currently is 90 dams.

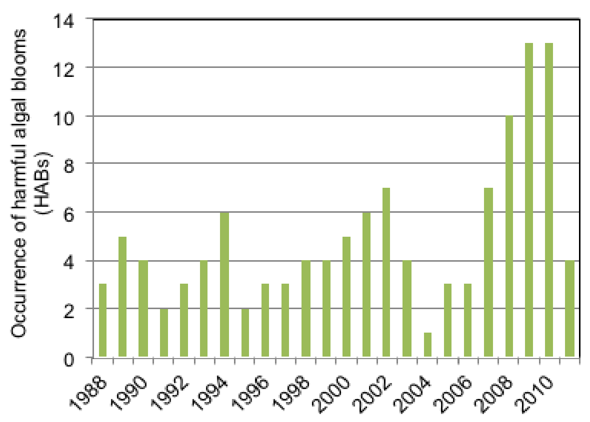
A number of important water projects are in the process of being implemented that are strongly linked to the above objectives. These projects address water exploration, hydrogeological mapping, protection of *falaj* systems, well inventory and maintenance, cloud seeding, and water efficiency (see Table 3-2).

3.5 Fisheries and the marine environment

The Arabian Sea and Sea of Sultanate of Oman have a high level of biodiversity and productivity that could be under threat from climate change. Currently, these waters are influenced by known physical effects that drive environmental parameters such as density, water temperature, nutrients, and Ph balance. Any changes in these physical effects can profoundly affect primary productivity and subsequently affect the entire marine ecosystem structure (Levy *et al*., 2009). This section summarizes baseline conditions as well potential vulnerability of fisheries and the marine environment in Sultanate of Oman.

3.5.1 Baseline conditions

Figure 3-8: Occurrence of harmful algal blooms in coastal waters off Sultanate of Oman



The coastal waters of Sultanate of Oman have been exposed to a variety of environmental pressures. These include inter-annual variability in monsoon forcing, coastal development, brine discharge from seawater desalination stations, and waste from synthetic fertilizer plants. These pressures combined directly or indirectly cause loss of habitat, introduction of new species and fish mortality. In 1999, various marine resources (i.e., abalone, shark, demersal, and pelagic species) showed a noticeable decline in number (Banse and English, 2000; Al-Kharusi et al; 2002). Overexploitation by commercial fisheries is considered as one of the key factors for this decline.

At present, several studies suggest that baseline conditions in the Arabian Sea and Sea of Sultanate of Oman are in flux. A recent analysis of the 50-year (1961-2010) record of Sea Surface Temperature off Muscat and Masirah, have reached a number of conclusions regarding changing baseline conditions, as outlined below.

- *Sea surface height (SSH):* Anomalies showed large variability in the Sea of Sultanate of Oman and along the eastern coast. Large fluctuations in SSH are associated with algae blooms leading to fish mortality (Parsanna et al, 2009; Sarma; 2012).
- *Sea surface temperature (SST):* There is a strong signal of increasing SST along Sultanate of Oman's coast, 0.32°C above the annual mean around Muscat and 0.53°C off Masirah (Sarma; 2012). An increase in SST by 2°C was noticed weeks before cyclones Gonu (2007) and Phet (2010). Changes in the SST may lead to the upper ocean becoming acidic and unsupportive of marine life.

Other studies suggest increasing frequency of harmful algae blooms, or "green tide" (see Figure 3-8). Phytoplankton species data collected off the coast of Sultanate of Oman since October 2004 indicate that large blooms of *Noctiluca miliaris* are becoming more pervasive in the Sea of Sultanate of Oman during the Northeast Monsoon season from November to January and are persisting into the Spring Inter-monsoon season from March through May (Al-Azri*et al*., 2007; Matondkar, *et al*., 2012).

3.5.2 Vulnerability and risk

The IPCC has reported that rising water temperatures from climate change will lead to adverse changes in marine biological systems (IPCC, 2007). Specifically, this is expected to cause declines in the health of phytoplankton communities and the abundance of fish populations (Bradbury, 2008) and changes in the physiology and behavior of marine species (Brander, 2010). Such changes will adversely impact commercial fishery production through alterations in the tropic systems during the planktonic stage and increased mortality of fish larvae. Moreover, the disruption of the phenology of fish larvae and their prey will reduce fish stocks.

Alterations in growth patterns in the North-western Arabian Sea and northeastern of the Gulf and the Sea of Sultanate of Oman are considered a likely outcome of climate change (Goes et al, 2005; Feary et al, 2010). A study by Goes et al. (2005) reported the trend of declining winter and spring snow cover over Eurasia as a major driving force causing a land-ocean thermal gradient resulting in summer monsoon wind intensification. This escalation in the intensity of summer monsoon winds is accompanied by enhanced upwelling and a 350% increase in average summertime phytoplankton biomass along the shoreline and over 300% offshore. These developments combined raise the possibility that the current warming trend of the Eurasian landmass is making the Arabian Sea more productive of algae, which will negatively impact the productivity of fisheries.

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4. National Roadmap in Response to Climate Change

4.1 Introduction

This chapter provides an overview of the constraints and gaps in preparing the national communication and a national strategy for responding to the challenge of climate change in the Sultanate of Oman. The chapter begins with a review of framework for action. The bulk of the chapter is a summary of goals and objectives, together with plans for institutional coordination, network development, and capacity strengthening.

4.2 Constraints and Gaps

The preparation of the initial national communication was participatory and has in its core objective the establishment of foundational national capacities to prepare subsequent national communications and other reporting obligations such as the Biennial Update Reports. The national team was selected primarily from the Ministry of Environment & Climate Affairs (the focal institution for climate change) and other relevant line ministries. This team was mixed with experts from the university and international experts assigned by UNEP to provide necessary technical guidance and support. Considerable learning process was in effect during the preparation period. Since this is the first report, some constraints and gaps were apparent such as:

GHG Inventory

i) Availability and accessibility of data. The GHG data needed for the inventory were scattered across sectors and responsible government agencies. There is not central repository for such data. Even if it is available, considerable efforts needed to harmonize and categorize them according to the requirement of the IPCC Guidelines.

ii) Limited trained personnel on preparing inventories. Sultanate of Oman has not prepared an inventory before. There was some difficulty finding trained national experts. With this project, a core group of national GHG experts was formed.

Vulnerability Assessment and Adaptation

Identifying priority vulnerable sectors was based on best available knowledge and expert judgment. Extensive impact assessment was not possible due to the limited information about the climate change dimension in these sectors. In other words, climate change is not yet mainstreamed into sectorial plans. Climate modeling was limited to climate and sea level rise because of limited historical observation data. In the second national communication, climate modeling will be extended in terms of time horizon and sectors covered. The Sultanate of Oman will develop a full-fledged national strategy based on assessment of impacts and vulnerabilities.

4.3 Framework for Action

Sultanate of Oman recognizes the need to develop a national strategy for climate change adaptation and mitigation. This is driven by the inherent threat of climate change, the depletion of oil and natural gas, and Sultanate of Oman’s vision for sustainable socioeconomic growth. The impacts of climate change discussed in the previous chapter will adversely affect the extent and the speed at which long-term, medium and even short-term national development goals can be achieved. It is clear that the cost of no action far outweighs the cost of actions to address the impacts of climate change.

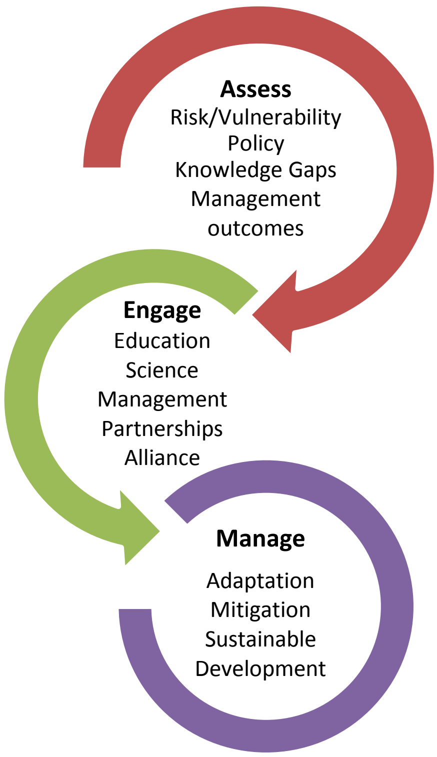
A national strategy to guide such actions is an urgent priority. The strategy should integrate and apply the best and the most promising approaches, tools and technologies. The involvement of policy-makers, researchers, the private sector and civil society in the elaboration of the strategy and actions plan is vital. Successful mitigation and adaptation will entail changes in individual behavior, technology, institutions, agricultural systems and socio-economic systems. These changes cannot be achieved without improving interactions among the full range of stakeholders and decision makers at all levels of society.

4.4 Institutional actions

In responding to climate change, the Ministry of Environment & Climate Affairs envisaged to adopt three types of actions. These are briefly described in the bullets below and illustrated on Figure 4-1.

- *Assessment:* This involves the assessment of current and future risks, vulnerabilities, policies, and knowledge gaps through coordinated and well-integrated technical studies;
- *Engagement:* This involves engaging internal and external partners in identifying and prioritizing strategies to reduce GHG emissions and adapt to climate change;
- *Management:* This involves managing for resilience, in ecosystems as well as in human communities, through adaptation, mitigation, and sustainable development strategies.

Figure 4-1: Levels of action to respond to climate change in Sultanate of Oman (source: Ministry of Environment & Climate Affairs, 2012)

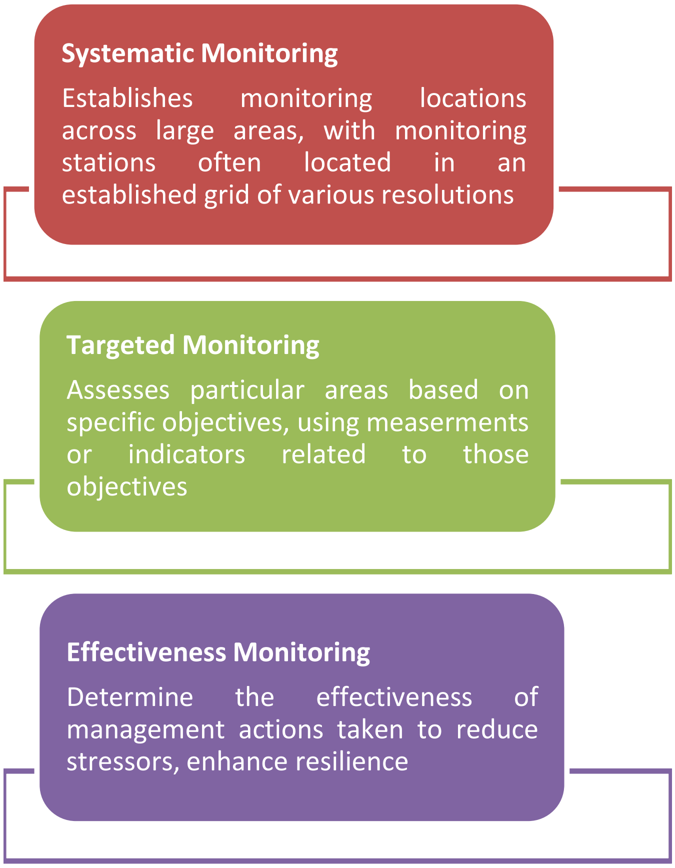


All three modes of action are dynamic and mutually reinforcing. They are interconnected through monitoring and evaluation, forming a continual feedback loop to allow opportunities for adjustment in direction.

The Ministry of Environment & Climate Affairs strongly believes that monitoring will be the key to the program's success. Monitoring paves the way for assessments to be updated and validated, revealing critical new issues. A unified, multi-scale monitoring system capable of detecting and evaluating national, regional, and local trends will enable land managers, for example, to develop and adjust adaptation and mitigation strategies to improve their effectiveness across different scales. Improved information delivery systems will provide reliable, timely, and transparent information for informed planning, decision-making, and project implementation at all levels.

While the Ministry of Environment & Climate Affairs and other government organizations like Ministry of Agriculture and Fisheries, have monitoring programs, they are currently not integrated. A comprehensive integrated approach is needed to connect various monitoring efforts and to fill information gaps. The vision of the Ministry of Environment and Climate Affaires is to undertake three interrelated forms of monitoring: systematic monitoring targeted monitoring, and effectiveness monitoring (see Figure 4-2).

Figure 4-2: Integrated forms of monitoring to respond to climate change in Sultanate of Oman (source: Ministry of Environment & Climate Affairs, 2012)



4.5 Information networks

The development of better information networks is a fundamental starting for successfully implementing the institutional actions described above. Highest priority is being given to the following elements of an integrated information network.

- *Techncial studies:* This involves the commissioning of priority studies on regional climatic modeling, vulnerability assessment for key sectors, and greenhouse gas mitigation analysis. Such efforts should apply state-of-the-art models and methodological approaches to produce an improved basis for policymaking regarding adaptation and mitigation.
- *Observation networks:*This involves the development of enhanced physical monitoring systems to observe changes to the terrestrial and marine environments due to climate change. Such efforts will improve understanding the key climatic changes, improve predictive capacity for future changes, and facilitate better planning and capacity building.
- *Database management:* This involves the development of systematic databases to ensure observations are effectively compiled and available for analysis.

4.6 Capacity strengthening

Capacity strengthening is targeted toward educational and public awareness-raising initiatives. Incorporating environmental education concepts in the curricula is needed to positively shape individual attitudes and values towards the environment. Key areas include rational use of water and electricity, natural resource conservation, preservation of terrestrial and marine wildlife, pollution prevention, and combating desertification (MECR, 2012).

The Ministry of Education has adopted a project for developing an environmental education strategy document in cooperation with the Ministry of Environment & Climate Affairs, Sultanate of Oman Environment Society and Shell's Sultanate of Oman Office. This document includes tools to assist the curriculum designer on the development, approach and the main criteria to be considered and followed in presenting the concept in the curricula. Also, the Ministry of Education has undertaken some reforms to better represent the environment in the education, as briefly described in the bullets below.

- Establishment of the Educational Awareness and Guidance Department;
- Establishment of the Environmental Life Skills Curricula Department;
- Establishment of health awareness sections in all educational Governorates;
- Establishment of environmental life skills curricula including various environmental education concepts and subjects. These curricula were put into action with the introduction of basic education in the academic year 1998-1999.
- Introducing an environment focus in the curriculum of phase one of basic education, followed by the establishment of environmental life skill sections in the first grades of all Governorates.
- Establishment of school activity groups concerned with the environment in all schools, as well as other organizations such as public service groups, camps groups and cultural activity groups. The mandate of such groups is to disseminate environmental awareness information and preserve natural resources.
- Holding of a competition for preserving cleanliness and health in the school environment.

Human educational capacity is built through continuous training at the level of the Ministry of Education such as Educational and and schools. Educational activities are constantly working to implement programs and projects through field work, school journalism, lectures and other activities. The Educational Information Department contributes to spreading awareness among students and society members through educational events, mainly environmental activities at different levels via mass media.

Public awareness programs and activities have a strong focus on partnership, and are designed to influence individual behavior and the adoption of principles and tendencies towards the serving of the common good as well as to enable the younger, upcoming generation to play a positive role in achieving national gains and accomplishments in the conservation and utilization of natural resources.

Awareness and information are therefore vital elements in addressing environmental issues and to enable the community to recognize its significance in the development process and for it to subsequently provide the required support and response to environmental programs. Environmental awareness must be founded on a wide base of scientific and technical knowledge that it is suitable for all community in order to ensure the best conditions to achieve the sough objectives through environmental awareness programs.

Environmental information and awareness are based on four main elements, namely education, culture, media and direct contact. These elements contribute to strengthening capacity and awareness through the following actions

- Promoting environmental friendly attitude and tendencies;
- Addressing negative attitude and habits towards environment and public health;

- Encouraging efforts and trends towards preserving the environment and natural resources;
- Concentrating on the role of families, schools, social activities and related establishments in this concern; and
- Stressing the importance of environmental laws and regulations via simple presentations to ease compliance and regulate human activities in matters that may have negative effects on environment and natural resources.

The awareness is achieved by publishing some booklets and magazines such as "Man and the environment", togetehr with postcards, newspapers, audio-visual media and electronic books and website. The Ministry of Environment & Climate Affairs, assigned to implement the annual plan in the area of environmental awareness, has won the GCC award for the best environmental work for the consecutive years (2001/2002), (2002/2003) and (2003/2004).

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