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Acronyms

AQCC	Air Quality Control Company
ARI	Acute Respiratory Infections
BOD	Biological Oxygen Demand: The amount of oxygen required by aerobic microorganisms to decompose organic matter in a sample of water, such as that polluted by sewage. It is used as a measure of the degree of water pollution.
BCM	Billion Cubic Meters
CEP	Caspian Environmental Program
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
COI	Cost of Illness
COPD	Chronic Obstructive Pulmonary Diseases
DALY	Disability Adjusted Life Year
DECRG	Development Economics Research Group at the World Bank
DHS	Demographic and Health Survey
DM	Dry Matter
DOE	Department of Environment
dS/m	deciSiemnes per meter (a measure of electrical conductivity)
ECe	Electrical Conductivity at crop root zone level
EER	Energy Environment Review
EMRO	East Mediterranean Regional Office of the World Health Organization
FAO	Food and Agriculture Organization
FRWO	Forest, Range and Watershed Organization
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gas
GLASOD	Global Assessment of Soil Degradation
GNI	Gross National Income
HCA	Human Capital Approach
ICM	Integrated Coastal Management
IFDC	International Center for Soil fertility and Agricultural Development
IPCC	International Panel on Climate Change
IRR	Iranian Rials
LRI	Lower Respiratory Infections
MAI	Mean Annual Increment
MENA	Middle East and North Africa
METAP	Mediterranean Environment Technical Assistance Program
MICS	Multiple Indicator Cluster Survey
NBSAP	National Biodiversity Strategy and Action Plan
NMVOC	Non-Methane Volatile Organic Compound
MNSRE	Water, Environment, Social and Rural Development Department in the Middle East and North Africa Region

MOH	Ministry of Health
MOJA	Ministry of Jihad and Agriculture
NPV	Net Present Value
NWFP	Non-Wood Forest Product
ODDS	Odds Ratio
ORT	Oral Rehydration Therapy
OWRC	Organization for Waste Recycling and Composting
PM	Particulate Matters
PSI	Pollutant Standard Index
RAD	Restricted Activity Days
SCI	Statistical Center of Iran
SRRI	Social Rate of Return on Investment
tC	Ton of Carbon
tCO_2	Ton of Carbon Dioxide
TDN	Total Digestive Nutrient
TSP	Total Suspended Particulates
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
US$	US dollars
WHO	World Health Organization
WTP	Willingness-to-Pay
YLL	Years of Life Lost

Executive Summary

THE OBJECTIVE

How much is a cleaner environment worth? For policy makers, that question often goes largely unanswered. It is not that the environment is seen as unimportant. It is simply easier to compare the costs and benefits of tangible projects such as airports or electrical grids than weigh the merits and value of a landfill cleanup or a change in emissions legislation.

The objective of this report is to provide an estimate of the cost of environmental degradation in Iran. Despite the difficulties involved in assigning monetary values to environmental degradation, such estimates can be a powerful tool to raise awareness about environmental issues and facilitate progress toward sustainable development. It is hoped that this study will provide an instrument for policymakers to better integrate the environment into economic development decisions.

Estimates of environmental damage presented in this report should be viewed as orders of magnitude. The accuracy of all estimates has been constrained by data availability and was subject to various assumptions and simplifications. A range of values has been presented to reflect this uncertainty. Nevertheless, the estimates presented in this report indicate the severity and magnitude of environmental degradation in Iran.

The reader should bear in mind that this report only shows one side of the coin. Any policy action that causes environmental damages also produces benefits to society. For example, deforestation is often a result of changes in land use to agriculture. While this report only focuses on environmental degradation costs, understanding and evaluating both the costs and benefits of each development actions is necessary for sound policy making.

THE RESULTS

In 2002, the annual cost of environmental degradation in Iran was estimated at 4.8 to 10 percent of GDP, with a mean estimate of 7.4 percent (equivalent to US$8.4 billion or IRR 67,300 billion). Estimated costs of environmental degradation are presented in Figure A and Table A. In addition to the damages to the national economy, Table A also presents damage to the global environment through greenhouse gas emissions.

Figure A. Annual cost of environmental degradation in Iran (mean estimate as a percentage of GDP, 2002)

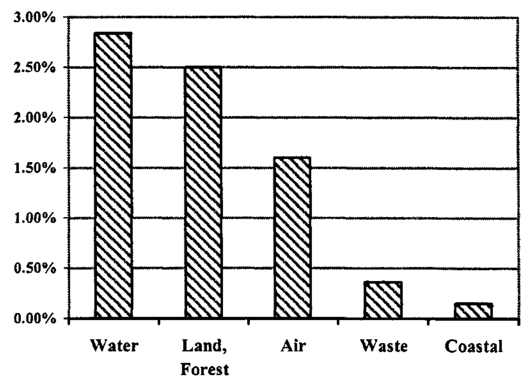


Table A. Annual cost of environmental degradation in Iran (mean estimate, 2002)[1]

Category	US$ millions	Rials billions	GDP %
Water	3,200	25,500	2.82
Land and Forest	2,840	22,600	2.50
Air	1,810	14,500	1.6
Waste	410	3,200	0.36
Coastal zone (limited to Caspian sea)	170	1,300	0.15
Subtotal	**8,430**	**67,100**	**7.43**
CO_2 emissions	1,540	12,300	1.36
Total	10,000	79,400	8.8

[1] Numbers may not add up exactly due to rounding

Detailed results of each environmental degradation costs are presented below.

Water

This section presents the health impacts resulting from the lack of water supply, sanitation and hygiene, and water pollution. It also presents the damages costs associated with over-pumping groundwater, water erosion and dam sedimentation. It should be noted, however, that there are other aspects of water resource degradation for which costs are not estimated due to data constraints. Therefore, cost estimates presented in this report are likely to underestimate total damage costs.

Health impact. Sub-standard quality and inadequate quantities of water for drinking and hygiene purposes, inadequate sanitation facilities and sanitary practices, and inadequate personal, food and domestic hygiene have a cost to society. It is well known that these factors are associated with waterborne illnesses and mortality. The most common of these illnesses and the one with the most established link between inadequate water, sanitation, and hygiene is diarrhea.

Based on information provided by health experts in Iran, diarrhea is estimated to be responsible for 12.5 percent of under-five mortality. This implies that more than 8,600 children under the age of five years die annually from diarrheal disease. If adequate water supply and sanitation services are provided and good hygiene practices are observed among the entire population, up to 85 percent of these cases could be avoided. Many more cases of non-fatal diarrheal disease occur in Iran each year, causing discomfort to victims and imposing the cost of treatment and the time of caregivers. Based on the most recent health survey in Iran, the number of mild and severe diarrheal is about 50 million per year for children under the age of five years. The number of cases for the population above five years of age is 65 million per year.

Mortality and morbidity resulting from diarrheal diseases are estimated to cost society between US$1 and 4 billion (equivalent to an average of IRR 20,000 billion or 2.2 percent of GDP).

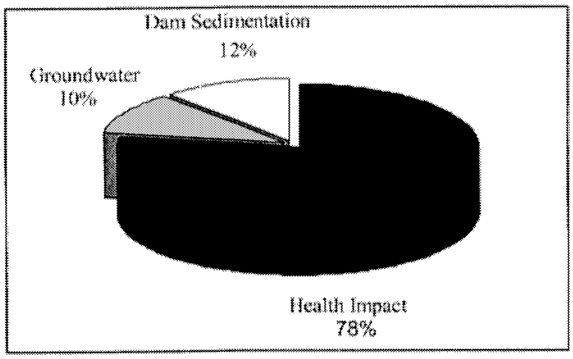
Groundwater. The main effect of unsustainable exploitation of groundwater is a decrease in the water table and the eventual exhaustion of the resource. Over the past 30 years, over-exploitation of groundwater – primarily through wells – has resulted in a decrease in water levels. Although the problem in Iran is not as severe as in other countries, information provided by the Groundwater Department of the Ministry of Energy indicate an average long-term annual decrease in water levels of 0.4 meter. To assess the damage costs resulting from a decrease in the water table, the additional pumping costs needed to extract water from a deeper level were calculated. The main additional pumping cost is likely to be fuel. As a result, the net present value of the damage cost associated with over-pumping was assessed at about US$190 million in 2002.

In addition to the above cost, overexploitation of groundwater also results in the necessity to abandon wells and to dig new ones. The cost of digging new wells to compensate for overexploitation was estimated to range between US$130 and 160 million in 2002. A smaller number of wells are also being abandoned due to groundwater pollution. This cost was estimated at US$ 3 million.

Water erosion and dam sedimentation. Over the last four decades, intensive deforestation and rangeland overgrazing have contributed to soil erosion in watershed areas. According to the Ministry of Jihad and Agriculture, soil erosion is leading to dam sedimentation which in turn is resulting in a loss in reservoir storage capacity of 236 million cubic meters per year. In this report, the damage cost resulting from dam sedimentation is assessed in terms of potential loss in irrigated crops. Since a significant portion of irrigated land (31 percent) in Iran is cultivated with wheat, the study focuses on the potential loss in wheat. The net present value of this loss in 2002 was assessed at US$370 million. In addition dam sedimentation also results in the need for dredging activities in irrigation networks. This additional operating cost was estimated at US$1.6 million.

In summary, environmental damage costs associated with lack of water supply, sanitation and hygiene, water pollution, groundwater depletion and water erosion amount to US$3,200 million (IRR 25,500 billion or 2.82 percent of GDP) per year.

Figure B. Share of damage costs in water sector



Air

Urban air pollution. Air pollution is one of the most significant environmental issues facing Iran, especially in its capital city, Tehran. Outdoor urban air pollution has significant negative impacts on public health, resulting in premature death, bronchitis, respiratory disorders, and cancer. The air pollutant that has shown the strongest association with these health endpoints is particulate matter. This report focuses mainly on the impact of particulate matter on health. It also addresses the impact of lead pollution and the loss of recreational value due to air pollution.

Morbidity health endpoints considered are chronic bronchitis, hospital admissions of patients with respiratory problems, emergency room visits, restricted activity days, lower respiratory infections in children and general respiratory symptoms. Based on concentration of air pollution in Iran's major urban centers, it is estimated that up to 13,200 person die prematurely every year due to air pollution. In addition, air pollution also leads to 12,500 new cases of chronic bronchitis every year as well as 29,000 annual hospitalizations and 560,000 emergency room visits.

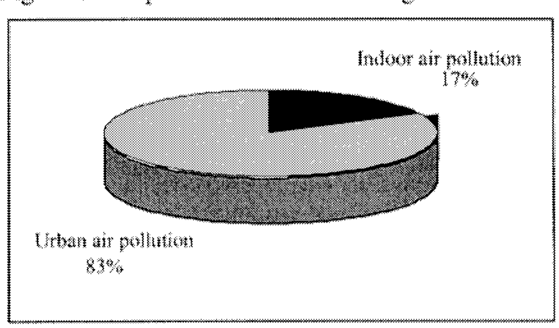
Annual damage costs associated with mortality and morbidity resulting from urban air pollution was estimated to range between US$610 and 2,275 million (equivalent to an average of IRR 11,500 billion or 1.28% of GDP).

While the greatest percentage of the cost of urban air pollution is associated with health effects, air pollution also causes discomfort, and reduces visibility and scenic beauty. The loss of recreational value due to urban air pollution in seven main cities in Iran ranges between US$44 to 54 million per year.

Indoor air pollution. The use of wood or other biomass fires for cooking is closely associated with indoor levels of particulate matter. Acute respiratory infections and chronic obstructive pulmonary diseases especially in young children and adult women are strongly related to indoor air pollution. In Iran, 786,000 tons of oil equivalent of biomass are used every year. Although there are no available statistics on indoor concentration of particulate matter in Iran, this report is based on ratios used in international studies. The estimated damage cost associated with mortality and morbidity resulting from indoor air pollution ranges from US$ 128 to 500 million per year (equivalent to an average IRR 2,500 billion, or 0.28 percent of GDP) in 2002.

In summary, the total damage cost associated with urban and indoor air pollution amounts to an average of US$1,8 billion (equivalent to IRR 14,400 billion or 1.6% of GDP).

Figure C. Air pollution: share of damage costs



Land

Under land resources, damage costs resulting from cropland salinity, rangeland and wetland degradation, floods and soil erosion, as wells as deforestation and forest degradation have been assessed. The results are presented below.

Cropland salinity. More than 70% of irrigated agricultural land in Iran suffers from different degrees of soil salinity. The main consequence of cropland salinity is the decrease of land productivity. The estimated annual cost of yield losses due to salinity is estimated at US$1,2 billion (equivalent to around IRR 10,000 billion or 1.1 percent of GDP).

Rangeland degradation. One of the main sources of rangelands degradation is overgrazing. There are about 46 million animal units above the carrying capacity of rangelands. Unsustainable production is an inevitable consequence which, in turn, causes declining trends in pastures, transformation of good pastures into poor ones and of the latter into non-productive pastures. Over the past 30 years, the condition of rangeland has worsened. Results of a recent survey show that rangelands in good condition have decreased by around five million hectares, rangelands in fair condition have decreased by around 23 million hectares, while rangelands in poor condition have increased by around 28 million hectares. Damage costs of rangeland degradation were estimated by the loss in dry matter resulting from the decline in rangeland quality. Annual loss of dry matter is estimated at 110 million kilograms, which represent a net present value of about US$172 million (equivalent to IRR 1,373 billion or 0.15 percent of GDP).

Wetland degradation. The importance of wetlands in Iran is recognized worldwide. A recent survey by the Department of Environment (DOE) has raised the number of wetlands of international significance to 76. However, some wetlands are increasingly under pressure because of human activity. Undoubtedly, the most serious threats to wetlands have been their drainage and reclamation for agriculture, industry and urban development, and the diversion of water supplies for irrigation. Wetlands provide a wide range of benefits and services, including protection of biodiversity and genetic resources, hunting and fishing, ecotourism and cultural heritage, supply of wood and fodder, microclimate regulation, air refreshment and wind break, water supply and regulation, transportation, medical, industrial and nutrimental plants, handicraft production, azotes fixation, and protection of coasts. The value of these benefits and services is estimated at an average of US$960/ha/year. The net present value of the damage cost resulting from the loss of around 23,000 ha of wetland per year amounts to US$350 million (equivalent to IRR 2,800 billion or 0.3 percent of GDP).

Floods and soil erosion. Flooding has increased during recent decades in Iran. The number of floods recorded in the 1980s and 1990s is more than five times the number recorded in the 1950s and 1960s. Poor land use management and deforestation can contribute to increases in the frequency and intensity of floods. Clearly identifying causes of floods is very complex and allocating a damage cost to the responsibility of manmade activities in flood occurrence is difficult. However, it is believed that the dramatic increase in the number of floods over the last three decades is closely related to increased deforestation, which took place over the same time period. Assuming that four fifths of the increase in floods is related to manmade activities would result in annual damage costs estimated at about US$150 million (equivalent to IRR 1,190 billion or 0.13 percent of GDP).

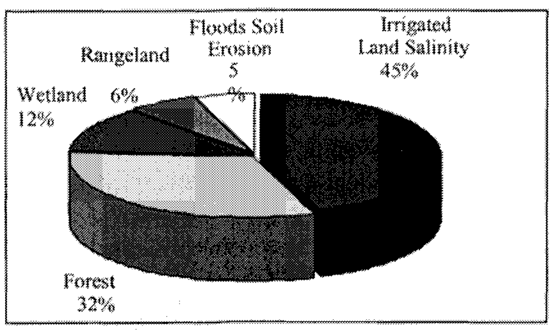
Deforestation and forest degradation. With 8,200 plant species, of which 1,900 are endemic, Iran is considered a unique country in terms of its plant diversity and genetic reserves. Climate diversity makes the country's forests heterogeneous, providing a wide range of benefits. Despite these benefits, Iran's forests have been severely degraded during the last half century. Forest clearing for agriculture, firewood and charcoal production reduced drastically the forest area. Overgrazing and over hunting are believed to be responsible for decreasing forest quality. According to data for the Forest, Range and Watershed Organization, between 1944 and

2000, total forest area diminished from 19.5 million to 12.4 million hectares with an average deforestation rate of about 125,000 hectares per year.

Forests provide a wide range of benefits and services, including timber, firewood, non-wood forest products, medicinal plants, hunting, recreation, watershed protection, water purification, carbon sequestration, biodiversity conservation, and cultural value. The net present value of damage costs associated with the total loss of forest benefits and services resulting from deforestation and forest degradation is estimated at US$906 million (or IRR 7,212 billion or 0.80 percent of GDP) in 2002.

To conclude, the damage cost of land degradation in year 2002 amounts to US$2.8 billion (equivalent to about IRR 23,000 billion or 2.5% of GDP). The shares of the different components of land resources in this cost are shown in Figure D

Figure D: Land: share of damage costs



Coastal zone

Iran's geography includes 2,900 kilometers of coastlines, which contribute to the unique natural diversity of the country. To the north, 900 kilometers border the Caspian Sea and to the south, 2,000 kilometers border the Persian Gulf. Due to time and data constraint, coastal zone assessment is limited in this report to the decline in fisheries in the Caspian Sea. In particular, the report focuses on the decline in sturgeon and kilka populations.

Recorded sturgeon catches have declined from 1,710 tons in 1993 to 643 tons in 2002. The most pressing threat for sturgeon is the widespread poaching throughout the Caspian Sea to feed the international demand for caviar. Sturgeons are also under stress due to natural habitat degradation including reduced access to spawning sites, caused by the construction of large dams. There are two monetary impacts arising from the sturgeon fishery collapse. The first one is linked to the lost fish catch. The second impact is the remediation effort undertaken by the government to sustain the fishery through fingerling releases.

An average of 2,500 tons per year is used as the "best estimate" of potential annual sustainable sturgeon catch. Under this consideration, the loss of sturgeon catch for 2002 would be 1,857 tons. This corresponds to a loss of US$148 million. Hatcheries played a crucial role in the rehabilitation and restoration of sturgeon stocks. The average annual release of fingerlings is estimated at 22 million and is estimated to cost about US$11 million.
The kilka fishery is threatened by comb jelly, an invasive species introduced by humans. It arrived in the Caspian in the late 1990s, carried by the ballast water of ships traveling the Volga-Don canal, linking the Black Sea to the Caspian Sea. Following the invasion of the comb jelly, the kilka fish catch has deceased dramatically since 2000. The catch of 2002 presents 44 percent of the average annual catch between 1993 and 1999. This loss is assessed at US$6.8 million.

In summary, the damage cost to Iran resulting from natural habitat degradation and poaching activities in the Caspian region as well as the manmade introduction of an invasive species amounts to US$170 million for 2002 (equivalent to IRR 1,300 billion or 0.15 percent of GDP).

Waste

Waste collection rates in large Iranian cities have improved significantly over the past decades to reach 90 and in some cases even 100 percent collection. Smaller urban cities have a collection rate averaging 70 percent. Collection rates in rural areas range from 50 to 60 percent. The cost to society of inadequate waste collection and street cleaning can be estimated by the willingness to pay of individuals and communities for improved waste collection services. This cost ranges from US$145 to 325 million per year (equivalent to an average of IRR 1,872 billion or 0.21 percent of GDP) in 2002.

Most municipal waste generated in Iran is sent to landfills that are generally well managed, but designed with few environmental considerations. For the purpose of this report, a comparison between the costs of landfills "with" and "without" taking into consideration environmental concerns is done. The difference in cost is then applied to municipal waste generated yearly in Iran to reflect the damage cost of environmental degradation. This cost is assessed at about US$90 million per year (or IRR 730 billion).

The three northern provinces of Iran are considered as popular destinations for local tourism. The presence of many dumping sites in these provinces results in a decrease of their recreational value, with a damage cost ranging between US$50 and 100 million annually.

In summary, the total damage cost resulting from inappropriate municipal waste collection, unsanitary landfills, and waste dumping in Northern provinces amounts to US$407 million (equivalent to IRR 3,230 billion or 0.36% of GDP).

THE METHODS

Obtaining monetary measures from physical damage is not an easy exercise; in everyday life, there are no market transactions for environmental quality. "Land quality" cannot be bought in a market. The same applies to air pollution. For example, there are not markets for "healthy lungs". Yet, once given the possibility to do so, people are indeed willing to pay money to reduce physical impacts. This willingness to pay, a key concept in economics, is implicit in people's behavior. The monetary valuation techniques used in the report exploit this fact.

The object of measurement is welfare. The way governments traditionally measure welfare is the Gross Domestic Product or GDP, that is, the total market value of all final goods and services produced in a country in any given year. The purpose of this report is to measure welfare changes due to environmental degradation, using the same measurement units used for GDP.

Measuring welfare changes due to environmental degradation

There are three simple criteria to measure changes in welfare due to environmental degradation: remediation or prevention actions, lost productivity and willingness to pay. The first two are easily linked to GDP, and are useful in 'greening' GDP types of measures, and the third goes one step further in the measure of true welfare.

Remediation and prevention actions. Some environmental damages are paid by society directly. Such is the case of dam flushing activities to eliminate the sediments caused by upstream deforestation. Other examples of remediation and prevention actions include: artificial hatcheries intended to restore productivity in degraded fisheries, and the purchase of bronchodilators to prevent respiratory symptoms.

The list can be extended. What matters, however, is that remediation and prevention expenditures are included in GDP and are usually easy to account for. A greener definition of GDP should then correct for this type of 'welfare' restoring activities, because they do not really add anything to welfare. Rather, they correct a decrease in welfare due to environmental problems.

Lost production. Another category of environmental damages appears in lower levels of production. Such damages are much less visible than the remediation and prevention costs and hence more difficult to estimate. An example is cropland salinity, which causes a lower yield than would be possible in perfect land conditions. Another example is the decrease in hours worked due to illness. The measure of damages in this case has to go through two steps: (i) the quantification of the physical impact, that is, the change in production of goods and services owing to environmental problems, and (ii) the monetary valuation of the physical damage. The second step is undertaken using market prices for the good being produced.

The way this category of environmental damages relates to traditional economic indicators is a lower level of GDP. So in the absence of salinity, the production of agricultural goods would be higher. In the absence of environment related illness, such as diarrhea, labor productivity would also be higher.

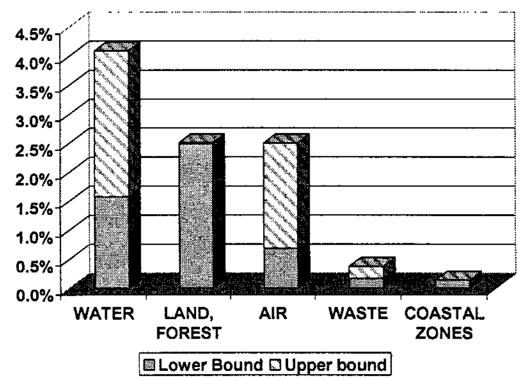
Willingness to pay: an upper bound measure of degradation A common feature of the remediation, prevention and lost production criteria for valuation is that they provide a lower bound measure of welfare changes. That is, society would be willing to pay at least the amount measured. This is easily demonstrated by the fact that society is already paying for such damages. A different issue is to measure the maximum amount society would pay if the opportunity arose. This would indeed provide a true measure of welfare changes linked to environmental degradation.

Willingness to pay measures are based on the observation of people behaviors and associate them with environmental damages. This report heavily relies on willingness to pay measures in the valuation of health impacts. The "Value of a Statistical Life" concept is used. So for example, the impact of diarrhea is accounted for by measuring both the lost productivity (lower bound measure) and the willingness to pay to avoid death or illness (upper bound measure).

Comparability across categories of damages

The use of lower and upper bound measures of damages reflect the fact that different valuation techniques are used. In particular, they introduce a potential breach between categories of damages measured using lower bound techniques and those measured using both lower and upper bound techniques. The interested reader will find in the report a thorough explanation of the different techniques, and will be able to separate lower and upper bound estimates.

Figure E. Annual cost of environmental degradation in Iran (lower and upper bound estimates as a percentage of GDP, 2002)



Environmental health issues are characterized by the largest variation. This is the case for diarrhea (in the water category) and respiratory illness (in the air category). This variation reflects the uncertainty linked to measuring the value of life. Using purely remediation, prevention and production changes criteria gives an estimated damage of 1 percent of GDP in the water category. Once the health damages are calculated using willingness to pay estimates, the estimated damage goes up to 3.5 percent of GDP.

While lower bound estimates make comparison across categories more precise, the consideration of upper bound estimates warns the policy-maker about the fact that environmental impacts can be very important and may need special attention.

CONCLUSION

Based on various methodologies – explained briefly above and in more detailed throughout the report– used annual environmental degradation costs have been estimated to range between 4.8 to 10 percent of GDP, with a mean estimate of 7.4 percent (or US$ 8.4 billion or IRR 67,300 billion) in 2002.

The most significant negative impact on health is caused by diarrhea diseases due to inadequate water supply, sanitation services and hygiene practices. The most severely impacted by diarrhea diseases are children under the age of five years. Urban air pollution –mainly in Tehran but in other large cities as well– also has a significant impact on public health.

The cost of natural resource degradation is predominantly from land and forest degradation. Cropland salinity as well as rangeland, wetland and forest degradation and increased occurrences of floods due to soil erosion all have significant economic impacts.

With regard to waste and coastal zone degradation, time and data limitations have prevented an in-depth estimate of these two sectors. Potential damage from suboptimal disposal of hazardous waste has not been included in the analysis. The assessment of coastal zone degradation is limited to fishery losses along the Caspian Sea. These two sectors would clearly benefit from a more thorough analysis in the future.

Because some damage costs have not been included in this analysis, it is believed that the damage costs estimated in this report is likely to underestimate the total costs of environmental degradation. Even with this possible underestimation, the amounts (7.4 percent of GDP) are substantial. As a reference point, they are 1.5 to 3 times higher than in other MNA countries

The importance of the environment is embedded in Iran's constitution. Major efforts are being undertaken – primarily by the Department of Environment – to protect the human and natural environment. This report suggests that Iran would significantly benefit from further action to restore and protect its environment. Further analysis and comparison between the costs and benefits of each environmental action will be necessary to identify priority areas of intervention.

1. Introduction

1.1 BACKGROUND

Iran's territory is diverse, both in terms of climatic variability and geological conformation. Iran's total land area is approximately 160 million hectares. Its altitude ranges from 26 meters below sea level – at the shores of the Caspian Sea – to 5,671 meters at the summit of Mount Damavand. Mean temperatures in January range from 20°Celsius along the sea of Oman to -2°Celsius in the northwestern region. Climatic conditions across the country range from hyper-arid (35 percent of the territory) to arid (30 percent), semi-arid (20 percent), Mediterranean (5 percent) and wet (10 percent). The country has enormous deserts, several mountain ranges, a large plateau and significant forest areas.

This diversity makes Iran wealthy in terms of natural resources and biodiversity. The country has more than 8,200 plant species – of which 1,900 are endemic (NBSAP, 2000) – 500 species of birds and 148 species of mammals. There are more than 280 wetlands in Iran, twenty of which are listed in the Ramsar Convention[2]. The wetlands are of particular importance as they are the resting grounds for several migratory birds, such as the Siberian crane, flamingoes and pelicans – all listed as global heritage.

The importance of the environment is embedded in the country's constitution. Article 50 of Iran's constitution states that "*In the Islamic Republic of Iran protection of the environment, in which present and future generations should enjoy a transcendent social life, is regarded as a public duty. Therefore, economic and any other activity, which results in pollution or irremediable destruction of the environment, is prohibited.*" Despite efforts undertaken primarily by the Department of Environment (DOE), the quality of the human and natural environment is being degraded at a high rate. Rapid population growth and economic growth that is not environmentally sustainable are both increasing pressure on the environment.

Major environmental challenges faced by the country are the degradation of land and forest resources, as well as water and air pollution

1.2 OBJECTIVE AND RATIONALE

How much is a cleaner environment worth? For policy makers, that question often goes largely unanswered. It is not that the environment is seen as unimportant. It is simply easier to compare the costs and benefits of tangible projects such as airports or electrical grids than weigh the merits and value of a landfill cleanup or a change in emissions legislation.

The objective of this sector note is to provide an estimate of the cost of environmental degradation in Iran. By putting numbers to environmental issues, it is hoped that this study will provide an instrument for policymakers to better integrate the environment into economic development decision making.

Despite the difficulties involved in assigning monetary values to environmental degradation, such estimates can be a powerful means of raising awareness about environmental issues and facilitating progress toward sustainable development. It is far easier for decision makers to incorporate and prioritize the environment when issues can be cast in clear economic terms. Such assessments are particularly relevant in light of mainstreaming efforts called for in the World Bank Environment Strategy.[3]

[2] "The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources".

[3] World Bank. 2001a. *Making Sustainable Commitments*, An Environment Strategy for the World Bank.

The sector note comes in a crucial moment for world's development. "*Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth*" (Reid et al., 2005). This is one of the major findings of the Millennium Ecosystem Assessment. The development challenges the world faces cannot ignore the environmental costs, which are bound to become more and more pressing if human quality of life is to be fostered.

1.3 THE PREPARATION PROCESS

This sector note is part of a series of studies on the *Cost Assessment of Environmental Degradation* supported by METAP.[4] The program aims at using environmental damage cost assessments as an instrument for environmental management. Seven studies[5] have already been completed in the Middle East and North Africa region and various training courses have been offered to build local capacity in environmental economics.

Preparation of this sector note began in January 2004. Three missions were undertaken to Iran (January 2004, September 2004 and January 2005) to collect data and consult various sector ministries, universities and research institutions.

During the preparation of this study, a review of relevant literature and documents was carried out. Data from numerous government documents, statistical analysis, World Bank economic and sector work, and reports from several international agencies were utilized. For environmental issues for which sufficient data and analysis were not available, the team's local expert carried out primary research and data collection. In addition, analysis from other countries was utilized to supplement the estimates for the cost of environmental degradation included in this report.

Chapter 2 provides an overview of the methodologies applied in this report. Chapter 3 provides cost estimate related to water resource degradation. Chapter 4 presents cost estimates related to both urban and indoor air pollution. Chapter 5 assesses the impact of land degradation. Chapter 6 presents the cost assessment of deforestation and forest degradation. Chapter 7 provides a brief assessment of coastal zone degradation focusing mainly on the Caspian Sea. And chapter 8 presents the impact of waste management as well as global impacts resulting form carbon dioxide emissions.

Annex I presents additional notes related to the forest sector. Annexes II and III present detailed cost estimates in Excel format for easy reference.

The reference year is 2002. To the extent possible, all physical damage is related to 2002 and all prices are expressed in 2002 prices. Calculations of each damage cost are presented in U.S. dollars (US$), Iranian rials (IRR) and as a percentage of gross domestic product (GDP). In the main report, most cost estimates are presented in U.S. dollars. In the annexes, all calculations are expressed in both U.S. dollars and Iranian rials.

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[4] Mediterranean Environment Technical Assistance Program

[5] References: Sarraf, M. 2004. Sarraf, M., B. Larsen and M. Owaygen. 2004. World Bank, 2002a and 2003a.

2. Methodology

2.1 What is the Cost of Environmental Degradation?

Everyday decisions require information. For example, entrepreneurs decide whether to invest in new machinery; workers decide whether to accept a job; and families decide where to go on vacation. In the same way, governments have to decide whether to spend more money on defense, hospitals, or protecting the environment. Ideally, implementing such decisions should mean trading off the benefits of action with necessary costs.

An important firs step in making decisions about environmental management is to calculate the benefits of policies and actions. Benefits are often referred as 'damage avoided' by taking action. Through the report, benefits are referred to as damage costs and the reader should not be confused by the terminology. Economic theory can be helpful in computing the costs used for the purposes of this report. Here, the range of techniques that are available to calculate the monetary value of benefits are explored. This chapter is intended to be a guide through the mechanics and practicalities of 'environmental valuation'.

2.2 What does this report tell?

This report provides first order estimates of the cost of environmental degradation in Iran.

The final result can be understood as a measure of the lost welfare of a nation due to environmental degradation. In this report, the cost of environmental degradation is expressed as a percentage of GDP to provide a sense of magnitude. It is also useful to compare the cost of degradation to GDP to assess the relative magnitude over time. If the cost of degradation as a percentage of GDP grows over time, it suggests that the welfare loss from environmental degradation is growing faster than GDP. This means that economic and human activities are having increasingly negative environmental consequences for the nation relative to their economic affluence. If the contrary is the case, it suggests that environmental consequences are being reduced relative to the nation's economic affluence.

This report only shows one side of the coin. Any policy action that causes environmental damages also produces benefits to society. This is the ultimate objective of public policy. The focus of the report is only on environmental damages. Environmental degradation always occurs as a byproduct of development. Deforestation is a result of changes in land use to agriculture for example. Urban air pollution is the effect of using faster and more comfortable ways of transport as well as the byproduct of industrial production. The reader should bear in mind that the report does not provide information on the benefits deriving from the development process. For example, concluding that air pollution costs every year 1.6 per cent of GDP, does not tell anything about the benefits of those processes that lead to air pollution.

The information about the cost of environmental degradation is however of prime relevance otherwise it will be neglected in decision making process. Environmental costs are often born by the poorest in society, which are often not in the position to be able to enjoy the benefits of development. The Millennium Ecosystem Assessment, recently completed, finds that "*the changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people. These problems will substantially diminish the benefits that future generations obtain from ecosystems*", Reid et al. (2005).

An attempt has been made to capture the most significant costs of degradation. However, data limitations are a constraint, implying that estimates in some environmental areas are not included. Hence, the total estimate of environmental degradation, as presented in this study, is likely to understate the true cost of degradation to society.

2.3 Type of Costs

This report is organized according to the medium in which the degradation occurs. The first column in table 2.1 contains the chapter titles. The second and third columns identify the source of the impact and the type of impact. The fourth column identifies the valuation method used for each impact.

Table 2.1 Sources, impacts and valuation of the cost of environmental degradation

Chapter	*Source of damage*	*Impact*	*Technique*
Water	Lack of water supply and sanitation	Health	HC; VSL; COI
	Groundwater depletion	Crop decline	CP
	Groundwater pollution	Health / Production	RC
	Water erosion, dam sedimentation	Crop decline	CP
Air	Indoor air	Health	HC; VSL; COI
	Urban air – PM10	Health	HC; VSL; COI
	Urban air – Lead	Health	HC; VSL; COI
	Urban air – general	Discomfort	CV
Land, Forests	Cropland	Salinity	CP
	Rangelands	Services loss	CP
	Wetlands	Services loss	CP; RC; CV
	Deforestation	Floods and erosion	RE
		Goods and services lost	CP; RC; CV
Waste	Lack of collection	Discomfort	CV
	Disposal	Discomfort	CV
Coastal zones	Over fishing and coastal degradation	Fishery productivity	CP; RC
Global Env.	CO_2 emissions	Various impacts	CP; RC; CV

Legend. HC: human capital approach; VSL: value of statistical life approach; COI: cost of illness; CP: changes in production approach; RC: replacement cost approach; CV: contingent valuation method; RC: remediation cost

The impacts (third column of table 2.1) can be grouped into four categories:

i. Impacts on health and well-being of the population (e.g.: premature death, pain and suffering from illness, absence of a clean environment, discomfort)
ii. Impacts on production (e.g.: reduced soil productivity and value of other natural resources, lower tourism revenues)
iii. Impacts on environmental services such as loss of recreation (e.g.: reduced recreational value of lakes, rivers, beaches, forests)
iv. Direct damage (e.g.: damage caused by floods)

The process of estimating the cost of environmental degradation involves placing a monetary value on impacts. The fourth column of table 2.1 summarizes the methods used in each case.

While the assessment of impacts requires environmental science, natural resource science, health science and epidemiology, the valuation of such impacts, and the quantification of the consequences of degradation, require environmental economics and natural resource economics.

2.4. Measuring Impacts

Several methodologies and approaches have been applied to provide quantitative estimates of the consequences of environmental degradation. An overview of the main principles is provided here.

Impacts on Health and Quality of Life. Impacts on health from environmental degradation are expressed as Disability Adjusted Life Years (DALYs). This is a methodology that has been developed and applied by WHO and the World Bank in collaboration with international experts to provide a common measure of disease burden for various illnesses and premature mortality.[6] Illnesses are weighted by severity so that a relatively mild illness or disability represents a small fraction of a DALY, while a severe illness

[6] See Murray and Lopez (1996) for a more detailed explanation of the DALY principle.

represents a larger fraction of a DALY. A year lost to premature mortality represents one DALY, and future years lost are discounted at a fixed rate of 3 percent.

For waterborne illnesses - associated with inadequate water and sanitation services and hygiene – 80 percent of DALYs lost presented in this report are due to mortality and morbidity in children under five years of age caused by diarrheal illnesses, while 20 percent are due to morbidity in the population above five years of age. Each child death represents the loss of 33 Years of Life Lost (YLL) or DALYs.

For urban air pollution, impacts on health are estimated based on ambient air quality data in Iranian cities and international studies on the negative impacts on health from air pollution. In this report, each premature death due to air pollution represents 7.5 YLL or DALYs.

For inadequate solid waste collection, no estimate of potential health impacts is provided in the report. The social cost of inadequate collection is estimated directly by the willingness-to-pay (WTP) approach.

Natural Resources. The main areas of natural resource degradation quantified in this report are agricultural land and rangeland degradation, coastal zone degradation, and some areas of water resources degradation.

The consequences of land degradation are quantified in terms of productivity declines in crop cultivation and rangeland forage yields.

The cost of coastal zone degradation is estimated based on an assessment of the lost catch due to over fishing and degradation of spawning sites.

For water resources degradation the analysis of the consequences of water pollution is limited to the incremental pumping costs associated with declining groundwater tables. As water resources quality is of great importance for the agricultural sector in Iran, further analysis in this area is considered important.

2.5. MONETARY VALUATION

Here a brief overview of the main techniques used for valuation is provided. The notes in annex II provide further details. A range has been used for most estimates to reflect uncertainties. An elaboration of some health impact valuation issues follows here.

Valuing health impacts. Health outcomes can be grouped into mortality and morbidity. Mortality will be expressed in terms of DALYs. Morbidity will be expressed both in terms of DALYs (to reflect the value of pain and suffering) and in terms of medical expenditures (to reflect cost of treating illness in terms of doctor's visits and medications). Once the number of DALY is estimated than it has to be multiplied by the value of a year of life lost. There are two approaches to valuation. The *human capital approach* values a life at the level of GDP per capita: if one year of a person's life is lost, society loses, at the very least, her contribution to production. This method provides a lower bound of a person's worth. An alternative method is the *Value of a Statistical Life (VSL)*, which provides an upper bound monetary value of health damages. It measures the willingness to pay to avoid death by observing individual behavior when trading off health risks and money.

The value of a statistical life method exploits the fact that risk of death is implicit in everyday actions and decisions. So for example, when accepting a job offer, we are implicitly valuing all the features of the job such as salary, career development opportunities, friendliness of the work environment and the health risk inherent in performing the tasks assigned. It is not the same to work as truck driver for a florist or for a company producing explosives. Assuming that health risks are reflected in the job market, the information about salaries will implicitly disclose information about people willingness to pay for avoiding a small chance in the risk of death.

The two elements needed for the calculations are the marginal Willingness to Pay for reducing the risk of death and the size of the risk reduction.

The following equation is then used to calculate the value of a statistical life.

$$VSL = \frac{\text{WTP to avoid risk of death}}{\text{Reduction in risk of death}}$$

This method does not try to measure the WTP to avoid death with certainty, but uses statistical techniques to record human behavior in trading off risk of dying with money.

In the report, we use DALYs as the reference unit to measure health impacts. The VSL is then divided by 25 to obtain the Value of a Life Year. The value of 25 is the number of discounted years of life that are lost on average with the death of an adult.

The WTP estimates are used as an upper bound value. As a lower bound, the human capital approach is used. It should be noted that the WTP approach provides a cost of mortality in this report that is about six times higher than the approach of DALYs valued at GDP per capita. Thus the lower bound estimate of the cost of a DALY lost due to adult mortality would be a gross understatement of the cost of environmental degradation if WTP provides a better representation of welfare cost.

Society also incurs direct costs related to illness. These are computed through the *cost of illness approach (COI)*. This approach estimates treatment costs and the cost of lost work days or time provided by caregivers. In this case, the calculations involve the estimation of the different health end-points (such as the number of hospitalizations, restricted activity days, doctor visits) and their multiplication by the relative unit costs.

Valuing productivity loss. Losses in crop yields linked to salinity or loss of fodder due to rangeland degradation are valued using a simple multiplication of quantity lost by unit price. Prices used are net of subsidies. This is in order to reflect the full opportunity cost of a good or service loss.

Replacement costs. Some impacts of environmental degradation are paid for by expenditure on replacing the good or service lost. For example, the depletion of underground water results in extra expenditures to reach the water table at deeper levels. In this case, the replacement cost is obtained by multiplying the price of diesel for pumping by the quantity of diesel necessary to pump water at deeper levels.

Box 2.1. Is it possible to value life?

One of the valuation approaches used in the report uses the concept of 'value of a statistical life'. The VSL does not capture the value of an identifiable person but rather the value of a small change in the chance of dying. That is, it does not ask individuals how much they are willing to pay to save their own life (or any other specific person's life) with certainty: presumably individuals could be willing to pay everything they have to avoid their own death or the death of a loved one. People face decisions involving risks every moment of their life, by smoking, crossing a trafficked street, traveling by car and using electrical appliances at home. The 'value of a statistical life' method uses rigorous econometric techniques to disentangle the effect of risks to life on the prices paid for goods and services and obtain in this way a monetary value of risk. The measure obtained in this way provides a maximum willingness to pay for health benefits. Many have expressed that the value of life discerned in this way may seriously underestimate health impacts. However, in many cases public policy decisions reflect much lower implicit values.

2.6. The Cost of Degradation and Time

Environmental degradation in any given year produces costs that are felt both at present and in the future. The approach used in the study is to account for the present and future costs of degradation occurred in year 2002. In other words, the physical impacts refer to a particular year, while its economic consequences are likely to span into the future. So, for example, a death today results in the loss of a person's contribution to society for the number of years that person would have lived if degradation had not occurred. The DALYs calculations embody this consideration.

In order to make valuation of natural resources losses consistent with the approach chosen, degradation that occurred in the base year is discounted for a period of 25 years using a discount rate of 4 percent.

The time horizon chosen refers to a generation's time span, under the assumption that, on average, a person would enjoy the benefits of the environment for another 25 years, until his/her death. The discount rate chosen reflects the social rate of return on investment (SRRI). Growth theory literature establishes that SRRI is given by:

$$SRRI = r + uc$$

Where 'r' is the pure rate of time preference (or impatience), 'u' is the elasticity of the marginal utility of income and 'c' is the rate of growth of per capita consumption. Estimates for industrial countries arrive at values in the range of 2 to 4 percent. In Iran, the rate of growth is presumably higher and a conservative value of 4 per cent has been used.

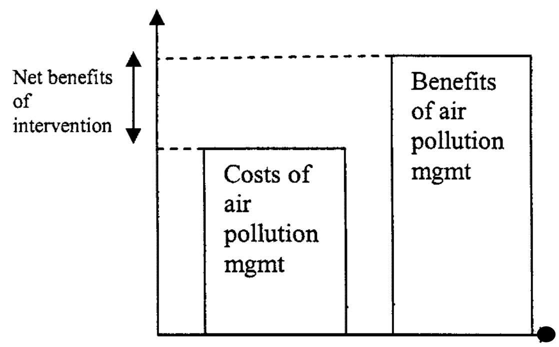
2.7. THE COSTS AND BENEFITS OF ENVIRONMENTAL MANAGEMENT

The objective of this report is to estimate the cost to society of environmental damage in the areas of water, air, land, waste, coastal zones, and the global environment. This provides a perspective on overall damage costs and areas of the environment with the highest cost.

For each area of the environment, however, careful consideration needs to be given to the cost of remedial action and the cost of such action in comparison to the benefits. This is the key to good decision making. One should refer both to the costs and the benefits of a given environmental policy or management action, in order to decide whether the policy or management action is worth from an economic point of view.

Figure 2.1 represents a hypothetical situation. The costs of urban air pollution management are lower than the benefits derived from reduced mortality, morbidity and health treatment costs. In order to decide whether air pollution management should take place, the benefits should exceed the costs (as in the graph). Policy making requires information on both!

Figure 2.1 Comparing costs and benefits of environmental management



The reader should keep in mind that the report is designed to provide an idea of the benefits of environmental management across different areas. While not providing an answer to decision making, it provides a first step to identify key areas of further analysis.

3. Water

3.1 OVERVIEW OF THE WATER SECTOR

Situated in West Asia, Iran is subject to highly diverse climatic conditions ranging from extremely arid to extremely humid. Rainfall varies greatly according to geographic area – from 2,000 millimeters per year along the Caspian coast to under 50 millimeters in the Lout Desert. Average annual rainfall nationwide is 250 millimeters. Total precipitation levels average 413 billion cubic meters (BCM) per year, 117 BCM of which replenishes surface and groundwater flows, the remaining being lost to evapo-transpiration (World Bank, 2004a). In addition to internal renewable resources, there are about 13 BCM of surface water flow from other countries. This makes total annual renewable water resources around 130 BCM.

Total water resources per capita have fallen from 5,800 cubic meters in 1965 to about 1,910 cubic meters in 2001. They are projected to decline to less than 1,000 cubic meters by 2025. Iran is therefore likely to become a "water stressed" country according to international categorization. By far, the largest user of water is the agriculture sector (92 percent) followed by the domestic sector (6 percent) and the industrial sector (2 percent) (Earth Trends, 2003).

Groundwater resources play an important role in Iran's development as they contribute 54 percent of total current withdrawal. However, they have recently been subject to overexploitation. Groundwater extraction has increased from 20 BCM in 1960 to more than 53 BCM in 2002-2003, exceeding safe yields. As a result, water tables have been dropping at an average of 41 centimeters per year (Ministry of Energy, 2005).

In urban areas, about 96 percent of the population is connected to public water supplies. By contract, only 15 percent is connected to public sanitary sewerage and only part of the sewage is treated before disposal (World Bank, 2002b). The remarkably high water supply connection in urban centers is not matched by connections to sanitary sewerage, creating an environmental hazard. Another risk to public health is the discharge of untreated sewerage. In cities where connection to sanitary sewerage is not available, sewerage is often discharged through open rainwater drains (World Bank, 2002b).

In rural areas, and according to the most recent estimates provided by National Water and Wastewater Engineering Company (NWWEC, 2004) about 57 percent of the population living in villages of more than 20 households has access to "safe"[7] potable drinking water. With regard to sanitation, it is estimated that in 2000 about 47 percent of rural population had either sanitary or semi-sanitary toilets within residence[8].

This chapter focuses on quantifying the economic damage costs resulting from inadequate water supply, sanitation services, hygiene practices and water resources management and water pollution. Health impacts related to inadequate water supply, sanitation and hygiene will be quantified in section 3.2. Potential damage costs resulting

[7] "Safe" drinking water is defined as (a) water that has been purified and chlorinated and is delivered either through a pipeline system of directly; (b) water that is delivered from a sanitized source either through a pipeline system or directly; or (c) water delivred from a non-sanitized source but is boiled and chlorinated before consumption.

[8] A Sanitary toilet is defined as having all 8 criteria below. A semi-sanitary toilet is defined as having the first 5 criteria below. The criteria are: (a) a walled cabinet with a door and roof; (b) a well cistern for collection of waste and sewage; (c) water outlet either inside or nearby outside the toilet, with a house connected to the outlet point; (d) the floor of the toilet should be sloped towards the drain hole and should be easily washable; (e) the drainpipe should be shaped like a swan's neck so that flies cannot have direct access to waste material; (f) the toilet bowl must be intact, without any cracks or defects, and must be washable; (g) must have either AC or a meshed window that opens to the outside; (h) the walls of the cabinet must be washable to a height of at-least 15 cm from the ground. This information was provided by NWWEC in a report entitled "*Report of Water supply Sanitation and Hygiene in Rural Areas*" and is based on demographic and health survey undertaken in October 2000.

from over-pumping groundwater are presented in section 3.3. Finally, section 3.4 presents partial cost estimates associated with water erosion and dam sedimentation. It is important to note that a range – with a lower and upper bound – is presented to reflect the uncertainty surrounding the estimates. It should also be noted that there are other aspects of water resource degradation for which costs are not estimated in this chapter due to data constraints. Therefore, cost estimates presented are likely to underestimate total damage costs.

3.2 HEALTH IMPACTS OF INADEQUATE WATER, SANITATION AND HYGIENE

Sub-standard quality and an inadequate quantity of potable water for drinking and hygiene purposes, inadequate sanitation facilities and sanitary practices, and inadequate personal, food and domestic hygiene have a cost to society. It is well known that these factors are associated with waterborne illnesses and mortality. The most common of these illnesses and the one with the most established link between inadequate water, sanitation, and hygiene is diarrhea. The World Health Report 2002 shows that *approximately 3.1 percent of deaths (1.7 million) worldwide are attributable to unsafe water, sanitation and hygiene.* Overall, 99.8 percent of deaths associated with this risk factor are in developing countries, and 90 percent of deaths are those of children.

Providing clean water and sewage collection and following good hygiene practice play an important role in reducing the risk of diarrhea. According to Hutton and Haller (2004) and WHO (2004) they are likely to reduce diarrhea illnesses by about 85 percent. This report uses that parameter to value the environmentally-related burden of disease associated with diarrhea. It implicitly assumes that the remaining 15 percent of cases are not attributable to environmental reasons or not avoidable in practice, given the country's conditions.

Inadequate water, sanitation and hygiene account for considerable losses in Iran. In this section, the costs associated with mortality and morbidity due to diarrheal diseases are presented.

Mortality (children under 5 years). This section assesses mortality costs associated with diarrhea diseases in young children. It will be limited to children under the age of five years because they are the most severely impacted by diarrheal diseases. In 2002, the total number of children in Iran under the age of five years was 8.5 million (SCI, 2004). The under-five mortality rate was 41 per 1,000 live births (World Bank, 2004d). Based on information provided by health experts in Iran, diarrhea is estimated to be responsible for 12.5 percent of under-five mortality. This implies that more than 8,600 children under five die annually from diarrheal disease. If adequate water supply and sanitation services are provided and good hygiene practices are observed among the entire population, than about 85 percent of the cases (or 7,300 cases) could be avoided[9].

Using the formula and assumptions in the Global Burden of Disease (WHO, 2004), it is calculated that the death of a child under the age of five represents a loss of 33 DALYs (disability adjusted life years) in Iran. Thus diarrheal deaths represent an annual loss of about 246,000 DALYs.

Morbidity (children under 5 years). Many more cases of non-fatal diarrheal disease occur in Iran each year, causing discomfort to victims and imposing the cost of treatment and the time of caregivers. Discomfort – and reduced well-being and restricted activity – associated with diarrheal illness is also expressed in terms of DALYs lost.

Based on demographic and health surveys (MOH, 1997) in Iran, it was reported that 22 percent of children under the age of five had diarrhea in the preceding 10 days.[10] Given a population of children under five years of age of 8.5 million (SCI, 2004), the estimated number of cases of diarrheal disease among children is

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[9] This is referred to as the "avoidance ratio" in the rest of the chapter

[10] The survey was conducted between the 7 and 17 of November 1997

about 50 million cases per year. Given (a) an average duration of diarrheal disease of 4 days; (b) an avoidance ratio of 85 percent; (c) a severity weight of 0.11 (Murray and Lopez, 1996);[11] and (d) an average weight of 0.31 (WHO, 2004), the estimated number of DALYs lost from morbidity in children under the age of five years is estimated at 15,000 DALYs per year.

Morbidity (population above 5 years). The incidence of diarrheal disease among the population over five years of age is also accounted for. No survey or study in Iran has assessed the prevalence of diarrheal disease among the population over five years. For the purpose of this study, the prevalence ratio – measuring the ratio of children under five years of age with diarrhea to the population above five years of age with diarrhea – will be based on the results obtained from studies conducted in Colombia, Vietnam and the provinces of Qena and Damietta in Egypt. The average prevalence ratio obtained is 5. Therefore, if 22 percent of children under the age of five are likely to have diarrheal diseases over a 10-day period, then about 4 percent of the population over the age of five is likely to have diarrheal diseases over a 10-day period. With a population (over five years of age) of about 57 million, the estimated number of cases of diarrheal disease is about 65 million per year. Based on (a) an average duration of 4 days; (b) an avoidance ratio of 85 percent; (c) a severity weight of 0.11 (Murray and Lopez, 1996); and (d) an age weight of 1 (WHO, 2004), the estimated number of DALYs lost from morbidity among the population greater than five years of age is estimated at 67,000 DALYs per year.

Valuation. Mortality and morbidity associated with diarrheal illness have a cost to individuals, families, and society at large. The cost is not only in the form of medical costs, but includes the cost of pain and suffering and loss of life.

For mortality, a monetary cost cannot be placed on the loss of life. However, valuation techniques have been developed to provide a monetary measure of an individual's or household's willingness-to-pay (WTP) to reduce the risk of mortality. The sum of WTP of individuals and households is then used as a measure of the cost to society of a particular risk of mortality. This approach has increasingly been applied in many countries in Europe and North America for more than 20 years to improve safety standards and environmental regulations. The WTP approach has largely been applied in studies of adult mortality risk.

A recent study in Iran (Farhoud, 2003) has compared the results of various WTP studies around the world and adjusted the results to Iran – using GNI[12] -- to derive a value of statistical life of US$251,000 in 2002. For a more detailed explanation of the concept of the value of statistical life, refer to chapter 2.

Another valuation technique is the human capital approach (HCA). This approach estimates the cost of mortality as the loss of lifetime income from the time of death. This estimate is based on income earned from age 20 to 65, with income approximated by GDP per capita.

Valuing DALYs lost. For the purpose of this study, a DALY lost was valued using the WTP approach as an upper bound and the HCA as a lower bound[13]. These estimates resulted in the valuation of a DALY at US$10,500[14] as an upper bound and US$1,740 as a lower bound. The total number of DALYs lost – combining mortality and morbidity) was approximately 328,000 in 2002. Therefore, the total annual cost of lost DALYs due to inadequate water and

[11] The severity rate of 0.11 was assumed given a scale of 0 (being in perfect health) and 1 (representing death).

[12] GNI: Gross National Income

[13] The value per DALY using the VSLY approach is 6 times the value of a DALY using the human capital (or lost productivity) approach. It could be argued that it is not appropriate to use the former when valuing minor illnesses such as a four-day episode of diarrheal disease. WTP studies to avoid minor illnesses are not likely to produce such large multiples of lost productivity as one finds when valuing more serious illnesses.

[14] It is assumed that one death corresponds statistically to 24 DALYs lost (see chapter 2 for a detailed explanation).

sanitation ranges from a low of US$600 million to a high of US$3,400 million (equivalent to average of IRR 15 billion or 1.76 percent of GDP).

Since there are many complex conceptual issues involved in the valuation of a child's life, neither the human capital approach nor the value of a statistical life provides a completely satisfying solution. Therefore, the calculations made above should be considered a first indication of damage, while further research would certainly be beneficial.

More generally, the large range given above reflects the fact that two different valuation methods have been used. The lower bound estimate of damage was obtained on the assumption that one year of life lost (due to death or disability) causes a monetary loss equivalent to an individual's average annual income (approximated by annual GDP per capita). However, evidence suggests that an individual's willingness to pay to avoid disability or death goes much beyond the amount implied by the human capital approach. As an approximation of willingness to pay, we use the "value of a statistical life" estimated in worldwide studies. We refer to this as the upper bound estimate. It implies a damage cost nearly six times higher than the one obtained with the human capital approach, a difference confirmed in other studies on the same subject.

Valuing the cost of treatment and care giving. In the case of morbidity, in addition to the cost of pain and suffering from illness – measured by DALYs – one should also add the medical costs of treating diarrhea and the time spent by family members to care for sick children.

Children with severe cases of diarrhea are often taken to a health clinic for treatment. According to data provided by health care experts in Iran, about 40 percent of diarrhea cases are treated in health facilities (i.e. about 20 million cases). The economic cost of visiting a doctor is on average US$7.5 and the cost of medication to treat severe diarrhea is about US$1.25.[15] Thus, the total cost of treating severe diarrhea in children is about US$170 million per year.

Based on *prevalence ratios* estimated in studies on Colombia, Vietnam and Egypt, it is estimated that if 40 percent of children under five years of age are taken to clinics for treatment, it is likely that about 22 percent of the population over five years of age would be treated in health clinics as well (about 14 million cases). Using the same economic costs –estimated above – the estimated treatment costs are about US$125 million per year.

In addition, when a child is seriously ill, time is taken from a caregiver, often a mother or relative, to look after the child. This time has an opportunity cost, either in terms of leisure or other activities. For each case of severe diarrhea, it is assumed that two days are taken by a caregiver to look after a child. This is a conservative assumption, given that on average each case is likely to last four days. This time is valued using the average household income in rural areas of about US$4.60 per day (SCI, 2004). The total cost of lost time due to care giving is therefore estimated to be US$178 million.

Children with mild and moderate cases of diarrhea are usually not taken to health clinics. According to MOH (1997) about 47 percent of diarrhea cases (or 23 million cases) are treated at home using oral rehydration therapy (ORT). At an estimated cost of US$1 per ORT treatment, the total cost of treating mild and moderate cases of diarrhea is estimated at US$23 million per year.

Total health costs related to inadequate water supply, sanitation and hygiene are presented in table 3.1.

[15] Equivalent to about IRR 60,000 for a doctor's visit and IRR 10,000 for medication.

Table 3.1 Water: valuation of health impacts in 2002

Water	Low Estimate	High Estimate
Mortality (DALYs lost)		
US$ millions	430	2,570
IRR billions	3,410	20,490
% of GDP	0.38%	2.27%
Morbidity (DALYs lost)		
US$ millions	140	860
IRR billions	1,140	6,840
% of GDP	0.13%	0.76%
Cost of illness		
US$ million	520	520
IRR billion	3,940	3,940
% of GDP	0.44%	0.44%
Total		
US$ millions	1,090	3,950
IRR billions	8,490	31,270
% of GDP	0.95%	3.47%

3.3 UNDERGROUND WATER

Groundwater plays an important role in Iran's development. Groundwater exploitation constitutes nearly 54 percent of current total water withdrawal. There are six main water basins and over 600 aquifers. The main water basin is the Central Plateau, which supplies about 44 percent of underground water resources.

Before the 1960s, groundwater extraction was estimated at 20 BCM per year. Extraction was mainly carried out by qanats (subterranean water canals) and natural springs (World Bank, 2004a). Today the bulk of the extraction is carried out through wells (see table 3.2). Since 1970, the number of wells has increased significantly. Currently there are about 450,000 wells in Iran (124,000 deep wells and 326,000 semi-deep wells).

Table 3.2 Underground water: sources and amount supplied in 2001-2002 (millions of cubic meters)

Main Basins	Wells	Qanats
Mazandaran	4,100	400
Persian Gulf &sea of Oman	10,600	1,100
Urumieh Lake	2,300	200
Central Plateau	25,300	5,700
Eastern Border	700	500
Ghara-Ghoom	1,900	300
Total	**45,000**	**8,200**

Source: Groundwater Section, Bureau of Water Resources Investigation, Water Resources Management Company, Ministry of Energy, 2005

Increase in underground water extraction. The rapid increase in the number of wells has contributed to a drastic increase in water extraction over the past three decades. In 2002-2003, water extraction (from wells and qanats) reached about 53.2 BCM. This figure was provided by the Groundwater Section of the Ministry of Energy. However it is important to note that there is no consensus on the exact amount of groundwater extraction in Iran. Some sources estimate it at 50 BCM and others at 58 BCM (World Bank, 2004a).

According to the Groundwater Section of the Ministry of Energy, the extraction of 45 BCM of water from deep and semi-deep wells exceeded the safe yield (of 41.8 BCM) by 3.2 BCM in 2002. The amount of water over-extracted from each basin is indicated in table 3.3 below.

Table 3.3 Over extraction of groundwater in main basins in 2002-2003 (millions of cubic meters)

Main Basins	Over-extraction from each basin
Mazandaran	170
Persian Gulf & Sea of Oman	320
Urumieh Lake	10
Central Plateau	2,410
Eastern Border	70
Ghara-Ghoom	260
Total	**3,240**

Source: Groundwater Department, Bureau of Water Resources Investigation, Water Resources Management Company, Ministry of Energy, 2005

Overexploitation of groundwater in Iran is not as severe as in some other countries (such as India, Mexico, and Yemen). Nevertheless, over-extraction takes place in about one-fourth of plain aquifers, mostly those located in the Central Plateau, such as Mashad, Kerman, Rafjsanjan, Esfahan and Qom. In extreme cases – such as in the Hamedan aquifer – the groundwater table has dropped by 20 meters (World Bank, 2004a). Severe decreases in underground water levels in some areas – such as Zarand – have damaged farms, gardens and residential areas. In other areas, this has led to the penetration of salty waters into the aquifers and the destruction of soil quality (MOJA, 2002).

Decrease in underground water level. The main effect of unsustainable exploitation of underground water is a decrease in the water table and the eventual exhaustion of the resource. Over the past 30 years, excessive exploitation of underground water – primarily through wells – has resulted in a decrease in water levels. Based on information provided by the Groundwater Department of the Ministry of Energy, the average long-term annual decrease in water levels is **0.41 meters** (table 3.4).

Table 3.4 Short and long-term annual changes in the groundwater table of main water basins (in meters)

Main Basins	Average change 2002-2003 (1)	Average long-term change (1)	Average change 1991-2001 (2)
Mazandaran	0.13	-0.24	
Persian Gulf & Sea of Oman	-0.26	-0.26	
Urumieh Lake	0.72	-0.06	
Central Plateau	-0.4	-0.47	
Eastern Border	-0.45	-0.25	
Ghara-Ghoom	-0.84	-0.79	
Weighted average	**-0.31**	**-0.41**	**-0.5**

(1)Groundwater Section, Bureau of Water Resources Investigation, Water Resources Management Company, Ministry of Energy, 2005
(2)Calculations undertaken for a sample of 135 aquifers by the Head of Groundwater Section at Ministry of Energy in 2005 for this report.

In the context of this study, a separate set of calculations were conducted, with the help of the Head of the Groundwater Section at the Ministry of Energy,[16] to assess the change in groundwater levels between 1991 and 2001 (third column of table 3.4). The reason for these revised calculations is to confirm the reliability of the findings of the first two columns in table 3.4. A sample of 135 aquifers – considered representative of total aquifers in the country – was selected. In 1991, the average groundwater level of these aquifers was estimated at 29 meters. This dropped to 34 meters in 2001. This means an average annual decrease of 0.5 meters, which is in line with the estimated long term annual change. For the purpose of this study, long term average annual change was considered.

Increase in pumping costs. To assess the damage costs resulting from decreasing underground water levels, the additional pumping costs needed to extract water from a deeper level were calculated. The main additional pumping cost is likely to be additional fuel consumption (variable costs). The average diesel consumption required to extract one cubic meter of groundwater per meter depth is about 0.004 liters.[17]

Considering a long-term annual decrease in groundwater levels of 0.41 meters, this would result in an annual incremental consumption of diesel of 0.002-liters per one cubic meter.

In 2001-2002, 45 billion cubic meters were extracted from deep and semi-deep wells in Iran (table 2). The safe yield is considered to be 41.8 billion cubic meters (the extraction of 3.2 billion cubic meters above the safe yield is considered overexploitation, and is not accounted for). The annual damage cost of underground water

[16] Our appreciation goes to Mr. Javad Javari, Head of the Groundwater Section, Bureau of Water Resources Investigation, Water Resources Management Company at the Ministry of Energy.

[17] This estimate is based on an average consumption of 0.15 liters of diesel to extract one cubic meter of water at a depth of 34.8 meters in 2003. This estimate is based on calculations provided by Mr. Anoosh Noori Esfandiari, Head of Water Economics Bureau, Iran Water Resources Company, Ministry of Energy, 2005.

overexploitation amounts to US$12 million (table 3.5).

Table 3.5 Damage cost of underground water depletion

Safe yield of water extracted from wells	41.71 billion m^3
Average consumption of diesel per one meter depth to extract one cubic meter of water	0.004 liter
Average annual decrease of ground- water levels	0.41 m
Market price of one liter of diesel[18]	US$0.18/l
Total annual incremental costs	US$12 million

Considering a time horizon of 25 years and a social discount rate of 4 percent, the average annual decrease of 0.41 meters would result in a present value incremental cost of around US$189 million in 2002.

Well replacement costs. In the previous sections, the cost of pumping water from deeper levels was assessed to approximate the damage costs of groundwater overexploitation. However, in addition to these costs, overexploitation of groundwater also results in abandoning wells and the digging of new ones. Between 1996 and 2003, about 28,000 wells were replaced in the country, with an average of 3,500 wells per year.[19] Usually, wells are replaced due to a decline in underground water levels resulting from overexploitation or worn out equipment. According to expert opinion at the Groundwater Conservation Bureau in the Ministry of Energy, 85 percent of average annual replacement is due to the decline in underground water levels. The unit cost of digging a new well ranges from US$43,000[20] to US$53,000.[21] As a result, the cost of digging new wells to compensate for overexploitation ranges from US$128 million to US$158 million in 2002.

The total annual damage cost of underground water depletion in terms of incremental fuel costs and well replacement is estimated at US$332 million (or IRR 2,643 billion or 0.29 percent of GDP).

Groundwater pollution. In addition to damage resulting from groundwater overexploitation, the costs associated with groundwater pollution must also be estimated. Groundwater pollution is the result of several factors including surface water pollution, untreated wastewater discharge through bores, and leachate from un-silted landfills. To date, specific data on the extent and type of groundwater pollution in Iran is not available. However, for the purpose of this study, a small survey was commissioned by the National Water and Wastewater Engineering Company to calculate the number of wells replaced due to groundwater pollution. In 26 provinces surveyed (see annex III for more details), about 1,800 new wells – for potable water – were developed in the Third Development Plan and 250 were abandoned because of water pollution. That is an average of 62 wells abandoned per year. Based on replacement costs ranging from US$43,000 to US$53,000 (explained above), the cost of replacing 62 wells per year is around US$3 million per year. It is important to note that this analysis is limited to the cost of replacing wells and does not represent the overall damage cost related to underground water pollution.

3.4 WATER EROSION AND DAM SEDIMENTATION

Iran has 151 dams in operation with a capacity of 25 billion cubic meters (BCM). More than 90 percent of this water – or 23 BCM – is currently used for irrigation (World Bank, 2004a). Water from storage and diversion dams is used to

[18] The diesel price is based on Singapore wholesale prices (average price in December 2002). Singapore is a major refinery center, considered to be operating at industry best practice levels. The price is widely used as a benchmark for pricing in the Asia-Pacific region. Reference: United States Energy Information Administration.

[19] Data provided by the Groundwater Section of the Bureau of Water Resources Investigation, Water Resources Management Company, Ministry of Energy in 2005.

[20] Reference: expert opinion provided by Mr. Anoosh Noori Esfandiari, Head of Water Economics Bureau, Iran Water Resources Company, Ministry of Energy, 2005. (2003 prices are adjusted to 2002).

[21] Information provided by Mr. Elahi Panah from the National Water and Wastewater Engineering Company in March 2005.

irrigate 22 percent of total irrigated areas (i.e. 1.6 million of 7.4 million hectares).

The watershed areas of dams under operation total some 10.6 million hectares.[22] Over the last four decades, intensive deforestation and rangeland overgrazing, in addition to other factors, have resulted in soil erosion in watershed areas. According to the Ministry of Jihad and Agriculture (MOJA, 2004) soil erosion is estimated at 30 tons per hectares per year and sedimentation at 10 tons per hectare per year. Based on the same source, dam sedimentation is resulting in a loss in reservoir storage capacity of 236 million cubic meters per year. In other words, every year, one per cent of potential dam capacity is lost due to sedimentation.

In this report, the damage costs resulting from dam sedimentation will be assessed in terms of the potential loss in irrigated crops. Since a significant portion of irrigated land (31 percent) in Iran is cultivated with wheat (World Bank, 2004a), this study will focus on the potential wheat yield loss.

As presented in table 3.6, the average productivity of one cubic meter of irrigation water is about US$0.10 (in terms of wheat production).

[22] Ministry of Energy Databank. 2003. "Information about Siltation in Irrigation and Drainage Networks." Water Resources Management Company.

Table 3.6 Productivity of irrigation water (in terms of wheat production) in 2001

(a) Average yield of wheat on irrigated land (National Coastal Profile, 2001)	3.42 t/ha
(b) Average yield of wheat on rainfed land (National Coastal Profile, 2001)	1.09 t/ha
(c) Incremental productivity of irrigation water (c) = (a)– (b)	2.33 t/ha
Water required to irrigate 1ha of wheat fields[23]	4,140 m^3
Water productivity (ton of wheat/m^3)	0.0005 t/m^3
World price of wheat	US$170/ton
Productivity of irrigation water	**US$0.10/$m^3$**

Assuming that dams are utilized at full capacity, the average annual loss of 236 cubic meters of dam reservoir storage capacity results in the loss of around 118,000 tons of wheat, with an estimated value of US$22 million. Using a social discount rate of four percent, the net present value of the damage costs due to dam sedimentation in 2002 for a time span of 25 years totals US$369 million.

In addition to the loss in irrigated area, dam sedimentation results in dredging activities in irrigation networks. In 2002, operating costs were estimated at US$1.6 million (Ministry of Energy Databank, 2003).

The total annual damage cost of dam sedimentation, therefore, amounts to US$370 million (or IRR 2,950 billion or 0.33 percent of GDP).

Another cost associated with sedimentation is the shortening of dam life and the necessity of building new dams. However, no information was available to enable us to calculate the additional infrastructure costs resulting from a shorter dam lifespan. Therefore, the estimates provided in this section are believed to underestimate the total cost of water erosion and dam sedimentation.

[23] Soil and Water Research Institute. 1997. *Estimation of Water Needs for Main Field Crops and Horticulture.* Volume I: Field Crops.

3.5 Total Damage Costs

Table 3.7 presents the environmental damage costs associated with water pollution, inadequate potable water, sanitation and hygiene, groundwater depletion and water erosion. In total, estimated costs are US$3,200 million (or IRR 25,500 billion or 2.82 percent of GDP) per year.

It should be noted that there are likely to be other aspects of water pollution and water management for which costs are not estimated in this report. Pollution of rivers and lakes by industry, sewage and agriculture – as is the case along the Karoon River – reduce the river's recreational value and associated quality of life for Iranian residents. However, no estimate was provided in this report due to a lack of data. Another aspect is agricultural water management. Continued pollution of surface and groundwater, and the over-extraction of aquifers could pose a serious threat to agricultural development in the long run.

Table 3.7 Water: annual damage costs (mean estimate, 2002)

Impacts	US$ millions	Rials billions	GDP %
Health impacts (mortality)	1,500	11,950	1.32
Health impacts morbidity)	500	4,000	0.44
Health impacts (cost of illness)	495	3,940	0.44
Groundwater depletion and pollution	335	2,670	0.29
Dam sedimentation	370	2,950	0.33
Total	**3,200**	**25,500**	**2.82**

4. Air

4.1 Overview of Urban Air Pollution

Air pollution is one of the most significant environmental issues facing Iran, especially its capital city, Tehran. The major cause of air pollution in Tehran is exhaust from 2.4 million motor vehicles. Most vehicles are over 20 years old, with poor fuel efficiency and no catalytic converters. Many of these cars are domestically produced. Cars spewing black smoke are a common sight in the streets of Tehran. The problem is compounded by topographical conditions (mountains to the north and east) and climatological factors (sunshine, frequent temperature inversions) that trap pollutants over the city. Tehran's high altitude also makes fuel combustion less efficient.

The index of air pollution, Pollutant Standard Index (PSI)[24], reported 282 "unhealthy" days in 2000.[25] On January 2, 2005, the pollution index reached 168 – close to "very unhealthy" levels. As a result, schools were closed and children, the elderly and the sick were advised to stay indoors. By comparison, on the same day the PSI in New York was 52 and in Bangkok 57.[26]

In response to record levels of air pollution in Tehran and other major urban cities in Iran, the government has recently taken steps to tackle the problem. It has, for example, limited the number of private cars that enter the city center (by allowing vehicles with odd and even license plate to enter on alternate days). It has launched a ten-year comprehensive plan to reduce air pollution in Tehran, Isfahan and other major cities. Unleaded gasoline was introduced in 2001 and diesel fuel with a minimal amount of sulfur also became available. Since 2000, all new Iranian-made cars are equipped with catalytic converters. Since 2002, the Department of the Environment and the Ministry of Industry began the installation of catalyzers and Compressed Natural Gas (CNG) systems in public vehicles.

An attempt is made in this chapter to capture the health impact of air pollution in major urban cities in Iran. The methodology used is explained step by step and the results are presented at the end of the chapter. More details about cost estimates are provided in annexes II and III.

4.2 Measuring the Impact of Urban Air Pollution on Health

There is substantial research evidence from around the world that outdoor urban air pollution has significant negative impacts on public health, resulting in premature death, bronchitis, respiratory disorders, and cancer. A comprehensive review of such studies is provided in Ostro (1994). The air pollutant that has shown the strongest association with these health endpoints is particulate matter (PM),[27] and especially fine particulates of less than ten microns in diameter (PM_{10}). Research in the United States in the 1990s and most recently by Pope et al (2002) provides strong evidence that it is even smaller particulates ($PM_{2.5}$) that have the greatest health effects. Gaseous pollutants (SO_2, NOx, CO, and ozone) are generally not thought to be as damaging as fine particulates. However, SO_2 and NOx may have significant health consequences because they can react with

[24] The PSI is an indexing system developed by US EPA to measure pollution levels of the major air pollutants. It is used to report to the public an overall assessment of a given day's air quality. The PSI is a composite indicator computed from ambient levels of ozone, nitrogen dioxide, sulfure dioxide, carbon monoxide and particulate matter. Once a day the highest concentration of each of the five pollutants is identified and converted into a value on the PSI scale. A PSI of 100 corresponds to the ambient air standard established under the Clean Air Act. A PSI value in excess of 100 means that the ambient air concentration violates the standard and the pollutant is in the "unhealthy" range". A PSI value in excess of 200 corresponds to a "very unhealthy" situation For more information refer to: www.aqcc.org

[25] www.atiehbahar.com

[26] www.aljazeerah.com

[27] Also called total suspended particulates (TSP).

other substances in the atmosphere to form particulates.

This report will focus mainly on the impact of fine particulates (PM_{10} and $PM_{2.5}$) on health. It will also briefly address the impact of lead pollution and the loss of recreational value due to air pollution.

Health effects of fine particulate (PM_{10} and $PM_{2.5}$)

There are five steps to quantify the health impacts of air pollution. First, pollutants need to be identified and their concentrations measured. Second, the number of people exposed to a pollutant and its concentration needs to be calculated. Third, the health impacts from exposure should be estimated based on epidemiological data. Once the health impacts are quantified, the value of this damage can be estimated (steps four and five).

Step 1: Monitor air pollutants

Air quality monitoring in Iranian cities is sparse. The government has made major efforts to build a monitoring network, but additional work still needs to be done. The main cities equipped with monitoring stations are Tehran and Isfahan. Monitoring data for PM_{10} were obtained for Tehran, Isfahan and Tabriz based on existing stations. Monitoring data for TSP were obtained for Shiraz and Ahwaz. As PM_{10} is a component of TSP, it is possible to estimate the levels of PM_{10} where TSP is available. No monitoring data exist for Karaj and Mashad, in these two cases, extrapolation from cities with similar conditions was used as an approximation. Other cities represent all cities in Iran with a population ranging from 0.1 million to 1 million persons. PM_{10} levels are based on average projections for all cities estimated by the Development Economics Research (DEC) group at the World Bank.[28] Most data obtained refer to 2002.

[28] www.worldbank.org/nipr/Atrium/mapping.html

Table 4.1 Air pollutants in major cities, 2002

Cities	Average PM_{10} monitored	Average TSP monitored	**Average PM_{10} estimated**
Tehran	100		100
Mashad			85
Isfahan	102		102
Shiraz		152	76
Tabriz	69		69
Ahwaz		162	81
Karaj			100
Other cities			77

Pollutants are expressed in average annual values (ug/m³).

Unfortunately, monitoring of $PM_{2.5}$ is not available for cities in Iran. It has therefore been necessary to convert PM_{10} to $PM_{2.5}$ based on observed ratios from the United States. The ratio depends on various factors: the topography of the city (arid, semi-arid, agricultural, etc.) and the type of emission sources (fuel combustion, industrial emissions, waste burning, mobile sources, etc.). Since large urban cities in Iran such as Tehran, Mashad, Isfahan, Shiraz, Tabriz Ahwaz and Karaj have high vehicle emissions, it is plausible that the PM ratio in these cities falls in the range of 0.55-0.75 (as in some eastern parts of the United States). For smaller cities – with populations less than one million persons – it is plausible that the PM ratio falls in the range of 0.4 - 0.5 (as in some parts of the Midwest in the United States).

Step 2: Determine the population exposed

The second step in estimating health impacts is to determine how many people are exposed to a pollutant. Most city population estimates were taken from the Statistical Center of Iran (2004). It was assumed that 90 percent of Tehran's population is exposed to air pollution, while 80 percent of the population of all other cities was exposed to air pollution.[29]

Some health outcomes affect only certain segments of the population such as adults or children. As only total population data is available at the city level, the number of adults and children in each city had to be estimated.

[29] Air pollution experts' advice was used to establish the population exposed to air pollution in each city.

This was done by applying national averages to a city's population.

Step 3: Establishing dose response coefficients

The third step is to determine the health impacts that result from exposure to PM_{10} and $PM_{2.5}$. For this, the study relied upon scientific literature. Based on the current status of worldwide research, the risk ratios, or dose response coefficients from Pope et al (2002) are likely to be the best available evidence for the mortality effects of ambient particulate pollution ($PM_{2.5}$). These coefficients were applied by the World Health Organization in the *World Health Report 2002* (WHO, 2002b), which provided a global estimate of the health effects of environmental risk factors. For morbidity effects, dose response coefficients from Ostro (1994) and Abbey et al (1995) have been applied. Ostro (1994) reflects a review of worldwide studies, and Abbey et al (1995) provides estimates of chronic bronchitis associated with particulates (PM_{10}). Mortality and morbidity coefficients are presented in table 4.2. While mortality effects are based on $PM_{2.5}$, the morbidity effects assessed in most worldwide studies are based on PM_{10}.

Table 4.2 Urban air pollution dose-response coefficients

Annual Health Effect	Dose-response coefficients	per 1 ug/m^3 annual average ambient concentration of:
Mortality (% change in cardiopulmonary and lung cancer mortality)	0.8%	$PM_{2.5}$
Chronic bronchitis (per 100,000 adults)	0.9	PM_{10}
Respiratory hospital admissions (per 100,000 population)	1.2	PM_{10}
Emergency room visits (per 100,000 population)	23.5	PM_{10}
Restricted activity days (per 100,000 adults)	5,750	PM_{10}
Lower respiratory illness in children (per 100,000 children)	169	PM_{10}
Respiratory symptoms (per 100,000 adults)	18,300	PM_{10}

Source: Pope et al (2002) for mortality coefficient. Ostro (1994) and Abbey et al. (1995) for morbidity coefficients.

Mortality. Pope et al (2002) provides the most comprehensive and detailed research study to date on the relationship between air pollution and mortality. The study found a statistically significant relationship between levels of $PM_{2.5}$ and cardiopulmonary and lung cancer mortality rates, controlling for various factors (age, smoking behavior, education, marital status, body weight, occupational risk factors, etc.). Therefore, in order to apply the mortality coefficient in table 4.2, baseline data on total annual cardiopulmonary and lung cancer deaths are required. These data were obtained from the Ministry of Health (MOH) in Iran.[30] Data for cardiopulmonary and lung cancer deaths for 2002 are based on the averages of 18 provinces surveyed by the Ministry of Health.

A threshold level for $PM_{2.5}$ of 7.5 ug/m^3 has been applied. Below this level, it is assumed there are no mortality effects. This is the same procedure as applied by the World Health Organization (WHO, 2002b). No threshold level has been applied to morbidity.

Morbidity. Morbidity health endpoints considered are chronic bronchitis, hospital admissions of patients with respiratory problems, emergency room visits (or hospital out-patient visits), restricted activity days, lower respiratory infections in children and respiratory symptoms. These are the most common health endpoints considered in worldwide studies on air pollution. In the absence of incidence data for Iran, coefficients are expressed as cases per 100,000. It should be noted that it would be preferable to have incidence data and use coefficients that reflect percentage change in incidence. However, these are not readily available for Iran.

The health effects of air pollution can be converted to disability adjusted life years (DALYs) to facilitate a comparison to health effects from other environmental factors and between mortality and morbidity using a common indicator. DALYs per 10,000 cases of

[30] www.mohme.gov.ir

various health end-points are presented in table 4.3 below.

Table 4.3 DALYs for health effects

Health Effect	DALYs lost per 10,000 cases
Mortality	80,000
Chronic bronchitis (adults)	22,000
Respiratory hospital admissions	160
Emergency room visits	45
Restricted activity days	3
Lower resp. illness in children	65
Respiratory symptoms (adults)	0.75

Source: Authors for mortality and Larsen, B. 2004 for morbidity. Morbidity estimates are based on best available information on the duration and severity of morbidity health end points.

Step 4: Health Impacts

Using the approach described above, the annual health effects of ambient particulate air pollution in major cities in Iran were estimated and are presented in table 4.4 below. More detailed information is presented in the annexes.

Table 4.4 Estimated health impacts of urban air pollution, 2002[31]

Health categories	Total Cases	Total DALYs
Premature mortality	13,200	105,600
Chronic bronchitis (adults)	12,500	27,500
Respiratory hospital admissions	28,600	500
Emergency room visits	560,300	2,500
Restricted activity days	83 million	24,800
Lower resp. illness (children)	1.6 million	10,300
Respiratory symptoms (adults)	263 million	19,800
Total		**191,000**

Urban air pollution is estimated to cause around 13,200 premature deaths annually. Estimated new cases of chronic bronchitis are about 12,500 per year. Annual hospitalizations due to pollution are estimated at 28,600 and emergency room visits/outpatient hospitalizations at 560,300. Moreover, every year every adult suffers 2.1 restricted activity days owing to urban air pollution. Cases of less severe health impacts are also presented in table 4.4.

Table 4.5 shows how many deaths could be averted in major Iranian cities if PM_{10} emissions were controlled.

Table 4.5 Estimated health impacts of urban air pollution in major Iranian cities, 2002

City	*Population (millions)*	*Deaths averted (Nb)*	*Deaths averted (%)*
Greater Tehran	10	5,320	8%
Mashad	3	1,100	7%
Isfahan	3	1,140	8%
Shiraz	1	450	6%
Tabriz	2	530	5%

In terms of annual DALYs lost, mortality accounts for an estimated 55 percent, chronic bronchitis around 14 percent, restricted activity days (RADs) 13 percent and respiratory symptoms 10 percent.

Step 5: Monetary Valuation of Health Impacts

Having quantified the health impacts of particulate emissions, it is possible to measure economic losses due to air pollution. There are several approaches to valuing the health impacts of air pollution.

Valuing DALYs lost. As discussed in chapters 2 and 3, a DALY lost will be valued using the HCA approach as a lower bound and the WTP as an upper bound. For the lower bound, GDP per capita of US$1,740 will be used. For the upper bound, VSL measured through WTP methods (Farhoud, 2003) of US$10,500 will be used. The total number of DALYs lost (combining mortality and morbidity) was approximately 191,000 in 2002. Therefore, the annual cost of DALYs lost due to air pollution ranges from US$330 million to US$2 billion.

Cost of illness. In addition to pain and suffering resulting from illness – already captured through DALYs – one should also add the cost of treating illnesses and lost work days. Interviews were conducted in Iran among health experts in 2004/2005 to identify the treatment costs of various respiratory diseases. The following costs

[31] Due to rounding, numbers may not add up exactly.

were provided and reflect an accurate economic cost for treatment by most privately-owned clinics and hospitals.

Table 4.6 Unit cost of illness and treatment in cities

Health problems	Unit costs (US$)	Unit costs (Rials)
Hospitalization (for respiratory illnesses)	75	600,000
Doctor visit	13	100,000
Emergency visits	50	400,000
Lost work day (including house work)	8	32,000
Lost caregiver time	8	32,000

Based on costs provided in table 4.6 the cost of treating respiratory problems and the value of work days lost was estimated at US$262 million in 2002.

Impact of lead on children's health

The Government of Iran recently took major steps to eliminate lead pollution. In 2001, it introduced unleaded gasoline and in 2005 it required all gasoline sold to be unleaded. There is no comprehensive monitoring data for lead levels in Tehran, though average concentrations in 2002 were estimated to be 0.67 ug/m^3 based on information provided by the Air Quality Control Company in Tehran (AQCC). This average is much lower than in previous years. According to Bahrami (2001), lead concentrations in dense traffic areas reached 3.8 ug/m^3 in 1998. Exposure to lead can have significant impacts on health, especially the neurological development of children (reduction in intelligence). Based on lead concentration in 2002, health impacts have been estimated at US$18 million to US$35 million. Further detailed are provided in annexes II and III.

Measuring loss of recreational value due to urban air pollution

While the greatest percentage of the cost of urban air pollution is associated with health effects, air pollution also causes discomfort, and reduces visibility and scenic beauty. No data are available to assess the costs of discomfort and reduced visibility and scenic beauty in Iran. However, a study in Rabat-Salé in Morocco (Belhaj, 2003) assessed households' WTP for improved air quality[32]. The study revealed a willingness to pay ranging from 67 to 82 dirhams per household in 1995. While most of this WTP is likely to be associated with health concerns, ten percent is retained to reflect the cost of discomfort. This figure was adjusted to Iran (using the GDP per capita differential) and adjusted to 2002 prices. It was applied to households of the seven main urban cities. This amounts to about US$44 million to 54 million per year.

Linkages to previous work

In this report, the total impact of air pollution is estimated at around 1.3 percent of GDP in 2002. It is interesting to mention that a study recently completed by the World Bank (2004e) on the impact of the energy sector on the environment in Iran, assessed the damage costs of urban air pollution. The Energy and Environment Review (EER) used a different methodology –than the one applied in this report- to compute the damage cost from air pollution. The EER relied on a technique called ExternE widely used by the European Union (EU). This methodology looks at total emissions of four major pollutants (PM_{10}, SOx, NOx and CO) and applies damage cost (per ton of pollutant) estimated in EU countries – that are adjusted to Iran using purchasing power parity (PPP) estimates of per capita GDP. In the EER annual damage costs from urban air pollution in 2001 were estimated at approximately 1. 6 percent of GDP.

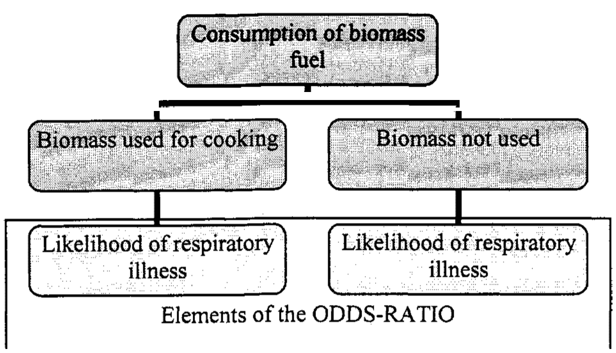
[32] This study assesses households' willingness to pay for a 50 percent reduction of air pollution caused by road traffic in Rabat-Salé using contingent valuation and hedonic price methods. Both empirical analyses are based on the same set of individuals. A sample of 400 households was interviewed (out of a total of 235,000 households in both cities).

4.3 MEASURING THE IMPACT OF INDOOR AIR POLLUTION

Overview. The use of wood or other biomass fires for cooking is closely associated with indoor levels of particulate matter. Epidemiological studies (see Smith et al. (2000) for a good review) show that acute respiratory infections (ARI) and chronic obstructive pulmonary diseases (COPD) are strongly related to indoor air pollution.

Data on PM10 indoor concentrations is not recorded in country statistics. Available studies make use of detailed health surveys or rely on *ad hoc* experiments. Other studies take another approach, that is, they measure the relationship between household characteristics and the likelihood of a particular disease occurring in the exposed population. The parameter that expresses, for example, the likelihood of dying due to COPD in a house consuming solid biomass for cooking is termed 'odds-ratio' and is the key element of the analysis.

Figure 4.1 Comparing the likelihood of respiratory illnesses under different biomass use assumptions



In Iran, there are no available statistics on indoor concentrations of PM10. Thus, the analysis used in this report relies upon the odds-ratio used in other international studies. There are two essential data requirements to apply the odds-ratio method to Iran: the first is to calculate the population living in households that use solid biomass for cooking; the second is baseline levels of mortality and morbidity in Iran.

Use of biomass for cooking in Iran. In Iran, 786,000 tons of oil equivalent of biomass are used every year (WB, 2004d). This is equivalent to nearly three million metric tons of biomass. Assuming that a household, using solid biomass for cooking, consumes three metric tons per year then one million households are using biomass. This is equivalent to 7.8 percent of total households in the country. This value is used as an approximation of the exposure rate to indoor smoke. A major shortcoming of the data is the lack of detail about cooking methods. Epidemiological studies show that health outcomes strongly depend upon the type of stove used, the existence of chimneys, and having a home's kitchen in a separate room.

Mortality from respiratory infections. The methodology also requires baseline data on mortality. Baseline data on ARI and COPD deaths are available for the EMRO-B WHO sub-region. We used the same mortality data and applied it to the Iranian population.

The data is summarized in table 4.7. Every year, some 6,000 children under the age of five die due to lower respiratory infections (LRI). Among female adults, it is estimated that nearly 14,000 die to LRI or COPD.

Table 4.7 Estimated mortality of children and female adults from LRI and COPD in Iran in 2002

Illness	*Group*	*Baseline Deaths*
Lower Respiratory Infection	Children under 5 years of age	6,000
Lower Respiratory Infection	Adult female (>15 years)	6,200
Chronic Obstructive Pulmonary Disease	Adult female (>15 years)	7,800

Source: WHO, 2004

Illness from respiratory infections. In order to obtain baseline data on morbidity, the population at risk has to be multiplied by the incidence rate of the illness considered. Two weeks' incidence of ARI in children is 24 per cent[33] (UNICEF website). The incidence of ARI

[33] This information has been obtained from the UNICEF website. The data sources for this information are DHS, MICS and other national household surveys.

for the female population over 15 is estimated to be 2 per cent (World Bank staff calculations based on WHO tables for Years of Life with Disability). The incidence of COPD on the female population over 15 is taken from Shibuya, Mathers, Lopez (2001). Baseline morbidity data is summarized in table 4.8.

Table 4.8 Estimated morbidity of children and female adults from LRI and COPD in Iran in 2002

Illness	*Group*	*Baseline Cases of illness*
Lower Respiratory Infection	Children under 5 years of age	35,109,000
Lower Respiratory Infection	Adult female (>15 years)	5,960,000
Chronic Obstructive Pulmonary Disease	Adult female (>15 years)	18,000

Source: WHO, 2004, UNICEF website, Shibuya, Mathers, Lopez (2001)

Health costs of indoor smoke. The odds-ratio adopted in this study assume that the probability of contracting a given respiratory illness if using solid fuels is twice as high as the probability if not using solid fuels (odds-ratio is 2.3). This assumption is based on Smith et al. (2004). A major simplification is being done here, since using solid fuels does not mean –per se - that people are more exposed to indoor air pollution.

Table 4.9 Mortality, morbidity and DALYs lost due to indoor air pollution in Iran in 2002

	Odds-ratio	*No. of deaths due to indoor air pollution*	*DALYs*
Mortality			
LRI children	2.3	552	18,230
LRI adult women	2.3	726	7,980
COPD adult women	2.83	770	6,160
Sub-Total		*2,048*	*32,370*
Morbidity			
LRI children	2.3	3,233,400	5,383
LRI adult women	2.3	548,900	3,770
COPD adult women	2.83	2,200	1,170
Sub-Total		*3,784,500*	*10,320*
Total			**42,700**

Source: For Odds-ratio: Smith et al. 2004. For DALY per type of death: WHO, 2004

An estimated total of 43,000 DALYs are lost due to indoor air pollution every year. The valuation part uses a value per DALY ranging from a lower bound, estimated by GDP per capita and an upper bound, estimated by the value of a statistical life calculations (see chapter 2 for detailed information).

Indoor air pollution causes about 3 million cases of LRI in children under five years of age every year. UNICEF estimates that 93 per cent of cases are taken to an appropriate health provider. This number is then used to compute the cost of illness linked to indoor air pollution (table 4.10). It is assumed that each case of LRI requires a day of caregiver's time. This time is valued using the average rural household wage income (US$4.60 per day).

Table 4.10 Cost of illness from indoor air pollution in Iran in 2002

	Numbers	*US$ millions*
Cases (LRI in children)	3,233,422	-
Cases taken to health provider	3,007,083	39
Days of caregivers lost	3,233,422	15
Total		**54**

Source: WHO, 2004, UNICEF website, Shibuya, Mathers, Lopez (2001)

Estimated total damage costs range from indoor air pollution range from US$128 million to US$500 million per year (equivalent to an average IRR 2,500 billion, or 0.28 percent of GDP) in 2002.

4.4 TOTAL DAMAGE COSTS

Table 4.11 provides a summary of damage costs associated with urban and indoor air pollution.

Table 4.11 Air: Annual damage costs (mean estimate, 2002)

Air	US$ millions	Rials billions	GDP %
Indoor air pollution			
Mortality	200	1,600	0.17
Morbidity	60	500	0.06
Cost of illness	55	430	0.05
Urban air pollution			
Particulates			
Mortality	640	5,100	0.57
Morbidity	520	4,100	0.46
Cost of illness	260	2,100	0.23
Lead	25	200	0.02
Recreational loss	50	390	0.04
Total	**1,810**	**14,420**	**1.60**

5. Land Resources

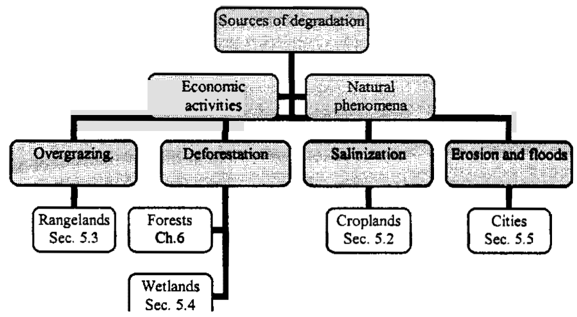
5.1 Overview of Land Resources in Iran

With a land area of 160 million hectares, Iran is one of the largest countries in the world. The key word to describe the country's territory is "diversity," both in terms of climatic variability and geological conformation. Land resources are categorized into: (a) forests which occupy seven percent of the country's area and constitute 20 percent of forests in the Middle East and North Africa region; (b) arable land; (c) crop land; (d) pasture land; and (e) deserts and savannas.

In 2002, agricultural activities contributed 15.2 percent of GDP and provided almost one-quarter of employment (World Bank, 2004a). In terms of irrigated land, Iran stands fifth worldwide, after China, India, Pakistan and the USA. Currently, about 7.4 million hectares are irrigated, some 34 percent with surface water and 66 percent with groundwater (World Bank, 2004a).

The relationship between environmental degradation and impacts on the rural environment are various and complex (figure 5.1). The main cause of land degradation is likely the change in land use from forest (or wetlands) to agricultural land. The impact is not only in the direct loss of forest products but in the loss of forest services such as the prevention of erosion and salinization. To quantify land degradation, one could focus on drivers, such as deforestation, overgrazing, erosion and salinization. An alternate approach, and the one used here, is to consider the recipients of degradation, that is, forests, wetlands, cropland, rangeland and cities. Figure 5.1 could be made more accurate by adding connectors between drivers and recipients of impacts, but the representation is intended to identify issues rather than accurately describe the linkages. Degradation of forest resources is more thoroughly detailed in chapter 6. This chapter focuses on croplands (section 5.2), rangelands (section 5.3), wetlands (section 5.4) and cities (section 5.5).

Figure 5.1 Threats to land resources in Iran



5.2 Cropland Salinity

Salinity is a natural phenomenon. The term is used to describe areas of land with high salt concentrations. Plants and living organisms are killed or their productivity severely reduced in areas with high levels of salinity. Concentrations of salt into land and water develop naturally, but the process can be enhanced by manmade activities. In Iran, a major driver is irrigation in dry land areas. All irrigation water contains salt. As croplands are irrigated and water evaporates, salt is left behind. If there is no drainage, salinity increases until the land becomes unproductive and agricultural activities must be abandoned. Salinity is expressed using the electric conductivity of soils, measured in deciSiemens per meter (dS/m). Table 5.1 (first two columns) associates levels of salinity with electric conductivity.

Salinity in Iran. Salt-affected soils are widespread in the country, particularly in central Iran, where salinity is one of the main factors threatening sustained food production. Slightly-to-moderately salt-affected soils (ECe= 4-16 dS/m)[34] cover about 25.5 million hectares and soils with high salinity (ECe= 16-32 dS/m) cover some 8.5 million hectares. Slightly-to-moderately salt-affected soils are mostly formed on the piedmonts at the foot of the Zagros and Alborz mountains. Lands with severe to extreme

[34] dS/m is deciSiemens per meter and is a measure of electrical conductivity (EC).

salinity are mostly located in the central plateau, the Khuzestan and southern coastal plains, and the Caspian Coastal Plain (Moameni, 1999).

Irrigated agricultural lands and their degree of salinity are presented in table 5.1. Much of these lands suffer from various levels of salinity. As much as 1.11 million hectares are reported to have soil salinity exceeding 32 dS/m. Even the most salt tolerant crops, such as cotton, wheat, barley and sugar beet, would have severe difficulties in such saline conditions.

Table 5.1 Soil salinity on irrigated lands in 2003

Salinity Level	dS/m	Area irrigated (million ha)	%
No salinity	0-4	2.67	36%
Slight salinity	4-8	0.87	12%
Moderate salinity	8-16	1.18	16%
Strong salinity	16-32	1.55	21%
Very strong salinity	>32	1.11	15%
Total irrigated land		**7.4**	**100%**

Source: Moameni., 2004

Assessing degradation through changes in productivity. The main consequence of cropland salinity is on productivity. Table 5.2 presents the irrigated cropping patterns in Iran and the soil salinity thresholds for the different irrigated crops. The third column of the table presents the percentage decline in yield per 1 dS/m over salinity threshold.

Table 5.2 Irrigated cropping patterns, salinity tolerance and yield decline

Irrigated crops	Cropping pattern (share of irrigated land)	Salinity threshold (dS/m)	Yield decline per 1dS/m
Pulses	8%	1.5	15%
Fodder	11%	2	7%
Fruits	14%	2	15%
Citrus	2%	2	15%
Vegetables	5%	2	10%
Maize	2%	2	12%
Potatoes	2%	2	12%
Rice	9%	3	12%
Soybean	1%	5	20%
Wheat	31%	6	5%
Sugar beet	3%	7	5%
Barley	9%	8	5%
Cotton	3%	8	5%

Source: Cropping patterns are from World Bank (2004c). Salinity threshold and yield decline are from FAO (1998), Gratten et al (2002), and Kotuby-Amacher, J. et al (1997).

There are no comprehensive data available of cropping patterns in relation to specific levels of soil salinity. To estimate the cost of salinity, it is therefore necessary to make a simplifying assumption. Farmers are likely to adapt to salinity conditions. Optimal adaptation, if salinity was the only soil characteristic affecting crop choices, would imply that all the salt sensitive crops (from pulses to potatoes in table 5.2) are cultivated on the land that has salinity lower than 4 dS/m (see table 5.1). Rice, soybean and some wheat would then be cultivated on land with 4-8 dS/m. The remaining wheat under cultivation would be found on land with 8-16 dS/m and on some land with 16-32 dS/m. All sugar beet, barley and cotton cultivation would also be on land with 16-32 dS/m.

These cropping patterns are in practice unlikely, but provide an opportunity to conservatively estimate the cost of salinity. An assumption also needs to be made regarding the land with salinity exceeding 32 dS/m. As a lower bound this land is ignored in the cost estimation. The upper bound assumes that the land is unproductive and implies a loss corresponding to net farm income if the land had minimal levels of salinity.

The estimated annual costs of soil salinity are presented in table 5.3. The estimate is based on the cropping patterns discussed above. The salinity threshold values and yield decline coefficients in table 5.2 were applied to those cropping patterns at yield levels expected to prevail in the absence of salinity. This provided the total quantity of yield losses, which were then multiplied by crop prices. As a conservative approach, it is assumed that there are no yield losses on land with salinity in the range of 0-4 dS/m. Therefore, no decrease in yield was attributed to the crops assumed to be cultivated on this land (pulses, fodder, fruits, citrus, vegetables, maize, and potatoes) as shown in table 5.3 (for more details, see annex III, Soil Salinity).

The yield levels in the absence of salinity were derived from World Bank (2001a) and FAO yield statistics on Iran. World prices were applied for wheat and barley, and the world price of rice (Thai) was adjusted by a factor of 1.3 to reflect Iranian rice quality premium (World Bank, 2001a). Iranian producer prices were applied to the other crops, as reported by FAO.

Table 5.3 Estimated annual cost of soil salinity

Irrigated crops	Average yield losses (in million ton)	Price/ton (in US$)	Total loss (in million US$)
Pulses	0		0
Fodder	0		0
Fruits	0		0
Citrus	0		0
Vegetables	0		0
Maize	0		0
Potatoes	0		0
Rice	0.75	325	245
Soybean	0.02	281	6
Wheat	3.07	170	522
Sugar beet	5.45	35	191
Barley	1.34	140	188
Cotton	0.27	408	112
Total			**1,265**

Total estimated annual cost of salinity is estimated at US$1,265 million (equivalent to around IRR 10,000 billion or 1.1 percent of GDP), not including the land with salinity exceeding 32 dS/m (unproductive land), and at US$2,450 million (equivalent to around IRR 19,500 billion or 2.16 percent of GDP) if that land is included in the cost estimation. As a conservative approach, the salinity damage cost excluding the unproductive land will be considered.

5.3 Rangeland Degradation

Iran's rangelands total about 90 million hectares. The main source of degradation is represented by the number of head of livestock exceeding the carrying capacity of available rangeland and overgrazing. Other factors relate to untimely grazing (early or late grazing), inefficient management of range and livestock in transhumance; competitive utilization of range among transhumant groups, fuel collection,[35] ploughing and expansion of the area of low yield rainfed farms on slopes.

Overgrazing. The number of animal units[36] in the country is nearly 83 million. Rangelands can meet the requirements of only 37 million animal units for a period of seven months, so there are about 46 million animal units in excess on rangelands (Badripour, 2004). Unsustainability of production is an inevitable consequence which in turn causes declining trends in the pastures, transformation of good pastures into poor ones and of the latter into non-productive pastures, leading to more desertification (MOJA, 2002).

Monitoring changes in rangeland quality. Overgrazing has deprived valuable flora species of reproduction and has replaced them with aggressive species. Vegetative cover is one of the major factors affecting the degree of soil erosion. In this report, rangeland degradation will be assessed based on its change in productivity. Biodiversity losses of valuable species will not be taken into consideration.

[35] Approximately 5.4 million cubic meters of range shrubs are cut-off or uprooted annually to provide fuel for rural people.

[36] Animal unit: a sheep of 45 kg which requires 276.5 kg TDN (total digestive nutrient) per year.

Therefore, damage costs should be considered a lower bound estimate.

Classifications of 1975 shows that out of 90 million hectares of rangeland, 14 million hectares were in good to fair condition, 60 million hectares were in fair to poor condition and 16 million hectares were in poor to very poor condition. Over the past 30 years, the condition of rangeland has drastically worsened. Results of a recent survey of rangeland shows that rangeland in good condition decreased to 9.3 million hectares, rangelands in fair condition decreased to 37.3 million hectares, while rangelands in poor condition have increased to 43.4 million hectares (table 5.4)

Table 5.4 Degradation of rangeland quality between 1975 and 2000 (millions of hectares)

Quality	Good/ fair	Fair / poor	Poor/ very poor	Total
Area in 1975	14	60	16	90
Area in 2000	9.3	37.3	43.4	90
Total change in area	-4.7	-22.7	27.4	0

Source: The Third Asian Thematic Program Network on Rangeland Management and Sand Dune Fixation. Yazd, Iran, 2001.

Change in productivity. Productivity in terms of dry matter (DM) on different qualities of rangeland is presented in table 5.5. The decrease in the quality of one hectare of rangeland from good-fair to poor-very poor is associated with a decrease in productivity of 264 kilograms of DM per hectare. The change in productivity for rangelands passing from fair-poor to poor-very poor is 66 kilograms of DM per hectare. It is assumed that one kg of DM is equal to 0.72 kilograms of barley.[37] To compute the annual loss of productivity for 2002, the 25-year change in productivity is divided by the number of years. The underlying assumption is that productivity has declined in a linear fashion.

With a world barley price of US$140 per ton, the annual damage cost of overgrazing, in terms of a decrease in rangeland productivity, amounts to US$11 million (table 5.5). This figure represents the damage cost associated with the average annual physical loss of the resource (average annual change in hectares from good and fair rangelands to poor rangelands between 1975 and 2000).

Table 5.5 Damage cost of rangeland degradation in 2002

	Good/fair	Fair/poor	Poor/ very poor
Productivity (kg DM /ha)[38]	290 (a)	92 (b)	26 (c)
25 years change in area (millions ha)	-4.7	-22.7	27.4
Average annual change (millions ha)	-0.18	-0.9	1.11
Change in productivity (kg DM/ha)	264 (a-c)	66 (b-c)	
Annual total loss (millions kg DM)	49.63	59.92	
Total loss (barley equiv. in millions of kg)	35.73	43.14	
Barley world price (in US$/kg)	0.14	0.14	
Total loss (US$ millions)	5	6	

Using a social discount rate of four percent, the net present value of the damage cost (flow of benefits in the future) resulting from a physical change in the quality of rangelands in year 2002, for a time span of 25 years, amounts to US$172 million (equivalent to IRR 1,373 billion or 0.15 percent of GDP)

5.4 WETLANDS DEGRADATION

Overview. Much of Iran's geographic area falls into the arid, semi-arid or semi-dry category. In these climatic conditions, the presence of wetlands, marshlands and water bodies plays an important role in sustaining the natural environment. There are more than one hundred sizable wetlands in Iran, twenty of which have been listed in the Ramsar Convention's "List of

[37] Reference: Opinion expert provide by Mr. E. Eskandari Shiri, Director General of Range Technical Bureau, Forest, Range and Watershed Management Organization, MOJA, 2005

[38] The Third Asian Thematic Program Network on Rangeland Management and Sand Dune Fixation. Yazd, Iran, 2001.

Wetlands of International Importance." covering 0.7 percent of the country's territory (MOJA, 2002). In the early 1970s, Iran was the first country in the Middle East to carry out a national wetlands inventory. A total of 286 wetlands were identified, 33 of which were considered to be of international importance (IUNC, 1995). Recent studies by Iran's Department of Environment have raised the number of wetlands of international significance to seventy-six (DOE, 2005).

Threats to wetlands. Wetlands in Iran are increasingly under pressure due to human activity. Undoubtedly the most serious threats to wetlands have been their drainage and reclamation for agriculture, industry and urban development, and the diversion of water supplies for irrigation. In addition, increased siltation is becoming a problem in some wetlands. Siltation and erosion are caused by deforestation and overgrazing in water catchments.

In some wetlands, heavy grazing of marsh vegetation by domestic livestock is inhibiting natural plant succession, and causing permanent damage to aquatic plant communities as highly palatable species are grazed to extinction. Some mangroves in the Persian Gulf have been degraded by excessive utilization for fuel wood and fodder. Many wetlands, especially those downstream of large urban centers and major farming areas, have been polluted with domestic sewage, herbicides, pesticides, fertilizers, industrial effluents and other waste products (IUCN, 1995).

For practical reasons this study distinguishes between two types of damage: (1) damage arising from man-driven droughts such as dam construction and agricultural activities; (2) damage from pollution.

Many wetlands in Iran (like the Ramsar sites of Anzali Mordab, the Shadegan Marshes and other internationally important wetlands such as Lake Zaribar, Ghara Gheshlaq Marshes, Akh Gol and Hashelan Marshes) are being damaged by pollution. Sources are sewage pollution, agricultural drainage with high salinity, sedimentation resulting from deforestation in upper lands, fish farming and mining activities. The total estimated degraded areas of these wetlands amount to 250,000 hectares.

This study limits its assessment to the first type of damage. The value of damage in this case can be obtained by multiplying the total service value of a hectare of wetland by the extent of the damage. Thus, given the difficulty in assessing the physical damage linked to pollution, no estimate is made.

Yet, in most regions of the country, many of the remaining wetlands are in relatively good condition. This is due in large part to the active policy of wetland conservation pursued by the government of Iran since the late 1960s, and the establishment of an effective network of protected areas which include many of the country's most important wetlands.

Valuing wetland services. A study conducted by Hormozgan University and published by the Department of the Environment in 2001 (Bagherzadeh Karimi, M, 2001), assessed the economic value of services of three types of wetlands in Iran (table 5.6).

Table 5.6 Value of services of three types of wetlands (in US$/ha/yr)[39]

Type and name of wetland	Type (1) Hara	Type (2) Inland Chogh akhor	Type (3) Amir kalaye
Protection of biodiversity and genetic resources	346	132	132
Hunting and fishing	703	640	679
Ecotourism and cultural heritage	5	2	2
Supply of wood and fodder*	270	2	136
Microclimate regulation, air refreshment and wind break	104	52	52
Water supply and regulation	..	7	17
Transportation	10	..	..
Medical, industrial and nutrimental plants**	37	15	18
Handicraft production	15	62	124
Azote fixation	102	31	51
Protection of coasts	25	..	..
Total (US$/ha/year)	1,620	940	1,210

Source: Bagherzadeh Karimi, M. 2001. "The Economic Valuation of Wetlands of Iran". Hormozgan University for the Department of Environment, Islamic Republic of Iran.
** Type (1) is based on Forest Chapter estimate, Type (2) and (3) are based on Karimi's study.*
*** Only the value of nutrimental plants has been calculated.*

Despite achievements in conservation, at least four Ramsar sites and five other internationally important wetlands have undergone degradation and drought during the last three decades, mainly due to dam construction and agricultural activities. As a result, a certain percentage of the area of these wetlands has dried out (table 5.7 column 4). For example, Yadegarlu and Dorgeh Sangi Lakes have completely disappeared while the size of other wetlands has been reduced. For each wetland, the area lost is divided by the time span of degradation to obtain a yearly degradation rate. The average annual loss totals some 23,300 hectares (table 5.7, column 7).

As a final step, the annual loss for each wetland is multiplied by the value of services estimated in table 5.6. The total damage cost of this loss is assessed at US$22.4 million for 2002 (table 5.7, column 9). This figure is a lower bound estimate as it excludes damage from pollution.

Using a social discount rate of four percent and a 25-year time horizon, the net present value of the damage cost (flow of future benefits lost) resulting from a loss of 23,321 hectares of wetlands in 2002 (based on annual average) equals US$350 million (equivalent to IRR 2,800 billion or 0.3 percent of GDP).

Other Ramsar sites, namely Hamoun-i Puzak, Hamoun-i Sabari and Hamoun-i Hirmand, covering an area of 60,000 hectares completely dried up due to dam construction in Afghanistan in areas bordering Iran. The damage cost of this degradation (assessed at around US$6 million per year) is not included since it was caused by external factors.

[39] The values in Iranian Rials of 2001 were adjusted to 2002 prices and converted to U.S. dollars.

Table 5.7 Estimate of damage costs resulting from wetland degradation

Name of wetland	Type*	Area (ha)	Percentage dried up	Area degraded (ha)	Degradation time span (years)	Annual degradation (ha)	Value of service (US$/ha/year)	Total loss (US$ millions per year)
Ramsar sites:								
Gavekhoni Lake	(2)	43,000	80%	34,400	30	1,147	940	1.08
Lake Orumiyeh	(2)	483,000	25%	120,750	10	12,075	940	11.35
Neyriz Lakes and Kamjan Marshes	(2)	108,000	25%	27,000	25	1,080	940	1.02
Yadegarlu and Dorgeh Sangi Lakes	(2)	500	100%	500	10	50	940	0.05
Other internationally important wetlands:								
Helleh	(1)	42,600	30%	12,780	20	639	1,620	1.04
Boralan	(2)	2,000	10%	200	10	20	940	0.02
Lavandavil Marsh	(2)	200	60%	120	20	6	940	0.01
Huralazim	(2)	35,000	20%	7,000	23	304	940	0.29
Jazmourian	(2)	200,000	100%	200,000	25	8,000	940	7.52
Total		**914,300**		**402,750**		**23,321**		**22.4**

Reference for the Area of Wetland: DOE. 2005. "Directory of Iranian Wetlands Designated Under the Ramsar Convention." Islamic Republic of Iran

**Type: (1): similar to Hara Wetland; (2): similar to Inland Choghakhor Wetland. Information on the Type of Wetland and percentage of area degraded provided by Mr. Masoud Bagherzadeh Karimi, senior expert on wetlands and focal point for the Ramsar Convention in Iran. Department of Environment in 2005.*

5.5 Flood Damage and Erosion

Flooding has increased during the last decades in Iran. The number of floods recorded in the 1980s and 1990s is more than five times the number recorded in the 1950s and 1960s (table 5.8). Poor land use management and deforestation can contribute to the frequency and intensity of floods. An exceptionally rainy period can result in more flooding due to changes in land use. Iran's forests have been severely degraded over the last decades (see chapter 6). Forest clearing for agriculture, firewood and charcoal production reduced forest area from 19.5 million hectares to 12.4 million hectares over the last 57 years. Vegetative cover is one of the major factors influencing the degree of soil erosion and floods.

Table 5.8 Number of recorded floods in Iran in the last five decades

Decade	Number of floods	Percentage of the total
1990s	1,341	41%
1980s	1,046	32%
1970s	432	13%
1960s	251	8%
1950s	192	6%
Total	3,262	100%

Source: DOE, 2004.

The country's most damaging floods occur in the Caspian region. Logging operations on the steep slopes of the northern part of the Alborz range are considered a major cause.[40] For instance, in the southeast Caspian Sea in Golestan province, a major flood occurred in 2001. This was estimated to have been the most severe flood in Iran in the last 100 years. The damage affected 5,000 square kilometers of rural and urban areas, killed more than 400 people and resulted in US$77 million in economic damage (DOE, 2004).

The Golestan flood of 2001 occurred under special circumstances. Natural phenomena and man-driven activities impacted it simultaneously. Human activities including deforestation, inadequate road construction, especially in the main Golestan river basin, road construction across the river bed, and earthen dam construction without the application of appropriate standards contributed to the severity of the flood impact. Another flood occurred in the province in 2002, leading to 45 deaths and economic damage of US$2.7 million (DOE, 2004).

Complete figures for the damage resulting from the flooding are not available. However, data analysis of some floods surveyed over 15 years (between 1987 and 2002) revealed an average annual damage cost (in terms of infrastructure) of US$164 million and an average human loss assessed at 154 persons per year (table 5.9).

Table 5.9 Damage costs of selected floods surveyed over the past 15 years

Year	Human losses (in persons)	Damage Cost (in US$ millions)
2002	55	62.7
2001[41]	400	77
1999	6	n.a.
1998	419	97
1997	42	25
1996	41	15
1995	131	194
1994	10	n.a.
1993	504	1,000
1992	119	143
1991	40	29.4
1990	11	n.a.
1989		0.3
1988	25	n.a.
1987	347	n.a.
Annual Average	**154**	**164.4**

Calculations were based on information provided to the authors by the Ministry of Energy in January 2005.

To assess the economic value of human loss, deaths are converted into disability adjusted life years (DALYs). Each premature death represents 24 DALYs[42] and each DALY is valued following the methodology described in chapter 2. With a DALY value ranging from a lower bound of US$1,738 to US$10,456, the

[40] Caspian Environment Program Web site.

[41] Reference: DOE, 2004

[42] The number of DALYs lost per death (due to flooding) is assumed to be equivalent to the number of DALYs lost due to non-intentional injuries (such as fires, accidents, etc.). The latter is based on WHO tables (WHO, 2004). There are no statistics that track the age distribution of flood victims.

value of human losses per year (in terms of statistical life losses) resulting from floods ranges from US$6 million to US$39 million, with an average of US$22.5 million. Thus, the total annual average damage cost of flooding, in terms of human losses and damage to infrastructure, amounts to US$187 million (that is, US$164.4 million plus US$22.5 million). This should be considered a lower bound estimate because it is limited to assessed damage of surveyed floods.

Bearing in mind the complexity of flood-causing factors, allocating a damage cost to the responsibility of manmade activities in flood occurrence is difficult. However, it is believed that the dramatic increase in the number of floods over the last three decades is closely related to increased deforestation, which took place over the same time period. Estimating the impact of deforestation on increasing flood damage requires valuing the annual damage caused by floods and quantifying the impacts of deforestation on these damages. Neither of these steps could be completed, thus no estimate could be made.

Taking into consideration that the number of floods recorded in the 1980s and 1990s is more than five times the number recorded in the 1950s and 1960s and assuming that this five-fold increase is totally related to manmade activities (particularly deforestation), then one-fifth of annual damage can be related to natural causes and four-fifths to manmade activities. This would amount to US$150 million, four-fifths of US$187 million, (equivalent to IRR 1,190 billion or 0.13 percent of GDP).

5.6 TOTAL DAMAGE COSTS

Table 5.10 presents the environmental damage costs associated with land degradation in 2002. In total, the estimated cost totals US$ 1.9 billion (equivalent to IRR 15,430 billion or 1.7percent of GDP).

Estimates include cropland salinity, rangeland degradation, wetland loss and flood damage. The numbers are likely to underestimate total damage for reasons that follow. Erosion may also contribute to crop productivity declines and this has not been estimated due to a lack of data. Damage to wetlands includes only losses due to drought. It does not consider the damage caused by chemical pollution, organic loads and erosion. Finally, flood damage only refers to reported costs and deaths. Human and economic losses are likely to exceed the figures presented.

Non-oil growth in Iran requires careful land resource management. Estimates provided here are a pioneering assessment of the benefits that a conservation policy could have in the long run.

Table 5.10 Land: annual damage costs (mean estimate, 2002)

Impacts	**US$ millions**	**IRR billions**	**GDP %**
Cropland salinity	1,265	10,070	1.11
Rangeland degradation	170	1,370	0.15
Wetlands loss	350	2,800	0.3
Floods	150	1,190	0.13
Total	**1,935**	**15,430**	**1.70**

6. Deforestation and Forest Degradation

With 8,200 plant species, of which 1,900 are endemic, Iran is considered a unique country in terms of its plant diversity and genetic reserves (NBSAP, 2000). Climate diversity makes the country's forests heterogeneous, ranging from humid and semi-humid to semi-arid and arid. This forest diversity provides a wide range of benefits, including increased biodiversity value and water and soil conservation.

Despite these benefits, Iran's forests have been severely degraded during the last half century. Forest clearing for agriculture, firewood and charcoal production reduced drastically the forest area; while overgrazing and over-hunting are believed to be responsible for decreasing forest quality.

This chapter estimates the costs of deforestation and forest degradation in Iran. It first gives an overview of the country's forest sector, focusing on forest areas and functions, and on institutional and economic aspects (section 6.1). It then discusses the main problems affecting the country's forests (section 6.2). The estimates of the costs of deforestation and forest degradation are then presented (section 6.3) and summarized (section 6.4).

6.1 Overview of the Forest Sector

Forest cover in Iran is estimated at 12.4 million hectares, or about 7.4 percent of the country's area.[43] Per capita forest cover (about 0.2 hectares per capita) is close to the estimated average for the Mediterranean region, and is only one-third of the world average. Moreover, commercially usable forest area in Iran is only about 0.02 hectare per capita.[44] This scarcity is one cause[45] of the high rate of forest degradation in the country.

Five distinct forest regions are identified in Iran and shown in table 6.1:

- *Caspian (Hyrcanian) forests*, situated in the north, cover about 1.85 million hectares, or 15 percent of Iranian forests. They are humid forests and the only forests in the country suitable for industrial wood production.
- *Arassbaran forests*, located in the northwest, cover about 144,000 hectares - only one percent of total forest area - and comprise semi-humid forests. These forests are mainly used for fuel wood.
- *Zagros forests*, located in the west, cover about five million hectares, or 40 percent of the country's forest areas and comprise semi-arid forests. These forests are especially important for their protective roles (water supply, climate regulation, etc).
- *Irano-Touranian forests*, located in the central plateau, comprise the arid forests. They cover about 3.3 million hectares, or 27 percent of the forest area, divided into mountain and plain forest types. These forests are often highly degraded and sparse and are important for water and soil conservation.
- *Khalijo-Omanian vegetation*, located in the southern part of the country, makes up arid tropical forests and covers about 2.1 million hectares, or 17 percent of total forest cover.

[43] Forests and Ranges and Watershed Management Organization, quoted by the Statistical Centre of Iran, 2004.

[44] Calculated with reference to a total population of 65.4 million in 2002 (World Bank, 2004d).

[45] See Annex I, note 1

Table 6.1 Forest inventory data in Iran

Forest regions	*Forest area (000 ha)*	*Growing stock (m^3/ha)*	*Increment (m^3/ha)*	*Biomass (t/ha)*
Caspian	1,850	280	2-8	100-110
Arassbaran	144	40-55	0.7	n.a.
Zagros	5,000	14	0.4	8
Irano-Touranian	3,300	n.a.	n.a.	5
Khalijo-Omanian	2,100	n.a.	n.a.	2
Total	**12,394**	**n.c.**	**n.c.**	**n.c.**

Sources: Sagheb-Talebi *et al.*, 2004 for forest area, growing stock, annual increment; NBSAP, 2000 for biomass.
n.a. = not available; n.c. = not calculated

Since 1962, forests have been entirely owned by the state.[46] The Ministry of Agriculture (*Jehad-e-Sazandegi*) is responsible for forests, which are managed by its Forest, Range and Watershed Organization (FRWO). Forest management is based on plans, though they have been prepared only for the Caspian forests. At present, the area under management is about 1.3 million hectares (of which plans for 914,000 hectares have been activated) and the rate of forest utilization is about 1.46 cubic meters per hectare (Sagheb-Talebi *et al.*, 2004).

Forest contributions to the national economy are estimated at 1.6 percent of GDP for 2002 (SCI, 2004) – if only wood products are considered — compared to agriculture's contribution of about 12 percent (World Bank, 2004b). Such a difference is not surprising, however, considering that the gap can be even greater in other MENA countries.[47] Of course, wood represents only a small proportion of the total value of forests. A study of forest values in Mediterranean countries found that wood accounts for less than 15 percent of the total forest value in most eastern Mediterranean countries of the Middle East and about 35 percent of the total forest value in the northern Mediterranean (Croitoru and Merlo, 2005).

Forest policy in Iran aims at forest conservation through management, afforestation and community forestry. During the last decades, considerable attention was given to implementing afforestation, silviculture, road construction, and wood transport projects. However, forest policy has largely failed to conserve the country's forests: overexploitation of industrial wood by logging companies and of forests by rural communities (for fuel wood and grazing) has contributed to forest destruction (NBSAP, 2001b). Deforestation and forest degradation has occurred especially in the Caspian and Zagros forests, accounting for more than 55 percent of total forest area.

6.2 Deforestation and Forest Degradation

Understanding changes in forest cover is difficult because, as in other countries, the term "deforestation" has been used in different ways (Pagiola, 2000) to describe: the complete loss of forest cover; the reduction of tree crown cover below a given proportion of land cover (UN-ECE/FAO, 2000); and the loss of *primary* forest alone. This term is often used to describe the permanent (long-term) loss of forests but sometimes includes temporary losses as well. The term "forest degradation" has also been defined in several ways. Definitions generally refer to reductions in the productive capacity of forests (Watson *et al.*, 2000).

In this paper, data insufficiency makes it difficult to use a precise definition. However, in broad terms, **deforestation** is understood as a complete and long-term loss of forest cover. At the same time, forest **degradation** is defined as "changes within the forest class that negatively affect the stand or site and, in particular, lower the production capacity." Accordingly, degradation is not reflected in estimates of deforestation (FAO, 1995).

Deforestation in Iran is mainly caused by forest conversion to agricultural lands and other land uses, and clear cutting for wood. It is interesting to note that in Iran, unlike many other MENA countries, fires are not a major cause of either deforestation or forest degradation (box 6.1).

[46] Before 1962, 80 percent of forests were privately owned, however, the government decided what could or could not be cut (World Bank, 1994).

[47] See annex I, note 2

Though it is commonly agreed that deforestation has been a major threat to Iran's forests, there is no consensus on the extent of annual deforestation. FRWO data show[48] that from 1944 to 2000, total forest area diminished from 19.5 million to 12.4 million hectares. If these figures are realistic,[49] this is equivalent to an average deforestation rate of about 125,000 hectares per year, or 0.8 percent annually. This estimate should be regarded with some caution: the annual deforestation rate may vary considerably over a long period; therefore, the average rate calculated over a 57-year period does not necessarily reflect the deforestation rate occurring in most recent years (e.g. in the last 10 years).

Other deforestation figures are reported in relation to different forest zones: for instance, Caspian forests have shrunk from 3.4 million to 1.9 million hectares over the past 22 years, an average of 45,000 hectares per year (CEP, 2001a). In addition, the average deforestation rate in Zagros forests appears to be twice as much as that in the Irano-Touranian forests.[50] Based on the above-mentioned figures, this would correspond to a deforestation rate of about 54,000 hectares per year in the Zagros forest and 27,000 hectares per year in Irano-Touranian forests (table 6.2).

Table 6.2 Average annual deforestation per sub-region

Forest sub-region	*Deforested area (ha)*	*Percentage of sub-region forest area*	*Percentage of country's forest area*
Caspian	45,000	2.4	0.3
Arassbaran	n.s.	n.s	n.s.
Zagros	54,000	1.1	0.4
Irano-Touranian	27,000	0.8	0.2
Khalijo-Omanian	n.s	n.s	n.s.
Total	**125,000**	**1.0**	**1.0**

n.s. = not significant

In addition to deforestation, Iranian forests are largely affected by degradation. This is primarily due to past and present wood overexploitation, overgrazing, and sometimes over-hunting. These threats are found throughout the country, but with different intensities in each forest zone. For example, in Caspian forests, past wood overexploitation reduced forest biomass from 300 tons per hectare to about 100 tons per hectare (National Coastal Profile, 2001). Grazing is a major problem: about 4.4 million head of livestock graze in these forests and overgrazing now affects more than 52 percent of the Caspian forest area (Sagheb-Talebi *et al.*, 2004). According to their state of degradation, Caspian forests can be divided in three broad groups:

1. Very degraded forests: forests that cannot regenerate naturally and where the stand is less than 100 cubic meters per hectare (about 496,000 hectares).
2. Degraded forests: forests covered by young masses of saplings and whose stand is 100 to 200 cubic meters per hectare. Operations to replant these forests are needed (about 480,000 hectares).
3. Good and high quality forests: the stand exceeds 200 cubic meters per hectare (about 856,000 hectare).

In Zagros forests, firewood overexploitation and overgrazing have been major factors in degradation. Due to pasture land scarcity, more than 14.6 million livestock graze in forest areas (about 2.9 head per hectare of forest), endangering wildlife due to food shortages, soil degradation, and erosion (Sagheb-Talebi *et al.*, 2004).

[48] See Annex I, note 3

[49] See Annex I, note 4

[50] See annex I, note 5.

Box 6.1 Forest fires in Iran

Most fires in Iran are caused by arson. Other causes include land-use change, the carelessness of hunters and pickers, and opium and oil smuggling. The number of fires affecting both pastures and forests increased from 15 in 1982 to about 772 in 1995 (Alexandrian and Esnault, 1998).

According to Allard (2001), the most fire-prone provinces are Kordestan, Golestan and Khuzestan. Fires usually affect large areas of pastureland, and then extend into sparse forests. Fires that start in or around forests are usually surface fires and only seldom crown fires; among them, fires in coniferous forests are most significant.

The Bureau of Conservation and Protection's database (report 2340.54:83-05-03) reports that about 405 forest fires affect about 4,300 hectares per year (average during 2000-2003). More than 99 percent of this area is affected by surface fires, which do not cause either deforestation or degradation. Therefore, the annual losses due to forest fires could be considered practically nil. However, fires have increased over the past years (e.g. due to drought), thus they can become a serious problem in the future.

6.3 Costs of Deforestation and Forest Degradation

Forests provide a wide range of benefits, including direct-use values (timber, firewood, non-wood forest products, etc.), indirect use values (watershed protection, carbon sequestration), option, bequest, and existence values (biodiversity, potential future recreation). This section attempts to estimate the impact of deforestation and degradation on each forest benefit to the extent that data allow.

Valuation is based on a few assumptions. First, estimating the cost of deforestation assumes that all forest benefits on the deforested area are lost for a long-term period. This is a strong assumption, because in reality, deforestation affects forest benefits to different extents, depending upon the alternative forest uses.[51] Secondly, the paper focuses on *gross* losses without considering the possible benefits of alternative land uses that replace forests. Thirdly, the NPV of damage cost is calculated based[52] on a time horizon of 25 years and a discount rate of four percent, so as to allow comparability with the estimates in other chapters.

It should be noted that valuation efforts were subject to data constraints. In these cases, benefits transfer of estimates from other MENA countries with similar environments was applied. The following subsections present these estimates together with the valuation approaches used.

Costs of deforestation

(1) Direct use values

Timber. Timber is only important in Caspian forests. These forests have already suffered greatly from misuse. The potential mean annual increment (MAI), once about seven cubic meters per hectare, is now only three meters per hectare (National Coastal Profile, 2001). Therefore, valuation assumes that any hectare of deforested land today forgoes a potential sustainable annual harvest of three cubic meters per hectare. Considering that half of this figure is timber (and the rest firewood) with an average stumpage price of about[53] US$150 per cubic meter, this is equivalent to an annual loss of about US$225 per hectare of forest under management plan (an average of US$158 per

[51] Extractive benefits that rely on standing trees (timber, firewood) are likely to be lost completely. NWFP benefits may not be lost completely, however; some NWFPs may actually improve with less forest cover. Similarly, benefits such as watershed protection are likely to be only partially affected, as these benefits also depend upon soils, slope, and other factors. Assuming a complete loss of benefits is thus a strong assumption, likely to result to a certain degree of damage over-estimate. Lack of data prevents a more precise analysis.

[52] See annex I, note 6.

[53] All price estimates for timber and firewood are drawn from the expert opinion of M. Seifollahian, member of the High Council of Forests and Forestry Organization of Iran.

hectare of Caspian forests). This corresponds to an annual loss of timber of about US$10.1 million.

Firewood. Firewood overexploitation affects primarily Caspian forests, but also the Zagros and Irano-Touranian forests. Based on a rate of firewood overexploitation of about 1.5 cubic meters per hectare of Caspian forests and a stumpage price of US$30 per cubic meter, the annual future loss of firewood is about US$45 per hectare of Caspian forests.

It is assumed that in Zagros and Irano-Touranian regions, the potential sustainable harvest is the MAI. This is about 0.4 cubic meters per hectare for Zagros and about 0.7 cubic meters per hectare for Irano-Touranian. Using a stumpage price of about US$10 per cubic meter, the annual future loss of firewood is about US$4 per hectare in Zagros forests and about US$7 per hectare in Irano-Touranian forests. Applying these estimates to the deforested areas in each forest region, the total annual loss of firewood is about US$2.4 million.

Grazing and other NWFPs. Grazing and other non-wood forest products (NWFPs) are important forest benefits countrywide. However, no reliable data was found on these values. The literature includes a wide variety of estimates. Lampietti and Dixon (1995) reviewed a range of studies and found values as low as US$5 per hectare per year and as high as US$422 per hectare per year, with many studies clustering around a value of about US$70 per hectare per year (about US$80 per hectare per year in 2002 values). Here, we use the benefit estimated in Turkey of about US$20 per hectare per year (based on Türker et al., 2005), as it is more likely to be applicable to Iran's conditions (none of the studies found in Lampietti and Dixon's review is from the MENA region). Of this value, about US$15 per hectare is grazing benefit whereas US$5 per hectare is the value of other minor NWFPs such as mushrooms, medicinal plants and forest fruits. Based on these estimates, the total annual loss of grazing and other NWFPs on the deforested area in Iran is about US$2.5 million.

Hunting. No data were found regarding hunting benefits in Iran. Therefore, we use the hunting benefit estimated in Turkey, of about US$1 per hectare of forests (based on Türker et al., 2005). Valuation was based on hunting permit price and license fees. While hunting occurs only in designated areas within forests, this estimate represents an average value calculated in relation to the entire forest area. This explains its low value compared to other estimates. Accordingly, the annual loss of hunting benefits on the total deforested area is about US$125,000.

Recreation. There are few studies estimating benefits from recreation and eco-tourism in protected areas (forest parks) in Iran (see e.g. Sharifi, 2004). Based on the cost of travel approach, the recreational benefits in several forest parks were estimated at[54] US$6 per person per year. ICM (2000) reports an annual number of 3.3 million visitors to Iran's coastal areas of Mazandaran and Golestan. Assuming that half of the visitors enjoy the recreational benefits of forest parks and other protected areas, this is equivalent to an average benefit[55] of US$13 per hectare of forest in these areas. It is reasonable to assume that deforestation occurs in forest area that area likely to be less valuable – from a recreational point of view - than forest parks. It is therefore assumed that the recreational value of deforested area is likely to be 50 percent the value of forest parks –US$6.5 per hectare. Therefore, the annual loss of recreational benefits on deforested areas is about US$812,500.

Overall, the direct-use values lost annually to deforestation are about US$15.9 million.

(2) Indirect use values

Loss of plant nutrients. Physical valuation is based on two steps: (1) estimating annual soil

[54] Morteza Sharifi, Forest and Range Organization, Head Expert of Parks, personal comments, 2005

[55] Based on environmentally-managed forest areas (national parks, wildlife reserves, protected areas) of 176,800 hectares in Golestan and 586,000 hectares in Mazandaran provinces (CEP, 2001b).

loss due to deforestation, wood over-collection and overgrazing in forests; (2) estimating the quantity of nutrients lost annually in the quantity reported in step 1.

Soil erosion is a major problem in Iran, affecting about 43 percent of the country's area[56] (FAO, 1996, based on GLASOD database). Two estimates of annual soil loss were found: about one billion tons, reported by the World Bank (1995), and about 1.5 billion tons, given by FAO (1996). This paper considers conservatively the lower value. Various sources (e.g. FAO, 1996; NBSAP, 2001a) argue that deforestation is a major source of soil loss;[57] in particular, FAO (1996) indicates that wood overexploitation is the most significant cause of soil erosion in Iran and is responsible for about 46 percent of total erosion;[58] it gives other important causes as overgrazing (24 percent) and deforestation (23 percent). However, the source does not specify how these figures are calculated. In the absence of more detailed information, valuation in this paper conservatively assumes that deforestation contributes only about[59] 1.8 percent to soil erosion annually, about 18 million tons.

No comprehensive study was found regarding average nutrient content in soil in Iran. However, if we assume that soil nutrient content is similar to that of Turkey, about[60] 0.1 percent nitrogen (N), 0.15 percent pentoxide (P_2O_5) and 0.154 percent potassium (K_2O), the losses of nutrients is about 72,720 tons.

Monetary valuation is based on the substitute cost method (or the replacement cost method[61]), using as a proxy the cost of fertilizers that would be necessary to substitute for the loss of nutrients. Using an average market price of fertilizers of[62] US$0.1 per kilogram, the annual cost of substituting nutrients would be US$7.3 million.

Agricultural losses. Estimates for agricultural losses due to upstream deforestation were not found in Iran. However, a valuation study in Tunisia (Daly-Hassen and Ben Mansoura, 2005) estimated that forests contribute to an increase in annual agricultural benefits of about US$9 per hectare of cultivated land (based on the change in productivity approach); this corresponds to a protective value of about US$10 per hectare of forest in Tunisia. It should be noted that the protective value of forests ranges widely from site to site, depending upon factors such as climate and soil type. Therefore, this value should be regarded as a crude estimate for the average value of the forest protection function. Assuming that deforestation damage to downstream agriculture in Iran is similar to that in Tunisia, the annual cost of agricultural losses in Iran would total US$1.3 million.

Dam sedimentation. This impact has been covered in chapter 3.

Protection of water reserves. A study carried out by the Tarbiat Modarres University in 2000 (Mayan, 2000) estimates the benefits of protecting underground water reserves at: US$17 per hectare of Caspian forest; US$8 per hectare of Zagros forests; and US$37 per hectare in Irano-Touranian forests. Assuming these figures are realistic,[63] and using the deforested areas per each forest type, the total annual loss of water reserves protection would be about US$2.2 million.

Water purification. Mayan (2000) estimates the annual benefits of water purification at[64] US$87 per hectare in each forest region: the Caspian, Zagros, and Irano-Touranian. This results in an annual loss of water purification function due to deforestation of about US$10.9 million.

Damages due to floods. This is covered in chapter 5.

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[56] See annex I, note 7

[57] See annex I, note 8

[58] See annex I, note 9

[59] See annex I, note 10

[60] Environment Foundation of Turkey, 1995 quoted by Bann and Clemens, 2001

[61] See annex I, note 11

[62] See annex I, note 12

[63] See annex I, note 13

[64] See annex I, note 13

Carbon. Physical estimates of carbon losses are drawn from Iran's national communication to the United Nations Framework Convention on Climate Change (UNFCCC). They are based on the 1996 revision of the International Panel on Climate Change (IPCC) methodology. This methodology was used to prepare the country's national inventory of greenhouse gases, based on specific recommendations and coefficients. Accordingly, the net emissions of greenhouse gases from the forestry sector include:[65]

- CO_2 emissions from forests and other changes in the stocks of woody biomass (19.5 million of tCO_2) – correspond to the difference between CO_2 released from wood exploitation (industrial wood harvested from commercial forests in the Caspian region and fuel wood consumption from other forests) (about[66] 20.7 million tCO_2) and CO_2 uptake due to the increase in forest area by afforestation, tree plantation around villages and the establishment of parks and green areas (about[67] 1.2 million tCO_2).
- CO_2 emissions from forest conversion (11.9 million of tCO_2) – considers an annual conversion of about 45,000 hectares of commercial forest area with a resulting biomass change from 183 tdm/ha (before conversion) to about 10 tdm/ha (after conversion). The estimate is obtained[68] by aggregating the CO_2 amount immediately released from burning (about 9.3 million tCO_2) and that released through decay and decomposition (about 2.6 million tCO_2).
- Other non-CO_2 gas emissions from forest conversion through burning, totaling about 161,560 t CO_2-equivalent (tCO_2e).

Overall, net emissions are estimated to be about 31.5 million tCO_2e, or about 8.5 million tC (after applying the conversion factor of 0.27).

Monetary valuation is based on the shadow price method, considering average prices currently adopted by the carbon markets. A World Bank review of the state and trends of carbon markets found quantity-weighted average prices for Kyoto-compliant emissions reductions to be between US$12.9/tC and US$18.1/tC, depending on who took the risk of Kyoto not being ratified (World Bank, 2003b). Using the prices of US$13/tC and US$18/tC, the annual cost of carbon losses due to deforestation in Iran ranges from US$111 million to US$153 million. This paper uses the average value, US$132 million. This estimate already represents a stock value (NPV) linked to the present deforestation.

In summary, indirect use values annually lost due to deforestation total some US$153.3 million. Note that this estimate does not include damage due to dam sedimentation and flooding, covered in other sections.

(3) Option, bequest and existence values

Option value of pharmaceutical products. No estimate was found for Iran. Most efforts to value undiscovered pharmaceutical drugs have focused mainly on tropical forest ecosystems, with estimates ranging as closely as US$0.9-1.3 per hectare per year (Mendelhson and Balick, 1995) and as widely as US$0.01-21 per hectare per year (Pearce and Puroshothaman, 1995). Such estimates are scarce in most Mediterranean countries. The only estimate, of US$6.3 per hectare of forest, was found for Turkey (Ban and Clemens, 2001). Valued on the basis of the rent capture approach,[69] this estimate is similar to that provided for Mexico (Adger *et al.*, 1995). Applying this estimate to total deforested area in Iran, it results in an annual loss of US$787,500.

Biodiversity conservation. Mayan (2000) estimates the annual benefits of biodiversity conservation at[70] US$16 per hectare in Caspian forests, US$8 per hectare in Zagros forests and US$16 per hectare in Irano-Touranian forests. If these figures are realistic, it would result in an

[65] See annex I, note 14
[66] See annex I, note 15
[67] See annex I, note 16
[68] See annex I, note 17
[69] See annex I, note 14.
[70] See annex I, note 13

annual biodiversity value loss due to deforestation of about US$1.6 million.

Cultural value. Iranian forests are attributed cultural value for their traditional and historical significance. Mayan (2000) estimates the cultural value of US$2 per hectare per each forest type (Caspian, Zagros, Irano-Touranian). Accordingly, the total annual loss of forest cultural value on the deforested area would be about US$250,000.

Overall, deforestation results in an annual loss of about US$2.6 million of option, bequest and existence values (conservative estimate).

In summary, total annual losses (direct and indirect use values, option, bequest and existence values) due to deforestation are about US$ 171.9 million. This corresponds to an average loss of US$1,375 per hectare of deforested area (table 6.3).

Total annual losses comprise annual flows of damage costs (US$40 million) and the annual stock value of carbon (US$132 million). Using a social discount rate of four percent, the NPV of the annual flows for a time span of 25 years totals US$628 million. Adding the value of carbon, the total NPV of the deforestation cost is about US$760 million.

Table 6.3 Economic losses due to deforestation (US$ per hectare of deforested area per year)

Type of value	*Caspian*	*Zagros*	*Irano-Touran*	*Country average*[a]
Direct use values				
Timber	225	n.a.	n.a.	81
Firewood	45	4	7	19
Grazing	n.c.	n.c.	n.c.	15
Other NWFPs	n.c	n.c	n.c	5
Hunting	n.c	n.c	n.c	1
Recreation	n.c	n.c	n.c	6
Indirect use values				
Plant nutrients	n.c	n.c	n.c	58[b]
Agricultural productivity	n.c	n.c	n.c	10
Protection of underground water	17	8	37	18
Water purification	87	87	87	87
Carbon	n.c	n.c	n.c	1056[b]
Option, bequest, existence values				
Pharmaceutical	n.c	n.c	n.c	6
Biodiversity conservation	16	8	16	13
Cultural value	2	2	2	2
Estimated partial				1375[c]

[a] calculated in reference to: the deforested area in each region for timber, firewood, protection of underground water; total deforested area for the rest

[b] This estimate is a result of deforestation and other forest degradation

[c] Total does not add up exactly due to rounding.

n.a. = not applicable; n.c. = not calculated

Costs of forest degradation

At present, only 1.3 million hectares of forest in the Caspian Sea region are commercially exploited. In these areas, potential annual growth is estimated[71] at about 7 cubic meters per hectare, while actual maximum annual growth is about three cubic meters per hectare. The difference of four cubic meters per hectare is mainly a result of past wood overexploitation. If a degradation time span of fifty years is

[71] Dorostkar, 1988; quoted by the Caspian Environment Programme, website [accessed February 2004].

considered, this would translate into an average annual loss of MAI of about 0.08 cubic meters per hectare. We assume that the current over-harvest will reduce future MAI at the same rate as past over-harvest (about 0.08 cubic meters per hectare). This results in a total loss of 104,000 cubic meters annually (1.3 million hectares multiplied by 0.08 cubic meters per hectare). Considering an equal distribution between timber and firewood and an average stumpage price of US$150 cubic meters for timber and US$30 per cubic meter for firewood, this is equivalent to a total annual loss of about US$9.4 million (about US$7 per hectare of degraded forest).

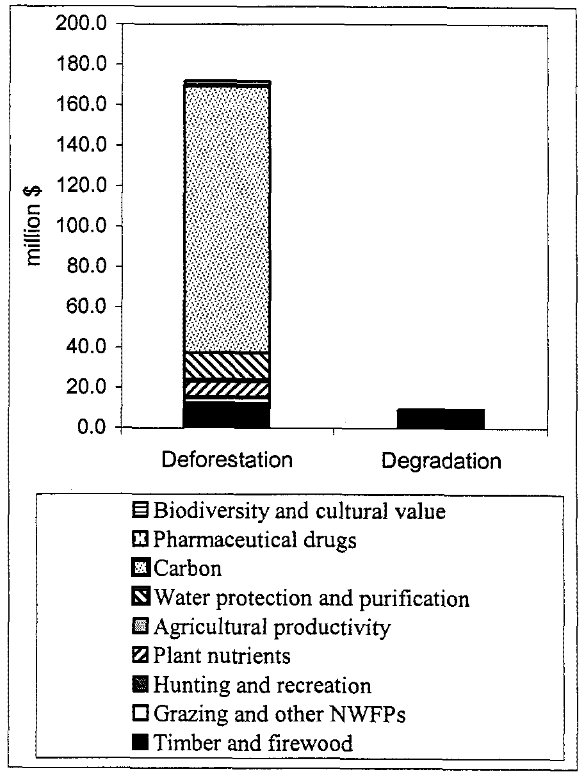
Using a social discount rate of four percent, the NPV of the damage cost (flow of benefits forgone in the future) resulting from a loss of 0.08 cubic meters per hectare of Caspian forest for a time span of 25 years totals US$147 million.

6.4 TOTAL DAMAGE COSTS

Estimated annual flows of damage costs are estimated at US$50 million and the annual stock value of carbon at US$132 million. Using a four percent social discount rate and a 25-year horizon the net present value of deforestation and forest degradation is estimated at US$906 million annually. Once again, the overall figure is an underestimate, since other important losses, such as floods and reservoir sedimentation, have not been included to avoid double counting. Were these values considered, the total annual cost of deforestation and degradation would increase to US$ 1.4 billion.

Even without considering these values, figure 6.1 suggests that losses of protective forest functions on deforested areas are more significant than timber and other extractive values. Among them, carbon loss alone stands out with about 73 percent of total annual damage. Such a high share is representative not only for the substantial annual damage as a global public "bad," but especially for being a stock value (much higher than the value of annual flows of other forest benefits).

Figure 6.1 Costs of deforestation and forest degradation in Iran



Overall, losses due to deforestation and forest degradation are felt differently by different segments of society: firewood and grazing are usually losses to forest users; water protection and purification and agricultural productivity are costs for downstream populations; recreation and biodiversity affect visitors; and carbon losses as a global public good affect the international community. This distributional issue has important policy implications in the country.

In summary, the NPV of damage cost from deforestation and Caspian forest degradation is about US$906 million (or IRR 7,212 billion or 0.80 percent of GDP).

7. Coastal Zones

7.1 Overview of Iranian Coastal Zones

Iran's geography includes 2,900 kilometers of coastline, which contribute to the climatic and unique natural complexity of the country. To the north, for 900 kilometers, Iran borders the Caspian Sea, a resource it shares with Azerbaijan, the Russian Federation, Kazakhstan and Turkmenistan. To the south, for 2,000 kilometers, it borders the Persian Gulf, one of the world's most strategic waterways due to its importance in world oil transportation, and the Oman Sea.

The Caspian Sea is the world's largest inner lake. The Iranian Coast includes three littoral provinces: Gilan, Golestan and Mazanderan whose dense forest and intensive rice cultivation provide a striking contrast to the dry plateau south of the Alborz range. The Caspian side of the Alborz is characterized by a multitude of valleys and rivers draining into the Caspian Sea. The area hosts a wide variety of landscapes, biodiversity and many recreational opportunities such as skiing and trekking, mountaineering and ecotourism in the sub-tropical coastal region.

While popular among Iranians, tourism in the Caspian does not attract many international tourists. Beach activities are limited: swimming and sunbathing are segregated according to gender due to Islamic law. A major economic activity is fishing. Iranian fisheries have been building a reputation for sustainable fishing, trying to keep up with the rapid depletion of sturgeon and bony fishes (particularly Kilka), the two main species present.

The Persian Gulf separates Iran from the Arabian Peninsula. The coast includes the provinces of Khuzestan, Bushehr, Hormozgan and Sistan and Baluchestan. Despite low precipitation, the climate is humid due to special climatic conditions, creating a unique environment. The Persian Gulf is populated by coral colonies and plant species crucial in the sustainability of global life. Mangroves provide breeding grounds for the incipient shrimp industry. Plants living on the seabed near the shore support turtles and other marine life. The area's natural beauty has attracted scientists and researchers, ancient civilizations – evidenced through remains – and a variety of biological species.

The Gulf constitutes a narrow water body. At its narrowest point (the Strait of Hormuz), the Gulf is only 34 miles wide. Its narrowness is inversely proportional to its strategic importance as a waterway for oil tankers. Nearly 90 percent of the Persian Gulf's oil transits the Strait of Hormuz and coastal areas and island territories in the Gulf have been long disputed by the countries in the area, the most famous of all being the Iraq-Kuwait conflict in the 1990s.

Major environmental disruptions along Iranian coasts have been triggered by massive, unrestrained urban and industrial development, the long Iran-Iraq War, which caused irreparable environmental damage, over-fishing and water infrastructure development.

The Caspian Sea area is among the most populous regions in Iran and the coastal area most subject to quantifiable economic costs. While degradation in the Persian Gulf is deemed high owing to oil operations, infrastructure development and wars, it is not possible to provide a monetary measure for it. This chapter concentrates on the Caspian coastal zones. Sections 7.3 to 7.5 quantify the cost of environmental degradation to fisheries in the Caspian. The next section describes qualitatively the situation in the Persian Gulf and Sea of Oman.

7.2 Pollution in the Persian Gulf and the Sea of Oman

Coastal pollution along the southern coast of Iran is one of the major causes of habitat destruction and biodiversity reduction. Estuaries and coastal wetlands such as mangrove forests are very vulnerable to water pollution. Habitat fragmentation is an increasing problem in the coastal regions. Wildlife sites have become fragmented because of increased coastal development, effectively removing and fragmenting scarce habitats. Major sources of coastal pollution include the ballast water of oil-tankers, off-shore oil exploration facilities, heavy metal pollution caused by import and export activities and thermal pollution from the return water in cooling systems of large industrial facilities (such as power plants).

Industrial pollution. Heavy industries are major contributors to the pollution load in the marine environment and are the main source of the chemical oxygen demand pollution load. Light industries include agricultural and livestock production and food and beverages, which are contributing generally to the bio-chemical oxygen demand loads. The refinery in Bandar Abbas is known to be the largest refinery in the world. Some of Iran's largest heavy industry plants are located in five industrial complexes and five cities in the Karun basin. The amount of industrial effluent discharge varies from 0.03 cubic meters per hour for Fakr Khorramshahr chemical company to 14,640 cubic meters per hour for the Abadan refinery, which discharges waste into the Arvand River. The most polluting industries in order of quantity of industrial sewage discharged into the Karun Basin are cellulose-processing industries, chemical and petrochemical plants and, most significantly, food processing and steel industries.

Residential pollution. About 151.7 million cubic meters per day of sewage enters the Karun and Dez rivers by cities. The contamination load ranges from 277 tons per year for nitrates to 448,500 tons per year for total dissolved solids.

Oil pollution. About 1.2 million barrels of oil are spilled into the Persian Gulf and Sea of Oman annually. The level of petroleum hydrocarbons in the area exceeds that in the North Sea. Oil pollution may be found anywhere in the marine environment and results from operational discharges due to shipping, river run-off, natural seeps, atmospheric inputs, coastal refineries, the petrochemical industry, offshore operations and tanker accidents. Such inputs are a great threat to the marine environment. Major fishing grounds are near oil production areas and transportation routes. Destruction of spawning grounds and nurseries are one of the major threats to biological resources in the Persian Gulf and the Sea of Oman.

Finally, over-fishing and illegal fishing by international fishing vessels is a major source of concern. Limited bottom trawling is still used for shrimp catches, which seriously threaten seabed habitats.

7.3 THE CASPIAN SEA

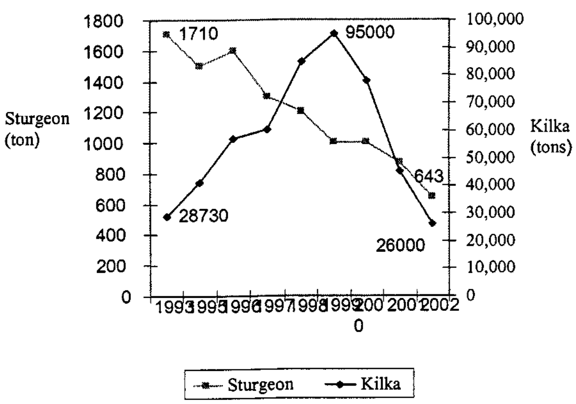
The Caspian Sea is the largest inland water body in the world. The total length of the Caspian coast is nearly 6,380 kilometers and is shared between five countries; Iran (992 kilometers) and four nations of the Commonwealth of Independent States, the Russian Federation, Kazakhstan, Turkmenistan and Azerbaijan.

About 130 rivers of various sizes drain into the Caspian with an annual freshwater inflow of about 300 cubic kilometers (km^3). The main tributary is the Volga River in Russia (80 percent of the total volume of inflow) while Iran's rivers contribute an inflow of four to five percent (CEP, 2002b).

About 130 fish species inhabit the Caspian Sea. Fish resources are commercially divided in two groups: sturgeons and bony fishes. The bony fishes are divided into kilka and other species. Fisheries in Iran have put a great emphasis on the sustainability of the resource. The department of fisheries has established clear regulations on fishing methods and conducts regular monitoring. However, declines in the fish stock have been dramatic and large amounts of money are spent every year to sustain the fish population through artificial breeding. The causes of degradation are linked to a lack of international cooperation and enforcement, leading to poaching, construction of infrastructure and man-driven introduction of invasive species (particularly for kilka fish).

This report focuses on sturgeon and kilka, the two fisheries that have experienced the most dramatic decrease in annual recorded catches over the past decade (figure 7.1). Recorded sturgeon catches have declined from 1,710 tons in 1993 to 643 tons in 2002. Kilka catches have tripled from 1993 to 1999, collapsing in the three years following.

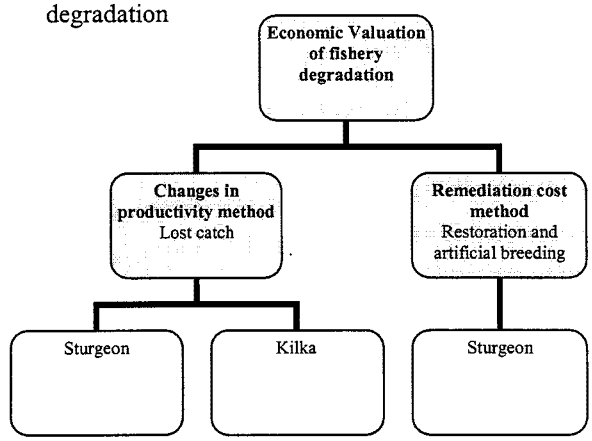
Figure 7.1 Iranian Sturgeon and Kilka Production in the Caspian Sea (in tons)



Source: SHILAT, 2002

Quantifying the economic cost of fishery degradation. To value the monetary impact of a fishery collapse, two major types of information are important (figure 7.2). Firstly, degradation means lost catch. There is a direct impact upon fishing income derived from a shrinking fishery. This approach is often referred to as "change in productivity" and is similar to the valuation method used to quantify losses in agricultural yields. Often the impact of degradation is partly masked by a government's intervention to remedy the damage. This is the case in Iran, where the department of fisheries has spent large amounts of money in fisheries restoration and artificial breeding. This approach is often referred to as the "remediation cost" method.

Figure 7.2 Economic valuation of fishery degradation



7.4 THE STURGEON FISHERY

In Iran, the sturgeon fishery is a government monopoly managed by the Iranian State Fishing Company (SHILAT). Sturgeons, which spawn in the rivers of the Caspian basin, are the most economically valuable fishes. The caviar derived from sturgeon roe is one of the most expensive products, by weight, on the world commodity markets. Market prices range from US$35 to US$75 an ounce depending upon source and type of sturgeon. Iranian Beluga[72] caviar is the most expensive.

Threats to the Sturgeon fishery. The most pressing threat for sturgeon is widespread poaching throughout the Caspian to feed the international demand for caviar. The collapse of the Soviet Union meant the dismantling of its centralized fishing authority and the formation of the newly independent states. This led to the development of large-scale, organized poaching, considered to be one of the main factors responsible for the dramatic decline in officially-recorded catch in the CIS as well as in Iran (figure 1). Uncontrolled poaching in the Caspian has devastated sturgeon populations that were already in decline. Despite efforts to develop regulations for sturgeon catches in the Caspian Sea basin, an international agreement between the four former Soviet republics and Iran has not yet been signed. Sturgeon poaching in the newly

[72] Beluga is the largest sturgeon species in the Caspian.

independent states increased dramatically, often resulting in poor-quality caviar since female sturgeons are caught at a very early age. Markets in the United States and Europe have experienced a detrimental rise in illegal trade accompanied by a decrease in product quality (Abdolhay, 2005).

Poaching arises largely due to the lack of job opportunities in coastal areas, combined with the presence of illegal networks of caviar exporters. It is estimated that poachers take about 12 times the volume of the officially recorded catch in the Caspian Sea. The sturgeon catch in the Caspian Sea has declined from 25,000 tons per year to 1,000 tons. Russian specialists believe that illegal fishing increases the official catch by a factor of eleven – by a factor of eight offshore and by three times for rivers (CEP, 2002b).

Sturgeons are also under stress due to natural habitat degradation including (CEP, 2002b):

- Reduced access to spawning sites beginning in the 1930s – caused by the construction of weirs, mostly for agricultural purposes, followed by the construction of large dams on Russia's Volga River in the 1960s and on the Kura (Azarbaijan) and Sefid Rud rivers in the early 1970s. Up to 90 percent of Beluga spawning grounds are estimated to be lost due to dam construction in rivers.[73]

- Destruction of natural spawning grounds due to quarry operations such as gravel and sand mining; stabilization of river banks and construction of pumps for agricultural development.

- Chemical and organic pollution from industrial activities and oil exploitation as well as agricultural (pesticides and fertilizers) sources. Pollution has accumulated in some parts of the sea (such as in Baku, Azerbaijan). As a response to pollution, reduced reproductive capability has been noticed.

Being a migratory species in the Caspian Sea, habitat degradation and poaching activities in one country affect sturgeon catches in other countries. The Caspian Sea sturgeon fisheries may follow the destiny of the sturgeon fisheries of the Black Sea and North America. The World Wildlife Federation already designated the Beluga sturgeon the fourth most endangered species on earth (CEP, 2002b).

There are two monetary impacts arising from the sturgeon fishery collapse. The first one is linked to the lost fish catch. If over fishing and coastal degradation had not occurred, fish catch in 2002 would be higher. This is accounted for in the next paragraph. The second impact is the remediation effort undertaken by the government to sustain the fishery through fingerlings release. If this mitigation had not taken place, the catch levels would be even lower, so the cost paid by the government must be taken into account as well.

Quantifying the lost catch. To value sturgeon fishery degradation, it is necessary to quantify lost yearly catches. If degradation had not occurred, catches under sustainable fishing would be at a higher level. We call such levels the "potential" maximum sustainable yield. The difference between this and the actual yield will give us the lost catch.

No data are available on the potential sustainable annual sturgeon catches without natural habitat degradation in the Caspian and without poaching activities. However, based on statistics, the annual catches in Iran from 1978 to 1990 averaged 2,000 tons (Taghavi, 1996). Going back in time, catches were at even higher levels. In the 1960s, annual catches in Iran increased continuously, reaching a peak of 3,000 tons just before the construction of the dam on Sefid Rud River in 1971 (CEP, 2002b). Major natural habitat degradation in the Caspian (mainly through dam construction) took place in the 1960s and early 1970s, resulting in lower fish yields, thereafter.

[73] The reproduction of Beluga occurs in these rivers: Volga and Terek (Russian Federation), Ural (Khazakhstan), Kura (Turkmenistan) and Sefid Rud (Iran), with the Volga being the most important.

The 2,000-ton yield is considered the lower bound estimate of the "potential maximum sustainable yield." It already incorporates the 1960s and 1970s degradation from infrastructure development into spawning grounds. The 3,000-ton yield is considered an upper bound for sustainable yield. It is the yield that would have been possible without infrastructure development. As a result, an average of 2,500 tons per year will be used as our "best estimate" of potential annual sustainable sturgeon catches. Under this consideration, the loss of sturgeon catch for 2002 would be 1,857 tons (2,500 minus 643).

The average percentage of caviar production out of meat production is assessed at 15 percent (based on Keiwan, 2003). This is equal to a loss of 278 tons of caviar for 2002 (1,857 tons multiplied by 15 percent). At an average export price of US$533 per kilogram, this results in a loss of US$148 million.

Measuring remediation costs. Numerous sturgeon hatcheries were created as mitigation for lost spawning habitat as a result of dam construction in the former Soviet Union and Iran (Sefid Rud, Gorgan Rud and Tajan rivers). Artificial breeding of sturgeon species and fingerlings release started in Russia in 1955. In Iran, the process began in 1972. The production and release of sturgeon fingerlings continued with the establishment of eleven centers in Russia and three hatchery centers in Azerbaijan and five in Iran. Hatcheries played a crucial role in the rehabilitation and restoration of sturgeon stocks. Based on expert opinion from the Iranian Fisheries Department at the Ministry of Agriculture and Jihad, 85 percent of Iranian sturgeon catches are related to fingerlings release. As an average, the survival of hatchery-produced fingerlings to the commercial fisheries is estimated at one to three percent. The production cost of each fingerling is US$0.50 (Abdolhay, 2005). No data were available on sturgeon fingerlings release for 2002. Therefore, the average annual release for the last recorded years, 1997, 1998 and 1999, has been used here. The average release during these years was 22 million fingerlings (CEP, 2002b). This results in a total cost of US$11 million. This amount is considered a reflection of the losses resulting from habitat degradation and poaching activities.

7.5 THE KILKA FISHERY

While economically less important than sturgeon, kilka, a species of bony fish, is a major contributor to Iranian fish production and a key element in the sturgeon food chain. Kilka species have been fished in Iran since the early 1970s, but the boom in catches was experienced only in the past decade when there was a major expansion in the kilka fishing fleet.

Threats to the kilka fishery. The kilka fishery is threatened by the comb jelly, *Mnemiopsis leidyi*, an invasive species introduced by humans. It arrived in the Caspian in the late 1990s, carried by the ballast water of ships traveling the Volga-Don canal, linking the Black Sea to the Caspian Sea. The invasive species spread through the entire sea and is most concentrated along the Iranian coasts. The comb jelly grows quickly (being able to double its size in one day), reaches maturity in two weeks, and reproduces rapidly.

Following the invasion of the comb jelly, the kilka fish catch deceased dramatically since 2000 (figure 1). The catch of 2001 and 2002 present 76 percent and 44 percent of the average annual catch between 1993 and 1999.

Quantifying the lost catch. As with sturgeon, an assumption has been made about the potential maximum sustainable yield of kilka had degradation not occurred. This is estimated as the average annual catch of kilka between 1993 and 1999, that is, before the introduction of the comb jelly. The level calculated is equal to 61,000 tons. As a result, the loss catch of kilka in 2002 amounts to 35,000 tons (61,000 minus 26,000 tons). Assuming an average wholesale price of US$0.20 per kilogram, this results in a loss of US$ 6.8 million.

7.6 TOTAL DAMAGE COSTS

Based on the above, the damage cost to Iran resulting from natural habitat degradation and poaching activities in the Caspian region as well as the manmade introduction of an invasive species amounts to US$166 million for 2002 (or IRR 1,323 billion or 0.15 percent of GDP). This figure represents the damage cost of degradation in the Caspian Sea and its river sources for 2002.

Table 7.1 Annual damage costs of fishery degradation (mean estimate, 2002)

Category of loss	US$ millions	Rials billions	GDP percentage
Sturgeon – lost catch	148	1,179	0.13
Sturgeon – remediation costs	11	88	0.01
Kilka – lost catch	7	56	0.01
Total	**166**	**1,323**	**0.15**

The results presented here are considered in light of two important caveats.

The table does not include the losses of non-timber forest products related to mangrove and coastal environment degradation. It does not consider recreation losses. It does not measure the loss of existence values. It is difficult to quantify such impacts. Moreover, the report does not consider the lost ecosystems in the Persian Gulf, where degradation from oil activities and infrastructure development may be high. Thus, the results presented here are to some extent an underestimate of damage.

Another important caveat is that the cost of degradation cannot be imputed totally to Iranian activities. Poaching activities appear to be more prevalent in the Commonwealth of Independent States than in Iran. The degradation of spawning grounds for sturgeon is more relevant in terms of area degraded in the CIS. Thus, assigning a portion of this cost to Iran is difficult.

8. Waste and Climate Change

8.1 Waste Sector

Municipal waste. Approximately 53,000 tons of waste is produced daily in Iran. (equivalent to 20 million tons per year). Average daily waste production in the country was 0.82 kilograms per capita in 2002 (DOE, 2004). Waste generation varies across the country. Some provinces, such as West Azerbajian, generate up to 1.4 kilograms per capita per day, while others, such as Khoozastan and Booshehr, generate as little as 0.4 kilograms per capita per day.

Collection rates in large cities with populations over 500,000, have improved significantly over the past decades to reach 90 and even 100 percent collection. Smaller urban cities with populations of 25,000 to 500,000 inhabitants have a collection rate averaging 70 percent.[74] Collection rates in rural areas range from 50 to 60 percent. This rate depends upon the village as some are estimated to have 100 percent collection rates whereas others have 40 percent.

The damage cost, or cost to society of inadequate waste collection and street cleaning can be estimated by the willingness to pay of individuals and communities for improved waste collection services. In the absence of any study in Iran on the WTP to improve waste collection and street cleaning, damage cost estimates are based on studies in other countries. Altaf and Deshazo (1996) estimate households' WTP for improved waste collection in Gujranwala in Pakistan using a contingent valuation method they surveyed nearly 1,000 households in 1990. Of the households surveyed, 71 percent were willing to pay an average of 11.2 rupees (US$0.52) per household per month. Adjusting this figure to 2002 prices and accounting for GDP per capita differentials between Pakistan and Iran, this results in a WTP of US$3.30 per household per month for 2002.

Another study by Belhaj (1995) assesses households' WTP to improve waste collection and street cleaning in the cities of Rabat and Salé in Morocco. An average WTP of Dh 40 (US$4.70) per household per month. Adjusting this figure to 2002 prices and accounting for GDP per capita differentials between Morocco and Iran, this results in a WTP of US$7.30 per household per month for 2002.

A lower bound of US$3.30 per household per month and an upper bound of US$7.30 will be used to evaluate households' WTP to improve waste collection and street cleaning in Iran. These adjusted WTP were applied to the portion of the population without adequate waste collection. It was applied to five percent of households in large urban cities, 30 percent of households in smaller urban cities and to 45 percent of rural households. It should be noted that when waste collection is inadequate, it impacts not only households without collection, but also their neighborhoods. This is because the resulting increase in odors, rodents and insects affects everyone. However due to a lack of data on the extent of the population affected, this analysis will be limited to the population estimated to be without adequate waste collection.

Based on the methodology described above (and described in greater detail in annexes II and III), the total willingness to pay to improve waste collection and street cleaning in Iran is estimated to range from US$145 million to US$325 million per year (or an average of IRR 1,872 billion or 0.21 percent of GDP) in 2002.

Hospital waste. Average daily hospital waste production in Iran ranges from 390 to 470 tons per day (DOE, 2004). Average daily per capita waste production is about 10.4 grams, with people in Kordestan province producing the highest amount of waste (49 grams per capita per day) and the people of Ilam province producing the least (2 grams per capita per day).

[74] According to the opinion of waste expert at the World Bank in March 2005

Nationwide, about 58 percent of hospital waste is buried. Thirty percent of it is stored and incinerated and seventy percent is only stored (DOE, 2004). Due to a lack of data, it was not possible in the course of this study to assess the potential environmental damage resulting from improper storage and disposal of medical waste.

Industrial waste. Industrial waste production has grown rapidly over the past decades. Waste production doubled between 1995 and 2000. In 2000, the total amount of industrial waste generated by industrial workshops of ten or more employees reached eight million tons (DOE, 2004), representing an average of 22,000 tons per day. The iron and steel industries are the largest producers of industrial waste. Some waste is stored inside facilities, while some is transported to dedicated disposal sites. A lack of information regarding industrial waste disposal and the extent of treatment has prevented computation of a damage cost for this study.

Landfills. Most municipal waste generated in Iran is sent to landfills that are generally well managed, but designed with few environmental considerations. For the purpose of this report, a comparison between the costs of landfills "with" and "without" taking into consideration environmental concerns will be done. The difference in cost is then applied to municipal waste generated to reflect the incremental cost to avoid environmental damage.

The first landfill considered is the one currently serving the Greater Tehran area. It is located at *Kahrizak,* thirty kilometers from the city center. The landfill can accommodate all waste generated in the city. The gate fee is estimated at about US$1 per ton. This fee includes waste reception, waste dumping and minimal soil cover. The fee excludes the price of land and any profit generated.

The current landfill in *Kahrizak* is expected to reach its maximum capacity by the end of 2006. Therefore the Organization for Waste Recycling and Composting (OWRC) has commissioned a feasibility study to select an alternate site and prepare a technical design.[75] The proposed new site will be located in *Houshang* about sixty to seventy kilometers from the city center. It has the capacity to receive three million tons of waste per year and a lifetime of approximately fifteen years. It has been designed as a simple, cost effective landfill that meets environmental concerns. The proposed landfill will include basic landfill design, a bottom liner (to control leachate and avoid polluting the surrounding environment), a leachate collection and treatment system, a gas collection and treatment system, replanted vegetation, site closure, aftercare requirements and operation, and site supervision and monitoring. The gate fee resulting from these investments and operation is about US$5.70 per ton of waste.

The difference between the gate fee of the current landfill that does not address environmental concerns and the proposed new landfill that incorporates environmental concerns is about US$4.70 per ton of waste. This difference represents the incremental investment cost to minimize environmental damage. Although it does not assess the direct damage costs resulting from "unsanitary" landfills, this difference provides an approximation of the cost of protection and will be used as a proxy for damage costs. This difference was applied to total municipal waste generated yearly in Iran. The result is about US$90 million per year (or IRR 730 billion). The following observation should be warranted: given the rough nature of this estimate, it is recommended that even further analysis be undertaken to assess the damage cost of "unsanitary" landfills on the environment.

Loss in recreational value in the northern provinces. The three northern provinces: Gilan, Golestan and Mazandaran are important from a touristic point of view. It is estimated that about five million visitors from other parts of the country make a trip every year to one of these

[75] BC Berlin. 2004. "Tehran Solid Waste Management Project: Landfill Preparation Study, Final Report," prepared for the Organization for Waste Recycling and Composting (OWRC) and the World Bank.

provinces.[76] Tourists are attracted to these provinces since they are well located, the landscape is interesting and the area is historically important. The provinces also have a good climate and border the Caspian Sea to the south and the Alboz Mountains to the north. However, in recent years, some two million tons of solid waste has been dumped onto riverbanks, near the sea or in the nearby forested areas (Sabour, 2002). Leachate from the waste, with high levels of BOD and COD, now pollute surface water. Groundwater is also at risk from contact with a contaminated plume[77] spreading from polluted surface waters and upper soil layers. Pollution of water bodies is impacting aquatic life (Sabour, 2002). The "spoiled" environment is beginning to impact decisions to visit the area. During preparation of this study, a few informal interviews were conducted among visitors to the Caspian area and a strong willingness to pay a premium to avoid further environmental degradation was expressed. However no formal study or survey has been conducted to assess the impact of the decline in "environmental quality" on domestic tourism and related revenues.

A study conducted in the Tropical North Queensland in Australia, which is primarily a nature-based destination for both domestic and international tourists, revealed that a decline in the region's environmental condition from "unspoiled" to "somewhat spoiled" could result in a decline in visitor expenditure by thirty percent (Huybers and Bennett, 2003). Applying a similar scenario to the three northern provinces of Iran, one could assume that the impact of "somewhat spoiling" the environment through waste dumping could result in a decrease in visitor expenditure in the range of ten to twenty percent (a range lower than thirty percent has been applied to reflect the fact that the northern provinces are not exclusively nature-based destinations).

[76] Reference: Annual Statistics of the provinces of Mazandarn, Gilan and Golestan for 2001-2002.

[77] A plume is a well-defined, usually mobile, area of contamination found in surface or groundwater.

Using an average expenditure of US$35 per day and an average time spent of three days per trip. That would result in a potential revenue decline ranging from: US$50 million to US$100 million annually.

Table 8.1 summarizes various impacts associated with sub-optimal waste management practices and their associated damage costs. However, as noted previously, damage associated with the limited treatment and disposal of industrial and hospital waste has not been included in the analysis. It is therefore expected that these results are likely to underestimate total damage costs.

Table 8.1 Waste: annual damage costs (mean estimate, 2002)

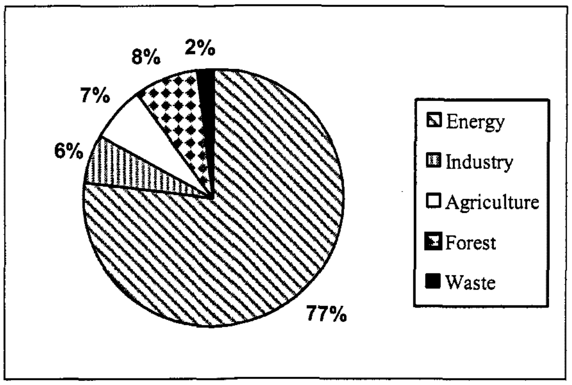
	US$ millions	Rials billions	GDP percentage
Municipal waste collection	235	1,870	0.21
Unsanitary landfills	92	730	0.08
Waste dumping in Northern provinces	80	630	0.07
Total	**407**	**3,230**	**0.36**

8.2 Global Impact from CO_2 Emissions

The international community has become increasingly concerned that certain gases released into the atmosphere – CO_2 often the largest – are causing an increase in global temperatures. The latter is then likely to result in sea-level rise, increased drought frequency, melting glaciers, and other environmental changes.

Greenhouse gas emissions in 1994. Iran prepared a national inventory of both direct greenhouse gases (CO_2, CH_4, N_2O) and indirect greenhouse gases (NOx, CO, NMVOC) for 1994 (UNDP, 2003). Accordingly, total CO2 emissions from different sectors were about 342 million tons. Total CO_2 equivalent emissions were estimated at 405 million tons. As an oil producing country, Iran emits large amounts of greenhouse gases in the energy sector. Figure 8.1 shows the contribution of each sector to CO_2–equivalent emission.

Figure 8.1 Greenhouse gas emissions in CO_2 equivalent in 1994



Greenhouse gas emissions in 2002. Based on projections in Iran's National Communication to the United Nations Framework Convention on Climate Change (UNDP, 2003), total CO_2 equivalent emissions are expected to reach 645 million tons in 2002. Since the impact of carbon released from the forest sector was computed in chapter 6, the contribution of the forestry sector will be deducted from the total to avoid double counting. Therefore, total CO_2 equivalent emissions in 2002 (without the contribution of the forest sector) are estimated at 609 million tons (or 164 tons of carbon, since each ton of CO_2 contains 12/44 tons of carbon).

How are these emissions affecting climate change? Are 100 percent of Iran's emissions increasing global warming? Or are emissions from Iran such a small portion of global emissions that they cause negligible damage? For purposes of the current study, the latest recommendations from Kyoto (requesting a 60 percent reduction in current global CO_2 emissions) will be applied to Iran. Therefore, about 365 million tCO_2-equivalent (or about 100 million tons of carbon) will be considered to be "damaging" the environment.

Monetary valuation. Monetary valuation is based on the shadow price method, considering average prices currently used in the carbon markets. A World Bank review of the state and trends of carbon markets found quantity-weighted average prices for Kyoto-compliant emissions reductions to be between US$12.9/tC and US$18.1/tC, depending on who took the risk of Kyoto not being ratified (World Bank, 2003). Using the prices of US$13/tC and US$18/tC, the annual damage cost of carbon emissions is estimated from US$1.3 billion to 1.8 billion (or approximately IRR 12,300 billion or 1.36 percent of GDP)

It's important to note that the above damage resulting from CO_2 emissions – and hence climate change – are likely to be at a global and not a local level. For this reason, they are kept separate from the estimate of environmental degradation presented in other sections of this report.

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Annex I

Notes related to the Forest Chapter

(1) Actually, the situation is more complex: besides being scarce, most forests and their benefits are publicly owned. Therefore, forest users, most of whom are poor, have little incentive to conserve forests. Rather, they prefer short-term benefits such as clear-cutting for wood, overgrazing and conversion to agriculture. The institutional and regulatory framework is quite weak, thus enforcement measures to limit illegal activities are rarely applied. This overexploitation usually results in a high rate of forest degradation and depletion. This phenomenon is common in most MENA countries.

(2) For example, in Turkey, the forestry contribution is only 0.5 percent of GDP, compared to agriculture's 13 percent contribution (Turker *et al.*, 2005).

(3) Meanwhile, FAO (based on official national sources) reports no annual forest change between 1990 and 2000. This figure is explained by very broad descriptive assumptions: plantations are reported to have increased and deforestation of natural forests is assumed to be low (FAO, 2003). Considering the recognized importance of the deforestation issue in Iran, a zero deforestation rate would be surprising.[78]

(4) Some local experts argue against the reliability of the 1944 inventory and sustain that the current annual deforestation rate is about 50,000 hectares per year, or 0.4 percent per year (Sagheb-Talebi, 2004, personal comm.).

(5) The NBSAP (2000) reports that Zagros forest area has fallen from 12 million hectares to 5.5 million hectares over the last fifty years; if these figures are correct, then the average deforestation rate in Zagros forests alone would be about 140,000 hectares annually. The same report also shows that in the Irano-Touranian forest region, the area covered by juniper forests (*Juniperus polycarpus*) diminished from 3.4 million hectares to 500,000 hectares over the last fifty years; this corresponds to an average annual deforestation rate of about 60,000 hectares for this forest type. These figures are considered too high to be considered for the most recent period. Calculations consider the ratio of average deforested areas between the two types of forests.

(6) It usually considers the impacts of deforestation and forest degradation on both current and future generations.

(7) Of which two percent of the country's area is affected by strong erosion, 15 percent by moderate erosion, and 26 percent by light erosion

(8) Overgrazing in high stocking areas has resulted in serious erosion and loss of vegetation and soil in many parts of the Caspian area which are now sensitive to desertification (Caspian Environment Programme, 2000, 2002a). Soil erosion in the Zagros mountains has increased from 2 to 3 tons per hectare to approximately 10 tons per hectare over the past several decades (GEF/UNDP, 2001). Forest conversion to agriculture and overgrazing in forests are the main causes of soil erosion in this region. A study assessing soil erosion and sediment yield processes in Rose Chai sub-catchement of Western Azerbaijan shows an annual erosion rate ranging from 3.5 tons per hectare per year to 7 tons per hectare per year (Najmoddini, 2003).

(9) In fact, this is the highest share among all Central Asian countries (FAO, 1996).

(10) Following FAO estimates, 46 percent of total soil loss is due to deforestation, or 460 million tons per year. But this erosion is the result of all past deforestation (of 7.1 million

[78] The difference may be due partly to the use of different forest areas. FAO gives a figure of about 7.3 million hectares, or 4.5 percent of the country's area.

hectares). We assume that new deforestation would increase erosion in proportion to the area affected. Annual deforestation of 125,000 hectares would increase deforested areas by 1.8 percent.

(11) The replacement cost method values environmental damage using the cost of replacing lost ecosystem services: either the cost of restoring the ecosystem so that it once again provides the service, or the cost of obtaining the same service in another way (as in this case: using artificially applied nutrients to replace lost soil nutrients). One should be aware of the limitations of this valuation method. Using it to estimate the value of an entire ecosystem results in an underestimate of the damage, as replacements rarely replace all services coming from the original ecosystem. However, when it is applied to estimate the value of a specific service, it usually results in overestimates. The replacement cost method is generally considered to provide valid estimates as long as (i) the replacement service is equivalent in quality and magnitude to the ecosystem service; (ii) the replacement is the least costly way of replacing the service; and (iii) people would be willing to pay the replacement cost to obtain the service (Shabman and Batie, 1978). However, few have verified whether these conditions hold (and indeed we are unable to do so here). Despite these caveats, in this particular case, we believe our estimate can be taken as a conservative estimate or minimum value of the damage caused by erosion, because: (1) we are conservatively assuming that only about one percent of all erosion is due to forest-related causes; and (2) this valuation only takes into account nutrient losses, without any effort to estimate other erosion damage.

(12) The estimate is based on the f.o.b. price of fertilizers supplied by Iran on the world market of about US$95 to US$107 per ton (IFDC, 2002). The resulting estimate is low if compared to the average price of fertilizer in Turkey, which ranges from US$0.45 per kilogram to US$2 per kilogram (Bann and Clemens, 2001).

(13) The estimates seem quite high; however details of their calculations were not provided, therefore, we are not able to assess their validity.

(14) Aside from the figures reported below, Iran's national communication reports under the heading "GHG emissions from forestry sector" two additional estimates: about 0.46 million tCO_2 as net emissions from the conversion of pastures, farmlands and other managed lands (other than forests); and a figure of 0.47 million tCO_2 as net uptake from the spontaneous regeneration of grasslands as a result of the abandonment of managed lands such as farmlands, orchards, pastures, and other lands (other than forests). As they are not referring to forests, these estimates are not considered in this chapter.

(15) The report gives no explanation of how this estimate was calculated. It only specifies that it refers to all legal and illegal harvest of industrial wood from commercial forests and fuel wood from other forests. However, it corresponds to an annual emission of about 5.6 million tC, or about 0.45tC/ha of forests. This coefficient is relatively high if compared to the estimate in Turkey (0.35tC/ha of forests; UNECE-FAO; 2000), probably due to the high incidence of illegal cutting (not accounted for in Turkey by UNECE-FAO).

(16) The report does not explain how this figure was calculated. However, it shows an increase in forest area of about 491,000 hectares (afforested area, tree plantations around villages, parks and green spaces). The estimate would then correspond to an annual carbon increase of about 0.7tC/ha. This indicator is similar to that annually sequestered in deciduous trees of other Middle East countries, such as Lebanon (Lebanon Ministry of Environment, 1999).

(17) The report gives no further explanation regarding the way in which these estimates were calculated. However, based on the given data, it appears that (1) the annual loss of dry matter due to forest conversion would be roughly about [180-10]*45,000 = 7.8 million tons of dry matter. Using a carbon

conversion factor of 0.5 (UNECE-FAO, 2000), it would result in(to) a loss of 3.6 million tC, which corresponds to about 13 million tCO_2. Therefore, the results of the reported calculations appear to be realistic, even though the assumptions and detailed calculations were not specified.

(18) The approach used the following parameters: the number of forest species yielding medicinal products; the royalty rates that would be payable to the host country; a coefficient of rent capture; the likely value of internationally traded pharmaceutical products; and the forest area.

Economic Data	(2002)
Population	65,368,000
Urban population (%)	61%
Rural population (%)	39%
Average household size	4.8
GDP Rials current (billions)	904,319
GDP US$ current (millions)	113,636
GDP/Capita (US$)	1,738
GDP/Capital (000 Rials)	13,800
Rials/US$ Exchange Rate 2002	7,960

ABBREVIATIONS
IRR = Iranian Rials
q = quintal
t = metric ton
ha = hectare
n.a. = non available
DALY = Disability Adjusted Life Year
WTP = Willingness-to-pay
ca = per capita
hsld = household

Damage Costs

WATER	Method	Quantity		Unit	Price		Unit	US$ million/yr		Discounted damage (US$ million/yr)		Discounted damage (Rials billions /yr)		% of GDP		Notes / Sources
Health/Quality of life		Low	High		Low	High		Low	High			Low	High	Low	High	
	DALYs - mortality	246,180		DALYs	1,738	10,456	US$/ DALY	428	2,574	428	2,574	3,407	20,489	0.38%	2.27%	See Annex III for detailed information
	DALYs - morbidity	82,128		DALYs	1,738	10,456	US$/ DALY	143	859	143	859	1,136	6,835	0.13%	0.76%	See Annex III for detailed information
- Inadequate Water, Sanitation, Hygiene	Cost of Illness - treating mild cases by ORT	22,751,000		No. of treated cases per year	1		Treatment cost per case (US$)	23		23		181		0.02%		See Annex III for detailed information
	Cost of Illness - treating severe cases							472		472		3,759		0.42%		See Annex III for detailed information
Natural Resources																
-Groundwater depletion	Incremental fuel cost	68,416,454		Incr. diesel consumption (liters)	0.18		US$/liter of diesel	12		189		1,506		0.17%		See Chapter 3 for details
	Wells replacement co	2,975		No. of wells	43,000	53,049	US$/well	128	158	128	158	1,018	1,256	0.11%	0.14%	The total number of wells replaced per year is 3,500. About 85% are replaced due to the decline in water table (Ministry of Energy).
- Groundwater pollution	Wells replacement cost	62		No polluted wells	43,000	53,049	US$/well	3	3	3	3	21	26	0.00%	0.00%	See Annex III for details
- Water Erosion - Dam Sedimentation	Loss in water storage capacity	236,000,000		m^3 of water	0.10		Productivity of irrigation water (US$/$m^3$)	24		369		2,935		0.32%		See Chapter 3 for details
	Dredging irrigation networks									2		13		0.00%		See Chapter 3 for details
- River Pollution	Loss of Recreational Value													n.a.	n.a.	Clean rivers have a recreational value to the population of a country. Estimates are not provided here due to lack of data.
- Impacts on Ecosystems														n.a.	n.a.	The impacts on ecosystems of water pollution has not been estimated due to lack of data.
	Damage Costs									1,756	4,648	13,976	36,999	1.55%	4.09%	
	Damage Costs (mean estimate)									3,202		25,487		2.82%		

AIR	Method	Quantity Low	Quantity High	Unit	Price Low	Price High	Unit	US$ million/yr Low	US$ million/yr High	Discounted damage (US$ million/yr) Low	Discounted damage (US$ million/yr) High	Discounted damage (Rials billions /yr) Low	Discounted damage (Rials billions /yr) High	% of GDP Low	% of GDP High	Notes / Sources
Health/Quality of life																
	DALYs mortality	32,370		DALYs	1,738	10,456	US$/ DALY	56	338	56	338	448	2,694	0.05%	0.30%	See Annex III for details
- Health - Indoor Pollution	DALYs morbidity	10,320		DALYs	1,738	10,456	US$/ DALY	18	108	18	108	143	859	0.02%	0.09%	See Annex III for details
	Cost of illness							54		54		429		0.05%		See Annex III for details
	DALYs mortality	105,600		DALYs	1,738	10,456	US$/ DALY	184	1,104	184	1,104	1,461	8,789	0.16%	0.97%	See Annex III for detailed information
- Health-Urban Air Pollution (PM10 particulates)	DALYs morbidity	85,400		DALYs	1,738	10,456	US$/ DALY	148	893	148	893	1,182	7,107	0.13%	0.79%	
	Cost of Illness							262		262		2,089		0.23%		See Annex III for detailed information
	IQ losses in children	46,765		IQ point	322		US$/IQ point	15		15		120				The health impacts of lead air pollution is estimated for Greater Tehran only, using available dose response functions from international studies (Ostro 1994). Other cities are not included because of a lack of monitoring data. IQ points are valued at estimated lifetime losses in income/earnings potential based on US studies, adjusted for inflation and per capita differentials for Iran. Mortality and morbidity is valued the same way as for PM10.
-Health Urban Air Pollution (Pb Lead)	DALYs mortality	833		DALYs	1,738	10,456	US$/ DALY	1	9	1	9	12	69	0.02%	0.03%	
	DALYs morbidity	755		DALYs	1,738	10,456	US$/ DALY	1	8	1	8	10	63			
- Quality of life - Discomfort from Urban Air Pollution	WTP	4,260,900		No. of households in 7 urban cities	82,000	100,000	Rials/ household/yr	44	54	44	54	349	426	0.04%	0.05%	According to a contingent valuation study of urban households in Rabat-Salè, Morocco (Belhaj 2003) the average WTP per household per month for a 50 percent reduction in air pollution is estimated at 67 to 82 dirhams in 1995. This WTP reflects concerns about health impacts as well as discomfort from pollution. While health impacts are estimated above, 10% of the WTP is retained to reflect the cost of discomfort. This figure was adjusted by GDP per capita differentials between Morocco and Iran and applied to households in Greater Tehran, Mashad, Isfahan, Shiraz, Tabriz, Ahwaz and Karaj (using an average household size of 4.6 people according to SCI, 2004).
- Quality of life-Real Estate Depreciation	Depreciation costs															Urban air pollution is known to degrade physical structures, such as buildings. No estimate is provided here due to a lack of data.
Natural Resources																
- Productivity Losses	Value lost															Estimates of losses associated with degradation of land quality and vegetation are not available.
	Damage Costs									784	2,845	6,243	22,645	0.69%	2.50%	
	Damage Costs (mean estimate)									1,815		14,444		1.60%		

LAND, FOREST	Method	Quantity Low	Quantity High	Unit	Price Low	Price High	Unit	US$ million/yr Low	US$ million/yr High	Discounted damage (US$ million/yr) Low	Discounted damage (US$ million/yr) High	Discounted damage (Rials billions /yr) Low	Discounted damage (Rials billions /yr) High	% of GDP Low	% of GDP High	Notes / Sources
Natural Resources																
- Soil Salinity	Productivity Losses	8.3	13.5	Million ton/yr	107	121	US$/ ton	888	1642	888	1642	7,070	13,073	0.78%	1.45%	Yield losses are average figures for different crops. Prices are weighted averages. See Annex III for more details.
- Rangeland Degradation	Fodder Productivity Losses	78,870		Tons of barley -equv/yr	140		US$/ton of barley	11		172		1,373		0.15%		See chapter 3 for details.
- Wetland Degradation	Loss of Services	23,321		ha	940	1,620	US$/ha	22		349		2,780		0.3%		See chapter 3 for details.
	DALYs Mortality	2,957		DALYs	1,738	10,456	US$/DALY	5	31	5	31	41	246	0.00%	0.03%	One fifth of annual flood damage is assumed to be related to natural causes and the rest (4/5) is the share from manmade activities. See chapter 3 for more details.
- Soil Erosion and Flood	Infrastructure Damage cost									132		1,047		0.12%		One-fifth of the annual flood damage is assumed to be related to natural causes and the rest (4/5) is the share from manmade activities. See chapter 3 for more details.
	Deforestation loss of flow							40		628		5,000				
- Deforestation and Forest Degradation	Deforestation - loss of stock of carbon									132		1,049		0.80%		See Chapter 6 and Annex III for details
	Forest Degradation - loss of flow							9		146		1,164				
	Damage Costs									2,453	3,233	19,524	25,732	2.16%	2.84%	
	Damage Costs (mean estimate)									2,843		22,628		2.50%		

WASTE	Method	Quantity Low	Quantity High	Unit	Price Low	Price High	Unit	US$ million/yr Low	US$ million/yr High	Discounted damage (US$ million/yr) Low	Discounted damage (US$ million/yr) High	Discounted damage (Rials billions /yr) Low	Discounted damage (Rials billions /yr) High	% of GDP Low	% of GDP High	Notes / Sources
Health/Quality of life Municipal Waste																
-Waste Collection	WTP to improve waste collection & street cleanliness in urban cities of <u>more</u> than 500,000 inhabitants	233,063		No of households (5% of total)	3.3	7.3	US$/ household/ month	9	21	9	21	73	163	0.01%	0.02%	Collection rates in large cities (with more than 500,000 inhabitant) have improved significantly and are between 90 to 100%. Collection rates in smaller urban cities (with less than 500,000 inhabitant) average 70%. Altaf and Deshazo (1996) estimate households' WTP for improved waste collection in Pakistan, and Belhaj (1995) estimate households' WTP to improve waste collection and street cleanliness in two cities in Morocco. After accounting for GDP per capita differentials and adjusting to 2002 prices, the results of both studies were applied to 5% of urban households of cities (larger than 500,000 inhabitants) and to 30% or urban household leaving in cities (smaller than Rural areas are estimated to have collection rates that average 50 to 60%. The WTP (as calculated above) was applied to 45 percent of rural households who do not have adequate waste collection.
	WTP to improve waste collection & street cleanliness in urban cities of <u>less</u> than 500,000 inhabitants	1,283,608		No of households (30% of total)	3.3	7.3	US$/ household/ month	50	113	50	113	402	899	0.04%	0.10%	
	WTP to improve waste collection & street cleanliness in rural areas	2,178,350		No of households (45% of total)	3.3	7.3	US$/ household/ month	86	192	86	192	682	1,526	0.08%	0.17%	
- Recreational loss	Northern provinces recreational loss	5,000,000		No. of tourists	11	21	Potential decline in tourist revenue (per stay)	53	105	53	105	418	836	0.05%	0.09%	
Natural Resources																
-Landfill	Impact on surrounding land prices; groundwater contamination	19,564,642		Municipal waste generated (t/yr)	4.7		Incremental cost US$/ton	92		92		732		0.08%		
Untreated Industrial Waste																
- Industrial Waste												n.a.	n.a.	n.a.	n.a.	Inappropriate storage and disposal of untreated industrial, hazardous and hospital waste pose risks to human health, water resources and land. There is
- Hazardous Waste												n.a.	n.a.	n.a.	n.a.	
- Health Care Waste												n.a.	n.a.	n.a.	n.a.	
	Damage Costs									290	522	2,306	4,157	0.25%	0.46%	
	Damage Costs (mean estimate)									406		3,231		0.36%		
COASTAL ZONES					Price		Unit	US$ million/yr		Discounted damage (US$ million/yr)		Discounted damage (Rials billions /yr)		% of GDP		Notes / Sources
Natural Resources		Low	High		Low	High						Low	High	Low	High	
- Caspian Sea	Sturgeon - lost catch	278		tons of caviar	533		US$/ Kg	148		148		1,179		0.13%		See Chapter 7 for details
	Sturgeon - remediation costs	22,000,000		fingerlinks	0.5		US$/fingerlink	11		11		88		0.01%		See Chapter 7 for details
	Kilka - lost catch	35,188		tons	0.2		US$/ kg	7		7		56		0.01%		See Chapter 7 for details
	Damage Costs (mean estimate)									166		1,323		0.15%		
GLOBAL ENVIRONMENT				Unit	Price		Unit	US$ million/yr		Discounted damage (US$ million/yr)		Discounted damage (Rials billions /yr)		% of GDP		Notes / Sources
					Low	High						Low	High	Low	High	
- CO_2	Global Damage	99,654,545		Tons of Carbon	13	18	US$/ ton Carbon	1,296	1,794	1,296	1,794	10,312	14,279	1.14%	1.58%	
	Damage Costs (mean estimate)									1,540		12,300		1.36%		
DAMAGE COSTS										5,449	11,414	43,371	90,856	4.80%	10.04%	
DAMAGE COSTS (MEAN ESTIMATE)										8,430		67,100		7.42%		
DAMAGE COSTS, AND GLOBAL ENVIRONMENT										6,744	13,208	53,684	105,134	5.94%	11.62%	
DAMAGE COSTS, AND GLOBAL ENVIRONMENT (MEAN ESTIMATE)										9,980		79,400		8.78%		

Annex III

WATER AND SANITATION (2002)			
MORTALITY (< 5 years of age)	**Source**	**Quantity**	**Units**
Total population	SCI, 2004	65,368,000	
Proportion of child population (<5 years)	SCI, 2004	12.9%	
Population <5 (total)		8,439,647	
Under five mortality rate (per 1,000)	WDI, 2004	0.041	
Annual under five deaths (all causes)		69,205	per year
Child diarrheal disease deaths	Iran Experts	12.5%	of child mortality rate
Child diarrheal disease mortality rate		0.005	
Annual child diarrheal disease deaths		8,651	
Percent of cases avoided per capita per year if clean water and adequate sanitation is provided to the entire population and hygiene practices are fully observed.	Hutton and Haller, 2004	85%	
Annual child diarrhea deaths from lack of WS&S and clean water		7,353	
DALYs per child death*	Murray Lopez, 1996	33	discounted years of life los
DALYs from child diarrheal disease deaths		**246,180**	per year
MORBIDITY (<5 years of age)		*Quantity*	*Units*
Population of children (<5 years)		8,439,647	
Diarrheal prevalence in children (< 5 yrs of age) in last 10 days	MOH, 1997	22%	
Total cases of diarrhea		48,407,400	
Average length per episode		4	days
Total diarrhea days per year		193,629,600	days
Percent of cases avoided per capita per year if clean water and adequate sanitation is provided to the entire population and hygiene practices are fully observed.	Hutton and Haller, 2004	85%	
Total diarrhea days per year related to lack of WS&S and clean water		164,585,160	days
DALY (disability severity weight)	Murray Lopez, 1996	0.11	
DALY (age weight)	WHO, 2004	0.31	
DALYs from child diarrheal disease morbidity		**15,213**	**per year**
MORBIDITY (> 5 years of age)		**Quantity**	**Units**
Population (>5 years)		56,928,353	
Diarrheal prevalence in people (> 5 yrs of age) in last 10 days	Authors' calculations**	4%	
Total cases of diarrhea		65,305,000	
Average length per episode		4	days
Total diarrhea days per year		261,220,000	days
Percent of cases avoided per capita per year if clean water and adequate sanitation is provided to the entire population and hygiene practices are fully observed.	Hutton and Haller, 2004	85%	
Total diarrhea days per year related to lack of WS&S and clean water		222,037,000	days
DALY (disability severity weight)	Murray Lopez, 1996	0.11	
DALY (age weight)	WHO, 2004	1.00	
DALYs from diarrheal disease morbidity (> 5 years old)		**66,915**	**per year**
COST OF ILLNESS		**Quantity**	**Units**
Cost of treatment, ORT (<5years old)			
Number of diarrhea cases per year (< 5 years)	as calculated above	48,407,400	
Percent of cases treated with ORT***	**MOH, 1997**	**47%**	
Cases treated with ORT		**22,751,478**	
Unit cost of ORT treatment	**Iranian health experts**	**1**	**US$** per case
Cost of ORT treatment		**22,751,478**	US$
Cost of treating severe cases of diarrhea in health facility (< 5 years old)			
Percentage of cases taken to health provider		**40%**	
Total cases of diarrhea treated in health facility		19,362,960	
Cost per treatment (Based on Rials 60,000 for doctor visit and Rials 10,000 for medication)	Iranian health experts	8.75	US$
Cost of treating diarrhea in health facilities		**169,425,900**	US$
Cost of treatment of severe cases of diarrhea in health facility (> 5 years old)			
Percentage of cases taken to health provider		**22%**	
Total cases of diarrhea treated in health facility		14,285,469	
Cost per treatment (Based on Rials 60,000 for doctor visit and Rials 10,000 for medication)		8.75	US$
Cost of treating diarrhea in health facilities		**124,997,852**	US$
Loss of caregivers' time to treat diarrheal cases (<5 years old)			
Percentage of cases involving caregiver's time		**40%**	
Number of cases of diarrhea****		19,362,960	
Value of one day lost to caregiver (based on average household wage income in rural areas)	SCI, 2004	4.6	US$
Cost of lost time due to care giving (assuming two days of care giver's time per case)		**177,786,421**	US$
	Total	**494,961,651**	

* Discounted years of life lost have been adjusted to Iran by taking into account the average life expectancy.

** Prevalence ratio (pop under 5 years / population over 5 years) for diarrheal diseases does not exist for Iran. The above was estimated based on ratios found in Vietnam, Columbia and Qena and Damietta in Egypt.

****ORT = Oral Rehydration Therapy*

****It was assumed that severe cases of diarrhea would require two days of care givers' time. This is a conservative assumption, given that on average each case is likely to last 4 days.

Annex III

POLLUTION OF WELLS					
Province name	No. of wells dug and equipped during the Third Development Program for drinking water (2000-2004)	No. of wells which are out of use because of pollution (2000-2004)	Average expense of digging and equipping a well in 2004 (Million Rials)	Average expense of digging and equipping a well in 2002 prices (Million Rials)*	Total expenses of new wells in 2002 prices (Million Rials)
Hormozgan	25	3	500	361	1,084
Chaharmahal-Bakhtiari	45	13	400	289	3,757
Zanjan	11	5	550	397	1,987
East Azerbaijan	138	17	350	253	4,299
Lorestan	12	3	700	506	1,517
Ghom	29	4	270	195	780
Semnan	25	2	1500	1,084	2,168
Khorasan	320	40	550	397	15,895
Ilam	12	6	800	578	3,468
Kashan (city)	29	6	360	260	1,561
West Azerbaijan	26	6	450	325	1,951
Qazvin	37	7	400	289	2,023
Bushehr	29	2	450	325	650
Yazd	18	10	214	155	1,546
Golestan	38	4	1100	795	3,179
Khohgiluye & *Boyerahmad*	9	0	800	578	0
Mazandaran	14	0	300	217	0
Tehran	632	50	600	434	21,675
Kordestan	17	7	350	253	1,770
Sistan & Baluchestan	36	4	302	218	873
Ardebil	25	4	400	289	1,156
Markazi	42	10	600	434	4,335
Khuzestan	7	9	500	361	3,251
Shiraz (city)	21	5	1200	867	4,335
Kerman	52	4	450	325	1,301
Fars	140	26	1100	795	20,664
Total for 4 years	**1790**	**247**	**584**	**422**	**105,223**
Average per year	**448**	**62**			**26,306**

* Applying an average inflation rate of 15.5 percent

This data was provided by Mr. Elahi Panah (National Water and Wastewater Engineering Company) in March 2005

URBAN AIR POLLUTION (2002) - Particulates

	Source	Iran	Greater Tehran Area	Mashad	Isfahan City	Shiraz	Tabriz	Ahwaz	Karaj	Other cities*			
Crude death rate (per 1,000 population)	SCI, 2004	6.5	6.3	6.6	5.8	6.4	6.5	5.4	6.3	6.5			
Cardiopulmonary (CP) and Lung Cancer (LC) mortality (% of all deaths)**	MOH		32%	32%	32%	32%	32%	32%	32%	32%			
Annual average PM10 (ug/m3)***	DOE/AQCC		100	85	102	76	69	81	100	77			
Annual average PM 2.5 (ug/m3)****			60	51	61	46	41	49	60	35			
PM 2.5 threshold level (ug/m3)		7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5			
Total population (millions)*****	WDI & SCI,2004	65.4	10.0	2.5	2.5	1.2	1.5	1.0	1.1	12.8			
Adult population >= 15 yrs (millions)	SCI, 2004	39.5	6.1	1.5	1.5	0.7	0.9	0.6	0.7	7.8			
Child population <=14 yrs (millions)	SCI, 2004	25.8	4.0	1.0	1.0	0.5	0.6	0.4	0.4	5.1			
Exposed total population (millions)******			9.0	2.0	2.0	0.9	1.2	0.8	0.9	10.3			
Exposed adult population >= 15 yrs (millions)			5.4	1.2	1.2	0.6	0.7	0.5	0.5	6.2			
Exposed child population <=14 yrs (millions)			3.6	0.8	0.8	0.4	0.5	0.3	0.3	4.0			
Health end-points	**Units**	**Impacts per 1 ug/m3**	**Cases**	**Cases**	**Cases**	**Cases**	**Cases**	**Cases**	**Cases**	**Cases**	**Total Cases**	**DALYs /10,000 cases**	**Total DALYs**
Premature mortality (PM 2.5)	% change in CP and LC mortality	0.8	5,324	1,095	1,140	454	528	342	516	3,801	13,200	80,000	105,60
Chronic bronchitis (PM 10)	per 100,000 adults	0.87	4,760	900	1,090	380	430	350	460	4,150	12,520	22,000	27,50(
Hospital admissions (PM 10)	per 100,000 pop.	1.2	10,850	2,050	2,490	870	990	790	1,050	9,470	28,560	160	500
Emergency room visits (PM10)	per 100,000 pop.	23.54	212,900	40,200	48,900	17,000	19,400	15,500	20,600	185,800	560,300	45	2,500
Restricted activity days (PM 10)	per 100,000 adults	5750	31,461,000	5,940,000	7,220,000	2,513,000	2,864,000	2,285,000	3,048,000	27,458,000	82,789,000	3	24,80(
Lower respiratory illness in children (PM10)	per 100,000 childre	169	604,000	114,000	139,000	48,000	55,000	44,000	58,000	527,000	1,589,000	65	10,30(
Respiratory symptoms (PM 10)	per 100,000 adults	18300	100,126,000	18,903,000	22,979,000	7,998,000	9,113,000	7,272,000	9,702,000	87,387,000	263,480,000	0.75	19,80(
													191,00

* "Other cities" include cities with a population of 0.1million to 1 million inhabitants in 2002 based on the 1996 census and applying average pop growth rate (SCI, 2004)
**Data for cardiopulmonary and lung cancer are based on information from MOH (*www.mohme.gov.ir*) and represent average for 18 provinces in Iran
Cardiopulmonary deaths include death from asthma, heart attack, pneumonia, etc.
***PM10 levels for Tehran, Isfahan and Tabriz are based on available data from monitoring stations. Data for Mashad are assumed to be approximately equal to the average for Isfahan and Tabriz.
PM10 levels for Shiraz and Ahwaz were obtained from dust data converted to PM10 using a factor of 0.5. Levels of PM10 for Karaj were assumed to be similar to those of Tehran
PM10 levels for "other cities" are based on average PM10 for all cities with a population from 0.1 million to 1 million in Iran, obtained from World Bank DEC estimations (www.worldbank.org/nipr/Atrium/mapping.html)
****Measures of PM2.5 do not exist for Iran. Approximations were obtained by converting PM10 levels using a conversion factor of 0.6 for Tehran, Mashad, Isfahan, Shiraz, Tabriz, Ahwaz and Karaj and 0.45 for "other cities'
*****Population projections for Iran, Karaj and Ahwaz for 2001 are based on the census of 1996 (SCI, 2004) and the average population growth rate
Population estimates for the Greater Tehran Area (area 2,300km2), Mashad, Isfahan, Tabriz and Shiraz are from the Wikipedia Encyclopedia www.en.wikipedia.org
****** 90% was assumed for the Greater Tehran Area (expert opinion at Ministry of Health, Jan05) and 80% for other cities

VALUATION OF MORBIDITY: COST OF ILLNESS - Particulat

			Costs in US$ Per Case					
	Units	**Unit Cost**	**Chronic bronchitis**	**Hospital admissions**	**Emergency room visits**	**LRI in children**	**RADs**	
Cost of illness								
Hospitalization	per day	75	206	452				
Doctor visits	per visit	13	229			13		
Emergency visits	per visit	50	138		50			
Value of lost work days (incl. household work)	per day	8	373	80	16		0.8	
Value of lost caregiver time*	per day	8				8	1.2	
Cost-of-illness per case (US$)			**947**	**532**	**66**	**21**	**2.0**	
TOTAL COST (ANNUAL CASES)			**Chronic bronchitis**	**Hospital admissions**	**Emergency room visits**	**LRI in children**	**RADs**	**TOTAL**
Cost of medical treatment US$			7,180,000	12,916,583	28,155,779	19,962,312		68,215,00
Cost of time lost to illness US$			4,671,000	2,284,198	8,962,436	12,708,648	165,534,337	194,161,00
Total			11,851,000	15,200,780	37,118,215	32,670,959	165,534,337	**262,375,00**

* Average wage rate in urban areas (SCI, 2004)
Cost of illness (hospitalization, doctor visits, emergency room visits) is based on information from doctors in Iran
Chronic bronchitis (CB): Estimated cost is based on monthly doctor visit for 25% and twice-a-year visits for 65% of individuals with CB; emergency doctor visit once a year for 30% of individuals, and average 6-day hospitalization once a year for 2.5% of individuals; and 5 working days lost per year for 35% of individuals. NOTE: Costs are discounted at 10% for a period of 15 years, reflecting the chronic nature of the illness. Data are based on findings from the United States and Europe (Schulman, Ronca, and Bucuvalas, Inc 2001and Niederman et al 1!
Hospital admissions: Estimated cost is based on an average of two days of hospitalization and two lost work days.
Emergency room visits: Estimated cost is based on cost of doctor visit and 1/2 day of work
Restricted activity days (RADs): Estimated cost is based on 1 work day lost per 10 RADs.

URBAN AIR POLLUTION (2002) - Lead (Pb)

Key parameters	**Source**	**Iran**	**Greater Tehran Area**		
Population (mill)	SCI, 2004	65.4	10.0		
Adult population >15 yr (mill)	SCI, 2004	39.5	6.05		
Adult population 40-60 yrs (mill)	SCI, 2004	9.2	1.40		
Children population <=14 yrs (mill)	SCI, 2004	25.8	3.95		
Annual average Pb ambient concentrations (u	AQCC		0.67		
Exposed population (mill) 90% of tot			9		
Exposed adult male pop 40-60 yrs (mill)			1.26		
Exposed children pop (mill)			3.56		
Health categories	**Units**	**Impacts per 1 ug/m3**	**Cases Greater Tehran**	**DALYs per 10,000 cases**	**DALYs Greater Tehran**
IQ loss (points)	per 1 child	0.975	46,765		
Hypertension (cases)	per 1 mill adult males	72600	74,669	100	747
Non-fatal heart attacks (cases)	per 1 mill adult males 40-60 yı	340	81	1,000	8
Premature mortality	per 1 mill adult males 40-60yr	350	83	100,000	833

Dose response coefficients (impacts per ug/m3) are from Ostro (1994), based on a survey of studies. These studies assessed the impacts of lead on adult males. However for the purpose of this current study, adult female have also been included.
Health impacts are assumed negligible for concentrations below 0.5 ug/m3 (i.e. estimated based on observed levels less 0.5 ug/m3).
The coefficient for loss in intelligence (IQ) is based on long term exposure. The loss is therefore divided by 14 to convert to annual losses in children ages 0-14 years.
There are no comprehensive monitoring data of Pb in Tehran for 2002. The ambient concentration used here is based on data available for 1998/1999 (AQCC). It's important to note that other sources (Bahrami A, 2001) indicate levels of lead in 1998 of 3.82ug/m3

Annex III

INDOOR AIR POLLUTION (2002)

Key parameters	**Source**	**Iran**
Total population (millions) 2002	WB, 2004d	65,540,000
Under five mortality rate (per 1,000 live births) 2002	WB, 2004d	41
Rural population share 2000	SCI, 2004	38.5%
Exposed population share (population equivalents as a % of total population)*	WB staff	7.8%
Prevalence of ARI in children under-5	Unicef	24%
Prevalence of ARI in >5 population	WB staff	2%
Population <5 (total)	SCI, 2004	8,439,647
Population >15 (female)	SCI, 2004	20,317,400
Disability weight (ARI)	WHO	0.28
Duration of ARI episode (days)	WB staff	7
% of under-fives with ARI taken to a health care provider (1998-2003)	Unicef	93%
Days of caregiver's time per case	WB staff	1

Mortality		**NBD deaths**	**Exposed population PP**	**Odds ratio OR**	**PAR**	**Deaths indoor air**	**YLL**
Lower respiratory infections	children < 5 yrs old	5,997	7.8%	2.3	0.092	552	18,230
Chronic obstructive pulmonary disease	adult females (> 15 yrs old)	6,164	7.8%	2.83	0.125	770	6,160
Lower respiratory infections	adult females (> 15 yrs old)	7,881	7.8%	2.3	0.092	726	7,980
	TOTAL loss per year					2,048	**32,370**

Morbidity		**Cases of illness per year**	**Exposed population PP**	**Odds ratio OR**	**PAR**	**Cases of illness per year indoor air**	**YLD**
Lower respiratory infections	children < 5 yrs old	35,108,932	7.8%	2.3	0.092	3,233,400	5,380
Chronic obstructive pulmonary disease (new cases)	adult females (> 15 yrs old)	17,811	7.8%	2.83	0.125	2,200	1,170
Lower respiratory infections	adult females (> 15 yrs old)	5,960,535	7.8%	2.3	0.092	548,900	3,770
	TOTAL loss per year					3,784,500	**10,320**
	TOTAL						**42,690**

Cost of illness <5 population	**Units**		**Unit cost**		**Total**
Health care provider visits (93% of cases)	3,007,100	admissions	13	US$	39,092,300
Caregiver's time	3,233,400	days	4.6	US$	14,844,200
Total					**53,936,500**

*Smith estimates 6.1% for EMR-B

PAR=PP*(OR-1)/(PP*(OR-1)+1)

DATA:

The National Burden of Disease (NBD) for IRAN is estimated based on extrapolation of Burden of Disease data by WHO and World Bank for similar countries, using 18% of child mortality due to lower respiratory illness, 2% of adult female mortality due to chronic obstructive pulmonary disease (COPD), and 3% of adult female mortality due to lower respiratory infection.

The odds ratios (OR) are from Smith (2000) and reflect a review of international studies. The exposed population (as a share of total population) to indoor air pollution from biomass fuel is based on rural population share and total biomass fuel use (WDI, World Bank).

METHODOLOGY:

The methodology presented in Smith (2000) has been applied here. The methodology is based on National Burden of Disease (NBD) statistics for illnesses/diseases that are associated with indoor air pollution, and odds ratios (OR) from international studies that reflect the increased risk of illness/disease associated with the indoor use of biomass fuel. DALYs are based on discounted years of life lost for each disease. Only mortality is included as Smith estimates that DALYs from morbidity are insignificant relative to mortality. DALYs are only estimated for children less than five years of age and adult women because these groups are likely to spend disproportionately more time indoors than school children and adult men

Annex III

POPULATION PROJECTION used for WASTE COLLECTION ESTIMATE		
	1996 Census	**2002 Projection***
Urban cities with population > 500,000 persons		
Greater Tehran Area	6,758,845	10,000,000
Esfahan	1,266,072	2,540,000
Mashhad	1,887,405	2,500,000
Tabriz	1,191,043	1,500,000
Shiraz	1,053,025	1,185,877
Karaj	940,968	1,059,683
Ahwaz	804,980	1,000,000
Qom	777,677	875,791
Kermanshah	692,986	780,415
Sub-total		***21,441,765***
Urban cities with population < 500,000 persons		
Orumiyeh	435,200	490,100
Zahedan	419,518	472,400
Rasht	417,748	470,500
Hamadan	401,281	451,900
Kerman	384,991	433,600
Arak	380,755	428,800
Arbdedil	340,386	383,300
Yazd	326,776	368,000
Qazvin	291,117	327,800
Zanjan	286,295	322,400
Sanandaj	277,808	312,900
Bandar Abbas	273,578	308,100
Khorramabad	272,815	307,200
Eslamshar	265,450	298,900
Borujerd	217,804	245,300
Abadan	206,073	232,100
Dezful	202,639	228,200
Kashan	201,372	226,800
Sari	195,882	220,600
Gorgan	188,710	212,500
Najafabad	178,498	201,000
Sabzevar	170,738	192,300
Khomeinishahr	165,888	186,800
Amol	159,092	179,200
Neyshabur	158,847	178,900
Babol	158,346	178,300
Khoy	148,944	167,700
Malayer	144,373	162,600
Bushehr	143,641	161,800
Qaemshahr	143,286	161,400
Qarchak	142,690	160,700
Qods	138,278	155,700
Sirjan	135,024	152,100
Bojnurd	134,835	151,800
Maragheh	132,318	149,000
Birjand	127,608	143,700
Ilam	126,343	142,300
Bukan	120,020	135,200
Masjed Soleyman	116,883	131,600
Saqqez	115,394	130,000
Gonbad-e-kavus	111,253	125,300
Saveh	111,245	125,300
Mahabad	107,799	121,400
Varamin	107,233	120,800
Andimeshk	106,923	120,400
Khorramshahr	105,636	119,000
Shahrud	104,765	118,000
Marvdasht	103,579	116,600
Zabol	100,887	113,600
Shahr-e-kord	100,477	113,200
Other urban cities with populations between 25,000 and 100,000 each	7,570,000	8,525,000
Sub-total		***19,682,100***
* Population projections are based on the average population growth rates reported in the censuses of 1991 and 1996		2%

Annex III

Cost of Soil Salinity

Irrigated crops	**Salinity level (dS/m)**		**Ha**	**Baseline**	**Threshold**	**Yield decline**	**Predicted yield (ton/ha**		**Yield losses (milion ton)**		**Price/ton**	**Average total loss**	**% of GDP**
	Low (1)	**High** (1)	**(million)**	**yield** (2)	**dS/m** (3)	**per 1 dS/m** (4)	**Low**	**High**	**Low**	**High**	**US $** (5)	**(million US$)**	
Rice	4	6	0.57	5.5	3	12%	4.84	3.52	0.38	1.13	325	245	0.22%
Soy beans	4	6	0.07	3	5	20%	3	2.4	0.00	0.04	281	6	0.01%
Wheat	4	6	0.14	5	6	5%	5	5	0.00	0.00	170	0	0.00%
Wheat	8	12	1.18	5	6	5%	4.5	3.5	0.59	1.77	170	201	0.18%
Wheat	16	20	0.63	5	6	5%	2.5	1.5	1.58	2.21	170	321	0.28%
Sugar beat	16	20	0.22	45	7	5%	24.8	15.8	4.46	6.44	35	193	0.17%
Barley	16	20	0.67	4	8	5%	2.4	1.6	1.07	1.61	140	188	0.17%
Cotton	16	20	0.22	2.5	8	5%	1.5	1	0.22	0.33	408	112	0.10%
Unusable land (6)			1.11									1185	1.04%
Total Loss (not including "unusable" land)													1.11%
Total Loss (including "unusable" land)													2.16%

(1) "Low" corresponds to the low bound of salinity level as indicated in Table 5.1 in the report (with reference to Moameni 2004). "High" is in the low-to-mid range of the salinity range.
(2) Tons per hectare for salinity below threshold. These yields are derived from the World Bank report (2004c) and FAO statistics.
(3) Salinity level below which salinity normally does not affect yields
(4) Percent yield decline per dS/m above threshold salinity level
(5) Price of wheat and barley are world prices. Price of rice is Thai rice with a 30% mark up on Iranian rice (premium quality) as done in the Iran Irrigation Improvement Project, ICT (WB, 2001a). The other prices are Iranian producer prices in 2002 reported by FAO. Exchange rate used is IRR 7960 per US $
(6) This is land with salinity > 32 dS/m. It is highly unlikely that this land can be cultivated any longer. Even the most saline tolerant crops have a maximum tolerance of less than 30 dS/m. Net income per ha has been used to value the loss of "unusable" land, applying a range of IRR 7-10 million. This is in the range of net income for various crops (World Bank, 2001a).

Note 1: As a conservative approach, it is assumed that there are no yield losses on land with salinity in the range of 0-4 dS/m. This land, and the crops assumed to cultivated on this land, is excluded from the of crops used in the estimation of the cost of soil salinity.

Note 2: The threshold values and salinity-yield response coefficients are from the international empirical literature. See for instance:
i) FAO (1998). FAO Irrigation and Drainage Paper 56. Prepared by Allen, R. et al.
ii) Gratten, Zeng and Shannon, Roberts (2002). Rice if more Sensitive to Salinity than Previously Thought. California Agriculture, Vol. 56, Number 56. November/December.
iii) Kotuby-Amacher, J. et al (1997). Salinity and Plant Tolerance. Utah Sate University. United States

Note 3: The irrigated areas of the different crops are based on the World Bank report (2004c).
Optimal adaptation, if salinity was the only soil characteristic affecting crop choices, would imply that all the salt sensitive crops are cultivated on the land that has salinity lower than 4 dS/m. Rice, soybean and some wheat would then be cultivated on land with 4-8 dS/m. The remaining wheat under cultivation would be found on land with 8-16 dS/m and on some land with 16-32 dS/m.
All sugar beet, barley and cotton cultivation would also be on land with 16-32 dS/m.

Annex III

DEFORESTATION and FOREST DEGRADATION (2002)					
Type forest benefit	**Physical estimate**	**Unit of measure**	**Price or unit value**	**Monetary estimate**	**Valuation method**
Deforestation					
Direct use values					
- Timber	67,500	m3/year	150	10,125,000	Stumpage price
- Firewood	108,000	m3/year	30a; 10b	2,430,000	Stumpage price
- Grazing	125,000	ha	15	1,875,000	Benefits transfer: substitute cost method (Turkey)
- Other NWFPs	125,000	ha	5	625,000	Benefits transfer: market price (Turkey)
- Hunting	125,000	ha	1	125,000	Benefits transfer: permit price and licence fees (Turkey)
- Recreation	125,000	ha	6.5	812,500	Cost of travel
Indirect use values					
- Plant nutrients	72,720,000	kg	0.1	7,272,000	Substitute cost method: price of fertilizers
- Agricultural losses	125,000	ha	10	1,250,000	Benefits transfer: change in productivity (Tunisia)
- Protection of water supply	125,000	ha	17a; 8c; 37d	2,196,000	Not specified; see Mayan (2000)
- Water purification	125,000	ha	87	10,875,000	Not specified; see Mayan (2000)
- Carbon	8,500,000	t	13e-18f	131,750,000	Shadow price: average market price on actual carbon markets
Option, bequest and existence values					
- Option value of pharmaceuticals	125,000	ha	6.3	787,500	Benefits transfer: rent capture approach (Turkey)
- Biodiversity conservation	125,000	ha	16a; 8c; 16d	1,584,000	Not specified; see Mayan (2000)
- Cultural value	125,000	ha	2	250,000	Not specified; see Mayan (2000)
Sub-total flow				**40,207,000**	
Sub-total stock				**131,750,000**	
Sub-total NPV				**759,866,968**	
Degradation					
- Sustainable wood productivity	104,000	m3/year	150a; 30b	9,360,000	Stumpage price
Total flow				**49,567,000**	
Total stock				**131,750,000**	
Total NPV (t = 25 years, 4%)				**906,089,637**	
Total NPV (%GDP)				**0.80%**	

Notes
a = for Caspian forests; b= for other types of forests; c = for Zagros forests; d = for Irano-Touran forests
e = lower bound; f = upper bound