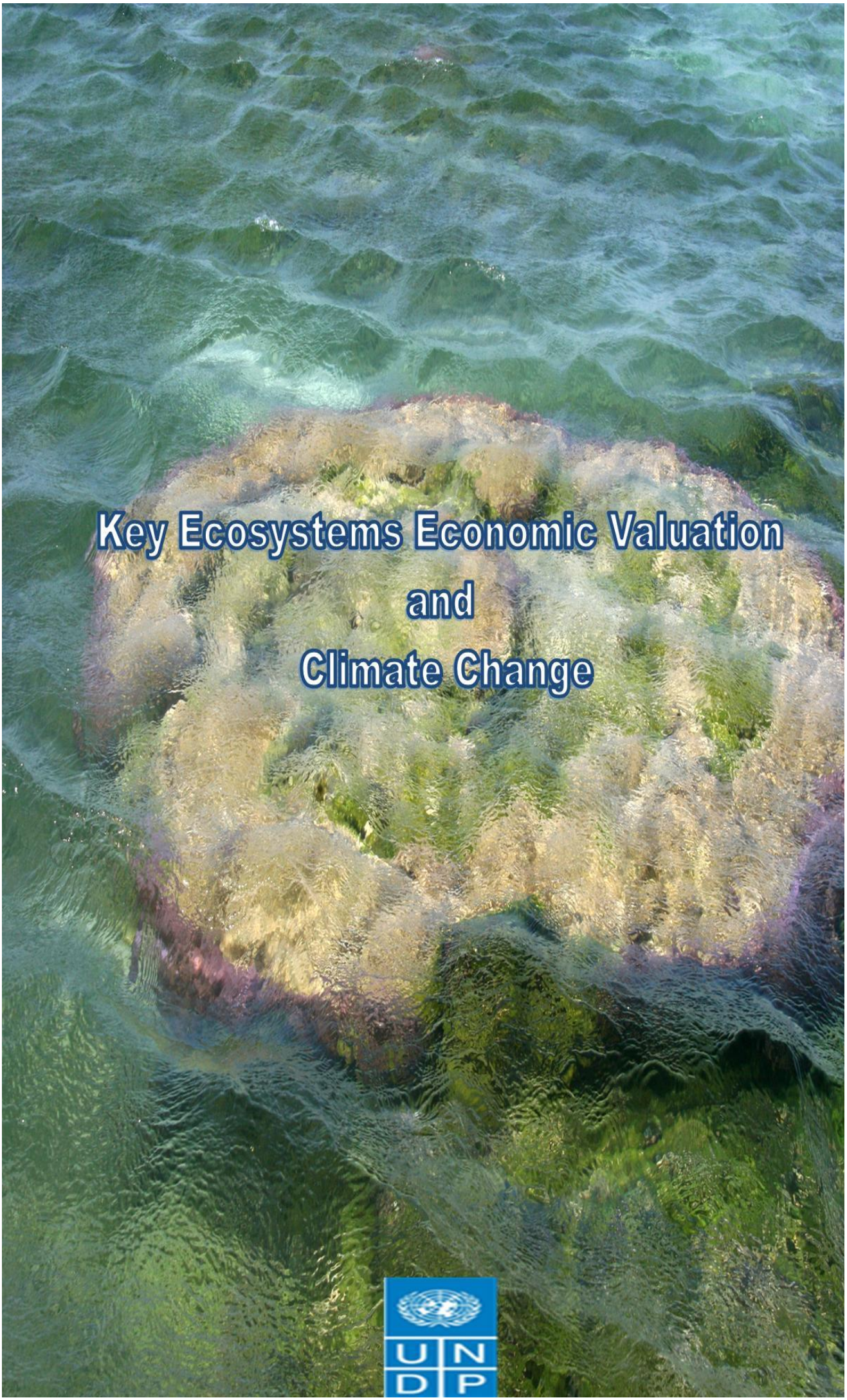
Key Ecosystems Economic Valuation
and
Climate Change
UNDP

Project Name	**Updating Yemen's National Biodiversity Action Plan through Biodiversity Valuation and Integration of Climate Change**
Report	**Key ecosystems economic valuation and climate change**
Prepared for	**UNDP, Yemen**

PREPARATION, REVIEW AND AUTHORISATION

Revision #	Date	Prepared by
Final Report	30 April 2014	Sennye Masike PhD

ISSUE REGISTER

Submission List	Date Issued	Number of Copies
UNDP office	30 April 2014	Electronic Copies (PDF and Microsoft Word)

DEFINITION OF TERMS

Adaptation is defined as by IPCC as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities

Biodiversity is the degree of variation of life forms within a given landscape, ecosystem, biome or an entire planet

Climate change is defined by IPCC as a change in the state of the climate that can be identified using statistical tests by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer

Climate scenario is a coherent internally consistent and plausible description of a possible future state of the world

Co-management is defined (amongst others) as a situation in which two or more social actors negotiate, define and quarantee amongst themselves a fair sharing of the management functions, entitlements and responsibilities for a given territory, area or set of natural resources

Green house gas is defined as a gas that absorbs and emits radiation within the thermal infrared range.

Economic valuation is defined as assigning monetary value to non-marketed environmental goods and services or goods and services with incomplete markets

Ecosystem is the community of living organisms (plants, animals and microbes) in conjunction with the non-living components of their environment interacting as a system

Protected Area is a clearly defined geographical space, recognised, dedicated and managed through legal or other effective means, to achieve the long term conservation of nature with associated ecosystems services and cultural values

Radiative forcing is defined as the difference of the radiant energy received by the earth and energy radiated back to space

Rangelands defined as any area of pasture or other grasslands available for stock grazing

Sea Level Rise is defined as an increase in high tide level over time

Vulnerability is the exposure unit of a system to a phenomenon

Willingness to Pay is the maximum amount a person is prepared to pay, sacrifice or exchange in order to receive a good or service or to avoid a decline in service or undesired impact such as environmental pollution or degradation

Willingness to accept is the minimum amount an individual is prepared to receive to give up a good or accept an undesirable situation such as a decline in service or environmental degradation

Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water the depth of which does not exceed six metres at low tide

EXECUTIVE SUMMARY

Yemen is one of the countries well endowed with natural resources ranging from forests, Arabic woodland, mountainous ecosystems to vast marine ecosystems. For instance, the country commands over 2500 km of shoreline. It is reported that the Yemen marine ecosystem is the most endemic and highly diversified. However, over the years the country's remarkable biodiversity and key ecosystems have been threatened and degraded by devastating land use changes and unsustainable consumption patterns (EPA, 2000). Consequently, the highly valued key ecosystems have been continuously depreciated through pollution, degradation and depleted through overstocking, deforestation, lack of maintenance of terrace amongst other factors.

One of the underlying factors for the degradation of Yemen's key ecosystems is lack of integration of ecosystems economic values in economic decision making at national and local levels, lack of recognition and acknowledgement that ecosystem-economy is a closed system and that ecosystem deprecation feedbacks into slow economic growth and increase in poverty level particularly at the rural population. Thus, until such association is made and some sombre efforts undertaken to ensure that environmental costs and benefits are integrated in economic decision making at both national and local planning, then ecosystems will continuously be riddled with uncountable unsustainable and myopic consumption patterns and practises.

In light of the underlying factors for key ecosystem degradation and abuse, the document entails results of the key ecosystems economic valuation in the country, mechanisms and tools for integrating economic values of ecosystems in decision making at the national and local planning levels. Moreover, the report discusses climate change impacts on key ecosystems and measures to enhance ecosystems' adaptation to climate change. Consequently, the main objective of the assignment is to provide information that will be used to update the NBSAPY by integrating the economic value of key ecosystems and climate change impacts.

Approaches and methods

In order to achieve the objectives of the assignment (Ecosystem Valuation and climate change in Yemen with the aim to integrate ecosystem services into National planning & Accounting) key ecosystems used for the assignment are forests, wetlands, marines (coral, mangroves, sea grass) and rangelands. The following methods were used to achieve the specific objectives of the assignment:

- Production Function Methods: these are valuation methods that infer to the value of ecosystems by determining their contribution in production of marketed goods and services

- Replacement/mitigation costs: the amount of money an individual incurs in replacing damage or mitigating an impact can be used as a proxy for their willingness to pay to protect/conserve that particular variable.
- Literature review: the method was employed to assess impacts of climate change on key ecosystems
- Systems thinking approach: it is a holistic approach to understanding how systems' constituents parts interact to determine the behaviour of the system over time. The approach contrasts with traditional analysis, which studies systems by breaking them down into their separate elements.

Key results/findings of the analysis

Economic valuation

Forests

Forests are multi functional providing various ecosystem services used directly and indirectly by economic agents. Some of the products, functions and services that were valued included fuelwood, fodder and medicinal plants, carbon sequestration, wildlife habitat, pollinators, honey production and soil erosion prevention. The economic value was estimated at USD 243,783 million per year. The value of fuelwood is inclusive of the contribution from rangelands.

Wetlands

Wetlands in this assignment are defined as *wadis*. They are an important source of water supply for rural population, irrigation and livestock. In addition, *wadis* are an important source of fodder for livestock during drought periods. Estimating the value of wadis as a source of water supply was based on the willingness to pay for water. The total economic value of water was estimated at USD 13,873 million per year.

Rangelands

Globally, rangelands are the most important ecosystems supporting majority of the world's population, covering over 70% of the ecosystems. Rangelands provide fuelwood, a source of energy for the rural poor population, fodder for livestock (cattle, camels, goats, sheep and donkeys) and medicinal plants. In addition, rangelands offer services and functions which support economic production processes such as habitat for wildlife, pollinators, soil erosion prevention and soil maintenance, carbon sequestration and watershed properties. Based on data availability and the value of goods and services produced in the country, the value of rangelands was estimated at USD 3,386 million. This excludes the value of fuelwood and carbon sequestration which have been estimated under forests. Acknowledgement that rangelands also contribute to these products is made.

Mangroves

Mangroves are forests but have been classified under marine ecosystems. Covering approximately 980 hectares, mangroves provide vital functions mostly protective roles for the coastline and other marine ecosystems such as sea grass. Mangroves are also known to have extraordinary properties of absorbing nutrients thus reducing marine pollution. Moreover, they provide food, in the form of fish to communities and are a source of tourism opportunities. Based on the assumptions and availability of data, the use values of mangroves were estimated at USD 482 million. Other functions such as absorption of nutrients, reduction of pollution and protective functions of mangroves were not estimated due to lack of data.

Thus, overall economic value of the key ecosystem was estimated at USD 261,524 million per year. The estimated economic values for the key ecosystems were for use values only (direct and indirect values). No attempt was made to estimate the non-use values due to lack of data. The unstable security condition in the country prevented undertaking such exercises.

Economic sector and impacts on the environment

Yemen's economy is characterised by high unemployment, with majority employed at the agricultural sector. Moreover, it is dominated by the informal sector with over 90% employed. Thus, the economy is typically of a least developed country. The main economic sectors are agriculture, oil and gas, manufacturing and industry, and service sectors. The service sector makes the main contributor to GDP at over 49% followed by the oil and gas sector. The manufacturing sector, though promising, is the least contributor at a meagre 7%. The country's economic activities are responsible for widespread environmental degradation and pollution. For instance, the agricultural sector is the major consumer at 90% of all water abstraction. Thus, the sector is the chief contributor to groundwater depletion. In addition, the agriculture sector adds significantly to water pollution both surface and groundwater, due to intensive and reckless use of pesticides and fertilisers. There is widespread rangeland and mangrove degradation from overstocking and overgrazing. The marine ecosystem has not been exempted from unsustainable use and degradation. There is overexploitation of fishery resources and reportedly the coral reefs have been destroyed by destructive fishing methods.

The economic costs of economic activities in the country are natural capital stock depreciation which will manifest in decline in production/output levels, household income and widespread poverty levels at the rural settings.

Climate change and key ecosystem

Climate change will worsen the current situation of widespread environmental degradation as evident from deforestation, pollution, grave groundwater depletion and mining, marine ecosystem destructions. GCMs project an increase in temperature while there is significant variance amongst the models on the directional change of precipitation. While some models project an increase of as much as 25% other models project a decrease of 34%. Coincidentally, Yemen is located on a region that is difficult to project precipitation. As impacts of climate change are based on climate scenario, variation in model prediction implies that assessing the impacts will be complex. However, based on the mid scenario, it is projected that runoff will increase slightly between 2030 and 2050 with a decline in 2080. Thus, in the future, climate change could worsen water situation in the country. For ecosystems such as forests, climate change could influence species migration and the country could experience some regions having more forests area coverage others devoid of forests. In addition, fire incidents could increase significantly due to increase in biomass as well as the drying of biomass due to high temperatures. Moreover, forests pests' outbreak could also be on the rise thus affecting forests' productivity.

One of the major envisaged impacts of climate change is SLR. The GCMs project a 3.3 mm/year rise in sea level, this resulting in inundation of ecosystems and built up areas. In consequence, the service and functions provided by ecosystems such as mangroves will be compromised.

Another potentially disastrous impact of climate change is increase in sea water temperatures. Marine species are generally sensitive to changes in temperature to the extent that a slight increase in temperature could shift the system to a new equilibrium. This has potential to affect marine productivity particularly fishery production.

Areas important for improving nature's ability to adapt to climate change

The potentially catastrophic climate change calls for stern actions in improvement of nature's ability to adapt to climate change. Improving nature's ability to adapt to climate change must be understood from the view point that relative to degraded ecosystems, healthy and diverse ecosystems have the ability to withstand impacts. Subsequently, the primary step is to enhance ecosystems' stability and resilience by improving management to sustainable levels. Some of the enhancement strategies include:

- Reducing pollution
- Reducing harvesting rates to sustainable levels
- Defining carrying capacities for rangelands, coral reefs and mangroves
- Introduction of individual transferable quotas for water use efficiencies

In addition, it is imperative that the following strategies be implemented

- Increase PA coverage through landscape management as opposed to zone management
- Adapt co-management approach to increase coverage area of the PAs
- Create corridors particularly Transforentier Conservation areas (TFCAs)
- Afforestation of the mangroves and forests

Areas important for carbon sequestration

Equally important is climate mitigation, and it involves carbon sequestration. Some of the areas identified include:

- Afforestration of the Arabic woodlands, forests and mangroves
- Conservation of sea Grass through declaring them as PA and encouraging co-management practises
- Conservation of coral reefs and declaration of vulnerable and threatened ones as PAs to be co-managed

Ecosystem stakeholders, conflicts and beneficiaries

As indicated, ecosystems offer various products, functions and services for use by stakeholders. Some of the ecosystem stakeholders include: timber harvesters, fishermen, livestock owners, farmers, members of communities, governmental departments and international communities. The varying uses by different stakeholders create conflicts. For instance, harvesting timber from forests potentially reduces its service of watershed properties and soil erosion prevention, these posing conflicts between stakeholders. Thus, there is need to determine tradeoffs such as reduction of harvest rate to sustainable levels, reduction of stocking rates and limitation of pollution levels to sustainable levels, to lessen conflicts amongst users. The ultimate goal of tradeoffs is to ensure that utilisation of ecosystems by one user does not result in decline of another users' decline.

Policy measures to restore and safeguard Yemen's ecosystem

The previous sections have demonstrated ecosystems' economic values and the corresponding general widespread environmental degradation culminating from pollution and unsustainable consumption. There is need to protect the country's valued natural capital stock from accelerated depreciation due to myopic decision making and planning. The primary step towards safeguarding and restoring the country's natural wealth is integration of the economic value of key ecosystems into national and local development planning levels. Selected tools and techniques to be used in the integration include WAVES, PES and development of the legal framework compelling all proposed projects to integrate environmental costs and benefits at the appraisal stages. Appraisal techniques that can be used in the exercise include CBA and MCDA.

In addition to integration of economic values of ecosystems at the national and local planning levels, it is important that harmful subsidies are removed and environmental friendly incentives implemented. Analysis has revealed that subsidies are the secondary causes for environmental degradation in the country. For example, subsidies on diesel have resulted in accelerated groundwater pumping leading to unsustainable water mining rates while subsidies on pesticides and fertilisers led to unprecedented utilisation of chemicals resulting in widespread pollution. Setting up of terrace fund for rehabilitation and restoration, preferential markets for organic and less water intensive crops make up some of the proposed environmentally friendly incentives.

NBSAP Priority Areas and Financing Action Plan

Findings of this assignment and the NBSAP are in agreement that Yemen has multiple and widespread environmental/ecosystem problems that need stern attention. However due to limited resources, it is judicious to priorities on the chief environmental concerns. According to NBSAP, priority areas for biodiversity investment are:

a. Comprehensive National Integrated Protected Area Systems
b. Integrated Coastal Zone Management
c. Development and enforcement of Policies, Legislation and Regulations on Biodiversity Issues
d. Conservation of Agro-biodiversity
e. Reviving traditional indigenous natural Resources Management Systems
f. National Biodiversity education and Awareness
g. National Biotechnology/biosafety Framework

Subsequently, it is important that a financing Action Plan be devised to enable fund raising for implementation of conservation and restoration projects that will culminate in the implementation of the priority areas of NBSAPY. A financing Action Plan detailing concrete activities for resource mobilisation for BD financing has thus been developed.

Conclusions

Key ecosystems in Yemen have astronomically high economic values and contribute immensely to both household and national income. Most importantly, they play critical roles in safeguarding food security and poverty reduction at the rural level. This insinuation is made from the findings that the economic value for the four (4) key ecosystems is ten (10) times the value of country's GDP. The implication of a highly substantial economic value of ecosystem relative to GDP is that a high proportion of these values are not currently integrated into economic decision making. Consequently, evidence of widespread unsustainable ecosystems utilisation accompanied by widespread ecosystems degradation and depletion (water and

marine resources) is partly a result of lack of accounting for values of ecosystem in economic decision making. It is therefore important that ecosystems economic values are integrated at both national and local developmental planning decision making levels. This can be achieved through implementation of WAVES, ensuring that at project appraisal stage environmental costs and benefits are integrated in decision making and ensuring that PES concept is embraced.

Ecosystems mainly forests, woodland and rangelands have huge potential to alleviate poverty at the rural areas through value addition. Globally there is a huge international demand for organic products mainly medicinal and cosmetics. As Yemen has various medicinal and cosmetic plants, this presents colossal opportunities to undertake rangeland value addition initiatives with the objective of alleviating poverty.

Economic sector (agricultural, oil and gas, manufacturing and industry and service) are the primary causes of ecosystem degradation in the country together with policies particularly on subsidies. It is therefore vital that subsidies be replaced with environmentally friendly incentives such as development of terrace fund for rehabilitation and preferential markets for organic and environmentally friendly products.

In addition to impacts of economic activities on key ecosystems, climate change will aggravate and intensify ecosystem degradation. According to IPCC, GCM are in agreement that Yemen would experience an increase in temperature in the range of between 1.8 to 4.5 °c by 2100. On the other hand, the GCMs are not in agreement on rainfall scenario, while some models project increases in precipitation by as much as 25% others project a decline of up to 25% by 2050. Changes in these ecosystem drivers (rainfall and temperature) will impacts key ecosystems in various ways such as SLR, inundation of mangroves, increase in incidents of forest fires, migration of flora and fauna. These impacts will culminate in decline of ecosystems services thus compounding poverty levels in the country

It is thus advisable to implement measures that will enhance ecosystems natural adaptation capacity to climate change. The enhancement measures should be targeted for ecosystems that offer preventive and protection functions. These include mangroves, forests, Sea grass and coral reefs. Moreover, it is important to come up with measures targeted at improving the health of key ecosystems such as reducing carrying capacity, decreasing pollution in marine ecosystems and reducing harvesting rate to sustainable levels. In addition, it is important to increase PA coverage and management at the landscape level and also create migration corridors as enhancement mechanisms.

Addition to implementation of ecosystem adaptation enhancement measures, it is crucial to improve key ecosystems ability to carbon sequestration. Identified areas for carbon sequestration include afforestation of the mangroves, forests and

woodlands, declaration of coral reefs and sea grass as PAs and sustainable management of rangelands.

Key ecosystems are multifunctional, offering diverse products and services to various users and non-users. Consequently, the multiple uses imply conflicts between the uses and users. Primary stakeholders include farmers, fishermen (commercial and subsistence), wood harvesters (commercial and subsistence), tourism operators, honey producers, herbalists, traditional doctors, tourists, governmental departments, international organisations and NGOs. Thus, tradeoffs in the form of reducing harvest rate and pollution rates to sustainable limits will ensure minimisation of conflicts.

PAs in the country are faced with various sombre challenges which hinder their operational effectiveness. Specific challenges include lack of human and financial resources, lack of institutional capacity to manage the PAs, limited coverage of PAs amongst others. Thus, there is need to define programme of works for the PAs in the country.

Situational analysis reveals that Yemen has a lot of ecosystems challenges. However due to limited resources, NBSAP has identified seven (7) priority investment needs as follows: National Integrated Protected Areas system, Integrated Coastal Zone Management Plan (ICZMP), Policies, Legislation and Regulations on Biodiversity Issues, Agro-Biodiversity, Reviving Traditional Indigenous Natural Resource Management Systems and National Biotechnology/Biosafety Frameworks. Thus a Financing Action Plan for these priority areas has been developed.

Recommendations

The following recommendations were made based on the findings of the assignment:

1. There is need to undertake ecosystem valuation of the non-use values (option and existence). This will give a clear picture on communities perceptions on ecosystems' contribution to household wealth
2. There is an urgent need to integrate economic value of ecosystem in decision making at national and local levels through appraisal techniques (CBA and MCDA), implementation of WAVES and PESs. This will ensure that environmental benefits are maximised while environmental costs minimised.
3. Conduct a value chain analysis of the ecosystems products. Natural resources have a huge potential to alleviate poverty in Yemen particularly in the Rural Yemenis population. There is an international movement towards use of organic products for health and wellness (nutrition), cosmetics and pharmaceutical
4. Undertake an assessment of the economic use of all natural resources products (seed for oil and cosmetic, bio-fuel, medicinal). Some of the products in high demand in western countries include *ximenia caffra* oil from Africa used for cosmetics, mainly in France and European countries

5. For PAs ecosystems effectiveness in adapting to impacts of climate change, it is recommended that landscape approach to PA management be employed
6. Establish TFCA through creation of corridors within and between neighbouring countries for both terrestrial and marine PAs
7. Adopt co-management as a way of PA coverage expansion and operational effectiveness. This will ensure that local communities benefit from operations of the PAs. The Co-management should be for key ecosystems such as mangroves, coral reefs, sea grass, forests, rangeland and woodland
8. Establish carrying capacities for mangroves, rangelands, and coral reefs, sustainable harvest rates and abstraction rates for groundwater. This will enhance ecosystem natural adaptation to climate change impacts. Highly stable and resilient ecosystems are able to withstand negative impacts relative to degraded ecosystems
9. Implement individual transferable quotas to encourage water use efficiency
10. Develop legislation on indigenous knowledge and local medicinal plants to protect against foreign exploitation. Rangelands and forests have high potential as sources of medicine and therefore susceptible to exploitation by international pharmaceutical and biotechnological multinational companies

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ACRONYMS

ADB	Asian Development Bank
BD	Biodiversity
BD EA	Biodiversity Enabling Activities
bpd	barrels per day
CBA	Cost Benefit Analysis
CBD	Convention on Biological Diversity
°C	Degrees Celsius
co	cobalt
CO_2	Carbon dioxide
Cr	Chromium
Cu	copper
EPA	Environment Protection Authority
FAO	Food and Agricultural Organisation
FRA	Global Forest Resources assessment
GCM	Global Circulation Model
GDP	Gross Domestic Product
GEF	Global Environmental Fund
GHGs	Green House Gas
GP	General Practionner
GOY	Government of Yemen
ha	Hectares
HHT	Highest High Tide
HR	Human Resources
Kg	kilogram
Km	Kilometer
ICZMP	Integrated Coastal Zone Management Plan

IPCC	Intergovernmental Panel on Climate Change
LDC	Least Developed Country
LNG	Liquefied Natural Gas
M^3	Cubic meters
MCDA	Multi Criteria Decision Analysis
M&E	Monitoring and Evaluation
MJ	Mega joules
Mn	manganese
NAPA	National Adaptation Programme of Action
NBSAP	National Biodiversity Strategy and Action Plan
NBSAPY	National Biodiversity Strategy and Action Plan for Yemen
NGOs	Non-governmental Organisations
Ni	nickel
NWRA	National Water Resource Authority
PA	Protected Areas
Pb	Lead
PERSGA	Regional Organisation for the Conservation of the Environment of the Red Sea and Gulf of Aden
PESs	Payment for Ecosystem Services
SFYP	Second Five-Year Plan
SLR	Sea Level Rise
TEEB	the economics of ecosystem and biodiversity
TEV	Total Economic Value
TFCA	Transfrontier Conservation Area
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USA	United States of America

USD	United States Dollar
USGCRP	United States Global Change Research Programme
WAVES	Wealth Accounting and the valuation of ecosystem services
WB	World Bank
WTP	Willingness to Pay
WTA	Willingness to Accept
Zn	Zinc

1.0. INTRODUCTION

This project is part of the second generation of Biodiversity Enabling Activities (BD EA) under the GEF. Yemen has been a Party to the Convention on Biological Diversity (CBD) since 1996. The project addresses the country's need to continue to fulfil its obligations under the CBD. Essentially, it is envisaged that the project will play a pivotal role in contributing significantly to Yemen's efforts towards implementing the CBD Strategic Plan 2011-2020 at the national level. The project builds on the current status and achievements of Yemen with respect to biodiversity planning and reporting. It aims to integrate Yemen's obligations under the CBD into its national development and sectoral planning frameworks through a renewed and participative 'biodiversity planning' and strategizing process. This process is expected to produce measurable targets for biodiversity conservation and sustainable use. It will equally ensure that the value of ecosystems' goods and services, as well as the challenges and opportunities for ecosystem-based adaptation and resilience are integrated into economic decision making process by updating NBSAP. Non-committal, it is expected that the project will achieve its objectives through implementation of three components as follows:

a. A participative stocktaking exercise on biodiversity planning takes place and national biodiversity targets are developed in response to the global Aichi Targets;
b. The NBSAP is revised/ updated and fully integrates new aspects of the CBD strategic plan, such as mainstreaming and anchoring the implementation of the plan into national development frameworks, valuing ecosystem services and promoting ecosystem-based adaptation and resilience.
c. National frameworks for resource mobilization, Convention reporting and exchange mechanisms are strengthened.

Subsequently, it is expected that the valuation exercise demonstrates the benefits and values of ecosystems at the national level, and aids in better mainstreaming ecosystem services into sectorial and national planning.

1.1. OBJECTIVE OF THE ASSIGNMENT

The main objective of the assignment is to value biodiversity and assess climate change impacts on key ecosystems in Yemen. Essentially, core activities for the project involve economic valuation of key ecosystems and assessment of climate change on the functioning of ecosystem services. The findings of the assignment will be incorporated into the NBSAP. Thus, the project aims to integrate the economics of biodiversity and climate change in NBSAPs. It is anticipated that this project will enhance and facilitate integration of ecosystem values in economic decision making and planning.

The project has four (4) thematic areas as highlighted below:

a. Valuation of key ecosystem services within Yemen

- Identify and assess the full range of values of key ecosystem services within Yemen, based on existing local, national, regional and global studies on the value of ecosystems and biodiversity, including: the national TEEB valuations, the valuation of protected areas, and other national ecosystems services studies that have been conducted (e.g. water, carbon) and existing global and regional maps and overlays of key ecosystems services
- Estimate and demonstrate the value of key ecosystem services (using methods appropriate to each service), including the value of the ecosystem services in contributing to climate resilience, adaptation and mitigation; reducing poverty and sustaining livelihoods
- Identify potential means of capturing the value of targeted ecosystem services including through policies such as Payment for Ecosystem Services (PES) and other positive incentives
- Identify and value the costs associated with biodiversity loss for major sectors and analyse their distribution

b. Impact of economic activities and policies on national biodiversity

- Assess the structure and composition of the economy, including major economic activities, macroeconomic and sectoral strategies and policies in relation to impacts on biodiversity and ecosystem.
- Investigate the impacts of economic activities and policies on national biodiversity
- Identify priority biodiversity investment needs and opportunities based on the NBSAP
- Identify future needs for economic data, analysis and assessment of biodiversity

c. Identification of stakeholders and their interest in national biodiversity

- Identify the implications of these services for different stakeholders groups within the country, including those who benefit from, and pay for, maintenance of these ecosystem services, and those that degrade ecosystems through unsustainable use
- Identify key beneficiaries stakeholders' interests, and desired outcome and hence identify potential conflicts and trade-offs and work towards mutually acceptable solutions, including strategies that serve mutually beneficiary interests and achieve mutually beneficiary outcomes
- Propose measures for embedding and institutionalizing these strategies in the institutions, policies, agreements, programs and mechanisms of each sector

d. Climate change and biodiversity in Yemen

- Assess the impact of climate change on the functioning of ecosystem services, And hence the delivery of its services such as water, forest and woodland products, fishery and crop products, amongst others, including the delivery of natural services

- Identify areas important for improving nature's ability to adapt to climate change, such as altitudinal gradients and conservations corridors
- Identify, protect and appropriately manage areas important for carbon sequestration

2.0. VALUATION OF KEY ECOSYSTEM IN YEMEN

2.1. INTRODUCTION

The section of the report deals with valuation of key ecosystems in Yemen. Key ecosystems that are valued include forests, wetlands, rangelands, mangroves and marines as identified in the National Biodiversity Strategy and Action Plan (hereafter NBSAP). Ecosystem valuation involves assigning monetary value on non-marketed environmental goods and services or environmental goods and services with incomplete markets. It forms an important basis for optimal environmental management through integration of ecosystem values in economic decision making. The environmental benefits of ecosystem valuation include:

- Valuation creates platform for ecosystem benefits maximisation and costs minimisation hence optimisation
- Valuation gives a strong supportive argument for environmental conservation
- The values of ecosystems can be integrated into national accounts to demonstrate the contribution of ecosystems to the national wealth.

Consequently, ecosystem valuation's main objective is to demonstrate the economic value and importance of natural resources in contribution to the country's wealth as measured by GDP. Ultimately, it is envisaged that valuation will advocate for sustainable use of ecosystem resources.

2.2. APPROACHES AND METHODS

Ecosystems are multi-functional, implying that they provide various products, functions and services to both the economy and environment. Therefore, the accurate approach to ecosystem valuation is taking into account all the values associated with ecosystem. This approach is based on the Total Economic Value (TEV) concept. TEV is simply defined as a summation of the uses and non-use values associated with ecosystems' functions and services. User values are those derived from direct and indirect consumption of ecosystems goods and services. On the one hand, non-use values are those values that have no association with utilisation of natural resources, they include option and existence values. Option value is the value associated with the premium an individual is willing to pay for ecosystem conservation to keep future resource utilisation open. It is based on the notion that even though a resource is not presently used, it has potential to be used in future. Lastly, existence value is payment for the respect of survival of the ecosystem. Thus, the approach for valuation of key ecosystems hinges or anchors around the concept of TEV. However, due to lack of data and information on individuals' willingness to pay (WTP) and willingness to Accept (WTA), the emphasis is on direct and indirect use values of key ecosystems in Yemen.

Methods used to value the key ecosystems include:

- Production Functions Methods: these are indirect valuation methods that infer to the value of ecosystem functions and services through their contribution to production of marketed goods and services. In many instances, ecosystems play an essential role in production of marketed goods and services. Therefore, the value of ecosystems is inferred through the contribution in production function.
- Market values: some ecosystems products such as timber are marketed. However, there are some market distortions due to externalities. For instance, the market price for timber excludes lost services such as carbon sequestration and soil erosion prevention. Even so, market values will be used to infer to the value of ecosystem services.
- Replacement and avoided costs: ecosystems provide services that reduce and prevent economic costs such as siltation of dams and water bodies. In addition, some households use plants medicinal products, thus avoid health care expenses. The method is then used in valuing the avoided economic costs. On the other hand the use of fertiliser in crop production can be used to infer to the value of functions of forests as watershed properties.
- Contribution of Ecosystems to household productivity. Agricultural processes are in many instances, dependent on ecosystem services. For example, pollination and soil productivity. Thus, the relationship will be used to infer to the value of ecosystems.

Table 1 below summaries proposed methods to be employed for key ecosystems functions and services.

Table 1: Proposed methods for biodiversity valuation

Ecosystem functions and services	Method/Approach	Advantage	Limitation
Timber	Market price for timber	Readily availability of data	Timber prices do not factor in externalities
Fuelwood and charcoal	Avoided costs of using LNG	Availability of data for price of gas which is an alternative source of energy and would reflect opportunity cost of forests	n/a
Medicinal products	Avoided health care cost	availability of data on cost of health care	Quantity of medicinal plants harvested lacking
Wild berries	Market price	Existence of market for berries and other edible products	Data is not readily available particularly on quantities
Honey production	Production function/dose response technique	Data available on the contribution of forests on honey production	Will undervalue if production is low
Fodder for livestock	Market price of fodder and avoided cost of supplementary feeding	fodder market price available	Will undervalue this service if the ecosystem is not used optimally
Soil conservation	Siltation and sedimentation costs and replacement cost	Market prices on dam replace readily available	Data is not readily available
Soil conservation (soil erosion control)	Replacement costs (utilisation of fertiliser)	Availability of Data for fertiliser utilisation	Require time series data to determine the impact of soil erosion on productivity
Carbon sequestration	Market price of carbon	Data is available	The price of carbon might not be the true cost of the impacts of carbon dioxide
Fresh water provision	Market price	Simplicity of the method and Data is available	Market distortions on water pricing

Water purification	Mitigation costs	The method is simple and requires a linear relations	Cannot be employed where there are no mitigation measures
Storm prevention/control	Mitigation costs	The method is simply	Cannot be employed where there are no mitigation measures
Tourism	Travel costs/market prices	Application of the method is easy	Based on the premises that tourism is a normal good which could be wrong
Groundwater recharge	Replacement costs	The method is easy to employ	Establishing the relationship between forests and recharge not easy and data might not be available
Pollination	Production function	Contribution of pollinator on agricultural for most of the crops available	Will undervalue the service if agricultural production is not optimal
Food (fish, berries, nuts etc)	Market price	Data is ready available	Suffers from market distortions

2.3. UNCERTAINITY AND LEVEL OF CONFIDENCE IN VALUATION OF KEY ECOSYSTEM

Ecosystem valuation is an exercise that is riddled with problems of uncertainty arising from lack of data and data accuracy and subtle functional relationships with economic activities. In this assignment, data used in estimating the economic value of key ecosystems was drawn from various sources mainly national accounts, FAO reports, and other numerous reports. In some instances, the reports were obsolete with gaps and inferences have to be made. Additionally, some assumptions were used in estimating the value of ecosystem services. In many instance, the researcher opted to use pessimistic assumptions. Therefore, there is a high level of uncertainty in the estimated ecosystem values. Consequently, a high level of uncertainty implies that there is a low confidence level placed on the valuation results. Hence, the results must be interpreted with caution. On the positive note, it is important to highlight that as the data used was mostly obsolete, the actual values of the ecosystem could be higher than those reported in this report.

2.4. VALUATION OF KEY ECOSYSTEMS IN YEMEN

Economic valuation is undertaken for key ecosystems in the country: Forests, Rangelands, Wetlands, Mangroves, marine/fisheries. This approach involves in-depth analysis on the linkages between ecosystem service and function and the economy. Through this analysis, the contribution to production of goods and service will be used to infer to its value.

2.4.1. FORESTS

Defining a forest is not an easy task as evident from the numerous definitions in literature. For instance, Lund (2008) found over 800 definitions of forests. Multiple definitions create confusions and complexity on classification of forests. The existence of multiple forest definitions has led to the formulation of criteria to classify and define forests as follows:

- a minimum threshold for the height of trees (5 m),
- at least 10 per cent crown cover (canopy density determined by estimating the area of ground shaded by the crown of the trees) and;
- a minimum forest area size (0.5 hectares)

Based on the set criteria for classification of forests, there are three categorises of forests in Yemen as depicted in Table 2 below.

Table 2: Forests classification and coverage in Yemen

Categories	Area (000)	% Coverage
Forests	549	1
Wooded land	1406	2.7
Other land with tree cover	500	0.9

Source: FAO, FRA (2010)

Forests provide a wide range of ecosystem functions and services. Incidentally, all the ecological functions and services of forests are beneficial to economic activities (Pearce, 2001). These can be divided into two main groups the direct and indirect uses. The direct uses are those that are associated with forests consumption, these include:

- Timber for commercial and subsistence utilisation
- Fuelwood and charcoal for energy, mainly cooking and heating purposes
- Extraction of genetic material for medicinal purposes
- Sources of food mainly wild berries, gums, nuts, flowers, seeds, wild cocoa, honey
- Fodder for livestock
- Wildlife habitat

Indirectly, forests contribute to economic activities through:

- Watershed properties: these vital functions of forests include soil conservation, control of water bodies siltation and sedimentation, water supply and water quality control and flood control.
- Carbon sequestration and storage: forests are the second main sources of carbon after sea which stores over 50% of the global carbon
- Soil erosion prevention: forests prevent soil erosion ensuring that vital soil nutrients are maintained. In cases where there is soil erosion, farmers resort to application of fertilisers to increase productivity.

These functions and services are valued under each subsection.

2.4.1.1. FUELWOOD AND CHARCOAL PRODUCTION

One of the immediate uses of forest products is fuelwood and charcoal for energy production. This use is mainly prevalent in the rural areas of Yemen. As fuelwood, and charcoal are used for heating and cooking, the two methods to estimate the value of forests as source of energy are:

- Market price of fuelwood
- The amount of energy produced from fuelwood and market price of LNG equivalence

Figure 1: Fuelwood harvesting in Rural Yemen

The market price for fuelwood was USD 60 per ton and based on this market price, Table 3 shows the market value of fuelwood over the years assuming a 5% increase in market prices. The value estimated is the economic value of forest as a source of energy mainly for the rural communities. It is important to note that the value estimated is for both forests, woodlands and rangelands as sources of energy.

Table 3: Economic value for forest as source of rural energy

Year	Harvest (m^3)	Tons	Price/ton	Value (USD)
2000	301900	3867348	46	179,548,812.31
2001	313800	4019787	49	196,448,518.34
2002	326300	4179913	51	215,025,163.65
2003	339200	4345162	54	235,290,531.83
2004	352800	4519379	57	257,604,579.29
2005	366900	4700000	60	282,000,000.42
2006	380500	4874216	63	307,075,634.15
2007	394100	5048433	66	333,953,831.24
2008	407700	5222649	69	362,752,158.96
2009	421300	5396866	73	393,595,434.88
2010	434900	5571082	77	426,616,157.99

Source: FAO (2008)

The second method to determine the economic value of forest as a source of energy for rural household is the use of market price for LNG. The argument advanced is that instead of using fuelwood as a source of energy, households could use LNG. Thus, the energy derived from the fuelwood was converted to LNG equivalence. Table 4 shows the amount of energy produced per year from fuelwood harvested.

Table 4: Energy produced per year from Fuelwood harvested

Year	Harvest (m^3)	Tons	Kg	Energy (MJ)
2000	301900	3867348	3,867,348,057.00	53,369,403,186
2001	313800	4019787	4,019,787,414.00	55,473,066,313
2002	326300	4179913	4,179,912,789.00	57,682,796,488
2003	339200	4345162	4,345,162,176.00	59,963,238,028
2004	352800	4519379	4,519,378,584.00	62,367,424,459
2005	366900	4700000	4,700,000,007.00	64,860,000,096
2006	380500	4874216	4,874,216,415.00	67,264,186,527
2007	394100	5048433	5,048,432,823.00	69,668,372,957
2008	407700	5222649	5,222,649,231.00	72,072,559,387
2009	421300	5396866	5,396,865,639.00	74,476,745,818
2010	434900	5571082	5,571,082,047.00	76,880,932,248

Source: FAO (2008)

Based on estimated energy from fuelwood (Table 4) and the market price of LNG, the economic value of forests and rangelands as energy sources is approximately USD 253,707 million.

2.4.1.2. Fodder production

Fodder production is one of the crucial sources of rural livelihood in developing countries. Fodder production supports livestock sector which sustains majority of the livelihoods in developing countries. Estimations indicate that forests support mainly goats, sheep and camel with fodder. Based on the fodder yield assessment and the total area of forest, table 5 shows the economic value of forests as a source of fodder for livestock.

Table 5: Estimated value of forest as source of fodder production

Forest type	Area	Yield per ton	Price/kg (USD)	Value
Forest	549000	10.7	0.17	1,032,783,906.98
woodland	1406000	10.7	0.17	2,644,980,279.07
other forest	500000	10.7	0.17	940,604,651.16
Total				USD 4,618 million

Source: Agricultural Statistics (2012)

2.4.1.3. TIMBER PRODUCTION

Forests are a source of timber which are either exported or used locally for both subsistence and commercial purposes in construction. The economic value of forest based on timber products is determined from timber harvest quantity and timber market prices. However, information on timber harvesting for commercial purposes is not readily available. For subsistence sector, households use timber for construction purposes such as boats, houses and livestock compounds. As information on number

of households reliant on timber for construction is not available, no attempt was made to estimate the value of forests and rangelands.

2.4.1.4. EXTRACTION OF GENETIC MATERIAL FOR MEDICINAL PURPOSES

One of the most prevalent uses of forest products is medicinal purposes mainly by the rural communities. It is reported that over 130 medicinal plants have been identified in Yemen with varying pharmacological properties. In Yemen, over 75 percent of the population resides in rural areas. High rural population coupled with the predominant poverty levels, pushes the demand and reliance on medicinal plants for health benefits. There are other reasons promoting the use of traditional medicine in the country as follows:

- It is highly original according to the number of plants indigenous or specific of the Yemenite pharmacopoeia
- Majority of the population cannot access health facilities due to geographic location and therefore further distance from health amenities,
- The high cost of public health sector makes it unaffordable to the majority of the Yemenis.

Valuation of the medicinal plants is estimated as the amount of money saved from purchasing modern medicine. It is the amount of money an individual would have incurred had they gone to the general health practitioner for medical attention. The health costs are a function of type of ailment, cure for the ailment and the frequency of GP visits. However, due to lack of data on most of the variables, this valuation method could not be used.

The method that was used to estimate the medicinal value of forests was the costs of visiting a GP in Yemen. According to the Yemen Health Account (2000), health cost per capita was estimated at US$40 per year. To derive the economic value of forest, this per capita cost was multiplied by the total number of people reliant on medicinal plants. The population of those reliant on medicinal plants was estimated from the following assumptions and facts:

- 75% of the population resides in rural areas
- Over 50% of the rural population are dependent on medical plants.
- As forest cover 1% of Yemen total surface area, it was assumed that forests supply only 25% of the medicinal plants the rest is obtained from rangelands

Table 6 shows the economic value of forests as a source of medical plants.

Table 6: Economic value of forests based on medicinal plants use

Health cost per annum per person	Total population reliant on medicinal plants	Economic value of forest as source of medicine
USD40.00	2,156,250	USD 86,250,000.00

Source: Yemen Health Accounts (2000)

2.4.1.5. CARBON SEQUESTRATION

Forests play a crucial role of carbon sequestration and storage, a role that has taken a forefront in climate change mitigation. One of the measures that have been advocated to incentivise forest conservation is that of carbon market. Therefore economic value of forest in Yemen was estimated based on the amount of carbon stored. Table 7 shows biomass stock for the forests, used to estimate carbon stock (Table 8) as derived from FAO, FRA (2010).

Table 7: Biomass stock in Yemen forest

Category	Biomass (million metric tonnes oven-dry weight)	
	Forest	Wooded land+agro forestry
Above-ground biomass	7.68	24.61
Below ground biomass	3.3	10.59
Deadwood	1.54	4.93
Total	12.52	40.13

Source: FAO FRA (2010)

Table 8: Carbon stock in Yemen forests

Category	Carbon (million metric tonnes)	
	Forest	Wooded land + agro forestry
Carbon in above ground biomass + carbon in below ground biomass	5.16	16.55
Carbon in dead wood + carbon in litter	1.87	6.32
Soil carbon	19.22	66.71
Total	26.25	89.58

Source: FAO FRA (2010)

According to expert assessment, carbon sequestrated per hectare for forests and woodland is estimated at 47.81 metric tonnes and 47.05 metric tonnes respectively.

Based on the estimated carbon stock and sequestration, Table 9 depicts the economic value of forests and woodland as sources of carbon sink.

Table 9: Economic value of forests as carbon sink

Category	Carbon (million metric tonnes)				
	Forest	Wooded land + agro forestry	Price	Forest value	Woodland value
carbon in above ground biomass + carbon in below ground biomass	5.16	16.55	20	103,200,000.00	331,000,000.00
carbon in dead wood + carbon in litter	1.87	6.32	20	37,400,000.00	126,400,000.00
soil carbon	19.22	66.71	20	384,400,000.00	1,334,200,000.00
Total	**26.25**	**89.58**	**20**	**525,000,000.00**	**1,791,600,000.00**

Source: FAO FRA (2010)

2.4.1.6. WILDLIFE HABITAT

Forests and woodlands are an important habitat for wildlife and birdlife. As wildlife and birdlife are a major tourism attraction, the indirect way to value forests as wildlife habitat is to determine the contribution of wildlife based tourism to national tourism sector. Forests in Yemen are home to various wildlife such as Arabic leopard (*panthera pardus nimir*), Arabian wolf (*Canis lupus*), Caracal Lynx (*caracal caracal*), striped hyena (*hyaena hyaena*), lesser Indian civet cat (*Viverricula indica*), wild Cat (*Felis sylvestris*), Arabian Oryx (*Oryx leucoryx*) and many others.

In order to estimate the contribution of wildlife to tourism, there is need to determine the contribution of wildlife based tourism to the overall tourism sector. Yemen has the following types of tourism:

- Cultural tourism
- Therapeutic tourism
- Mountaineering Tourism
- Ecotourism
- Desert tourism
- Marine tourism
- Wildlife based tourism

Based on the fact that Yemen is highly endowed in marine ecosystems with low wildlife species abundance, secondly, its fame for cultural and therapeutic tourism, a conservative figure of 2.5 percent contribution to the total tourism revenue is given to wildlife based tourism. Table 10 depicts the value of forests as habitat for wildlife-based tourism based on 2009 revenue figures.

Table 10: Value of forests as wildlife habitat

Tourism revenue (USD million)	Contribution of wildlife based	value of forests as wildlife habitat (USD million)
903	2.5%	22.575

2.4.1.7. WATERSHED SERVICES

Forests watershed properties are vital for water bodies particularly water quality, reduced sedimentation and siltation. The watershed properties of forests and woodlands include absorbing and breaking down waste and chemical, in the process purifying both surface and groundwater. In addition, by reducing runoff to considerable speed, forests enhance water infiltration and thus improve groundwater recharge rates. Thus, similar to other functions and services, the role played by forests in water conservation can be valued. Water in the rural Yemen is mainly informal, residents are dependent on groundwater, spring, and streambeds called *wadis* which are seasonal. The aquifers are recharged from *wadis*. Perceptibly, *wadis* and aquifers (groundwater) are the main sources of water supply for both the rural and urban population. Studies elsewhere found that timber harvest and slash burning increase stream sedimentation (Adams and Taratoot, 2001). Another important function of forest is fog drip from forests which add significantly to water bodies (Adams and Taratoot, 2001). Thus, it can be deduced that the economic value of forest watershed is quite significant in terms of maintaining water bodies capacity, recharge of groundwater and improved water quality. For instance, with forest, runoff and deposition of agricultural inputs (fertilisers and pesticides) is reduced thus maintaining water quality. However, due to data unavailability and the complexity of estimating contribution of forests to recharge, reduced sedimentation and siltation of the *wadis,* it was not possible to put a monetary value to watershed properties.

By reducing runoff to considerable velocity, forests control flooding and thus reduce the costs associated with flood events. Consequently, the function of forests as flood control is significant and will become increasingly vital with climate change and extreme events. However, due to complex relationship between forests and flooding and lack of required data, it is not possible to estimate the value of flood control.

2.4.1.8. SOIL FERTILITY MAINTENANCE AND EROSION PREVENTION

According to FAO, forests and trees contribute to household food security by crafting optimal conditions required for agricultural production. Chiefly, forests maintain and stabilise soils, by reducing soil erosion. In the process, they maintain soil nutrients and fertility and enhance soils capacity to store water. Consequently, from this end, the value of forests can be traced through increased agricultural productivity. There are several ways/methods that can be used to estimate the economic value of forests in agricultural production.

The first method is to analyse production levels of farms that are near the forested areas and those that are far from forested areas. It is envisaged that farms in the proximity of forests will have high yields relative to those that are a distance from forests. Alternatively, farms that are far from forests would have high use intensity of fertilisers. Thus, the difference between yields of the farms would be attributable to forests functions in maintaining soil fertility or the difference in fertiliser use.

Another method would be to use the avoided costs of fertiliser utilisation, thus a replacement costs. For farms not using fertilisers, the avoided costs could be taken as a proxy for the value of forests in maintaining soil fertility and optimal conditions for agricultural productivity.

The second method of avoided costs is used to infer to the value of the forest. Analysis reveals that fertiliser utilisation has been declining (Figure 2) while cultivated area and yield per hectare have experienced growth over time. This could be attributed to the functions of forests, vegetation and terraces in maintaining soil fertility.

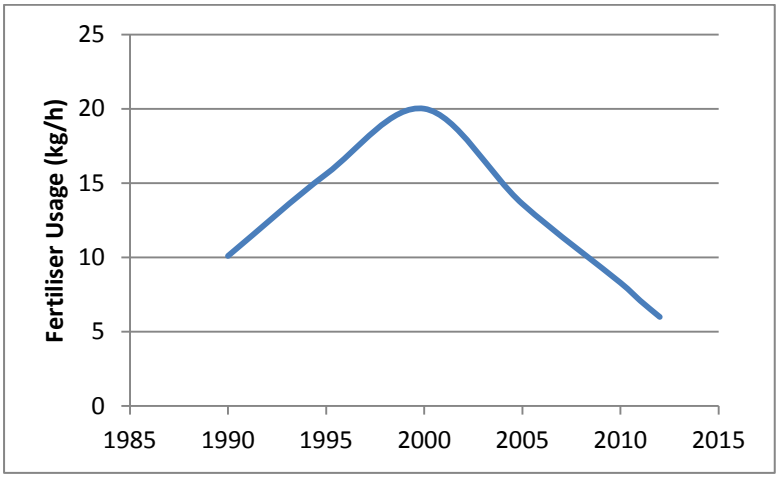

Figure 2: Fertiliser usage in the country

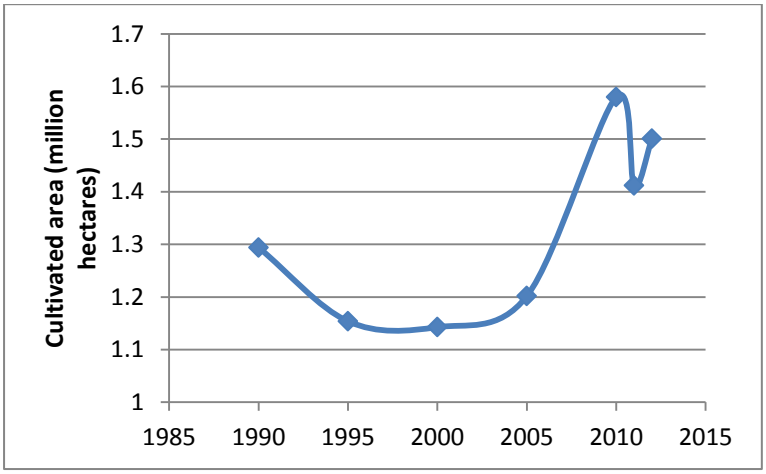

Figure 3: Cultivated land in the country over time

Given that forests and woodland cover only 1 percent of the country surface area, estimating the function of forests in maintaining soil fertility and optimal conditions for agricultural system was based on the following assumptions:

- 10 percent of farms are in the proximity of forests, this translates in 150,100 hectares of cultivated land near forests.
- The decline in the use of fertiliser is attributed to forests maintaining soil nutrients and hence sustaining non-declining yields.

Based on these assumptions, the avoided cost of fertiliser use is estimated as per Table 11.

Table 11: Economic value of forests on agricultural production

Reduced fertiliser use per hectare	Number of hectares for farm on proximity of forest (hectares)	Price of fertiliser per kg (USD)	Avoided cost of fertiliser (USD)
15kg/hectare	150,100	0.54	1,222,606.21

Source: agricultural Statistics (2012)

2.4.1.9. HONEY PRODUCTION

Forests play a significant role in the production of honey. They provide nectar which is a primary input in honey production. In fact, FAO argues that "without bees there would be no flowering plants, and without flowering plants there would be no bees". Forests only cover 1 percent of Yemen, thus, the contribution to honey production is assumed to be low, estimated at 10 percent and the remaining 90 attributed to rangelands. In addition, as honey production in Yemen is natural, it is assumed that forests contribute 100 percent to its production. Based on this assumption Table 12 shows the value of forests in honey production.

Table 12: Economic value of forest based on honey production

Total value of honey per year (USD)	Assumed contribution of forest	Value of forest in honey production (USD)
80,488,372.00	10%	8,048,837.20

Source: Agricultural statistics (2011)

2.4.1.10. POLLINATION

Food production is highly dependent on insect pollination, and among the pollinating insects, bees are the major pollinators. The dependence of trees and crops on pollination various greatly. Karimzadegan *et al.,* (2007) studied the dependence of crops on pollination and Table 13 depicts dependence of various crops on pollinator insects. The dependence of crops on pollinators can be used to infer to the value of forests, as forests act as a habitat for pollinators.

Table 13: Dependence of crops on pollinators

Crop	Dependence on pollinators
Hay	1
Cotton	0.2
Bean	0.1
Onion	1
Cucumber	0.9
Watermelon	0.7

Source: Karimzadegan et al (2007)

Based on the average of 0.5 as crop dependence on pollinators Table 14 shows the economic value of forests as habitat for pollinators.

Table 14: Value of forests as habitat for pollinators

Agricultural value (USD)	Contribution of pollinators	percentage of forests as habitat for pollinators	economic value of forests as habitat (USD)
5,925,404,651.00	0.5	1%	29,627,023.26

Source: agricultural Statistics (2011)

2.4.2. WETLANDS

Various definitions for wetlands have been coined over the years. RAMSAR convention defines wetlands as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water, the depth of which does not exceed six metres at low tide. According to Frazier (1996) Wetlands can generally be classified into five basic systems, namely: Lacustrine, Riverine, Palustrine, Marine and Estuarine. Thus, wetlands include lakes and rivers, swamps and marshes, wet grasslands and peatlands, oases, estuaries, deltas and tidal flats, near-shore marine areas, mangroves and coral reefs, and human-made sites such as fish ponds, rice paddies, reservoirs, and salt pans. The importance of wetlands in human livelihoods cannot be overemphasised as evident on the fact that over 75% of the human population resides in the proximity of wetlands.

Similar to other ecosystems such as forests, wetlands are multi-functional providing ecological services and functions which cannot be delinked from economic activities. Wetlands functions and services are used both directly and indirectly by human kind. The direct uses of wetlands services include the following:

- Food provision: wetlands support the agricultural production systems. In addition, they provide fruits and fish for consumption and sale
- Fresh water: wetlands are a source of freshwater for both consumption (urban and rural), industrial and agricultural activities
- Forest products and medical plants: wetlands play a critical role in forests products such as timber, fuelwood, peat and fodder and medical plants

Indirectly, mankind benefit from wetlands functions and services in the following manner:

- Climate regulation: similar to forests, wetlands capture and store carbon, thus regulate both micro and macro climate. Consequently, mankind benefit from the avoided impacts of climate change from carbon storage and sequestration

function of wetlands. In addition, through regulation of micro climate, wetlands create optimal conditions for agricultural productivity.

- Water regulation: wetlands are generally known to play an important role in groundwater recharge. Part of the water stored in wetland filters into ground and recharge aquifers. It is estimated that over a billion people in Asia are totally dependent on groundwater (Wildfowl and Wetland Trust, undated).
- Habitat for wildlife: wetlands play a critical role as habitat for various wildlife species including Pollinators such as bees which have a significant impact on agricultural productivity and honey production.
- Water storage: by storing water, wetlands particularly the mangroves, act as flood and soil erosion control. The wetland's vegetation stabilises shorelines and act as protection against storms and control wind speed. Moreover, they minimise the impacts of waves, water flow and runoff.
- Retention of nutrients: wetlands have the most peculiar ability to remove nutrients from economic activities (nitrogen and phosphorus). This makes them the most highly biological productive ecosystem. The added benefit of retention process is the prevention of eutrophication of water bodies downstream and hence suppresses algal blooms. Adding to that, wetlands have the capacity to remove toxic substances.
- Recreational and tourism activities: wetlands present ample opportunities for tourism and recreational activities owing to their aesthetics and flora and fauna diversity.

Identified wetlands in Yemen, included mangroves, steambeds (*wadis*) and coral and marines and these are discussed below.

2.4.2.1. MANGROVES

Mangrove ecosystems are arguably the second most productive ecosystems in the world. In Yemen, the Mangroves are distributed along the Red sea and the Gulf of Aden, extending along the coastal line over 730 km. Current coverage of mangroves is estimated at 980 hectares.

It is estimated that one square kilometer of mangrove forest contributes to over 600 tonnes of plant material each year to the estuarine food webs.

Some of the ecological and economic functions played by mangroves are as follows:

- act as a buffer zone between land and the sea
- Protect the coast, coral reefs and ship lining against erosion from wind, waves tidal waves
- Absorb pollutants and thus protect wildlife species from pollution
- Provide flood protection from extreme events such as typhoon and hurricanes
- Habitat for various sea species including avian species

- Provide wide range of forest products for human consumption such as timber, fuelwood, fodder for livestock, medicinal plants, honey production,
- Absorb pollutants (such as fertilisers) and thus maintain a healthy marine life

Similar to other ecosystems, the economic value of mangroves, is estimated, based on functions they perform in production of economic goods and services or their contribution to livelihoods. Valuation of the functions of mangroves proved difficult due to data unavailability. Services and functions excluded from valuation included the following:

- Provision of flood protection from extreme events such as typhoon and hurricanes
- Protection of coral reefs and shoreline from erosion
- Absorption of pollutants (such as fertilisers) and thus maintain a healthy marine life

2.4.2.2. VALUE OF MANGROVES AS SOURCE OF FUELWOOD AND CHARCOAL

Mangroves provide energy for rural communities through the use of fuelwood and charcoal. This value was estimated through establishing the population along the mangroves forests and their fuelwood daily requirements. It is estimated that an individual in Yemen consumes in the range of 0.9-3 kg fuelwood per day. This is equivalent to approximately 12.42-41.4 MJ. In order to estimate the quantity of fuelwood harvested it is critical to determine the number of communities residing in the proximity of Mangroves. PERSGA (2004) did a detailed assessment on the status of the mangroves in the Red Sea and Gulf of Aden. Their assessment covered over 95% of mangroves ecosystem in Yemen. The study indicated that most of the mangroves are sparsely populated. Based on the estimated energy requirement and the total population of communities in the proximity of mangroves, Table 15 depicts the use value of mangroves as a source of energy.

Table 15: Value of mangroves as energy source

Total population	Daily fuelwood demand	Total wood annually	Energy from fuelwood (MJ)	Price of LNG per kg	Economic value of energy (USD)
20000	1	7,300,000.00	100,740,000.00	3.33	335,464,200.00

2.4.2.3. VALUE OF FODDER

Mangroves are grazing grounds for livestock mainly camels, sheep and goats. Rouphael *et al* (undated) noted that "Grazing of mangroves by camels was observed on numerous occasions near Al Hudaydah and Al Luhayyah" in some instance over 100 camels sighted. In addition, investigations reveal that all mangrove forests in the country have been subjected to over-grazing mainly by camels. Estimating the value of mangroves as a source of fodder for livestock was

based on the value of alternative livestock feed supply. The argument is that farmers have the alternative of feed supplementing the livestock. Therefore, the value of mangroves is the avoided costs of supplementary livestock feed. Estimation of value of mangroves was based on the following parameters:

- The population density of camels, estimated at 0.84 camels per m^2 while goats were estimated at 17 goats per m^2 for the whole country
- Size of mangroves in the country was estimated at 81 km^2 based on Spalding *et al* (1997).
- Total population of camels and goats supported by mangroves is estimated at 68 and 1405 respectively

In addition, the following assumptions were made:

- camels and goats intake per day is 10 % of their live weight
- Weight of the average camel and goat was estimated at 600 kg while goat average weight is estimated at 45 kg
- Contribution of pasture to feeding is 60% (FAO, 2000)

Based on the above assumptions, Table 16 depicts the economic value of mangroves as a source of fodder.

Table 16: Value of livestock fodder from Mangroves

Livestock	contribution of pasture to feed (%)	number of livestock	intake per day (kg)	total fodder intake (kg)	price of fodder (USD)	Value (USD)
Camel	0.6	68	60	893520	0.17	157,093.28
Goats	0.6	1405	5	1538475	0.17	261,540.75
Total						418,634.03

Source: Agricultural Statistics (2012)

2.4.2.4. VALUE OF TIMBER FROM MANGROVES

Mangrove forests are a source of building material for communities living in the proximity of the mangroves forests. The mangroves are mostly harvested and used for construction of bird traps and houses. Studies have highlighted the suitability of mangroves trees for house and boat construction. Thus, the value of timber from mangroves is a function of the following:

- number of people harvesting mangroves for house construction
- number of boats constructed from mangroves
- price of alternative building material
- price of modern boat

Due to lack of data on the parameters of timber utilisation, it was extremely difficult to estimate the value to mangroves as a source of timber.

2.4.2.5. CARBON SEQUESTRATED IN MANGROVES

In the same way as other forests, mangroves, store and sequestrate carbon therefore act as a mitigation measure against the impacts of climate change. The amount of carbon is a function of size and mangrove growth rate. Based on the surface area of mangroves in the country, Table 17 depicts carbon stored in forests and their total value in a year.

Table 17: Economic value of carbon stored in mangroves

Size of Mangroves (hectares)	Carbon per hectare in Yemen forest (metric tonnes)	Total carbon (above and below ground biomass) metric tonnes	Price of carbon USD/ton)	Economic value (USD)
8100	10.58494	85738.05	20	1,714,760.98

Source: FAO FRA (2008)

2.4.2.6. HABITAT FOR FISH

Mangroves are highly productive ecosystems, with estimates that one (1) square kilometre of mangrove forests produce over 600 tonnes of plant material each year to the estuarine food webs. They are breeding or spawning grounds for various fish species such as shell, crabs, prawn, shrimps, and bivalve molskes. It is estimated that one hectare of mangroves yields between 1000-1200 kg of fish. Basing on the estimated 81 km^2 of mangroves in the country, and the mean 3,600 kg per hectare, the total yield of Yemen mangroves is estimated at 29,160,000 kg which is equals to 29,160 tonnes of fish. The price of fish species in the Mangroves habitat is estimated at USD 5/kg. Thus the economic value of mangroves as habitat for fish is estimated at USD 145.8 million per annum.

2.4.2.7. OTHER VALUES OF MANGROVES

It is critical to highlight that there are other uses both directly and indirectly of mangroves that were not estimated due to lack of data. For instance, due to the diversity of mangroves in terms of avian and reptiles and other species, mangroves are a hotspot for tourism and recreational activities. In addition, mangroves provide food for communities. There are also other indirect uses of mangroves such as harvesting timber to make bark and honey production. These values have not been estimated due to data unavailability.

2.4.3. MARINE ECOSYSTEM

Yemen is one of the countries endowed with marine resources. Its coastline covers approximately 2200 km, the Gulf of Aden and Red Sea covering 1460 km and 730 km respectively. It is estimated that the Red Sea coast supports 25 percent of coral reefs as opposed to the Gulf of Aden supporting 5 percent of the fringing coral communities or reefs. The coral reefs in the country support over 300 species in 60 genera and 14 families of *scleractinian* stony coral. Coral reefs are highly diverse marine ecosystems that are a habitat for various fish communities in the sea. Some of the vital functions and services played by the coral reefs communities include:

- Acting as a barrier by preventing sediments from corroding the shoreline
- Carbon sequestration
- Construction purposes
- Medicinal purposes and manufacturing of jewellery
- Habitat for fish used for aquariums

The other highly diverse ecosystem in the marine is the sea grass. The sea grasses community comprises of flowering plants that can be categorised in four plants families being *Posidoniaceae, zosteraceae, hydrocharitaceae*, and *cymodoceaceae*, which are tolerant to saline environments. Studies indicate that the Gulf of Aden coast supports few communities of sea grasses compared to the Red Sea coastline. The functions and services of the sea grass ecosystem that contributes to economic productions include:

- Habitat for various species from all phyla, such as juvenile and adult fish, epiphytic and free living macroalgae and microalgae, molluscs, bristle worms and nematodes
- Carbon sinks and sequestration: it is estimated that the sea grass ecosystem accounts for over 15% of the sea total carbon storage and that the sea grass, stores and absorbs twice the carbon as rain forest
- Protection against coastal erosion: the ecosystem absorbs intense wave and thus protects the coastal line from erosion
- Absorption of nutrients from agricultural runoff and thus control pollution and the level of pollutants
- Manufacturing of fertilisers
- Manufacturing of furniture

Consequently, the interactions between coral reefs, sea grass and mangroves contribute to fish production. It is estimated that value of fish harvest in the country is approximately USD 541 million, which is the value of coral reefs, mangroves and sea grass.

2.4.3.1. WADIS OR PERENNIAL RIVERS

Wadis ecosystems are multifunctional with diverse functions and services beneficial to the economic activities. *Wadis* have both use and non-use values community

members are willing to pay for. Similar, to the other ecosystems, estimating the value of *wadis* can be inferred through their contribution to the production of marketed goods and services. For instance, *wadis* are a source of water for both domestic and agricultural sectors. In addition, they are a source of grazing area for livestock particularly during the drought periods. Most importantly, the rivers provide food sources such as fish for communities. Estimating the value of *wadis* as a source of water supply for both domestic and agricultural sectors was based on the following parameters:

- Percentage of agricultural production dependent on *wadis*
- Number of people dependent on *wadis* as a source of water supply
- Willingness to pay for water at the informal sector.

Analysis reveals that over 50 percent of the country's poor population have no access to improved water supply and therefore are dependent on *wadis* and water wells (UN, 2011). Therefore, *wadis* play a critical role as a source of water supply for the rural population. In rural Yemen, it is estimated that daily water consumption is approximately 40 litres (IRIN, Undated). The informal price of water which defines the willingness to pay for water is about USD40 for 2500 litres which translates into USD0.016/litres. Based on the above information and assuming that *wadis* only supply water for 6 months in a year, Table 18 depicts the value of water supplied from *wadis*.

Table 18: Value of water from the wadis

Population dependent on wadis (millions)	water consumption per day (l)	total water supply from wadi (million l)	Price of water at informal sector (USD/l)	Value of water from wadis (millions)
8.625	40	62100	0.016	993.60

Source: UN (2011)

Wadis are also a source of water supply for the agricultural sector. It is estimated that the agricultural sector consumes about 90 per cent of available surface and ground water. According to Al-Asbahi *et al* (2005) of Yemen's nearly 1.6 million hectares cultivated land approximately 45% relies on rainfall while 55% is irrigated by groundwater (67%) or season water floods i.e. "spate irrigation" (23%). Spate irrigation systems feed 120-150,000 ha in the low lands and there are approximately 800 dams for rainfall water harvesting in the highlands (Al-Asbahi *et al,* 2005). Therefore, *wadis* supply 23 percent of water which translates into 805 million m^3. Based on the USD0.016/l total value of water is USD12,880 million

Based on these findings and assumptions, the total use value of *wadis* as source of water is calculated at USD 13,873 million per year.

2.4.3.2. SOURCE OF GRAZING AND MITIGATION AGAINST EXTREME EVENTS

Wetlands such as *wadis* are important grazing sources for livestock particularly during the extreme events such as drought. In order to estimate the value of *wadis* as a source of fodder and mitigation against extreme events, the following parameters are a prerequisite:

- Size of the grazing land supported by the *wadis*
- Number of livestock grazing within the *wadis*
- Livestock mortality avoided due to grazing within the *wadis*

However, due to lack of data, it was not possible to estimate the value of *wadis* as grazing ground for livestock.

2.4.4. RANGELANDS

Rangelands are the most extensive ecosystems globally, covering approximately 70 percent of the world surface area. Rangelands can be categorised into 9 types being Prairie, Grasslands, steppe, Pampas, scrubland, woodland, Savannah, deserts and tundra. They are defined by FAO as any area of pasture or other grassland available for stock grazing. Due to the vast area coverage, rangelands are critical to the sustenance of livelihoods. They play a significant role in providing functions and services to economic and environmental activities. The primary functions and services offered by rangelands include the following:

- Grazing resources for livestock
- Food and fiber production
- Source of energy for communities
- Climate regulation through carbon sequestration
- Water purification properties
- Wildlife habitat
- Pollination of agricultural products and increased productivity
- Recreational and tourism functions and services
- Soil erosion prevention

2.4.4.1. VALUE OF RANGE AND PASTURE TO LIVESTOCK

One of the main functions of rangelands is the production of fodder for livestock. Rangelands are therefore the backbone for livestock production and by-products such as beef and milk. In developing countries, rangelands support livestock with virtually no supplementary feeding needed. The total area coverage of the rangelands in Yemen is estimated at approximately 22 million hectares and provides fodder, grasses and shrubs/trees for cattle, goats, sheep, donkeys and camels. It is estimated that natural grazing in the county contributes over 80% of annual livestock feed requirement particularly for sheep and goats (Alabsi, undated). In contrast to small livestock, it is revealed that cattle in most places are housed and stall-fed through the year and occasionally grazed. Thus, it is assumed that pasture

contributes to 50% of the cattle requirement. On the other hand, camels and donkeys are grazed freely. Using the contribution of pasture to livestock production, its value was estimated as the avoided supplementary feed costs that the farmer would have incurred. Table 19 below depicts the value of pasture on livestock production system.

Table 19: Value of pasture on livestock sector for 2012

Livestock	Contribution of pasture	Number	Food requirement (% of body weight)	Weight	fodder intake (million tons)	Price of fodder	Economic value (USD million)
cattle	0.5	1684000	0.1	700	21	0.17	3,657
sheep	0.8	9419000	0.1	50	13	0.17	2,337
Goat	0.8	9158000	0.1	50	13	0.17	2,273
camels	0.9	443000	0.1	600	8	0.17	1,484
Total							**9,752**

Source: Agricultural Statistics (2012)

2.4.4.2. HONEY PRODUCTION

Alike forests, rangelands vegetation specifically the flowering plants play a significant role in the production of honey. They provide nectar which is a primary input in the production of honey. Based on the total value of honey produced in the country, Table 20 depicts the value of forests in the production of honey. The value is based on the assumption that rangelands vegetation provides 70% of the nectar and the rest is obtained from inorganic and garden flowers.

Table 20: Economic value of forest based on honey production

Total value of honey per year (USD)	Assumed contribution of forest	Value of forest in honey production (USD Million)
80,488,372.00	70%	56,341,860.40

Source: Agricultural Statistics (2012)

2.4.4.3. MEDICINAL PLANTS

Similar to forests and woodlands, rangelands are sources of medicinal plants. Some of the medicinal plants include *Boswellia Sacra, Jatropha unicostata, Commiphora socotrana, Euphorbia arbuscula, Dracaena cinnabari*. It is estimated the dragon's blood tree products is sold for as much as USD 33/kg. Relative to forests, the spatial coverage of rangelands is larger and therefore, their role in provision of medicinal plant is significantly higher. Estimation on the utilisation of medicinal plants was based on the earlier assumptions for forests. Table 21 shows the estimated value of medicinal plants based on the avoided modern health costs.

Table 21: Economic value of rangelands as source of medicinal plants

Health cost per annum per person (USD)	Total population reliant on medicinal plants	Economic value of forest (USD)
40	6,468,750	258,750,000.00

Source: Health Statistics (2005)

2.4.4.4. RANGELAND AS HABITAT FOR POLLINATORS

As rangelands are habitats to pollinators, rangelands indirectly contribute to food production. An assumption made in estimating the economic value of rangelands is that, rangelands habitats account for only 70%, the other habitats being forests, woodlands and gardens. Table 22 shows the estimated economic value of rangelands through indirect contribution to food production.

Table 22: Value of rangelands as habitat for pollinators

Agricultural Revenue (USD)	Contribution of pollinators to food production	Percentage of rangeland as habitat for pollinators (%)	Economic value of forests as habitat (USD million)
5,925,404,651.16	0.5	0.7	2,073

Source: Agricultural Statistics (2012)

2.4.4.5. WATERSHED VALUE OF RANGELAND

Rangeland similar to forests, have watershed properties that are vital for water bodies mainly water quality, reduced sedimentation and siltation. In addition, by reducing runoff to considerable speed, rangelands vegetation enhance water infiltration and thus improve groundwater recharge rates. As Yemen is 90% reliant on groundwater, the role played by rangelands in enhancing recharge is invaluable. In addition, there are various *wadis* which supply farmers and the Yemen rural population with water. These *wadis* are protected from sedimentation and siltation by rangeland vegetation. However, due to data unavailability mainly erosion rates and recharge rates, it is difficult to estimate contribution of rangelands vegetation to groundwater recharge, reduced sedimentation and siltation of the *wadis*. However, it is emphasised that the economic value of recharge and maintenance of wadis capacity to hold adequate water are significantly high.

2.4.4.6. CARBON STOCK AND SEQUESTRATION

Rangelands vegetation capture and store carbon dioxide and therefore controls climate change and global warming. However, as the rangelands vegetation are highly dynamic due to grazing, slash and burn, estimating the carbon storage is extremely complex and the carbon stored cannot be traded due to uncertainty in

the dynamics of land use change. Nonetheless, the contribution and role played by rangelands as a source of carbon is enormous.

2.4.4.7. SOIL EROSION PREVENTION AND MAINTENANCE OF SOIL NUTRIENTS

Rangelands vegetation acts as wind shield and their roots maintain soil structure and thus prevent soil erosion. Thus, rangelands vegetation directly and indirectly contributes to food production by maintaining soil nutrients. The economic benefit of rangelands vegetation can be estimated as the avoided costs of fertiliser utilisation to either maintain certain production levels or increase production. Basing on the assumption made early and the fact that range and pasture occupy 40% of the total land, it was assumed that over 60% of the cultivable land is located around the rangelands.

Table 23 shows the estimated economic value of rangelands for preventing soil erosion and maintaining soil nutrients.

Table 23: Avoided cost of fertiliser use due to rangeland vegetation

Reduced fertiliser use per hectare	Number of hectares for farm on proximity of forest (Hectares)	Price of fertiliser per kg (USD)	Avoided cost of fertiliser (USD)
15kg/h	900,600	0.54	7,335,637.26

Source: Agricultural Statistics (2012)

2.4.4.8. RANGELANDS AS SOURCE OF FOOD AND CONSTRUCTION MATERIAL

Rangelands provide food and construction material to the rural population. They are a source of berries, wildlife fruits and fibre which the community collect for home consumption and sale at urban centers with high demand. Therefore, rangelands are an important source of revenue for the rural community. Some of the important berries and wildlife fruits that are harvested by the rural population include dates fruits, *Ziziphus spina-christi, Sterculia sp. Tamarindus indica, Ficus sp, Rhis sp* and *cordial sp*.

The income generated from sale is highly significant. However, due to lack of data it is not possible to put a monetary value of these vital functions of rangelands.

2.5. ESTIMATED ECOSYSTEM ECONOMIC VALUE AND GDP

Total estimated value of key ecosystem in the country is estimated at approximately USD 261,542 million as shown is table below, whilst the country's GDP is estimated at approximately USD 20,000 million per year. Therefore, the ecosystem value is ten times the value of GDP. From this end, it can be deduced that only a small fraction of the ecosystem value is integrated in the country's value of goods and services produced in a year (GDP). Most of the ecosystem values such as value of energy

from fuelwood, the medicinal values of forests, pollinators etc are not taken into account when estimating GDP. Thus, a significant value of ecosystem services and functions are ignored in economic decision making. One of the factors contributing to the overlooking of ecosystem values in derivation of national income accounts is the informal sector as majority of trading in ecosystem functions and service occurs in the informal sector (energy, traditional health sector, water sector etc). It is therefore important that efforts be geared towards integration of the ecosystem values in deriving national income accounts and at all levels of decision making.

Table 24: Economic value of key ecosystems

Key ecosystem	Economic value (USD Million)
Forest	260,787
Rangeland	2,404
Wetland	13,873
Marine	541
Mangroves	482.9

The ecosystem values are derived from their contribution to various economic production sectors. One of the issues arising is whether the estimated economic values are sustainable over time. Due to the fact that there is high dependence on fuelwood as a source of energy, water resources and marine resources are depleted at an accelerated rate, it can be concluded that there is a need to reduce consumption and utilisation of key ecosystem to sustainable rates in order to achieve non-declining ecosystem values over time.

2.6. OPPORTUNITIES FOR POVERTY REDUCTION THROUGH ECOSYSTEM VALUE CHAIN ADDITION

Analysis revealed that poverty levels in the country are high, estimated at over 34% of the population. One of the ways in which poverty can be reduced particularly at the rural areas is through value addition of forests and rangeland products. Yemen has numerous plants that have medicinal and cosmetic properties whose potential have not been tapped into. Through rangeland products value addition initiatives, the rural communities can benefit in the production processes through employment and income generation activities such as collection, transportation, processing and storage. Through these activities rural communities have opportunity to benefits through multiplier effects. As most disadvantaged households are women headed, it is important that value addition projects emphasis on such vulnerable groups and the youth. Among opportunities that present amble prospects for poverty alleviation include:

- huge demand for medicinal and cosmetic products in European and Asian markets
- abundance of plants with known medicinal properties in Yemen

- existence of substantial traditional and indigenous knowledge on medicinal plants in the country
- available of funds from organisations such as GEF aiming at supporting poverty reduction initiatives in developing countries particularly on sustainable rangeland products

3.0. ECONOMIC ACTIVITIES AND ECOSYSTEM INTERACTIONS

3.1. INTRODUCTION

This section of the report addresses the following specific objectives:

- Assess the structure and composition of the economy, including major economic activities, macroeconomic and sectoral strategies and policies in relation to biodiversity and ecosystem impacts; and,
- Investigate the impact of economic activities and policies on national biodiversity.

Consequently, an assessment of the contribution of different economic activities to GDP in the country is undertaken. Adding to that, a detailed description of the activities within the major economic sectors is undertaken. In order to achieve these specific objectives, the following methods were employed:

- Literature review: literature review on GDP in the country was conducted to identify key economic sectors and the various activities within each sector.
- Interviews with key stakeholders: key informants were consulted with the objective of identifying the key economic sectors in the country.
- Systems approach: this is a methodological approach that assesses the impacts of the system on interrelated variables through establishing a system boundary. The method studies how factors interact to determine the systems behaviour and the resultants feedbacks based on the causal loops.

3.2. YEMEN ECONOMIC STRUCTURE

Yemen is a least developing country and as such characterised by high unemployment, levels of chronic poverty and a skewed informal sector. It is estimated that over 90% of the labour force is employed in the informal sector. Nonetheless, the key economic sectors are similar to any other economy being, agriculture, industry and manufacturing, construction, and services (trade, transport, financial). Table 25 depicts contribution of key economic sectors to the national GDP as of the year 2010. During the 1990s, the country registered an impressive real GDP growth estimated at 5.5% (World Bank, 2002). This was despite the major international and local shocks of civil war, drought and the Gulf war. It is argued that the growth was attributed to factor accumulation both labour and capital (World Bank, 2002). However, the economy has experienced some major fluctuations as evident from GDP.

Table 25: Structure of Yemen Economy

Sector	%Share to GDP
Agriculture	11.1
Cereals	0.8
Cash crops	3.6
Qat	3.5
Livestock	2.2
Fishery	1
Industry	43.2
Oil and gas	19.4
Food processing	3.5
Other industry	12.7
Electricity and water	1.2
Construction	6.4
Services	45.8
Trade and transport	20
Other private service	11.3
Education and health	5.8
Other public services	8.7

3.2.1. THE AGRICULTURE SECTOR

The agriculture sector in the country is practised on approximately 1.08 million hectares arable land (UNDP, 2006) on four (4) agro-ecological zones, the Highlands, The eastern Plateau, the *Tihâma* and the coast. Thus, the agriculture sector takes approximately 2% of the Yemen land. The sector is classified as traditional as opposed to modernised (Republic of Yemen and UNDP, 2010). It is characterised by high dependence on rain-fed, and primitive production methods with apparent lack of modern technology (Republic of Yemen and UNDP, 2006). The most important agro-ecological zone is the Highland and its productivity is based on terraces. Crops that are produced in this zone include cereal, legume cropping, Qat, coffee, fruits and olives. *Tihâma* is the second important agro-ecological zone. The production system is based on rain-fed water management systems and aquifers recharge from the highland *wadis.* Similar to the highlands zone, crops that are cropped include Qat, grain, fruits and vegetables. The Eastern Plateau is of similar importance to the *Tihâma.* Table 26 depicts proportion of the different agro-ecological zones to agricultural systems in the country.

Table 26: Agro-ecological zones and percentage of cultivated area

Agrico-ecological zone	% of cultivated area	Number of farms
The Highlands	44	61
the eastern Plateau	26	19
The Tihama	26	10
The coast	4	10

Source: FAO 2005

Table 27 below shows the percentage of cultivated land for the different crops in the country. Clearly cereal (mainly sorghum and maize) are the most planted crops, followed by qat at 11%.

Table 27: Percentage of cultivated land for different crops

Crop type	% of cultivatable land
Cereal	50
Sorghum/maize	35
Wheat	8
Cash crop	18
Qat	11
Coffee	3
Fodder	11
Fruits	9
Vegetables	7
Pulse	5

Source: FAO, 2005

Analysis of the agricultural production dynamics reveal that there is a significant shift in the production of cash crops with majority of household farmers favouring qat over other crops. It is estimated that qat cultivation grew from 9% in 2000 to over 11% by 2005. Second to fruits production, qat has enjoyed a significant growth of 4.8% while fruits experienced a growth of 5.8% between 2000 and 2005 (Republic of Yemen, 2006). The significant increase in qat production is fuelled by the domestic demand, as evident from the fact that it accounts for over 26% of the household income and 9.3% of household expenditure (Republic of Yemen, 2006). Figure 4 below shows trends in qat production and cultivated area over the years.

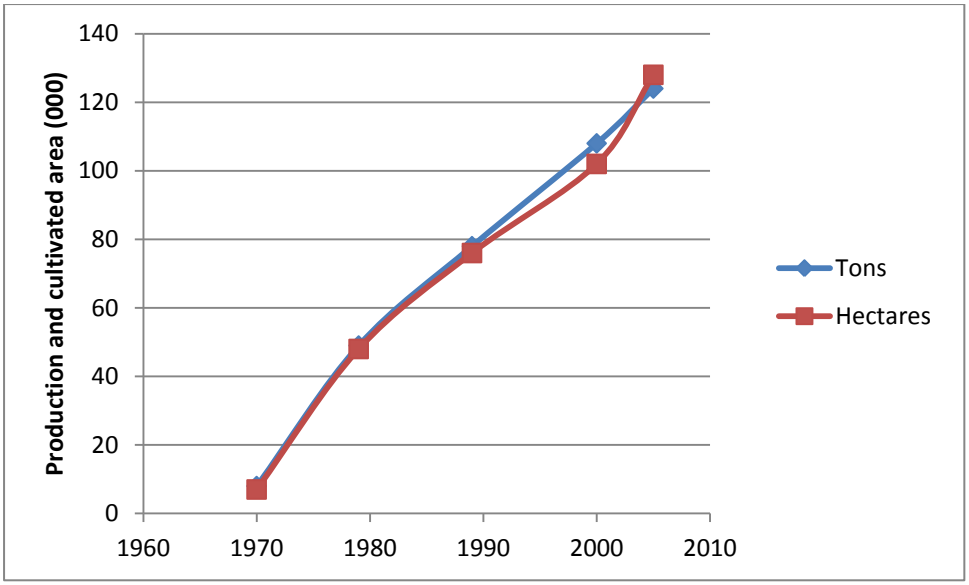

Figure 4: production and cultivated area of Qat over time
Source: Republic of Yemen (2006)

In terms of performance, the contribution of the agricultural sector to GDP has been on a decline. For instance, between 1993 and 2003, its contribution declined from 21.4 to 15 %. Conversely, the rate of growth of agricultural value-added increased from 4.4 % to 5.9 %. Thus, the decline in contribution to GDP is attributed to a significant increase in proportion of value-added generated by the oil sector (UNDP, 2006). The sector is an important source of employment as it employs over 30% of the national workforce. The agricultural sector is one of the most important economic sectors in the country as a source of household income for over 73.5% of the population (Republic of Yemen, 2006). Table 28 shows the dynamics of the agricultural sector in contribution to GDP and GDP growth between 1991 and 2000.

Table 28: Agricultural sector growth over time

	1991-1994	1995-2000	1991-2000
Growth rate (%)	6.3	5.8	5.9
Share of GDP (%)	22.1	17.8	19
Contribution to GDP growth	1.4	1	1.1
Share in GDP growth (%)	28.9	16	19.3

Source: world Bank (2002)

Yemen is one of the most water stressed countries in the world. It is estimated that the per capita share is 120-150 m^3 per year (UNDP, 2006). Thus, water scarcity and the rapidly dwindling water resources as evident from depletion of groundwater, threatens the agricultural sector. It is estimated that the agricultural sector is the major water consumer at approximately 90% with qat accounting for over 23% of the agricultural water withdrawals (UNDP, 2006).

The traditional nature of the agricultural sector and its reliance on erratic water supply and inefficiency makes it highly vulnerable to extreme events associated with climate change, particularly drought and flooding. Importantly, the future of the sector is becoming highly bleak and unsustainable due to its water inefficiency and dwindling water resources. Another factor that is a threat to the future of agricultural sector is lack of investment on terrace thus affecting productivity of this sector. Terraces are the backbone of agricultural sector with majority of agricultural production based on terrace. Therefore, degradation of the terraces will negatively impact on agricultural productivity.

3.2.2. OIL AND MINERAL SECTOR

Oil was discovered in Yemen in the 1980s and production commenced in the same year. The discovery and production of crude oil and gas resulted in a significant increase in government revenue. By 1990, the contribution of gas and oil to GDP was estimated at 10% and steady decline for sequence consecutive four year to a low of approximately 5% and then raised to 27% in 1997 followed by a decline to 10% in 1998. Onwards it then maintained a high percentage contribution of 30% with slight decline but hovering within the 30 % mark. However, by 2009, oil and gas contribution declined to a low of approximately 18%. Oil sector has over the years dominated the export products, accounting for over 82 % of the exports. During the same period, production from the oil fields in the country reached a record mark of 375 000 barrels per day (bpd). An oil refiner with the capacity of 120000 bpd was constructed for export mainly to the Far East. However, contribution of the oil and gas sector has been extremely volatile. This has been attributed to volatility in oil international price and the decline in oil reserves.

By 2010, the contribution of gas and oil to GDP was estimated at approximately 19 percent, making the sector the major contributor to GDP and a decline from 33% by 2005. The fluctuation in the contribution of the oil sector to GDP was a result of international price velocity. For instance, it was estimated that the oil sector's contribution to real GDP declined to 12.4% in 2005 compared to 17% in 2000 due to a 2.7% average decline in annual crude oil production (Republic of Yemen, 2006). The contribution of gas and oil was estimated at 24.1 percent in 2000 while in 2006, it was estimated at 26.3%. Projections indicate that the oil reserves will be depleted in the near future, therefore it is expected that government revenue from the sector be significantly affected. As a result, the GOY is putting up measures to diversify economy from the oil sector. While it is projected that the oil reserves will be depleted in the near future (10-15 years), the gas reserves are estimated at 16.2 trillion ft^3 which will be exported and used locally as Liquefied Natural Gas (LNG).

3.2.3. MANUFACTURING AND INDUSTRIAL SECTOR

The manufacturing and industry sector has been identified as one of the most promising sectors in the countries alongside tourism and agriculture. The sector is dominated by small enterprises estimated at 94.1 percent followed by medium and large companies at 7.3 and 1.4 percent respectively (GOY, 2006). Subsectors that make up the manufacturing sector are as depicted in Table 29 below.

The performance of the manufacturing sector measured by its contribution to GDP and annual growth has been below expectations. During the Second Five Year Plan, growth was estimated at 4.7 percent and the contribution to GDP was estimated at 7%. It is estimated that the sector employs a meagre 4% of the work force in the country.

Table 29: Subsectors of the manufacturing sector

No	Activity
1	Food and Beverages
2	Tobacco products
3	Textiles
4	Clothes and Fur
5	Bags, Shoes and Tanning
6	Wooden products excluding furniture
7	Paper and associated products
8	Printing and Publishing
9	Oil Derivatives
10	Chemical Products and derivates
11	Plastic products
12	Non-metallic Products (construction)
13	Moulded Metal Products
14	Tools and Machines
15	Machines and Electrical Apparatuses
16	Other Transportation Tools

3.2.4. SERVICE SECTOR

The service sector comprises of tourism, financial, telecommunication, and electricity. The service sector is the biggest contributor to GDP and economic growth. In 1990, this sector was contributing approximately 48% and steadily growing until it reached a peak at 60% in 1993. Between 1993 and 1997, the contribution of the service sector declined to a low of 50% in 1997. However, the sector still remained the highest contributor to GDP. Table 30 depicts the growth rate and contribution of the service sector to GDP.

Table 30: Contribution of service sector to GDP

	1991-1994	1995-2000	1991-2000
Growth rate	4.4	5.4	5
share of GDP	54.7	44.6	47.7
Contribution to GDP growth	24	2.4	2.4
share in GDP growth	50.1	37.3	41

Source: World Bank (2002)

3.3. THE ECONOMIC ACTIVITIES IMPACTS TO THE ENVIRONMENT

The relationship between the environment-economy is defined as a closed system, with the economy wholly dependent on the environment for factors of production and as a waste sink (Figure 5). Thus, the economy impacts the environment in two ways: firstly, through harvesting factor inputs (water, timber, mineral, etc). Through this activity there is bound to be depletion of resources culminating in secondary and tertiary impacts. Secondly, the economy sector impacts the environment through waste disposal from production and consumption processes. It is important to note that the magnitude of the impacts is a function of harvest rate and disposal rate. If these are higher than the growth rate or replenish rate of renewable resources and assimilative capacity of the environment in breaking down waste, then the impacts magnitude increases. The closed system nature of the environment-economy dictates that the relationship between the two systems will be non-linear and not linear as human mind frequently operates (Figure 6). Thus, the environment affects economy which in turn affects the environment and the process continues to a balance loop. Therefore, as the objective of this section is to assess the impacts of economy on the environment, this can be done by assessing the impacts of the environment over time through feedback mechanism (Figure 6).

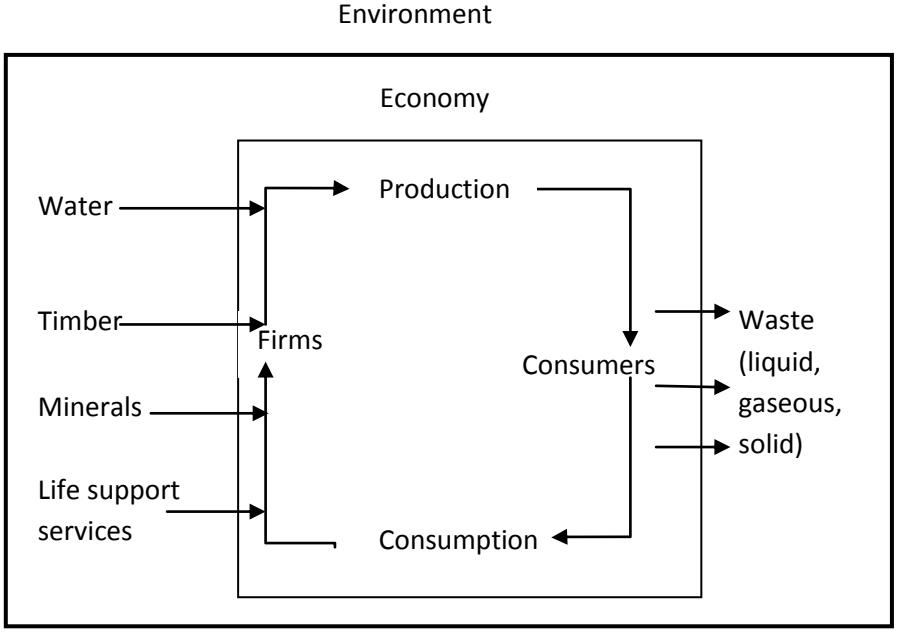

Figure 5: Relationship between environment-economy as a closed system

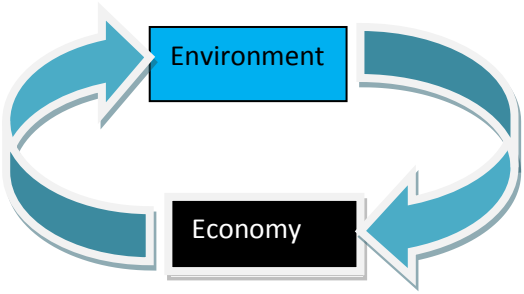

Figure 6: Feedback between environment-economy

3.3.1. IMPACTS OF THE ECONOMY ON ENVIRONMENT

Impact of the economy on the environment is assessed for the key ecosystems being wetlands (including marines and groundwater), forests, mangroves, and rangelands. In addition, primary causes of environmental impacts and the contribution of various policies are discussed.

3.3.1.1. IMPACTS OF ECONOMY ON WETLANDS

Wetlands in the instance are defined broadly as entailing water resources including groundwater, marines and the associated systems such as mangroves, sea grass and coral reefs. The impacts are discussed for each ecosystem.

1. Groundwater depletion

One of the possible disastrous impacts of economic activities in the country is groundwater depletion. Yemen is water stressed and about 90 percent of its water resources is from groundwater. As recharge rates are lower and the abstraction high, this has resulted in significant drawdown and in some cases drying of the aquifers. Water depletion is sombre. It has been estimated that groundwater will be depleted in the near future. It is argued that at the current rate of groundwater abstraction in Sana'a, "*it will be depleted in 10 years and the fresh water in the country will be depleted in this century*". Agriculture sector is the main consumer of water estimated at 90%, thus making it the main culprit in water depletion. Within the agricultural sector, qat is the main consumer of water hence accounts for water depletion. Another factor that is linked to groundwater depletion is inefficiency in water utilisation. Water inefficiency in the country is high to the extent that over 70% of the water is unaccounted for.

The primary causes of groundwater depletion are population growth, agricultural activities and industrial developments. With an estimated population of over 23 million and a growth rate of 3 percent, the Yemenis population is putting a

significant stress on groundwater resources. Perceptibly, groundwater abstraction is a function of the water demand which is driven by population and economic activities. However, it is important to note that immediate and primary causes of groundwater depletion are population growth in the country.
The underlying causes of groundwater depletion are the legal framework. Firstly, government policy on agricultural sector through subsidises for lift pump has resulted in widespread drilling and mining of groundwater. Secondly, subsidies on diesel have resulted in lowering the cost of water pumping to the extent that it increased groundwater pumping to mining level. Thirdly, it is reported that there exist no policies controlling water pumping and abstraction in the country. This has thus resulted in uncontrolled groundwater harvesting to unsustainable levels. Equally important, the government policy on water use has been biased towards water use at the expense of water demand management strategies.

2. Water pollution

Linked to water depletion, is water pollution (both surface and groundwater) in the country. Water pollution is a result of waste and biocides from the industries, agriculture and domestic waste. Freshwater such as the Socotran are at a high pollution risk. Agricultural use of pesticides and fertilisers are the major contributor to water pollution in Yemen. Another factor that contributes to water pollution is the small capacity of sewer treatment plants thus releasing untreated sewer into water bodies. Salinization of aquifers is another form of pollution on the increase in Yemen. This is a process where there is intrusion of salty water in groundwater aquifers.

Primary causes of water pollution (surface and groundwater) in the country include agricultural sector, domestic and industrial sectors through wastewater, industries such as petroleum. High population results in high production of liquid waste from domestic and commercial sectors and the capacity of the treatment plants are not able to treat the sewerage to the required standards.

The underlying factors are the legal framework. Specifically, policy on agricultural subsidies has resulted in fertilisers becoming affordable to farmers and being used inefficiently. According to UNDP (2006) intensive use of fertilizers and pesticides in the rural areas and the waste from urban areas has resulted in water pollution.

3.3.1.2. IMPACTS ON MARINE RESOURCES

Similar to the water resources in the country, marine ecosystems are also under enormous stress from economic activities such as agriculture, mining and industry and manufacturing.

1. Mangrove deforestation

One of the primary environmental impacts that have been identified on the marine ecosystem is marine and coastal habitat degradation. Of these coastal habitat that

has been gravely degraded is the mangroves. Over 95% of the mangroves sampled on the coast of the Red Sea were found to be gravely overgrazed. The main offender identified in mangrove destruction is camels. In addition, anthropogenic activities such as fuelwood harvesting are other primary causes of deforestation of mangroves.

2. Destruction of coral reefs and underwater habitats

Coral reefs are an important marine ecosystem which provides habitat for various types of fish and thus highly diverse. Investigations reveal that coral reefs are unsustainably utilised and hence result in destructions. Coral reefs are collected for various uses such as jewellery, medicine, coral fragments, construction material and liming. These uses lead to the destruction of the coral reefs in the Red Sea and the Gulf of Aden.

It is reported that anthropogenic activities mainly rapid industrialization accompanied by coastal infrastructural development such as ports and oil terminals damage the natural capital of coral reefs and associated systems. Due to accessibility of the Red Sea and the fact that it is in shallow water, it is highly vulnerable to over-exploitation and hence destruction.

Another factor that has been identified for the degradation of the coral reefs is the unsustainable fishing methods. Some of the identified fishing methods that are destructive to coral reefs include dynamite fishing and bottom trawling Destruction of coral reefs and underwater habitats caused by bottom trawling.

3. Biodiversity loss and depletion of marine resources

Yemen is one of the countries well endowed with fishery resources. Some of the valuable fish stocks include lobster, shrimp, crayfish and cuttlefish. Marine resources particularly fish is one of the main exports of the Yemen economy. Over the years, harvesting of fish has increased drastically to levels deemed as over-exploitation of the renewable resource in the Red Sea, Arabian Sea, Gulf of Aden and Yemeni Islands. Over-exploitation has been observed on the valuable fish species such as rock lobster and shrimp stocks and some demersal fish species. Though there is lack of data to substantiate the extent of over-exploitation of the fish resources, decline in landing with increase in effort has been observed for economically viable species.

Thus, interaction of multiple factors mainly overfishing, pollution from heavy metals and habitat destruction (mangroves, sea grass and coral reefs) has significantly added to the decline and depletion of fish resources in the country.

The most underlying factor for over-exploitation and depletion of the fish resource is lack of comprehensive fisheries policies and institutional capacity (manpower and infrastructure to allow policy development and monitoring of the fish harvest).

Additional compounding factor to the depletion of Yemen fish resource is harvest by illegal operating industrial fisheries and their direct transfer to other countries (Morgan, 2004). It is reported that illegal operators land significant harvests which contributes to depletion in fish resources.

4. Marine pollution

Another major environmental impact noticed to be on the rise is pollution of the marine ecosystems. According to UNEP (2007) main polluters of marine ecosystems in Yemen are power and desalination plants, sewage treatment facilities, industrial facilities, port facilities, agricultural activities, coastal constructions, mining and quarrying activities. Within the port of Aden the following metals/pollutants were observed in high concentration lead (Pb), Chromium (Cr), Zinc (Zn), Cobalt (Co), Nickel (Ni), Cu (Copper) and Manganese (Mn). Source of heavy metal pollution include untreated wastewater, desalination plants, electrical power station, refinery plants and oil spills (Nasr, *et al*., 2006).

The causes of marine pollution are mainly domestic and industrial sectors (untreated waste water), as well as plants (desalination, power, and industrial). Thus, the drivers for pollution are population and corresponding growth which accelerates the rate of waste water production. In addition, underlying causes are the absence of legal framework regulating wastewater quality and monitoring of pollutants quality.

3.3.1.3. IMPACTS ON FOREST RESOURCES

1. Deforestation

Yemen forests cover approximately 1 percent of the country's area. There are other forested areas defined as woodlands which cover approximately 1,401 million hectares. Forests (including woodlands) are subjected to intense felling pressures emanating from the agricultural sector and population growth driving settlement expansions. Thus primary factors for deforestation include population growth, agricultural expansion into forested area, mostly the slash-and-burn agricultural practises. The other primary cause for deforestation is the livestock sector. According to the UNEP (1997) overgrazing is the major contributor to deforestation in the highlands of Yemen. The energy Sector is also responsible for deforestation in the country.

The secondary factor causing deforestation is the government policy of importing grain for distribution at heavily subsidised prices which undercuts grain production in the rain-fed areas and thus contributing to deforestation (UNDP, 2006).

Other secondary factor responsible for deforestation is abject poverty estimated at 34 percent of the population living under poverty datum line. The consequence of

poverty is total dependence on fuelwood for energy due to lack of alternative sources of energy such as LNG and electricity. Dependence on fuelwood fuels deforestation rates. The combination of high population growth and high population living under poverty seriously aggravates deforestation.

However, there are no data to substantiate the rate of deforestation in the country.

2. Habitat loss and soil erosion

These are the secondary environmental impacts associated with deforestation. They are discussed under rangelands and biodiversity loss.

3.3.1.4. IMPACTS ON RANGELAND RESOURCES

1. Degradation of the rangelands

Livestock in the country comprises of camels, cattle, goats, sheep and donkeys. The livestock is reared in rangeland (pastures) and also grazed in ploughing fields after ploughing seasons. One of the impacts of livestock sector that has been reported is rampant rangeland overgrazing. According to Alabsi (undated) the carrying capacity for sheep and goats is 4.8 and 4.2 million respectively. Contrary to the estimated carrying capacity, the current numbers are estimated at 9.4 and 9.1 million for sheep and goats respectively which is double the carrying capacity. Overstocking and overgrazing of rangelands result in loss of plants cover, loss of habitat for species and general biodiversity loss. Furthermore, this affects agricultural productivity through reduced yields and low honey production rates.

As noted, the primary cause of rangeland degradation is uncontrolled livestock population. This emanating from lack of comprehensive policy regulating the stocking rate and monitoring of carrying capacity. In addition, lack of economic valuation and integration of the costs of degradation into decision making are some of the causes of rangeland degradation.

2. Soil erosion and loss of soil fertility

Overgrazing and deforestation of rangelands, woodlands and forests exposes bare soil to erosion by wind, water, compounded by livestock movements. Incidentally, this results in decline in soil fertility as soil nutrients are washed away. Analysis reveals that agriculture productivity is on the decline due to degradation of rangelands which culminates and worsens soil erosion.

As soil erosion and loss of soil fertility are linked to deforestation and overgrazing of rangelands, the major economic activities responsible for these environmental

impacts is the agricultural sector both crop and livestock rearing. In addition, government policy of importing grain for distribution at heavily subsidised prices.
The government macro-economic policies which have failed to curb poverty levels in the country are also to blame for deforestation and overgrazing as majority of the population are entirely dependent on natural resources such as fuelwood as a source of household income and energy.

3. Degradation of the terraces

Terraces are important man-made ecosystems that have been developed to increase agricultural productivity through water-management and control of soil erosion. They are mainly constructed on hills/mountainous area along the steep slopes to control water runoff and for water harvesting purposes. Observation is that maintenance of the terrace is lacking and thus resulting in degradation of the terraces. One of the reasons liable for their degradation is the government's policy of importing grain for distribution at heavily subsidised prices. This has resulted in undercutting grain production in the rain-fed areas and thus contributed to degradation of terraces, deforestation and a lack of attention to sustaining traditional water-harvesting systems.

Another factor that is responsible for terrace degradation is the erosion of the tradition farming methods and indigenous knowledge. This has significantly affected the terrace status.

3.3.1.5. BIODIVERSITY LOSS

The cumulative impact of groundwater depletion, deforestation, pollution and overgrazing in the country is rampant biodiversity loss. For instance, depletion of groundwater has had an effect on springs which were habitat and sources of water for various wildlife species.

Other factors that have been alluded to in various reports as contributing to biodiversity loss in the country includes illegal hunting and indiscriminate killing of wildlife particularly the ungulates and carnivores for consumption purposes.

Therefore, almost all the economic sectors contribute to biodiversity loss. The agriculture sector through deforestation contributes to the loss of biodiversity. Government policies of subsidies such as importation of agricultural products, subsidies on diesel and water pumping equipment are secondary factors contributing to biodiversity loss. Furthermore, government macroeconomic policies which have failed to create employment and improve household income have a significant role in biodiversity loss.

3.4. VALUE OF THE ECONOMIC COSTS TO KEY ECOSYSTEM

Valuing the economic impacts on biodiversity involves, identification of the impacts emanating from economic activities and putting a monetary value on them. Similar to economic valuation of the ecosystem, this is an important exercise as it enables integration of the biodiversity costs in economic decision making. Perceptibly, this allows identification of the optimal production levels through minimisation of the costs and maximisation of benefits. However, valuing the costs of economic activities to the ecosystem is not an easy task for the following reasons:

- requires precise data on production, emissions and impacts which in most cases is not readily available
- the environmental impacts from economic activities do not occur in isolation to the extent that an impact can cause rippling effect to the ecosystem. For instance, deforestation causes the following impacts, carbon emission, global warming, extreme events, soil erosion, wetland siltation and sedimentation, decline on agricultural fertility, habitat loss, biodiversity loss, loss in future fuelwood *etc*.

In any case it is critical that economic impacts be estimated as a way of demonstrating the cost that the economic sector creates through feedback (Figure 6).

The economic impacts on biodiversity are estimated as the value of ecosystem per unit (hectare) and the total quantity of ecosystem degraded. Table 31 below depicts the value per unit of ecosystem. As there is no information on total area degraded, it is not possible to estimate the total cost of economic impacts.

Table 31: Economic value for the key ecosystem

Key ecosystem	Economic value (USD Million)	Value per unit
Forest	260,787	0.1 million
Rangeland	2,404	1.47
Wetland	13,873	N/A
Marine	541	N/A
Mangroves	482.9	0.5 million

4.0. CLIMATE CHANGE AND ECOSYSTEM

4.1. INTRODUCTION

According to Intergovernmental Panel on Climate Change (IPCC), climate change is unequivocal and recent IPCC publications have demonstrated that climate change impacts will be catastrophic across regions and continents. Perceptibly, countries have invested enormously in research on the impacts of climate change on various economic sectors and key ecosystems (marines, mangroves, coral reefs, forests and rangelands). Yemen, has not been an exception, it has taken significant strides in conducting research on climate change impacts, adaptation and vulnerability assessments. Most importantly, the country has completed their climate change communication reports for various sectors such as water, agriculture, fishery sector, marines *etc*. Climate change projections of Yemen show a steady rise in temperature, an increase in the variability of rainfall and heavy precipitation events (UNDP 2012). As Yemen's economy is hinged on natural resources such as water, forests, agriculture, its vulnerability to climate change is assumed to be high. Presently, Yemen's ecosystems are experiencing degradation due to over-exploitation and pollution, thus impacts of climate change could push key ecosystems to highly unstable conditions.

Thus, this section discusses impacts of climate change on key ecosystems, based on findings from past assessment studies. Furthermore, the section identifies climate change mitigation and adaptation measures. Moreover, the section identifies areas important for improving nature's ability to adapt to climate change, such as altitudinal gradients and conservations corridors and lastly identifies, protects and appropriately manages areas important for carbon sequestration.

4.2. WETLANDS/WATER RESOURCES

Yemen is one of the worst water strained countries in the world. Currently, it is estimated that water withdrawals approximate 3,400 million m^3/year while the sustainable water harvest is 2,500 million m^3/year resulting in water mining at 900 million m^3/year. Due to lack of perennial rivers, the country's water resources are dependent on rainfall events. However, due to high temperatures and erratic rainfall events, evapotranspiration in the country far exceeds precipitation culminating in water deficits/scarcity. Thus, water sector vulnerability to climate change is high due to the already stressed situation.

Projecting the impacts of climate change on ecosystems is not an easy task. Projection of impacts of climate change on any system is a function of climate scenarios used. Assessment based on high emission scenarios will yield high projected impacts due to the corresponding high radiative forcing of GHGs. Conversely, low emissions scenarios will yield low impacts. It is thus advisable to use a range of scenarios encompassing low to high emission scenarios.

In the main, climate change will impact water sector in the country through the following processes:

- Changes in rainfall variability
- Changes in Intensity and frequency of extreme events mainly drought and flooding
- Increase in temperature and resultant increase in evapotranspiration
- Increase in water demand for sectors such as irrigation to offset increase in evapotranspiration and demand for water cooling (domestic, and outdoor activities and livestock sector)

Thus, assessment of the impacts of climate change on water sector should be pivoted around these interrelations. Most importantly, an integrated assessment model which links demand driven by socio-economic factors and climatic variables and supply driven by climatic variables should be used to assess the impacts of climate change on water sector. In this way, the models will indicate the water index based on demand/supply ratio integrating the influence of climate change.

Climate scenarios are pivotal to climate change impact assessments. For Yemen, the fact that scenarios are pivotal to climate change impacts assessment presents a challenge. Findings are that the country is located in an area where Global Climate Models (GCMs) produce a wide range of results reflecting uncertainties in both climate model structures and emissions scenarios (HR Wallingford Limited, 2009). The most conflicting climatic parameter is annual and seasonal precipitations which displace highly significant fluctuations from increase to decline across GCMs.

For instance, it is noted that half of the 21 Global Climate Models presented increases in average annual rainfall. This makes the development of scenarios for the water sector a complex task (HR Wallingford Limited, 2009). The IPCC suggests, tentatively, a small increase in average rainfall, whilst anecdotal evidence of recent trends suggests a significant decrease. Two of the models quoted in the NAPA project significant increases in rainfall (of 10 percent and 21 percent in spring), whilst the other suggests a decrease of 13 percent. They also suggest an increase in rainfall variability, which will effectively reduce useful average rainfall during the growing season. On the other hand, it is generally recognised that the probability of drought in the region is high (IPCC, 2007).

Various scenarios have been used to assess the impacts of climate change on water resources in the country and their findings are depicted in Table 32, Table 33 and Table 34. Clearly, the scenarios yield significantly different results. Adopting the average scenario, Mid, climate change is projected to result in increase in temperature and rainfall and a 3% decline in rainfall by 2080. Basing on the scenario, by 2030, there will be slight improvements in water situation as runoff could increase and infiltration which is a parameter for groundwater recharge could also slightly increase. By 2050, the scenario projects an increase in runoff by 30% which would

contribute significantly to surface water availability, while recharge would be marginal at 2%. However, water crisis is projected to worsen by 2080 based on the mid scenario, it is expected that there will be significant decline of 22% and 12% for runoff and infiltration respectively. Therefore, water situation in the country could worsen.

Table 32: Average change in annual average runoff and infiltration for different climate scenarios

Scenario	Year	Runoff (%)	Infiltration(%)
Baseline	1990	0	0
Mid	2030	4	4
	2050	30	2
	2080	-22	-12
Hot and dry	2030	-55	-31
	2050	-32	-32
	2080	-78	-55
Warm and wet	2030	147	54
	2050	137	41
	2080	66	27

Source: HR Wallingford Limited (2009)

Table 33: Climate scenario for 2030

	Climatic variable by 2030	
Scenario	Temperature	Rainfall
Warm and wet	1 °C	25%
Mid	1.6 °C	2%
Hot and dry	2 °C	-3%

Source: UNDP (2013)

Table 34: Climate scenario for the country

	Mid			Hot and dry			Warm and dry		
	2030	2050	2080	2030	2050	2080	2030	2050	2080
temperature	1.6	2	3.1	2	2.6	4.5	1	1.2	1.6
Rainfall	3%	3%	-3%	-13%	-13%	-24%	25%	20%	13%

Source: HR Wallingford Limited (2009)

Similarly, other studies concluded that climate change will result in increases in temperatures, and an increase in variability of rainfall, in heavy precipitation events and wind intensity. Furthermore, an extreme event analysis was conducted for The Hadramaut and findings were that the "mean annual flood could increase by 10 percent and higher flood flows could occur more frequently under the 'mid' scenario" (HR Wallingford Limited, 2009)

Therefore, based on the two scenarios (Mid, hot and dry) climate change might worsen the water situation in the country by 2080. On the other hand, warm and wet scenario is more optimistic depicting a favourable condition for the water sector.
Other studies such as IPCC project that temperatures across the country are expected to rise by a region of between 1.4 and 2.8 °C by 2050 while annual precipitation is projected to either decrease or increase by 24% and 35%, respectively depending on the Global Circulation Model (GCM) used. Wilby (2009) projected temperature to increase between 1-4.5 °C by 2100 and rainfall change of between +45 percent to -46 percent.

In addition to the impacts of climate change on water availability, it is projected that water quality will be impacted by climate change. It is projected that water quality in coastal areas will be highly vulnerable to rising sea level and changes in precipitation. Rising sea level and the occurrence of drought could increase the salinity of both surface water and ground water through salt water intrusion.

Overall, it is predicted that climate change will worsen the water situation in the country due to increase in intensity and frequency of drought, wind speed intensity and rainfall variability. Most importantly, all assessment studies unequivocally highlight that water sector is the most vulnerable in the country as it is already stressed.

4.3. MARINE/COASTAL ECOSYSTEM

Commanding approximately 2240 km coast line encompassing the Gulf of Aden and Red Sea, Yemen is well endowed in Marine resources. Some of the marine ecosystems in abundance in the country include mangroves, Sea grass and Coral Reefs. Climate change will impact these ecosystems within the marine in varies and diverse ways as discussed below:

Sea Level Rise (SLR): one of the potentially severe impacts of climate change is Sea Level Rise. SLR is defined as an increase in high tide level over time. The phenomenon is caused by a combination of thermal expansion of sea water due to increase in sea temperature and the melting of the glacier ice. Based on the emission scenarios, SLR scenarios project rise over the next years for the Gulf of Aden as depicted in Table 35 below.

Table 35: Sea Level Rise Scenario for Aden Governorate

Scenario	SLR in meters relative to 2008 levels				
Year	2008	2020	2050	2080	2100
Observed SLR baseline scenario					
Scenario 1: observed SLR rate of 3.3 mm/year at HHT		0.04	0.14	0.24	0.3
Scenario 2: Global Extreme SLR rate of 5.9 mm/year at HHT		0.06	0.25	0.42	0.54

Source: UNDP (2013)

Based on the SLR scenario, the projected impacts of SLR in the Aden Governorate will be 43 km^2 of the area inundated. It is estimated that this will affect approximately 100,000 people and the economic costs could be approximately USD 2 billion in today value (UNDP, 2013). Other associated impacts of SLR based on the 3.3 mm/year are the erosion of sandy shores, inundation of the low land, destruction of coastal critical habitats, saltwater intrusion to both surface and ground water, and increases of the flood (UNDP, 2012). It is projected that the SLR scenarios of 33 and 60 cm will result in 48 hectares and 86 hectares of sandy shore erodes respectively UNDP (2012). The projected SLR has led to Aden been listed among the top 20 cities in the world where most people will be at the greatest risk from sea level rise and storm surges in the developing world (Dasgupta *et al.,* 2009).

SLR will inundate mangroves and their possible response will be a shift or migration to shallow water, hence replacing the existing habitats. Understandably, it will take some time for the mangroves ecosystem to get established thus affecting the functions and services of the mangroves during the time lag. As mangroves are highly productive marine ecosystems and breeding and spawning ground for juvenile fish, fish population will decline affecting household income and country's GDP.

Other impacts of climate change on marine ecosystem have not been easy to quantify. For instance, climate change will alter the frequency and intensity of storms. The impacts will be disturbance of the breeding pattern and population of various species such as fish, birds and turtles. In addition, sea grass ecosystem and the mangroves will be negatively impacted upon, thus affecting the food chain of the marine system.

Additional impacts of climate change will be increase in atmospheric concentration of GHGs particularly carbon dioxide (CO_2). The associated risk will be increase in absorption of CO_2 resulting in acidification of the oceans. This process has significant impacts on the coral reefs structures and formation and thus affects the marine ecosystem productivity due to the central role played by the coral reefs.

Another highly probable and disastrous impact of SLR is intrusion of seawater into freshwater bodies (both surface and groundwater). This results in salinity of the freshwater in the country. As highlighted, Yemen is a water-stressed country, the

climate change could compound the situation to a catastrophic state. This impact is highlighted by Nicholls *et al*., (2007) with high degree of certainty.

As highlighted, increase in atmospheric temperature will culminate in warming up of the ocean temperatures by a low magnitude (USGCRP, 2009). The warming of the sea temperature has potential to offset marine ecosystem balance. It is reported that some coastal areas have already seen range shifts in both warm and cold water fish and other marine species. Pollock, halibut, rock sole, and snow crab in Alaska and mangrove trees in Florida are a few of the species whose habitats have already begun to shift (USGCRP, 2009).Coastal areas in Yemen are also going to experience similar range shifts in marine fish.

4.4. FORESTS AND WOODLAND PRODUCTS AND RANGELANDS

GCMs are in agreement that temperature in the country will steadily rise to a range of 1.4 to 2.8 °C by 2050. Equally, the GCM are in disagreement on the direction of change in rainfall with other models projecting an increase of over 25 percent while other models project a decrease of as much as 35 percent. Therefore, the impacts of climate change on forests, woodlands and rangelands will vary markedly depending on the model used.

Compared to other ecosystems there is no detailed study done on climate change impacts on forests in the country. Therefore, the discussion on the impacts of climate change is mainly speculative based on scenarios.

Fire outbreak: One of the probable impacts of climate change is frequency and intensity of veldt fires in the country. Through increases in temperature (1.4 to 2.8 °C by 2050) and possible increase in rainfall, climate change will result in accumulation of biomass and through increase in temperature create optimal conditions for veldt fires. Therefore, climate change could increase the intensity and frequency of fire in the forests. Consequently, the associated impacts could be suppression of certain plant species that are fire intolerant and hence decline in forest diversity. Forest fires have adverse impacts on mortality, productivity and growth rate. In addition, with the forecasts increases in temperature and variation in precipitation, the episodes of droughts and their intensity may worsen, these possible increase in wildfire risks, since dry trees and shrubs provide fuel to fires. This possible impact is supported by Littell *et al.,* (2009) who assert that in the 20th century burned areas have been due to climate conditions, than human induced fire outbreaks.

Pest outbreak: another impact associated with climate change on forest is the outbreak of pest and diseases. With increase in temperature and changes in rainfall variability, optimal conditions for pest and disease outbreak could be crafted by climate change resulting in forest degradation and decline.

Forest migration: climate change will undoubtedly alter optimal conditions for different plant species and it is possible that forest migration will occur. Thus, some

areas in the country will be devoid of forest while other areas will experience afforestation due to ideal conditions created by changing in climates. Other consequences of high temperatures are a shift in the geographic ranges of some tree species. It is thus important that migration corridors be created for anticipated migration of both plants and wildlife species.

Forest growing season: another aspect of forests that will be affected by climate change is the forest's growing season. With projected increase in temperature, forest growing season could be extended and hence increase in their productivity. This is a possible positive climate change impact on the forests.

4.5. RANGELANDS

Changes in mean climatic trends and increased variability will impact on the ability of rangelands to provide ecosystem services and support human livelihoods. Increase in temperature variability has the potential to increase the severity and frequency of wildfires in grasslands. The impacts of fires on rangeland are alteration of the structure of vegetation affecting nutrient cycling. The impacts of a change in the vegetation significantly affect provision of goods and services, for economic growth. Vegetation is the main feed resource for livestock rearing. Animal production provides Yemenis with a source of food. Livestock is also important in association with arable agriculture, as it provides power for cultivation and manure for increased fertility.

Carbon dioxide increases due to climate change pose negative impacts on the quality of forage and palatability owing to increase in carbon to nitrogen ratios (Chapin *et al.,* undated). The projected temperature increases will lead to reduction in species diversity.

4.6. AREAS IMPORTANT FOR IMPROVING NATURE'S ABILITY TO ADAPT TO CLIMATE CHANGE, SUCH AS ALTITUDINAL GRADIENTS AND CONSERVATIONS CORRIDORS

Climate change adaptation is defined by IPCC as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploit beneficial opportunities". As climate change is unavoidable even if GHGs were to be reduced to sustainable levels, this implies that adaptation measures are inevitable. Thus, for key ecosystems to continue providing goods and services optimally to economy and livelihoods, it is imperative that their ability to adapt to climate change is enhanced. Enhancing nature's ability to adapt to climate change involves coming up with holistic and comprehensive management programs to assist the ecosystems' abilities to function optimally under

climate variability and extremes. Some of the proposed enhancement strategies are discussed below:

Increase PA coverage and landscape management: Protected areas are some of the remaining hotspots for biodiversity. Under climate change, PAs will become the most havens to biodiversity conservation. However, there will be a need to increase their coverage and management scope. It is therefore important that management shifts from PA management as defined by the boundaries to landscape level. This is an innovative new approach to PA management, where a wildlife matrix model of conservation, with local communities and their villages, crops and livestock are embedded in a spatially planned manner within a wildlife matrix (Fynn *et al*., 2011; Lewis 1995). This new approach is being discussed and implemented in some parts of the world.

The model suggests that instead of creating broad zones of restricted use types, which fragment ecosystems, wildlife and rural farming activities be allowed to co-exist (Fynn et al., 2011; Mishra et al., 2010), thus creating innovative ways for local communities to benefit from these PAs in a controlled manner.

Creation of corridors and connectivity within and between countries for ecosystem: another way in which ecosystems can be aided in adapting to climate change is creation of spatial corridors and connectivity between ecosystems. This will create a conducive environment for wildlife species to migrate and thus aid in reducing overgrazing and degradation of the ecosystems. Under climate change, it is expected that both flora and fauna could migrate to optimal climatic conditions as an adaptation measure. Therefore, corridors and connectivity between ecosystems could enhance their adaptation.

Specifically for the marine ecosystems such as Gulf of Aden and Red sea, enhancement could be in the form of promotion of shore protection methods and open space preserves that will permit beaches and the coastal wetlands to gradually move inland as sea level rises. TFCA could play a crucial role in enhancing ability of ecosystems to adapt to climate change by opening up corridors between countries.

Sustainable utilisation and management of ecosystems: ecosystems in the country are under immense pressure from utilisation through high livestock stocking rates and harvesting. The cumulative impacts of anthropogenic and climate change could exuberate pressure on the ecosystems. Therefore, another way to enhance ecosystem adaptation is to reduce anthropogenic pressures on ecosystems. This can be done by identifying sustainable harvest rates for renewable resources. It is important that sustainable harvest rates be identified factoring in the impacts of climate change. Most critically, the sustainable harvest must be dynamic.

Emphasis is placed on key ecosystems that offer preventive and protective functions mainly forests, mangroves and rangelands. Under climate change the role of ecosystems in preventing soil erosion, flood control will increasingly become critical

as a mitigation strategy to strengthening livelihood resilience of vulnerable groups to climate change. Additionally, these roles will reduce negative impacts of climate change in worsening poverty in the rural areas. Climate change could worsen poverty levels in the future through decline in agricultural yields and increase in costs associated with flood events.

Defining dynamic carrying capacities: rangelands and mangroves in the country are overstocked and hence degraded. For these ecosystems to adapt to climate change, stocking rate must be reduced to sustainable carrying capacities. This will ensure that ecosystems are able to recover and be healthy to withstand the impacts of climate change

Sustainable pollution levels: mangroves and sea grass ecosystems and other wetlands are highly polluted in the country and for them to adapt to climate change, it is imperative that these ecosystems be used as waste sink sustainably.

4.7. AREAS IMPORTANT FOR CARBON SEQUESTRATION

Climate mitigation measures are important for reducing the impacts of climate change. One of the mitigation measures is carbon sequestration. Yemen has a huge potential to sequestrate significant amounts of atmospheric GHGs. Table 36 depicts some of the important areas for carbon sequestration and activities that can be implemented to enhance the process.

Table 36: Areas important for carbon sequestration and proposed activities

Key ecosystems	Activities to enhance the process
Forests	• forest conservation through Forest Reserves, • Afforestation • Encourage non-consumptive uses in the forests such as ecotourism, honey production
Mangroves	• Afforestation of the mangroves, • Encourage non-consumptive uses of the mangroves, • Monitor grazing activities in the mangroves, • Co-management of the mangroves
Sea Grass	• Preservation of the Sea Grass ecosystem • Conservation of mangroves • Protection of the shoreline to reduce erosion • Declare sea grass ecosystem PA
Coral reefs	• Declare coral reefs as PA • Encourage non-consumptive uses of the coral reefs • Co-management of the coral reefs
Rangeland	• Reduce overstocking and degradation, • Sustainable utilisation of the forests

5.0. ECOSYSTEM STAKEHOLDERS AND BENEFICIARIES

5.1. INTRODUCTION

This section of the report identifies the main stakeholders in key ecosystem (rangelands, wetlands, water, forests and marine systems). A stakeholder is defined as a person with vested interest or stake in a resource and could be affected by change in the status of the resource. In addition to identification of the stakeholders, the objective of this segment is to identify their interest in natural resources, conflicts amongst the stakeholders and come up with recommendations for conflict resolution. Lastly, the section endeavours to design measures for embedding and institutionalising these strategies in institutions, policies, agreements, programs and mechanisms of each sector

5.2. FORESTS

Forests including woodlands and mangroves are multifunctional, providing diverse services such as fuelwood, habitat for pollinators, honey producers, and watershed properties. In addition, there are conservation agencies whose interest is in forest conservation as a mitigation measure against climate change. Therefore, the stakeholders for forests are diverse encompassing direct, indirect users and non-users. Direct users harvest forests for fuelwood, indirect users benefit from services offered by forests such as honey production and watershed properties. Between these users their objectives are bound to be at variance, breeding conflicts. A conflict generally arises when one's consumption affects another consumer's utility mainly from scarcity of service provided by ecosystems. Table 37 depicts the forests stakeholders, their objectives, functions and the conflicts arising from consumption patterns.

Table 37: Forest stakeholders, their objective functions and likely conflicts

Stakeholder Type	Objective	Action	Likely conflicts	Possible Tradeoff
Commercial wood harvesters	Maximise revenue from sale of fuelwood	increase harvest rate	competition with subsistence harvesters and honey producers, NGOs resulting in scarcity and degradation	Reduce harvest rates
Subsistence wood harvesters (rural communities)	meet daily energy requirement	harvest at minimal to ensure availability	scarcity of fuelwood due to overharvesting by commercial harvesters and livestock	Find alternative sources of energy
Crop producers	maximise ecosystem functions and services of forest (pollination)	conserve forest	Conflict with commercial and livestock owners due to deforestation and reduced forest services	n/a
Crop producers	Maximise food production	clear forest for agricultural production	Conflict with other farmers and Government agency whose objective is to keep forest intact	Reduce slash and burn activities
Honey producers	maximise functions and services of forest	conserve forest	Decline in honey production and therefore conflicts with commercial harvesters, crop producers practising slash and burn and livestock owners	n/a
Government agencies	conserve and keep forest intact	forest conservation	In conflict with commercial harvesters, crop producers practising slash and burn and livestock owners	Allow minimal harvesting of forests
Livestock owners	maximise livestock numbers	Increase stocking rate and reduce cost of supplementary feeding	In conflict with government agency, commercial harvester, herbalists and NGO and honey producers	Reduced stocking rate and dependence on rangelands
Herbalists	Increase revenue from harvest of medicinal plants	Increase harvest of medicinal plants	In conflict with livestock owners particularly browsers due to competing uses	n/a

Table 37 demonstrated the complexity of forests ecosystem utilisation and management arising from competing and conflicting uses. While the conflicts from forests utilisation are numerous due to the multiple uses, the desired states for forests management in Yemen are as follows:

1. Enhance and encourage sustainable use of forest resources in the country
2. to have multiple forest products such as honey, and protection of life support systems,
3. to reduce deforestation from anthropogenic activities such as overgrazing, slash and burn, fuelwood collection

It is thus important that mutually acceptable solutions and strategies be devised and implemented to manage conflicts amongst the forests and woodland uses. Some of the strategies that can be implemented as solutions for the conflicts include:

1. Establishing a livestock carrying capacity in the proximity of the forests
2. Issue of harvest permits for commercial fuelwood and timber harvesters , the total permits to be set below forest growth rates
3. Introduce forest reserves which are for purely conservation purposes and allow non-consumptive activities
4. Introduce permits for medicinal harvesters
5. Revive the traditional ways of fuelwood harvesting
6. Encourage eco-tourism and participation of the locals in eco-tourism activities
7. Implement co-management of forests resources
8. Provide local communities with alternative sources of income from non-forest products such as cheese, dairy, honey, ecotourism and involvement in handy craft

Thus, it is important that forest management plans be developed.

5.3. WATER RESOURCES STAKEHOLDERS AND CONFLICTS

The country is faced with acute water scarcity mainly due to low rainfall, high evapotranspiration, and high populations. The major source of water is groundwater. Major sectors (agriculture, domestic and industrial) are all competing for the groundwater resources. Thus, the water crisis in the country culminates in water conflicts from competition for scarce water. Table 38 below depicts the objectives of the different stakeholders in the water resources, and actions to attain their objectives with likely conflicts arising from their actions.

Table 38: Stakeholders identification and conflicts on water sector

Stakeholder	Objective	Action	Likely conflict	Possible tradeoff
Farmers upstream	Increase agricultural production	Dam *wadi* upstream Drilling of borehole upstream	Drying of *wadis* downstream Decline in groundwater downstream	• Capture allowable limits to allow adequate water downstream • Improve water efficiency management strategies • Grow crops that require less water • Implement tradable water permits
Farmers downstream	Increase agricultural production	Increase irrigation efforts	Decline in water downstream and depletion of groundwater downstream	• Plant crop strains that require less water • Implement water harvesting techniques to capture rain water
Domestic sector	Meet the domestic demands	Increase abstraction of groundwater and surface water	Depletion of groundwater and surface	• Implement water demand management strategies • Optimal water tariff to encourage water use efficiency
Agriculture sector	Increase production	Intensify use of fertilisers and pesticides Intensify abstraction rate	Pollution of both surface and groundwater Groundwater depletion	• Curb use of fertiliser and pesticides • Reduce production of qat and replace with less water intensity crops • Maintain terrace for improved water management

Industrial sector	Increase production	Increase waste	Pollution of both surface and groundwater	• Improve waste management practises
NWRA	Sustainable use of water resources	Monitors water consumption and resources availability	Conflict with those who pollute and deplete water resources	• Implement allowable harvest rate • Implement allowable pollution levels
Informal water traders	Increase revenue from water sales	Abstract more water for sale	Depletion and decline in water quantity and quality	• Introduce tradable water permits

Literature review and consultation with stakeholders are all in agreement that there are diverse conflicts in the water sector. Consequently, it is important that the desired water sector state is attained. According to the water governing body, NWRA the desired state of the water sector is as follows:

- enhanced water sustainability
- reduced water depletion and widespread pollution to sustainable levels

In order to achieve the desired state the following strategies are proposed

- Develop guidelines for water drilling with the objective of controlling boreholes
- Implement individual tradable quotas for different sectors and the quotas must be based on groundwater status and recharge. In addition, the quotas must be traded to encourage water use efficiency
- Develop integrated water resource management for the country. Currently, the government policy promotes water consumption while strategies to curb escalating water demand have lagged behind
- Water in the country is viewed as a public good and less regarded as an economic good hence low to no tariffs. It is important that optimal water tariffs based on volumetric charges are imposed. Water tariffs must take into account opportunity costs, scarcity and externalities.
- Establish charges for over pumping of water
- Improve land tenure ownership particularly in watershed
- Public awareness on water resource management as a common and economic good

5.3.1. WETLANDS STAKEHOLDERS AND CONFLICTS

Wetlands discussed in the section include, mangroves and marines ecosystems. Therefore, the discussion is divided into mangroves and other marine ecosystems.

5.3.2. MANGROVES STAKEHOLDERS AND CONFLICTS

Mangroves stakeholders are members of communities utilising services provided by the ecosystem. These include livestock owners, fishermen, wood harvesters, tourism operators and government agencies. The uses of mangroves are diverse and obviously conflicting as depicted in Table 39.

Table 39: Mangroves ecosystem stakeholders and conflicts

Stakeholders	Objectives	Action	Likely conflict	Possible tradeoff
Fuelwood harvesters	Harvest to meet the daily energy demand	Harvest the mangroves forest	Depletion of mangroves and reduced fish productivity	• Reduce reliance on fuelwood from mangroves • Find energy alternative sources
Livestock owners	Maximise livestock number	Increase stocking rates and reduce supplementary feeding costs	Depletion of mangroves and reduced fish productivity and other services	• Reduce stocking rate • Supplement feed livestock
Commercial Fishermen	Maximum revenue	Keep mangroves intact and harvest fish	Depletion of fish resources In the mangroves ecosystem	• Reduce harvest rate and efforts • Find alternative fishing grounds
Subsistence fishermen	Meet the daily food requirement	Minimal harvest for sustenance	Depletion of fish resources from commercial fishermen and deforestation of the mangroves	• Introduce fish farming in the mangroves
Tourism operators	Maximum revenue from mangroves	Keep mangroves intact and aesthetics; increase tourists number	Degradation of the mangroves aesthetic	• Determine the carrying capacity and reduce tourist traffic
Tourists (local and international)	Maximise utility from visiting mangroves	Keep mangroves intact and increase visitation rates	Pollution and degradation of the mangroves	• Reduce pollution • Determine carrying capacity
Government agencies	Conserve mangroves and maximise ecosystem services and	Conservation of mangroves	Conflict with fuelwood harvesters, livestock owners, fishermen, tourism operators and	• Allow minimum utilisation of the forests • Define limits of

	functions		tourism	acceptable change for the mangroves ecosystem
International + local Organisations promoting conservation	Conservation of mangroves ecosystem	Advocacy for conservation and preservation of Mangroves	Variance of objectives with other stakeholder results in conflict	• Acknowledge other stakeholders interest and allow for limited utilisation particularly non-consumptive uses

The desired states for mangroves in the country are as follows:

- Maintain health mangroves ecosystems with diverse optimal functions and services beneficial to the community

In order to achieve the desired states, the following solutions are proposed:

- reduce grazing pressures on mangroves particularly for goats and camels to sustainable levels
- identify alternative sources of energy for the local communities
- Monitor fish harvest rate in the mangroves
- Stipulate the size of fishing vessels and the individual transferable quotes per vessel
- Promote co-management in the mangroves as a strategy of increasing community participation in the conservation efforts of the ecosystem.

5.3.3. CORAL REEFS STAKEHOLDERS AND CONFLICTS

Similar to other ecosystems, coral reefs are multifunctional and have different users and non-users with vested interests in their existence and survival at local and international levels. Consequently, with diverse stakeholders and sporadically competing users there is bound to be conflicts amongst the stakeholders as shown in Table 40.

Table 40: Coral reefs stakeholders and possible conflicts

Stakeholder	Objective	Action	Likely conflict	Possible trade-off
Tourism operators	Maximise revenue from tourism activities	Maintain aesthetics of the coral reefs and diversity	Increase traffic amongst the operators and fishermen resulting in degradation of the coral and loss in aesthetic appeal	• Reduce tourism activities to sustainable levels
Tourists	Maximum utility from coral reefs visits	Visit the coral reefs	Increase in traffic and damage the reefs through driving and other human movements resulting in loss in aesthetic appeal of the reefs	• Reduce visitation rates to sustainable levels
Coral reef harvesters (construction material)	Maximum revenue from harvest of reefs	Increase harvest rates	Damage and degradation of the reefs Decline in coral reefs diversity Loss in aesthetic appeal for the tourists Loss in income to the tourism operators	• Reduce harvesting activities of the coral reefs • Engage in non-consumptive uses
Coral reef harvesters (jewellery and medicine	Maximise revenue from reef harvest	Increase harvest rates	Decline in reefs system, degradation and decline in aesthetics Loss in income to the tourism operators Loss in income to the fishermen	• Reduce harvest activities • Engage in non-consumptive uses
Fishermen (aquarium fish harvester)	Maximise revenue from fish harvest	Increase harvest rates	Decline in diversity of the ecosystem, decline in numbers of tourists Loss in income to the tourism sector	• Reduce harvest activities
Government agencies	Maintenance of health and diverse coral reefs	Increase monitoring and protection of	Conflicting objectives with other uses (conservation vs consumption)	• Allow sustainable harvest rates • Define the carrying

		activities in the coral reefs		capacity and limits of acceptable change
International agencies	Maintain coral reefs diversity	Advocate for coral reefs protection	Reduced revenue from the users (tourism operators and harvesters)	• Recognise that coral reefs are sources of livelihood and advocate for sustainable use

The desired states for coral reefs are as follows:

- Maintain diversity and multi functions of the coral reefs
- Reduce degradation of the coral reefs

The following strategies will enhance attainment of the desired state of the coral reefs in the country:

- Designate the threatened coral reefs and vulnerable coral reefs as PAs and encourage co-management with the community
- Establish tourism carrying capacity for the coral reefs as a means to limit traffic and congestion into the reefs
- Monitor and control harvest rates for all harvestable materials in the reefs

5.3.4. RANGELAND RESOURCES STAKEHOLDERS AND CONFLICTS

Rangeland resources utilisations include grazing, fuelwood, food production, timbers products and indirect consumption through climate regulation. Due to the multiple uses and competing needs for the same resource base, conflicts occur. Table 41 identifies major stakeholders in rangelands, their ultimate objectives and possible conflicts.

Table 41: Rangeland stakeholders and conflicts

Stakeholder	Objectives	Action	Conflicts	Possible trade-offs
Livestock owners	Maximise revenue from rangeland	Increase stocking rate	Rangeland degradation and reduced services beneficial to other users	• Reduce stocking rate to sustainable limits • Increase supplementary feeding efforts
Crop producers	Maximise food production	Increase area planted through slash and burn	Reduced grazing size conflict with livestock owners	• Reduce expansion into rangelands
Honey producers	Increase honey production	Maintain healthy rangeland resources	Degradation from grazing and crop production results in loss of habitat for bees and pollen	n/a
Commercial Timber harvesters	Increase timber harvest to maximise revenue	Harvest more timber	Rangeland deforestation and reduced service for other users	• Harvest at maximum sustainable yield
Subsistence fuelwood harvesters	Meet daily energy requirements	Harvest at rate that meets the daily energy requirements	Scarcity in fuelwood created by commercial harvesters and depletion by livestock	• Find alternative sources of energy
Herbalists	Meet the demand for traditional medicine	Increase harvest of medicinal plants to meet the demand	Competition with livestock and other herbalists resulting in medicinal plants scarcity	• Harvest plants using sustainable methods at maximum sustainable yields
Government agencies	Maintain healthy and highly diverse rangeland ecosystem	Increase monitoring and implementation of rangeland conservation programmes	Conflicting objectives with other uses (conservation vs consumption)	• Allow sustainable utilisation of rangeland resources
NGOs (international and local)	Conservation of rangeland resource	Advocacy for rangeland conservation	Conflicting objectives with other stakeholders	• Allow sustainable utilisation of resources

The desired state for rangeland ecosystem is:

- Maintenance of healthy rangelands with optimal functions and services to meet the needs of all users

In order to achieve the desired state, the following strategies are proposed:

- Establish and maintain carrying capacity which is dynamic to the rangelands conditions
- Monitor and enforce the established carrying capacity
- Restrict slash and burn practises to enclosed compounds
- Develop management plans for the rangelands.

5.4. AN ASSESSMENT OF THE ECONOMIC IMPACTS ON KEY ECOSYSTEMS AND STAKEHOLDERS

Impacts from economic activities affect stakeholders either directly or indirectly depending on the nature of the resource utilisation. For instance, stakeholders involved in direct utilisation of the resources are affected directly with immediate impacts. On the one hand, stakeholders who benefit indirectly will be affected through the relationship between production function and the ecosystem services. In this case, the impacts are mainly subtle and not immediate.

Table below highlights the impacts of economic activities on key biodiversity and stakeholders.

Table 42: Impacts of economic sector to key ecosystem and to the stakeholders

Economic sector	Key ecosystem	Environmental impact	Stakeholders affected	Socio-economic impacts
Agriculture **Manufacturing and industrial (including mining)** **Service sector (including tourism)**	Rangeland	overgrazing and degradation of rangeland	farmers	• vulnerability of the livestock during drought years resulting in increase in mortality and loss in income
		deforestation	honey producers	• decline in honey production • loss of income • worsens poverty situation
		soil erosion and loss of soil fertility	crop producers	• decline in agricultural yields • loss in household income • worsens poverty situations
	Water resources	depletion of groundwater and surface water resources	all stakeholders	• loss in production of all economic sectors (e.g. Crop production, increase in livestock mortality), • decline in economic growth • worsens poverty situation
		pollution of water resources	all stakeholders	• Increase in incidents of water borne diseases, • Increase in child mortality, • increase in health costs, • increase in purification expenditure, • loss in income due to illness, • increase in household expenditure for bottled water
	mangroves/coral reefs	deforestation of the mangroves	local communities (fish farmers, tourism operators, fuelwood harvesters)	• loss in source of nutrition, • loss in household income, • increase in food insecurities, • worsens poverty situation
		Erosion of the coast line	tourism operators, fishermen	• loss in income, • loss in employment
		loss in species habitat	local communities (fish farmers) and commercial	• loss in income, • loss in employment • increase poverty levels,

			fishermen	• loss in socio-economic status
		loss in fish diversity	local communities (fish farmers)	• loss in income, • increase in vulnerability in food insecurities
	Forests	deforestation	local communities, tourism operators, tourists	• decline in tourism revenue, • loss of energy source, • increase in household energy expenditure
		soil erosion and decline in maintenance of soil fertility	Farmers and community members	• decline in agricultural yields • loss in household income
		sedimentation and siltation of water bodies	farmers, local government (water supplier)	• decline in capacity of water bodies to supply water, • increase in vulnerability to water scarcity • decline in agricultural yields • loss in household income
		degradation of environment	farmers, honey producers	• decline in farmers income, • increase in vulnerability of farmers to climate change, • increase in food insecurity

6.0. POLICY MEASURES TO RESTORE AND SAFEGAUARD YEMEN ECOSYSTEM

Yemen key ecosystems are highly valuable and contribute immensely to the country's wealth and economic growth as evident from the economic values. However, these key ecosystems are under tremendous pressure from economic activities, driven by underlying factors such as high prevalence of poverty rates and high population growth. In order to restore and safeguard these key ecosystems, the fundamental step is recognising and appreciating their net value, through integration of their economic value in decision making at the national and local levels. Secondly, it is important to devise legal framework to ensure implementation of strategies as a measure towards ecosystem restoration and safeguarding.

6.1. TOOLS AND MEASURES FOR INTEGRATING THE VALUE OF BIODIVERSITY INTO NATIONAL AND LOCAL DEVELOPMENT AND POVERTY REDUCTION STRATEGIES, SECTORAL PLANS AND NATIONAL ACCOUNTING

The economic value of ecosystems as contributing to the national and household income is immense. Both direct and indirectly, functions and services of biodiversity contribute to economic production and services. In order to recognise the vital role played by the ecosystem, it is essential that the ecosystem values are accounted in national income and also integrated in decision making. Integration of ecosystem values will ensure maximisation of ecosystem benefits while ecosystem costs are minimised. Therefore, there is need to devise a framework for integration of ecosystem economic values into national and local development plans and poverty strategies, sectoral plans and national accounting. Three tools are discussed that can be used to coerce decision makers and economic agents to integrate natural resources capital values in decision making.

WAVES: One of the tools used in integrating ecosystem values to national and local development strategies and national accounting is the Wealth Accounting and the valuation of ecosystem services (WAVES). WAVES is a World Bank initiative/programme to implement green accounting in both developed and developing countries. Its goals and objectives as defined by the World Bank are to promote sustainable development worldwide through the implementation of comprehensive wealth accounting that focuses on the value of natural capital and integration of "green accounting" in more conventional development planning analysis. One of its specific objectives is to incorporate the green accounts into policy analysis and development planning.

Project appraisal techniques: Another tool that is critical for the integration of ecosystem values to national and local development and poverty reduction strategies is the emphasis of project appraisal techniques in economic decision making. Project appraisal techniques such as Cost Benefit Analysis (CBA) and Multi Criteria Decision Analysis involve appraising the viability of the project based on identified costs and benefits. Traditionally, CBA and MCDA have been used to appraise projects with less emphasis on the environmental aspects (benefits derived from the environment, opportunity costs of loss). However, these tools have great potential in enhancing integration of environmental costs and benefits at the planning stage (national and local).

Environmental tax: In many instances, environmental costs are externalised resulting in unsustainable utilisation of ecosystem services such as wetlands, forests, marine ecosystems. Therefore, it is important that tools such as environmental tax are implemented as a way of integrating ecosystem services in national and local development. As taxes are government revenue, it is important that revenue generated from the unsustainable environmental utilisation be integrated into GDP to demonstrate the value of ecosystem functions and services. Thus, various tax regimes for abstraction, deforestation, groundwater depletion, emission, harvesting of mangroves must be implemented. The effective way of deriving effective and efficient tax is to estimate the marginal value (benefit) of ecosystem and charge at a point where marginal value of ecosystem equals marginal cost of environmental degradation (Figure 7). The T* is the optimal tax for utilisation of the resource and Q* is the optimal harvest rate for the ecosystem services

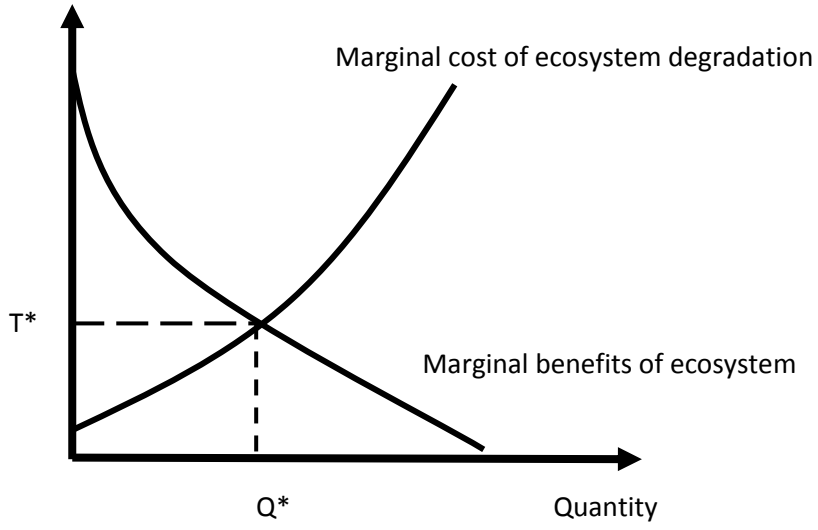

Figure 7: Optimal environmental tax as incentive for integrating value of ecosystem

Payment for ecosystem services (PES): PES is defined by Wunder (2005) as a voluntary transaction where a well-defined ecosystem service is identified and bought from the ecosystem service provider based on the condition that the

ecosystem service provider secures ecosystem provision. Based upon the creation of the market, PES is one of the tools that can be used to integrate the value of ecosystem services at national and local development and for poverty reduction strategies. Consequently, rural communities are mostly endowed with ecosystems, thus, PES can be targeted to the rural communities as a source of income generation and hence poverty alleviation.

6.2. MEASURES TO INTEGRATE ECOSYSTEM VALUE

The identified tools to integrate ecosystem values into national and local development including poverty reduction strategies as highlighted, must be supported by measures. The measures must be based on the national and local legal framework. Table 43 depicts the proposed action plan for integrating ecosystem values in national and local development planning.

Table 43: Guideline on integrating ecosystem value to national and local development

Tools	Enabling environment	Critical activities
WAVES	embrace and endorse the concept at the national and local planning level	• Capacity building on WAVES, • Undertake resource and wealth account, • develop green accounts for the country
Appraisal techniques (CBA, MCDA)	emphasise on the extension of environmental aspects into project appraisal through application of CBA and MCDA	• Capacity building on economic valuation of ecosystem, • Legislation on integration of environmental aspects in projects appraisal • For all planned central and local government projects emphasise on integration of environmental costs and benefit in appraisal
PES (Environmental Tax)	Design appropriate legal frameworks that will allow incorporation and adaptation of suitable PES	• Identify ecosystem and define owner • Design appropriate PES systems • Design a market for ecosystem services

6.3. POLICY OPTIONS AND MEASURES FOR INCORPORATING INCENTIVES AND REMOVING HARMFUL SUBSIDIES

Analysis revealed that key ecosystems in the country are under immense pressure from interaction of intricate factors encompassing policy options on subsidies. Subsequently, one of the measures towards restoration and safeguarding of key ecosystems in the country is removal of subsidies and replacing them with incentives

that will enhance sustainable management of the resource. Table 44 depicts some of the subsidies deemed harmful to ecosystems in the country.

Table 44: Types of subsidies and the impacts on the environment

Economic sector	Type of subsidy	Impacts on environment
Agricultural	fertiliser subsidies	widespread use of fertiliser resulting in water pollution
Energy	energy subsidies	cheap diesel resulting in low cost of water abstraction leading to water depletion
Agricultural	import subsidies	cheap food imports undercut rainfed grain resulting in degradation of terrace

Thus, having taken measures to integrate values of key ecosystems to national and local planning, it is vital to implement measures to correct market distortions arising from existing subsidies and replace them with a set of environmentally friendly incentives. It is recommended that incentives be devised for sustainable management of the key ecosystems (Table 45).

Table 45: Proposed incentives for key ecosystem services

Incentives	Target	Source of revenue
Terrace fund	terrace restoration	revenue offset from subsidies
Preferential markets	crops and crop strain less water intensive	revenue offset from subsidies
PES	co-management on specific ecosystem and revenue from PES	Climate change Fund, Environmental Fund, Carbon markets
Preferential international markets for organic products and production of environmentally friendly products	Key ecosystems	Environmental Fund

The recommended incentives will end in sustainable management for key ecosystems as communities will be incentivised to utilise their ecosystem sustainably. For instance, co-management gives a sense of entitlement and ownership by communities to the extent that resources are utilised sustainability. In addition, the revenue generated from PES becomes an incentive for safeguarding ecosystem integrity. It is important to highlight that introducing programme of work of PES has double-edged benefits. Firstly members of the communities are able to derive benefits from the services offered by the ecosystem. Secondly, they derive revenue from PES programmes.

In order to integrate ecosystem values, replace subsidies with environmental conservation incentives supportive policy framework is a prerequisite. The following activities are important:

- Undertake a thorough and holistic review of economic, sectoral and environmental policies, strategy and plans to identify areas appropriate for integration of environmental values and incentives
- Strengthen institutional structures to support integration of environmental values and incentives at the national and local planning levels
- Ensure full stakeholder participation in integration of environment value and incentives decision making and planning at all levels (national and local planning)
- Establish nationally determined procedures for integrating environmental value and incentives into decision making

6.4. PROTECTED AREAS PROGRAMME OF WORK

Yemen similar to other countries has declared some ecosystem as PAs. A PA is defined by UNEP as a clearly defined geographical space recognised, dedicated and managed through legal or other effective means to achieve the long time conservation of nature with associated ecosystem service and cultural values. There are ten (10) declared PAs six (6) of which are listed under the IUCN categorisation, covering 0.53 percent and 1.77 percent for land and marine respectively. Some of the primary PAs in the country are as follows:

- Bura Community Protected Area
- Dhamar Montane Plains Mahjur traditional reserve
- Jabal Bura Valley Forest National Park
- Ras Isa Marine Park
- Socotra Island Protected Area
- Zuqur Island Marine National Park

PAs are critical for the conservation and management of biodiversity primarily because they are the remaining hotspots habitats for species many of which are either endangered or threatened. However, globally PAs are riddled with inadequate management systems and Yemen is not an exception. NSBAP report highlighted some of the issues and inadequacies surrounding PAs management in Yemen as follows:

- Lack of effective administration and conservation management for PAs;
- Limited geographic coverage of PAs.
- Insufficient staff and resources such as finance and equipment required in the operations of the PA.
- Incomplete legal framework for PAs.
- Lack of Institutional capacities for PA

- Lack of precise information on the number of fauna and flora species within PAs
- Weak individual and institutional capacities in the management of PAs.

There is an urgent need to improve the current status for operational effectiveness of the PAs in the country. This requires establishment of programme of works as detailed in Secretariat of the Convention on Biological Diversity (2004). The programme of works entails expansion of PA area coverage, co-management of the PAs, establishment of TFCAs and PA management at the landscape areas.

In addition, there is need to develop code of conducts and operational standards for the PAs. This must be based on the ecosystem approach (Box 1).

Box 1: 12 Principles underpinning the Ecosystem Approach

1: The objectives of management of land, water and living resources are a matter of societal choice.
2: Management should be decentralized to the lowest appropriate level.
3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.
4: Recognising potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should;
a. reduce those market distortions that adversely affect biological diversity;
b. align incentives to promote biodiversity conservation and sustainable use;
c. internalise costs and benefits in the given ecosystem to the extent feasible.
5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.
6: Ecosystems must be managed within the limits of their functioning.
7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.
8: Recognising the varying temporal scales and lag-effects that characterize ecosystem process, objectives for ecosystem management should be set for the long-term.
9: Management must recognise that change is inevitable.
10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.
11: The ecosystem approach should consider all forms of relevant information including scientific, indigenous, and local knowledge, innovations and practices.
12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

7.0. NBSAP INVESTEMENT PRIORITY AREAS AND FINANCING ACTION PLAN

7.1. INTRODUCTION

This section addresses two specific objectives being identifying priority Biodiversity investment needs and opportunities based on the NBSAP and, preparation of NBSAP Integrated Financing Action Plan summarising concrete activities required to mobilise BD finance for the 10-year period of the implementation of the NBSAP. Subsequently this section was achieved through review of the NBSAP to identify the investment priority areas. On the other hand, the development of the financing action plan involved identification of activities to be undertaken in financing implementation of the NBSAP.

7.2. NBSAP INVESTMENT PRIORITY AREAS

According to the NBSAP report, the country is faced with sombre ecosystem/biodiversity arising from key ecosystem depletion and degradation (marine ecosystem, forests, rangeland, water resources, mangroves, coral reefs). However, the report concluded that "Given the large number of issues covered by the strategy, considering the country limited resources, it was necessary to prepare a set of criteria for prioritizing actions and projects contributing to the implementation of the Strategy" (EPA, 2005-p59). Thus acknowledging that resources are limited while biodiversity/ecosystem investment priority areas are numerous, NBSAP identified seven (7) priority investment areas and the existing opportunities as listed in Table 46 below

Table 46: Priority investment area for Yemen

No	Priority area	Opportunities
1	Establishing a comprehensive National Integrated Protected Areas system	• Already the country commands a sizable number of protected areas which can be integrated into the system • There already exist traditional protected area system (mahjur) which could be improved • There is international commitment to assist in conservation of biodiversity including funding ready to support such an initiative • Government commitment to undertake vigorous measures to address problems hindering effective management of the PA • There exist some legal frameworks for PA though incomplete
2	Developing an Integrated Coastal Zone Management Plan (ICZMP)	• The country's commitment to develop Integrated Coastal Zone management plan • The county has expertise in development of biodiversity coastal zone management plans • There is international commitment particularly in terms of funding to assist in the development off the ICZM
3	Developing and Enforcing of Policies, Legislation and Regulations on Biodiversity Issues	• There exist policies, legislation and regulation on biodiversity which will require realignment and strengthening such as environmental policy • There is huge awareness and information on biodiversity to facilitate development and enforcement of policies • The country has experience in drafting of policies, legislation and regulations. Therefore, this is not something new to the country • There is availability of international support both manpower and finance to assist in such endeavour
4	Conservation of Agro-Biodiversity	• There exist productive traditional agricultural practises which can be revived and support the conservation of Agro-Biodiversity programmes • The country has extensive terrace though degraded can be revived • Knowledge on traditional conservation practises still entrenched in the rural communities
5	Reviving Traditional Indigenous Natural Resource Management Systems	• Knowledge on traditional indigenous National Resources Management system still prevalent at the rural communities where natural resources utilisation is prevalent

		• There is international acceptance that indigenous to natural resources management systems is one of the effective management strategies. • Government and political buy-in to revive traditional indigenous natural resources management systems
6	National Biodiversity Education and Awareness	• Political will and buy-in to integrate national biodiversity in education and public awareness • Universities already offering courses on environmental management, water resources management, coastal and marine ecosystems • Readily available international funding on biodiversity issues
7	National Biotechnology/Biosafety Frameworks	• International cooperation on biotechnology and biosafety issues • The acknowledgment at the national levels on potential risks and implications of biotechnology on already vulnerable and fragile ecosystems in the country

7.3. NBSAP INTEGRATED FINANCING ACTION PLAN

To implement the ambitious NBSAP, GOY must find and develop a solid foundation of long-term sustainable financing strategy based on domestic commitment and adequate resource (manpower and finance). Implementation of the NBSAP will entail the following operational costs:

- Secretariat whose role will include overseeing and facilitation of the development and implementation of the programme of works for NBSAP. The core costs will entail staff salaries and office space
- Programme of works for NBSAP which will include implementation of projects, additional staff, capacity and monitoring projects, and detailed studies,

Assessment of the NBSAPY indicates that the total funding required to implement the seven (7) projects to attain the biodiversity priority areas is USD 23 million. It is thus important that an integrated financing action plan be devised to guide financing of the NBSAP. This integrated financing action plan summarises concrete activities required to mobilise the required finance for the 10 year period of the implementation of NBSAP.

7.4. POTENTIAL SOURCES OF FINANCING NBSAP IMPLEMENTATION

It is envisaged that the sustainable funding for the NBSAP implementation will come from three sources being domestic, regional and international. The domestic funds can be raised through the following direct or indirect transfers, polluter and user-pay schemes. On the other hand regional and international finance is obtained from donors, mainly the GEF, WB, ADB and Kuwait Fund and others. Below is an action plan on source funding.

Table 47: Financing action plan for NBSAP

Stage	Activity	Responsibility	Time frame	Resources required	Progress indicators
Stage 1: Financing strategy	Development of the financing strategy detailing targeted amount from different sources	EPA	2 month	Consultant	A financing strategy
Stage 2: Resource mobilisation	Identification of sources/mechanism of financing for implementation of NBSAP	EPA	1 month	Office +HR	At least one domestic, regional and international sources
	Compilation of the minimum requirements for accessing financing for each source (to include proposals, legal framework, creation of markets)	EPA	1 month	HR	Develop comprehensive tailor made funding proposal for those that require proposal. This should be inclusive of relevant funding generation mechanisms
	Determine the maximum amount possible to source from each identified funding source	EPA	1 month	HR	Each proposal to state the funds requested based on the available maximum funding amount
	Estimate total possible fund and the difference with the required amount	EPA	1 month	HR	To be based on the total amount of funds to be raised and the total fund required
Stage 3: Sourcing of funding	Legal framework to support domestic funding	EPA	1 month	HR	Put in place supportive legal framework to permit and guide sourcing of funding for PES schemes such as polluters pay principles and others
	Implementation of mechanism/economic instruments for domestic funding	EPA	6 month	HR	Operation of at least one market based fund generation scheme. At least one policy such as tax laws must be implemented
	Setting up environmental fund organisation	EPA	1 month	HR	Should have completed all three phases of establishing environmental fund being feasibility phase, design phase and implementation phase
	Development of proposal and manpower for negotiations	EPA	1 month	HR	
Stage 4: Human resources mobilisation	Set up a financial team to oversee disbursement of the finance	EPA	1 month	HR	A legally endorse financial expertise team
	Set up a vote for management of the funds	EPA	1 month	HR	A government endorsed vote for funds management
	Develop a project implementation schedule commencing	EPA	2 months	HR	Existence of policies, enforcement

Stage 5: Fund allocation	with logical enabling environment project such as development of legal frameworks				regulations on biodiversity conservation issues
	Disburse funds as per the project implementation schedule	Financial team	2-10 years	HR	an approved project implementation schedule
Stage 6: Monitoring and evaluation	Internal and external auditing and monitor the disbursed funds	Financial team	2-10 years	HR	Development of a monitoring tool (scorecard)

8.0. CONCLUSIONS

Key ecosystems in Yemen have astronomically high economic values and contribute immensely to both household and national income. Most importantly, key ecosystems play critical roles in safeguarding food security and poverty reduction at the rural level. These insinuations is made from findings that the economic value for the four (4) key ecosystems is ten (10) times the value of country's GDP. The implication of a substantially high economic value of ecosystem relative to GDP is that a high proportion of these values are excluded in economic decision making. Consequently, evidence of widespread unsustainable ecosystem utilisation accompanied by widespread ecosystem degradation and depletion (water and marine resources) is partly a result of lack of economic decision making in accounting for values of ecosystem. It is therefore important that ecosystem economic values are integrated at both national and local developmental planning to enhance sustainable utilisation of ecosystems in the country. This can be done through implementation of WAVES, ensuring that at project appraisal stage environmental costs and benefits are integrated in decision making and ensuring that PES concept are embraced and implemented.

Ecosystems mainly forests/woodlands and rangelands have huge potential to alleviate poverty at the rural areas of the country through value chain addition. Globally, there is an international demand for organic products particularly for medicinal and cosmetic purposes. As Yemen has various medicinal and cosmetic plants this present colossal opportunities to undertake rangeland value addition initiatives with the objective of poverty alleviation.

Yemen economy comprises of agriculture, oil and gas, manufacturing and industrial and service sectors. The main sector in terms of contribution to the GDP is the service sector at over 40 percent, followed by the oil and gas sector. The manufacturing sector, though classified as the promising sector is the least contributor to GDP at less than 10%. The agricultural sector is classified as being traditional, lacking modernised production systems. The main cash crop that is steadily replacing other crops in the country is Qat consuming over 40% of water spent by the agricultural sector, while overall the agricultural sector is the major consumer of water accounting for over 90% of water abstractions.

The economy sector is responsible for widespread environmental degradation in the country in the form of water resources pollution and depletion, deforestation on forests, woodlands and mangroves, degradation of the rangelands, destruction of marines ecosystems particularly Sea grass, coral reefs and the mangroves. Virtually, all the economic sectors contribute equally to these degradations. In addition, policies on subsidies are the secondary factors contributing to environmental degradation.

In addition, to the impacts of economic activities on key ecosystems, climate change will aggravate and intensify ecosystem degradation. According to IPCC,

GCM are in agreement that Yemen would experience an increase in temperature in the range of between 1.8 to 4.5 °c by 2100. On the other hand, the GCMs are not in agreement on the rainfall scenario while some models project increases in precipitation by as much as 25% other project a decline of up to 25% by 2050. Thus, projecting the impacts of climate change on key ecosystem proves to be complicated by the variations in the models predictions. However, it can be concluded that the impacts of climate change would reduce the services and support functions offered by key ecosystems. For instance, climate change would result in increase in evapotranspiration, reduced runoff and less infiltration. This process will aggravate water deficit in the country. SLR is also projected to rise by 3.3 mm/year. This will inundate the mangroves affecting their protective services of flood control and coastal erosion prevention. In addition, sea temperature increase could affect marine productivity with decline in fish production.

Consequently, the impacts of climate change on key ecosystems could be disastrous there is an urgent need to implement measures to enhance their adaptation capacity. The enhancement measures should be targeted for ecosystems that offer preventive and protection functions. These include mangroves, forests, Sea grass and coral reefs. Moreover, it is important to come up with enhancement measures that will improve the health of key ecosystem by reducing carrying capacity, reducing pollution in marine ecosystems and reducing harvesting rate to sustainable levels., it is also vital to increase PA coverage and management at the landscape level. Creation of migration corridors as an enhancement mechanism is also important.

Similarly, to implement enhancement ecosystem adaptation measures, it is crucial to improve key ecosystems ability to carbon sequestration. Some of the identified areas for carbon sequestration include afforestation of the mangroves, forests and woodlands, declaration of coral reefs, sea grass as PAs and sustainable management of rangelands.

Adding, to enhancing the ability of the environment to adapt to climate change, it is critical that a conducive environment is created. This can be done through removal of subsidies and replacing them with incentives for environmental protection. Some of the identified incentives include creating a fund for terrace rehabilitation, preferential markets for environmentally friendly agricultural products such as those using less water, less fertilisers and international preferential markets for organic crops.

Key ecosystems are multifunctional offering services to various users and non-users. Consequently, the multiple uses associated with ecosystems imply existence of use conflicts. Stakeholders for ecosystems include all members of the community at international, regional and local levels. The primary stakeholders include farmers, fishermen (commercial and subsistence), wood harvesters (commercial and subsistence), tourism operators, honey producers, herbalists, traditional doctors, tourists, governmental departments, international organisations and NGOs. These

stakeholders benefit differently from the services offered by the ecosystems. Stakeholders who use the resources directly through harvesting are in conflict with those who use the ecosystems indirectly (honey producers, tourism operators) and it is those who use the resources indirectly who bear the environmental degradation costs.

PAs in the country are faced with various sombre challenges which hinder their operational effectiveness. Some of the challenges include lack of human and financial resources, lack of institutional capacity to manage PAs, limited coverage of PAs amongst other. Thus, there is need to define programme of works for the PAs in the country.

Situational analysis reveals that Yemen has a lot of ecosystems challenges. However due to limited resources, NBSAP has identified seven (7) priority investment needs as follows: National Integrated Protected Areas system, Integrated Coastal Zone Management Plan (ICZMP), Policies, Legislation and Regulations on Biodiversity Issues, Agro-Biodiversity, Reviving Traditional Indigenous Natural Resource Management Systems and National Biotechnology/Biosafety Frameworks. Thus a financing action plan for these priority areas has been developed.

9.0. RECOMMENDATIONS

The following recommendations were made based on the findings of the assignment:

1. There is need to undertake ecosystem valuation of the non-use values (option and existence). This will give a clear picture on communities perceptions on ecosystems' contribution to household wealth

2. There is an urgent need to integrate economic value of ecosystem in decision making at national and local levels through appraisal techniques (CBA and MCDA), implementation of WAVES and PESs. This will ensure that environmental benefits are maximised while environmental costs minimised

3. Conduct a value chain analysis of the ecosystems products. Natural resources have a huge potential to alleviate poverty in Yemen particularly in the Rural Yemenis population. There is an international movement towards use of organic products for health and wellness (nutrition), cosmetics and pharmaceutical

4. Undertake an assessment of the economic use of all natural resources products (seed for oil and cosmetic, bio-fuel, medicinal). Some of the products in high demand in western countries include *ximenia caffra* oil from Africa used for cosmetics, mainly in France and European countries

5. For PAs ecosystems effectiveness in adapting to impacts of climate change, it is recommended that landscape approach to PA management be employed

6. Establish TFCA through creation of corridors within and between neighbouring countries for both terrestrial and marine PAs

7. Adopt co-management as a way of PA coverage expansion and operational effectiveness. This will ensure that local communities benefit from operations of the PAs. The Co-management should be for key ecosystems such as mangroves, coral reefs, sea grass, forests, rangeland and woodland

8. Establish carrying capacities for mangroves, rangelands, and coral reefs, sustainable harvest rates and abstraction rates for groundwater. This will enhance ecosystem natural adaptation to climate change impacts. Highly stable and resilient ecosystems are able to withstand negative impacts relative to degraded ecosystems

9. Implement individual transferable quotas to encourage water use efficiency

10. Develop legislation on indigenous knowledge and local medicinal plants to protect against foreign exploitation. Rangelands and forests have high potential as sources of medicine and therefore susceptible to exploitation by international pharmaceutical and biotechnological multinational companies

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