



PRESIDENCY OF METEOROLOGY AND ENVIRONMENT  
KINGDOM OF SAUDI ARABIA



# MILLENNIUM ECOSYSTEM ASSESSMENT

Sub-Global Arab Millennium Ecosystem Assessment

## Summary of Chapters

Saudi Arabian Millennium Ecosystem Assessment  
For  
Assir National Park  
June 2010





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## Chapter 1- Introduction

The sub-global Arab Millennium Ecosystem assessments were designed to meet needs of decision-makers at the scale at which they are undertaken and also to strengthen the global and local findings with global perspectives, data and models. There are three sites which have been selected from across the Arab region:

- **Asir National Park (ANP), Kingdom of Saudi Arabia** (the current study); located in Asir Mountains which contain one of the most important ecological hotspots in the Arab region. The Park encompasses three main habitat types: sandy desert, high altitude habitats, and Marine habitat of the Red Sea.
- **Sinai Peninsula, Egypt**; The ecosystems include desert, mountains, wetlands, coastal, agricultural and marine ecosystems
- **Tafilalt Oasis, Morocco**; located in the Sahara SE Morocco, with an area of about 1,370 km<sup>2</sup>. It contains date groves, palm trees and small trading settlements

The main goal of MA project is to promote the adoption of integrated assessment approaches in the Arab region at the local, national and regional levels. An integrated assessment approach will provide the information to decision-makers for designing a comprehensive and sustainable management plan for the environment.

The MA study will provide the scientific information base to support decision-making and policy formulation in order to protect and promote sustainable management of the ecosystems in the selected sites and related areas.

It has been well documented that ecosystems and human well-being are inextricably linked together. Improved ecosystem productivity, and the services that the ecosystem provide such as water, food and fuel to the local population, services for the tourist industry and actions required to protect and conserve the natural resources of the Asir National Park will also improve.

The basic aims of the project are two-fold (i) to reduce impacts of park degradation on ecosystems and (ii) to enhance community livelihood through improving the existing linkages between local authorities in the Asir region, researchers, NGOs and national development organizations. A framework has been developed by the Ministry of Agriculture (MoA), the Presidency for Meteorology and Environment (PME), the National Commission for Wildlife Conservation and Development (NCWCD) which is now known as “**Saudi Wildlife Commission**”, Universities and other stakeholders for the assessment of ecosystem studied in this report. The specific objectives include:

- (i) To establish a reference baseline from which future changes to the various ecosystem components may be measured.
- (ii) To assess the level of Sustainable Management of National Park (SMNP) implementation or development in selected sites.
- (iii) To demonstrate at selected sites that increased integration of park management can contribute to improved ecosystem protection management.
- (iv) To increase information dissemination and to enhance expertise exchange within the national, regional and international institutions.
- (v) To adopt and refine a model methodology for ecosystem assessment that can be applied to the Arab region.
- (vi) To promote alliance between local communities, researchers, and NGOs in order to protect the park and its environment from degradation, and to conserve the biodiversity of ANP.

It is widely recognized that stakeholder participation in planning and decision-making is essential for any proposal to be successfully implemented. While stakeholder participation often results in a slower and more costly process of implementation, it has the advantage that such involvement creates ownership in the policy being developed, acceptance of the policy by the participants and commitment to a successful implementation of the policy. To ensure the involvement of stakeholders, public education and awareness is considered to be the most effective tool.

The information that is needed for the process to succeed includes the assessment of the resources required to implement the participatory approach and the resources needed once the policy is implemented. This would require effective monitoring and reporting in formulating ecosystem response policy.

The main user groups involved in this study include:

- Pastoralists whose animals graze the park area
- Farmers who do farming in ANP
- Tourists that visit the Asir National Park
- Local agencies such as the Asir Governorate
- Ministry of Agriculture who produced the original report on the Asir National Park.
- Presidency of Meteorology and Environment who is the central environmental protection agency and lead agency in this study.
- Municipalities and local communities
- Universities such as King Saud University and King Abdulaziz University who have conducted agricultural and environmental research in maintaining Bedouin's culture and traditional way of life.
- Other government agencies including King Abdulaziz City for Science and Technology (KACST), Ministry of Water & Electricity and National Commission of Wildlife Conservation and Development (NCWCD).

The project has adopted a multidisciplinary approach that addresses issues from bio-physical, technical, socio-economic, cultural, institutional, and policy perspectives and stimulates interactions among researchers, policy-maker, and community leaders. Such an integrated approach ensures that all resources are studied together within the system and that socio-economic and policy issues are considered throughout the process.

## Chapter 2: Study Area

Asir National Park (ANP) in Saudi Arabia was established in 1981, has an area covering over 45,000 ha., population about 650000. Topographic features of the study area (ANP) are comprised of highlands, plateaus, coastal plains and marine environment. In the past, agriculture terraces were constructed in the ecosystem as means of conserving soil and to increase water infiltration into the soil for crop cultivation. The study area includes a combination of four ecosystems namely mountain ecosystem having juniper forest and terrace agriculture, agricultural and grazing land, coastal and marine ecosystems. Rainfall (about 300 to 500 mm per annum) is the main source of water in ANP in addition to desalinated water and groundwater.

Generally, Juniper forests are considered to be responsible for the protection of watersheds and soils; and regulation of rainwater flow. The forest ecosystem has been the source of wood, grazing material and medicinal plants. In the past, these forests were protected by the inhabitants through traditions and customs using a system called Al Hema where every tribe or a clan has its own part of the forests and no one was allowed to get into it without permission. In recent times, the life of the inhabitants has improved with the improvement of socio-economic condition in the country. An open grazing system has been established replacing the traditional system.

In spite of the improvement of the economic situation due to oil based economy, the local people still depend on the forest ecosystem for their wellbeing as this ecosystem still provides environmental protection and some other goods and services. For example the forests provide water, grazing material, background for honey production, food, fuel, education, recreation and eco-tourism as well as the provision of other environmental services to ANP. This is in addition to the conservation of natural resources such as soils, wildlife and biodiversity. These ecosystem goods and services have significant economic value even if some of these goods and most of the services are not traded by a market value.

Asir Region of Saudi Arabia, and hence ANP presents a striking biodiversity. This is because of the presence of the natural forest ecosystem which supports the majority of the biodiversity elements. Conservation of ANP ecosystem is the direct concern of three national agencies:

- (i) Ministry of Agriculture (MoA).
- (ii) Presidency of Meteorology and Environment (PME).
- (iii) National Commission of Wildlife Conservation and Development (NCWCD) now known as **“Saudi Wildlife Commission.”**

The current irreversible and major threats to the forest ecosystem in ANP include settlement and associated road construction, as well as agricultural expansion. Moderate threats include overgrazing, deforestation, hunting, overfishing, pollution, and littering which is associated with tourism and recreation, pesticides and insecticides, land invaded with exotic plants, and invasive species, such as *Opuntia ficus-indica*, *Argemone Mexicana* etc.

The last three decades have seen socio-economic, educational, technical, environmental, political and institutional changes in Saudi Arabia. These changes have their own direct and indirect negative impacts on forests. These are likely to worsen in future as a result of driving forces which include increase in population, pollution, drought, increased environmental tourism etc. The indirect drivers of change are primarily demographic, economic, sociopolitical, technological, cultural and religious. These include population size, national and per capita income, rate of adopting new technologies.

### Chapter 3 - Assessment Approach

Assessments of ecosystems and human well-being done at smaller scales can help identify the dynamics of the system that might otherwise be overlooked. Time scale is also important in conducting assessments. Assessments that cover a shorter time period than the characteristic temporal scale may not adequately capture variability associated with long-term cycles.

As for water it is probably the most critical resource in the Asir region and is a key concern for national and regional security. The degradation of watersheds and its consequences on the water supply, including irrigation, have been widely reported. While soil erosion and watershed degradation are recognized as important problems, it is necessary to assess the potential role of forests in providing a solution, especially in the context of several factors that influence the hydrology in the region.

Rainfall and resulting runoff is the main source of water in Asir region. A portion of this water recharges shallow aquifers, which are then tapped by wells. The erratic nature of rainfall in both time and space, and the growing demand for water by an increasing population necessitates the development of more permanent renewable source(s) of water.

Forest spreading on mountain sides plays an effective role in the regulation of water flow and minimizes loss by reducing evaporation due to the moderate climate provided by forests. Forests also help in the reduction of water flow to valleys and dams

and safeguard against flood hazards and destruction.

As a result of a survey, local inhabitants reported using shallow wells, springs and runoff water in Wadis as their source of water in the past. Approximately 40% of those surveyed said that they used shallow wells, while the others used springs or water captured and stored from Wadis. Currently, 50 % of the inhabitants use desalinated water, and the other 50% use well water.

Food security is the outcome of complex interactions among natural resource management and political, social, and economic factors. Forests, as an important element in this matrix, affects food security in several ways, including the provision of foods, directly from forest, assisting in sustaining agricultural productivity and in providing economic opportunities. Trees in agro-forestry ecosystem, as the case in Asir National Park, provide direct and indirect benefits for farms. Indirectly they provide shelter and shade for livestock as well as the amelioration of land degradation problems such as soil erosion and higher water tables. Agro-forestry is a key interdisciplinary approach to addressing food security that integrates trees and shrubs into crop and livestock production systems. Instead of relying on expensive inputs of modern agriculture technologies, agro-forestry depends on the interaction between trees and the soil, crops and livestock to improve overall farm productivity. All the pastoralists depend mainly on tree fodder to feed their animals. Trees provide shade for livestock, important to their health and productivity in hot, dry areas. Grazing is a normal practice in Asir National Park thus milk and meat are produced indirectly from the ecosystem.

Trees, in the form of fuel wood and charcoal, are the most important source of energy mostly used for domestic cooking. In the past, a survey revealed that 80% of the local inhabitants used fuelwood for cooking and heating as their main source of fuel, while 20% used charcoal and kerosene. Currently, however, gas and electricity are used by two-thirds of the surveyed inhabitants, while one third still use fuelwood and charcoal.

The MA uses both biophysical and socio-economic indicators as tools for assessing the relationships between ecosystems and human well-being. In addition, models may be used to show the interactions between systems and drivers. For example, models can be used to determine the impact of change in land cover on river flow and land erosion. Then, there is the situation where human system model looks at the changes in ecosystems on production, consumption and the investment made by households.

Models can also be used to overcome data deficiencies by using probabilistic estimates in those cases where observations are not available. In Saudi Arabia, there are many situations where scientific, traditional and local knowledge may be so lacking that the use of models will not produce reliable results.

The methodological tool that was used to assess the forest ecosystem was the his-



toric satellite imagery with GIS and ground level verification. Forest area by species, change in forest area and condition were the indicators used. As for terrace agriculture, the methodology used was satellite imagery with ground level verification and local interviews while the indicators comprised terraced area, condition of terraces and crop production.

The key factors and their indicators for assessing human well-being include finances, health, education, infrastructure and social relations, while the indicators comprised land ownership and employment, access to clean water, health care nutritious food and sanitation, education and availability of training programmes, roads access to utilities and availability of cultural religious services respectively.

There were six different methodologies used to assess and evaluate the status of ecosystems and human well-being in the Asir National Park. These methodologies could be illustrated as follows:

- Literature review and survey of published reports.
- Visits of ANP by study teams.
- Survey by questionnaires.
- Interviews and discussions with local inhabitants.
- Analysis of socio-economic indicators.
- Analysis of remote sensing and satellite imagery data.

The LANDSAT Thematic Mapper (TM) satellite image analysis was performed at the GIS and Remote Sensing Unit of the PME, Jeddah for preparing change detection maps of the temperature, and chlorophyll of the vegetation in Asir National Park. The general approach involved the acquisition of two sets of LANDSAT TM data for two different dates (Aug. 1990 and June 2000), followed by extraction of digital numbers (DNs) from TM Bands, development and verification of correlation of selected vegetation variables to the spectral data, application of the models to the entire intensive study area, and the production of color coded resultant images showing the difference in temperature and vegetation. Two TM scenes - Path/Row 167/047 acquired on 29-08-1990 and Path/Row 163/042 acquired on 21-06-2000 were utilized for analysis.

## Chapter 4 - Results and Discussion

Fifty eight percent of farmers interviewed in the study area stated that they grew only wheat, maize and barley, while forty two percent added millet and 17% said they grew vegetables, fruits and millet in addition (questionnaire survey 2007). The aforementioned study revealed that most of inhabitants' food habits have changed. People now rely on rice instead of wheat and on white flour bread instead of millet's

flour bread. Terraces have been deteriorating for the last two to three decades. Maintenance has not kept up due to lack of labor. With a forecast of agricultural water to decrease in the future, crop production will decline, and food imports to the area will increase.

The trend of the availability of fuel in ANP in the near future is that the use of oil and gas will continue to replace wood and charcoal because of its ease and availability, according to the local inhabitants. Although, oil and gas is more expensive, its use will increase causing a decrease in wood cutting resulting in increase of vegetation cover in the area.

In discussions with local inhabitants, it was found that eco-tourism, will increase. Those interviewed believe that the government will continue to improve educational facilities, and thus, the benefits from education will spread amongst greater numbers. This is also clear from the government budgetary allocation for education at national and regional (ANP) level. An increase in the number of educational institutions and the number of teaching staff and students entering these institutions also confirms this trend.

Global climate change is predicted to play a major role in determining the availability of water for drinking, agriculture, and other purposes in the world. A strong consensus of scientists proposes that arid zone temperatures will increase resulting in decreased precipitation. However, the preliminary results of PRECIS, the Hadley Centre's regional climate model, run by PME for the period 2070-2100 time horizon showed an increasing trend in the south-western Saudi Arabia, which include ANP and some inland areas while the analysis has shown decreasing trend of precipitation over north-western parts of Saudi Arabia.

Among all the ecosystem resources, water has the greatest impact on people and the environment as neither can exist without its availability. Too much water in the form of floods can also be as problematic as not enough water. Not only the quantity is of concern to decision makers, but also quality. Water pollution can adversely affect practically all other ecosystem services.

As for the terraces, the labor shortage has been the result of younger generation that grew up on the terrace farms, leaving the area to seek better education and employment in the Kingdom's larger cities. Even with a land-use change to more agricultural land, pressure on groundwater resources will increase.

The MA conceptual framework defines cultural services as the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development and recreation. These benefits include cultural diversity, a sense of place, tourism, educational value and aesthetic values. Cultural drivers include changes in lifestyles,

such as from traditional to more– modern values and norms with respect to the environment and knowledge, education and health-care.

Due to the driving forces and continuous human activities and lack of forest management, this has contributed to the continuous deterioration of the forest ecosystem both in extent and health, consequently the ecosystem services are deteriorating which put great responsibilities on decision makers, stakeholders, users and the local communities to act as soon as possible for the sustainable management of the forest ecosystem to secure the goods and services mentioned above in favor of human well-being.

## Chapter 5 - Ecosystem Services and Trends

The concept of an ecosystem provides a valuable framework for analyzing and acting on the linkages between people and the environment. For that reason, the MA uses an “ecosystem approach” which has been endorsed by the Convention on Biological Diversity (CBD). The CBD states that the ecosystem approach is a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way. This approach recognizes that humans, with their cultural diversity, are an integral component of many ecosystems.

### **Ecosystem Composition:**

From a topographic perspective, the ANP is comprised of highlands, plateaus and coastal plains. The mountain ecosystem is found in the Asir mountains at elevations starting from 2000m to more than 3000m. The kind and composition of trees in these forests change with elevation. On the crests of ridges above 2000m, there are almost pure stands of Juniper trees (*Juniperus procera*) accompanied by *Asparagus asiaticus*, *Lavandula dentate*, *Euryopus arabicus*, *Rosa abyssinica*, *Calutea* spp, *Helichrysum* spp, *Lactuca* spp, *Euphorbia schemperiana* and others.

Within the boundaries of Asir upland watersheds, a number of land practices occur in separate areas, including protection and/or production forestry, agricultural cropping and grazing by domestic livestock. As such, these multiple–use watersheds define an agro-forestry system of land use.

### **Forest Vegetation:**

Asir National Park is located in the region that consists of the only prominent forest in the Kingdom, situated in the Sarawat Highlands, extending from Al Taif in the north to Najran in the south.

The medium altitude mountains (1500-2000m a.s.l.) support evergreen forests, mainly consisting of *Olea africana* accompanied by some members of *Juniperus* spp. The less elevated mountains (1000m – 1500m a.s.l.) support *Acacia – commiphora* scrub community.

### *Agro-Forest Ecosystem - Terrace Agriculture:*

The topography of the ecosystem in ANP is characterized by moderate to steep slopes. Soils are shallow and exposed to a continuous process of erosion, mainly by rainwater. In the past, terraces were constructed as means to conserve the soil, and to enhance water infiltration into the soil. Crops were cultivated on these terraces. Due to the discovery of oil in the country and the improvement of economic situation, these terraces were not maintained, and have consequently been gradually damaged. As a result of this deterioration, Juniper forests in Asir National Park have suffered severe soil erosion and drought stress. Despite general deterioration, some new terraces exist in privately owned households. These are well maintained and are used for cereal production.

In Asir region little research has been conducted on genetic diversity, but some research has been conducted on forest diversity. The mountain heights of Asir are divided into natural zones according to height.

History shows that human well-being, and indeed the persistence of civilizations, is strongly linked to the capacity of their environments to continue to deliver ecosystem services at the local to regional scale. The linkage works in both directions:

- human well-being depends, to a large measure, on many services provided by nature; and
- state of the environment is affected by the size and consumption patterns of human populations in ways that reduce or increase (at least temporarily) the supply of ecosystem services. (Millennium Ecosystem Assessment, 2005)

The most important ecosystem services provided by the forested areas of ANP include water, soil, food, fuel, medicine, and cultural services.

The indirect benefits of forests are particularly important as they are fundamental to the conservation of the natural environment through the following:

- Conservation of the plant cover that helps in the soil fixation by the roots and improved aeration.
- Decreasing the velocity of rainwater flow, soil surface and the mountain slopes which prevents soil sliding and erosion.
- Decreasing wind speed and the sand creeping process.
- Decreasing the temperature and the water loss through evapo-transpiration.
- Providing organic materials that build the soil and increase its fertility.
- Providing fodder for domestic and wild animals.
- Improvement of the local climate and increase the crops productivity.
- Providing parks and interior tourism sites.

- Decreasing environmental pollution through the absorption of harmful gases including carbon dioxide and reducing sound pollution.
- Clearing of the weather that contributes in the condensation of clouds and increases the chances of rainfall especially in high altitude regions.
- Conservation of the wild life by providing suitable shield and safe refuge for animals during their normal migration.
- Production of honey, medicinal substances and tanning material.

In the foreseeable future, it is believed by locals that the use of terraces for agriculture will decline primarily due to the lack of terrace maintenance and non-availability of labour. Local inhabitants predict that land-use changes will continue to take place; for example, forest areas will be cleared for the production of agricultural crops, because of the economic advantage of crops over forest products. On the other hand, forests have an environmental advantage over cropland in that they protect the soil from erosion by transforming intense rainfall into a more gentle rainfall run-off. Another observed trend is the introduction of intensive agriculture at the higher altitude where rainfall averages 400-500mm per year. Dams installed across wadis are used to divert water for irrigation.

## Chapter 6 - Scenarios

Scenario development allows to explore a possible set of outcomes that might result if there is a change in the basic assumptions. Scenarios reflect different assumptions about how current trends will unfold, how critical uncertainties will play out and what new factors will come into play (UNEP 2002). Scenarios do not predict what the future will be. However, if probabilities can be attached to a full range of uncertainties, this may be translated into a set of futures that has probability associated with each possible future.

Storylines were developed using UNEP guidelines for sub-global assessments. A wide range of stakeholders were consulted, including the ministries of Water and electricity, Municipal and Rural Affairs, Agriculture, Planning, NCWCD which is now known as **“Saudi Wildlife Commission,”** PME, King Abdulaziz and King Saud Universities, farmers, pastoralists, fishermen, youth, society leaders and other local inhabitants. Several communication tools were used, such as interviews, working meetings, discussions, visits, and questionnaires. The response was good from the local community. However, cooperation and coordination from the public sector was not as strong.

MA scenarios assess the consequences of contrasting development paths for ecosystem services. Ecosystems are dynamic and always changing. To complicate matters further, the pressures on ecosystems are increasing which can lead to reduced services provided by ecosystems or increased costs of maintaining services. As with all other components of the MA conceptual framework, stakeholder participation in the development of scenarios is essential for a successful endeavor.

### **Types of Scenarios used:**

Of several different types of scenarios which can potentially be utilized, including quantitative analysis, qualitative analysis and modeling, the ANP assessment applied a qualitative and exploratory scenario analysis, where options for policy interventions are explored in each of the three different storylines. The approach was adapted from the Millennium Ecosystem Assessment scenario methodology and applied in the local context of the ANP. Although four different types of ecosystems are presented in the assessment, the scenario exercise focused on two: agriculture and forest ecosystems in the mountainous region of the Park.

### **Scenario Storylines:**

The three scenarios to be discussed herein refer to three different levels of interventions on how the mountainous region of the Asir National Park will be managed in the future, and what the outcome will be with respect to their impact on human well-being and the environment. Examples of interventions include policy development and implementation to address climatic variability and resources management; investments in research and technology to support local management of ecosystems, water and wastewater treatment and increased access to energy sources. Interventions can derive from either government or the private sector, both of which have interests in the ANP. The three different scenarios presented as part of the ANP assessment are:

- (i) No intervention-market forces dominate; locally called “Al-Na’amah”
- (ii) Public awareness, capacity building and training programs; locally called “Al-Maha Al-Arabi”
- (iii) Strong government policies and control measures geared up for sustainability; locally called “Al-Nimr Al-Arabi”.

Each scenario describes the state of both ecosystems (forests and agriculture), and the potential changes to the human well being of the local inhabitants. All the scenarios will be subject to the same uncertainties, such as the future climate, the impacts of international policies on local market forces, and environmental disasters.

In laying the foundation for the scenarios, it becomes necessary to identify drivers and select critical uncertainties. A list of possible driving forces, based on the results from the assessment, both direct and indirect include: economic, land use change, science and technology, biological and physical- climate variability and change, demographic and urbanization.

Based on the information collected during the assessment and the discussions documented during the scenarios process, the most plausible scenario would most likely be scenario iii, where interventions will occur, but not to the effect needed immediately. The Saudi government has already been working towards implementing and reinforcing new policies on sustainable forest and agriculture management, yet the challenge will be

to work with the local inhabitants to support these policies over time. Public awareness and education initiatives will serve to inform the local population and the government on the importance of local policing and reinforcement of certain ecosystem management policies, which could potentially strengthen the effectiveness of future policy development initiatives. The more policies that are developed with the local population involved, the more effective and successful policies will be in meeting the needs of the local population and offsetting any negative impacts on the ecosystems in the ANP.

## Chapter 7 - Responses

Ecosystems are dynamic in nature. As such, decision-makers must understand their dynamic nature and consider changes in the decision-making process themselves. Management of these changes should be adaptive and flexible to benefit from past experiences, to hedge against risk and to consider uncertainty.

The new challenge to decision-making is to make effective use of information and tools in the changing context so as to improve the decisions. The following is a list of elements of the decision-making processes that tend to improve the decisions related to ecosystems and human well being:

- Use the best available information.
- Ensure effective and informed participation of important stakeholders.
- Recognize that some decision-making processes have significant subjective elements as not all values can be quantified.
- Consider equity and vulnerability in terms of the distribution of costs and benefits.
- Ensure accountability and provide for regular monitoring and evaluation.

Wide ranges of tools are available to assist the decision-making processes in connection with ecosystems and their services. Examples of such tools include:

- Tools which facilitate stakeholders' participation, such as neighborhood forums, community issues groups, focus groups and ecosystem service user forums.
- Information-gathering tools, primarily those that are focused on collecting data and opinions.
- Planning tools to evaluate potential policy options such as consensus participation, cost-benefit analysis, multi criteria analysis, stakeholders decision analysis and trade-off analysis.

It has been shown that past actions to slow or reverse ecosystem degradation while yielding significant benefits have not kept pace with growing pressures and demands. Effective responses that tend to result in sustainable management of ecosystems, must address the pressures that lead to the degradation of ecosystems and their services and overcome a range of obstacles to the improvement of ecosystems. Some of these obstacles include:

- Lack of knowledge concerning ecosystem services and ecosystem management, policy, behavioral, technological and institutional responses that could enhance benefits while conserving resources.
- Market failures and the non-alignment of economic incentives.
- Social and behavioral factors such as those groups who are particularly dependent on ecosystem services.
- Low investment in the development and spread of technologies that could increase the efficiency of ecosystem services by enhancing benefits and conserving resources.

Furthermore, positive steps are needed to address the following threats to the ecosystem failing which the situation will further deteriorate.

- Population in the Kingdom is expected to reach 60 million by 2050 with an annual rate of 2.4%, population in forest areas will amount to 30 million. The roads are also expected to increase in the future to 15463 km (approximately 1.5 million ha) thus affecting the vegetation cover in forests and rangelands.
- Diseases, pests, dieback and mass mortality currently surround Forests. If no intervention occurs, the situation will worsen with time.
- Given the establishment of the Supreme Commission for Tourism, the efforts to promote the internal tourism especially the eco-tourism during the hot summer and the increasing number of national and foreign tourists, Asir National Park will not be able to cope with these numbers.
- Given the arid climate of the Kingdom, the water scarcity and the high costs of afforestation, expansion of forests will be very slow.

There are many response options for enhancing ecosystem services, which may be made effective by meeting the following conditions.

- Ensuring better information, and data on beneficiaries and those hurt by changes in ecosystem services, for having an effective system of payment for ecosystem services.
- Address lack of knowledge concerning ecosystem services, management policy, behavioral, technological and institutional responses that could enhance benefits while conserving resources.
- Address market failures and the non-alignment of economic incentives.
- Evaluation of social and behavioral response of those groups who are particularly dependent on ecosystem services.
- Increase investment in the development and spread of technologies that could enhance the efficiency of ecosystem services and their benefits.

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- Address lack of knowledge concerning ecosystem services, management policy, behavioral, technological and institutional responses that could enhance benefits while conserving resources.
- Address market failures and non-alignment of economic incentives.
- Evaluation of social and behavioral response of those groups particularly dependent on ecosystem services.
- Increase investment in the development and spread of technologies that could enhance the efficiency of ecosystem services and their benefits.

A list of promising interventions needed in the areas of institutions and governance, economics and incentives, market mechanisms, social and behavioral responses, technological responses and knowledge responses are as follows:

- Development of institutions to regulate interactions between markets and ecosystems.
- Development of institutional frameworks that promote a shift from highly sectoral resources management approaches to more integrated approaches.
- Elimination of subsidies that promote excessive use of ecosystem services.
- Measures to reduce consumption of unsustainable managed ecosystem services.
- Improved communication and education.
- Promotion of technologies that increases agriculture and livestock production without any harmful impacts on the land or water resources.
- Use of all relevant forms of knowledge and information in assessments and decision-making.

In producing successful responses, consideration should be given to the concept that trade-offs among ecosystem services may be necessary to produce the best possible set of benefits to stakeholders. Another factor to consider is the necessity for monitoring an ecosystem and its services in order to be able to evaluate the effectiveness of a given response.

In addition, successful implementation of relevant international Conventions such as Convention on Biodiversity (CBD), Convention to Combat Desertification (CCD), United Nations Framework Convention on Climate Change (UNFCCC) and the Ramsar Convention on Wetlands etc. will certainly increase the efficiency of ecosystem services and consequently improve human well-being.



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