# Integrated Biodiversity Management

## Training Manual

**Authors: Desalegn Ejigu[1], Mulugeta Worku[2] and Dagim Fikir[3]**

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## About Bees for Development Ethiopia (BfDE)

BfDE is an Ethiopian resident charity established in May 2012 (registration number 2753). It aspires to see communities in Ethiopia whose livelihoods are sustained through integrated apiculture and natural resources management. Its mission is promoting beekeeper friendly apiculture development in Ethiopia that is well integrated with the environment thereby contributing to sustainable livelihoods.

With the aim of contributing to improvements in and sustainability of rural livelihoods in Ethiopia, BfDE has three mutually reinforcing strategic objectives. These are:

1. *Increase income of poor and marginalized rural households through apiculture development;*
2. *Enhance status of natural resources; and*
3. *Build knowledge and skills in sustainable apiculture and natural resources management.*

BfDE started itsprogramme implementationin three model districts in Amhara region of Ethiopia. It strides to expand its geographical scope in to other parts of Amhara region and the country at large while its execution capacity increases over time.

**Contact address:** Tilahun Gebey, Director of Bees for Development Ethiopia; Telephone: +251918761182; Email: **tilahun_gebey@yahoo.com**; Website: **www.bfdethiopia.org.et**

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# Acronyms

| | |
|---|---|
| BfDE | Bees for Development Ethiopia |
| BSC | Biological Species Concepts |
| CBD | Convention on Biological Diversity |
| CEPF | Critical Ecosystem Partnership Fund |
| DNA | Deoxyribo Nucleic Acid |
| EDGE | Evolutionary Distinctiveness and Global Endangerment |
| GIS | Geographic Information System |
| ibn | Institute of Biodiversity Network |
| IUCN | International Union for Conservation of Nature |
| PAs | Protected Areas |

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# 1. INTRODUCTION

## 1.1 Background

Under the *Small Grants Programme* of the Critical Ecosystem Partnership Fund (CEPF), Bees for Development Ethiopia (BfDE), since April 2015 isimplementingtwo complementary development projects on integrated biodiversity management and institutional capacity building in which the later builds on the former.

The institutional building component stemmed from the fundamental importance of key stakeholders' understanding, ownership, and competence for sustainable biodiversity management and the corresponding need to ensuring these stakeholders[1] have the required level knowledge and skills in planning, implementation and monitoring of biodiversity interventions including coordination amongst them.

One of the activities designed by BfDE to address the knowledge and skill enhancement needs is production of training and reference materials in integrated biodiversity management and GIS and remote sensing applications. This training manual addresses the integrated biodiversity management part whose contents are detailed in subsequent sections. The "GIS and remote sensing applications in integrated biodiversity management" manual is also presented by BfDE as a separate but complimentary document.

## 1.2 Objectives

In accordance with the main focus of the project, the objectives of this training manual are to: primarily increase the knowledge and skills of government experts working in project locations in integrated biodiversity management; and additionally serve as a reference material for applications related to planning, implementing, monitoring and evaluation of biodiversity management interventions within and outside project locations.

## 1.3 Structure

This resource on integrated biodiversity management is structured in to fourmain parts. Part one contains introductory elements – providing a brief description of the background, objectives and structure of the training manual. Part two deals with fundamentals of biodiversity with a specific focus on: concepts, description of the levels at which biodiversity is dealt,

[1]Key stakeholders in this project refer to relevant government institutions particularly at the woreda and zonal levels who take the prime responsibility for planning and resources allocation for wise use of their natural resources.

its benefits, and the interaction between humans and biodiversity. Part three bears issues of biodiversity in the Ethiopian context and specifically addresses trends and current status, hotspots, and challengesof biodiversity in the country. Part four is aboutintegrated biodiversity management planning in which conceptual frameworks and approaches for designing, implementation, monitoring and evaluation of integrated biodiversity interventions are dealt. Additional sets of information that supplement this training material are given as addendum.

# 2. BASICS OF BIODIVERSITY

## 2.1 What is Biodiversity?

As described by the German based Institute for Biodiversity Network (ibn), the word biodiversity is believed to have originated from the Greek word *Bio*means life and the Latin word *Diversitas* means variety or difference – in combination giving the meaning "variety of life".

The most commonly used definition of biodiversity is the one given under the Convention on Biological Diversity (CBD) by the United Nations (UN) in 1992 and is stated as follows.

*"Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."*

According to the German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (Schaltegger and Beständig, 2012), biodiversity is conceptualized as the diversity of ecosystems and species as well as the genetic variation within the species.

Biodiversity therefore includes the differences in genes among the individuals of a species, the variety and richness of all species, and the variety of ecosystems in which the species reside at different scales in space and time. In simpler terms, biodiversity is the assemblage of different life forms. It explicitly recognizes that every biota can be characterized by its genetic, taxonomic and ecological diversity that could vary spatially and temporarily.

While scanning the definitions given above, one can understand two key aspects of biodiversity. These are the levels at which biodiversity is dealt and the environment under which life varieties co-exist, both of which are described below.

## 2.2 Levels of Biodiversity

Biodiversity may be considered at different levels. The most common and universally employed hierarchical organizations of life forms are: Genetic, species, and ecosystem levels.

### 2.2.1 Genetic diversity

Genetic diversity refers to the total number of genetic characteristics in the genetic make-up of a species. It is the variation of genes within a species.Genes are the conduits of DNA, and DNA is the inheritable unit that makes variation possible between individuals, populations, communities and species. Genetic diversity enables a population to adapt to its environment and to respond to natural selection. Genetic diversity within a species oftenincreases with environmental variability and the amount of genetic variation is the basis of speciation.

Genetic diversity pertains to the range of diversity in the genetic resources of the organisms. Every individual member of a plant or animal species differs from other individuals in its genetic constitution. Each individual has specific characters, which is due to the genetic makeup or code. The genes present in the organisms can form infinite number of combinations that causes genetic variability.

Thus, we find that each human, who is representative of the same species, i.e. *Homo sapiens*, is distinct from another. Similarly, there are many varieties within the same species such as rice, wheat, apples, mangoes, etc. that differ from one another in shape, size, colour of flowers and taste of fruits and seeds due to the variations at the genetic level.

The term ‘gene pool’ has been used to indicate the genetic diversity in the different species.This also includes the diversity in the wild species, which through intermixing in nature over millions of years have given rise to newer varieties. The domesticated varieties of agricultural crops and animals have also evolved from the wild gene pool.

The genetic variability is essential for healthy breeding population, the reduction in genetic variability among breeding individuals leads to inbreeding which in turns can lead to extinction of species. In the recent decades, a new science named ‘biotechnology’ has emerged. It manipulates the genetic materials of different species through various genetic re-combinations to evolve better varieties of crops and domestic animals.

Populations benefit from some genetic diversity, so as to avoid inbreeding or disease epidemics.

### 2.2.2 Species diversity

Species diversity refers the number or variety of species in a particular region.In modern biology (Wilson, 1988), species are regarded conceptually as a population or series of populations within which free gene flow occurs under natural conditions. This means that all the normal, physiologically competent individuals at a given time are capable of breeding with all the other individuals of the opposite sex belonging to the same species or at least that they are capable of being linked genetically to them through chains of other breeding individuals. By definition they do not breed freely with members of other species.

In Biological Species Concepts (BSC), species is a basic unit of classification and is defined as a group of similar organisms that interbreed with one another and produce fertile offspring's and share a common lineage. Species diversity refers to biodiversity at the most basic level and is the variety and abundance of different types of individuals of a species in a given area.

Certain regions support more diverse populations than others. Those regions rich in nutrients and having well balanced climatic factors such as moderate temperature, proper light and adequate rainfall, show high degree of diversity in their life forms. The tropical areas support more diverse plant and animal communities than the desert and polar areas. For example, tropical forest has higher species diversity as compared to a timber plantation. The regions that are rich in species diversity are called **hotspots** of biodiversity.

Each species are playing a specific role in the ecosystem. In nature, the number and kind of species, as well as the number of individuals per species vary, leading to greater diversity. It has been estimated that more than 50 million species of plants, animals and micro-organisms are existing in the world. Out of these, about 1.4 million species have been identified so far.

#### *Why it is difficult to answer the 'how many species' question?*

The vast majority of species are microorganisms or small invertebrates, making them hard to discover. Some species live in inaccessible, remote or harsh environments. Conversely, the opening up of some environments such as a road built by loggers in a rainforest may bring more species to the attention of scientists.

Different estimates and models of species diversity have widely differing results. New technologies and methods may clarify species' relationships or even their presence in particular areas. For example, recent work on giraffe genetics suggests that some giraffe subspecies may be distinct enough to be considered full species. Other work concludes that there are two giraffe species and eight subspecies. The best results are obtained using a variety of evidence from genetics and molecular research to comparative anatomy and developmental biology.

Each species is adapted to live in specific environment, from mountain peaks to the depth of seas, from polar ice caps to tropical rain forests and deserts. All this diversity of life is confined to only about one kilometre thick layer of lithosphere, hydrosphere and atmosphere which form the **biosphere**.

### *Measuring Species diversity*

Biological diversity at species level can be quantified in many different ways. The two main factors taken into account when measuring diversity are r**ichness** and **evenness**. Richness is a measure of the number of different kinds of organisms present in a particular area, while evenness compares the similarity of the population size of each of the species present. Evenness is a measure of the relative abundance of the different species. As species richness and evenness increase, so diversity increases.

The more species present in a sample, the 'richer' the sample. Species richness as a measure on its own takes no account of the number of individuals of each species. It gives as much weight to those species which have very few individuals as to those which have many individuals.Species richness is the simplest way to compare the number of species. It is usually estimated from a sample of individuals in a given community. Not all species have the same probability of being observed in a sample because some of the species are **common** and some are **rare**.

Small samples have common species and few rare species. Larger samples pick up more rare species. So, when comparing the species richness of two or more communities, you must correct the estimate of species richness from samples for differences in sample size.

### *Simpson's diversity indices (D)*

Simpson's Diversity Index (D) is a measure of diversity that takes into account both richness and evenness. It is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the abundance of each species.

Simpson's Diversity Index measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species). There are two versions of the formula for calculating D.

I. To estimate an infinite population:

$$\mathbf{D = \Sigma (n/N)^2}$$

II. To estimate a finite population:

$$\mathbf{D = \Sigma n (n-1)/N (N-1)}$$

Where: n = the total number of organisms of a particular species,
N = the total number of organisms of all species

The value of D ranges between 0 and 1.

With this index:

0 = represents infinite diversity, and 1 = indicates no diversity.

i.e., the higher the value of D, the lower the diversity

'D' is often subtracted from 1 to give **Simpson's Index of Diversity (1 – D).**

The value of this index also ranges between 0 and almost 1 i.e., the higher the value, the greater the sample diversity, which makes more sense. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species.

Another way of overcoming the problem of the counter-intuitive nature of Simpson's Index is to take the reciprocal of the Index.

### *Simpson's Reciprocal Index (1/ D)*

The value of this index starts with 1 as the lowest possible figure, which represent a community containing only one species. The higher the value, the greater is the diversity.

For example the value of D for a single quadrat sample of ground vegetation in a woodland habit is shown (Table 1). Several samples would have to be taken and the data pooled to give a better estimate of overall diversity.

**Table 1: A single quadrat plant species composition in woodland habitat**

| Species | Number (n) | n(n-1) |
|---|---|---|
| Woodrush | 2 | 2 |
| Holly | 8 | 56 |
| Bramble | 1 | 0 |
| Fog | 1 | 0 |
| Sedge | 3 | 6 |
| **Total (N)** | **15** | **64** |

**Simpson's Index (D) is calculated as:**

$D = \Sigma n(n-1)/N(N-1) = 64/15(14) = 64/21 = 0.3$

Then:

**Simpson's Index of Diversity (1-D)** = 1 - 0.3 = 0.7

**Simpson's Reciprocal Index (1/D)** = 1/0.3= 3.3

All these three different values represent the same biodiversity. It is therefore important to ascertain which index has actually been used in any comparative studies of diversity. i.e., a value of Simpson's Index of 0.7 is not the same as a value of 0.7 for Simpson's Index of Diversity. Simpson's Index gives more weight to the more abundant species in a sample. The addition of rare species to a sample causes only small changes in the value of D.

### *Simpson's Similarity Index (SI)*

It is used to assess the similarity between different habitats with reference to the composition of species

SI = 2C / A+B

Where:

SI = Simpson's Similarity Index

C = Number of species common in sites

A = Number of Species only in site A

B = Number of species only in site B

**Table 2: Species composition in different sites**

| Species in site 1 | Species in site 2 | Species common to sites 1 & 2 | Similarity index (SI) = 2C / A+ B |
|---|---|---|---|
| A | C | C | |
| B | E | E | |
| C | F | F | |
| D | H | H | |
| E | I | I | |
| F | J | | |
| G | K | | |
| H | L | | |
| I | M | | |
| | N | | |
| | O | | |

SI = 2C / A+B

Σ (A) site 1 = 9; Σ (B) site 2 = 11; Σ (C) = 5

SI = 2*5/ 9+1 = 10/2= 0.5

Therefore, there are 50 % of species which are common to the two sites.

### *The Richness Index (RI)*

RI = S-1/*ln*I

Where:

S = number of species in each habitat;

*ln* = the natural logarithm; and

I = Number of individuals or species in each habitat

When the species richness index moves towards 0, it indicates high richness of a group of organisms in a habitat.

## *Shannon-Wiener Index (H'):*

Information is needed to characterize a community.

How much?

Shannon index is a measure of the amount of information needed to describe every member of the community. If $p_i$ is the proportion of individuals (from the sample total) of species i, then diversity (H') is:

**H' = -Σ (pi ln pi)**

As more species are included, the average $p_i$ gets smaller and so its log gets more negative, and the total value of the index increases. This is a useful measure because one can calculate evenness using this index.

**Evenness in organisms' distribution (E)**

**E = H'/$H_{Max}$**

Where:

E = Shannon-Wiener Evenness Index,

H' = Shannon Wiener Diversity Index

$H_{Max}$ = lnS = Natural logarithm of the total number of species in each site, and

S = Number of species in each site.

For any given sample size containing S species, the value of H' will change when evenness changes. The maximum H' value (Hmax), without adding individuals or species, is attained when the numbers of individuals of every species is equal (here, the proportion would be 1/S). Evenness (E) is then the ratio of the actual H' value to the maximum value (Hmax).Thus it ranges from 0 to 1. In this index, both species richness and evenness matter. When the number of species increases, H' increases, when one species dominates (and evenness decreases), H' decreases.

Table 3: Summary showing species diversity

| Species(S) | Number (I) | Proportion Pi=I/ΣI | $Pi^2$ | PilnPi | Species Richness(R) |
|---|---|---|---|---|---|
| A | 30 | 0.36 | 0.130 | -0.368 | 1.176 |
| B | 26 | 0.32 | 0.102 | -0.365 | 1.227 |
| C | 18 | 0.22 | 0.048 | -0.333 | 1.384 |
| D | 5 | 0.06 | 0.004 | -0.169 | 2.485 |
| E | 3 | 0.04 | 0.002 | -0.129 | 3.640 |
| Σ S = 5 | ΣI= 82 | ΣPi = 1 | $\Sigma Pi^2$ = 0.286 | Σ PilnPi = -1.364 | Σ S - 1/lnI |

## Exercise 1

From the Table 3 above, find the value of:

A. Shannon-Weiner's diversity index;
B. Simpson's Index;
C. Simpson's Index of Diversity; and
D. Simpson's Reciprocal Index.

### 2.2.3 Ecosystem diversity

An ecosystem is a collection of living components and non-living components that are connected by energy flow. Ecosystem diversity refers to the variability among the species of plants and animals living together and connected by flow of energy and cycling of nutrients in different ecosystems or ecological complexes. It also includes variability within the same species and variability among the different species of plants, animals and microorganisms of an ecosystem. Thus, it pertains to the richness of flora, fauna and microorganisms within an ecosystem or biotic community.

The richness of the biosphere in terms of varied life forms is due to the variations in the ecosystems. The earth has a number of ecosystems like grasslands, forests, semi-arid deserts, marine, freshwater, wetland, swamp, marshlands etc. each one having its distinct floral, faunal and microbial assemblages. Ecosystem diversity represents an intricate network of different species present in local ecosystems and the dynamic interaction among them. The ecological diversity is of great significance that has developed and evolved over millions of years through interactions among the various species within an ecosystem.

The world's species interact and depend on each other in complex webs of life based on energy flow through the processes of eating and avoiding being eaten. Ecosystems vary from polar zones to the rich forests of the wet tropics. Even within broad ecosystem categories, scientists disagree over the finer points of ecosystem classification. Diversity at the level of community and ecosystem exists along three levels (Fig.1). It could be within-community diversity (**alpha diversity**), between-communities diversity (**beta diversity**) or diversity of the habitats over the total landscape or geographical area (**gamma diversity**).

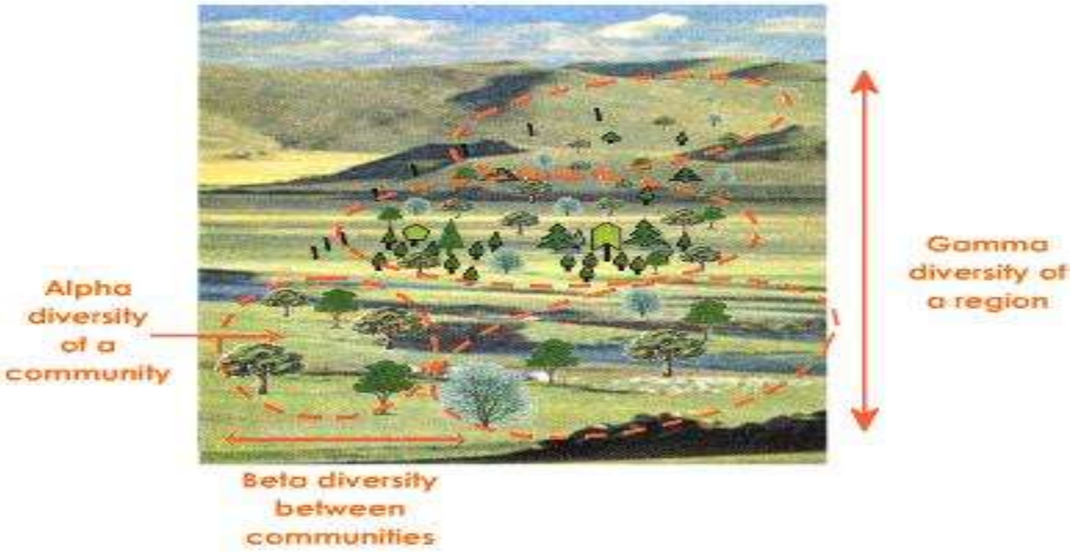


Figure 1: Three perspectives of diversity: alpha, beta and gamma diversity

**Alpha diversity**: refers to the diversity within a particular area or ecosystem, and is usually expressed by the number of species i.e.,species richness in that ecosystem. For example, if we are monitoring the effect that Ethiopian farming practices have on the diversity of native birds in a particular region of the country, then we might want to compare species diversity within different ecosystems, such as an undisturbed forest patch, grassland and farmland. We can walk a transect in each of these three ecosystems and count the number of species we encounter; this gives us the alpha diversity for each ecosystem

**Beta diversity**: if we examine the change in species diversity between these ecosystems then we are measuring the beta diversity. We are counting the total number of species that are unique to each of the ecosystems being compared. Thus, beta diversity allows us to compare diversity between ecosystems.

**Gamma diversity**: is a measure of the overall diversity for the different ecosystems within a region. Gamma diversity is a "geographic-scale species diversity".

**Landscape diversity:** landscape is a mosaic of heterogeneous land forms, vegetation types, and land uses. Thus, assemblages of different ecosystems (the physical environments and the species that inhabit them, including humans) create landscapes diversity.

Species composition and population viability are often affected by the structure of the landscape; for example, the size, shape, and connectivity of individual patches of ecosystems within the landscape. Conservation management should be directed at whole landscapes to ensure the survival of species that range widely across different ecosystems.

Diversity within and between landscapes depends on local and regional variations in environmental conditions, as well as the species supported by those environments. Landscape elements can be described and categorised under different aspects: as habitats or  as land cover categories. Such land cover categories represent the interface between natural conditions and human influence both over time and in different historic periods.

The spatial mosaic of landscape elements determines to a great extent the physiognomy, the visual appearance and the human perception of a landscape. On the other hand the spatial configuration and composition of landscape elements (habitats and biotopes) play an important role in the ecological functionality and biological diversity.

**Cultural diversity:** is the coexistence of different ethnic, gender, racial, and socioeconomic variety in a situation with one social group. Cultural diversity makes one country richer by making it a more interesting place in which to live. Cultural diversity also makes the country stronger and better able to compete in the new global economy.This is because people from diverse cultures bring language skills, new ways of thinking, and creative solutions to difficult problems including biodiversity management, and negotiating skills.

## 2.3 Benefits of biodiversity

Everything that lives in an ecosystem is part of the web of life, including humans. Each species has a place on the earth and plays a vital role in the circle of life. Plant, animal, and insect species interact and depend upon one another for what each offers such as food, shelter, oxygen, and soil enrichment. Maintaining a wide diversity of species in each ecosystem is necessary to preserve the web of life that sustains all living things.

Biodiversity is the most precious gift of nature the mankind is blessed with. The uniqueness of our planet Earth is due to the presence of life manifested through the diversity in flora and fauna. As all the organisms in an ecosystem are interlinked and interdependent, the value of biodiversity in the life of all the organisms including humans is enormous.

Biodiversity provides ecosystem services including water purification; clean air, soil formation and protection, pollination, fertile soil, climate regulation, flood control, as well as pest regulation and disease resistance, which is essentially for the cost of letting natural systems function. However, these services are not widely recognised, nor are they properly valued in economic or even social terms.

Reduction in biodiversity affects ecosystem services. The sustainability of ecosystems depends to a large extent on the buffering capacity provided by having a rich and healthy diversity of genes, species and habitats. Losing biodiversity is like losing the life support systems that we and other species depend upon.

Biodiversity has evolutionary, ecological, economic, social, cultural, and intrinsic values. It is considered as **nature's insurance policy** i.e., the more variety there is now, the more there can be in the future, and the greater the chances of adapting to major changes in environmental conditions. Biologically diverse ecosystems offer a variety of natural products including medical ingredients that enhance human health and standard of living.

Biological diversity is key to long term ecosystem sustainability, for example 75% of cash crops rely on a variety of insects and other organisms for pollination; a biologically diverse agricultural ecosystem provides stability, nutrients to the soil and natural pest resistance.

Biologically diverse ecosystems maintain a stable environment capable of providing a high quality of life. Healthy, stable, diverse environments are able to respond to change more efficiently than degraded or simple systems. Thus,biodiversity is key in sustaining the natural beauty of national and regional parks and green spaces for recreational use and heritage preservation.

The conservation of biodiversity is fundamental to achieving sustainable development.Thus, conservation of biodiversity is crucial to the sustainability of sectors as diverse as energy, agriculture, forestry, fisheries, wildlife, industry, health, tourism, commerce, irrigation and power. Ethiopia's development in the future will continue to depend on the foundation provided by living resources and conserving biodiversity.

The overall values of biodiversity to humans can be grouped in to seven forms of benefits. These include: productive values; consumptive values; social values; aesthetic values; ethical & moral values; ecological values; and ecosystem services.

### 2.3.1 Productive value

Biodiversity provides us many products such as fuel, timber, fish, fodder, skin, fruits, cereals and medicines. These are commercially harvested for exchange in formal markets and are the only values of biological resources that are accounted in national income.

Product value is assigned to products that are commercially harvested and marketed. Almost all the present day agricultural crops have originated from wild varieties. Researchers continuously use the wild species of plants for developing new, better yielding and disease resistant varieties.

Biodiversity represents the original stock from which new varieties are being developed. Similarly, all our domesticated animals came from wild-living ancestral species. Through scientific breeding techniques animals giving better yield of milk, meat, etc are being developed. The commonly used animal products used by the modern society come from the advances made in the fields of poultry farming, pisciculture, silviculture, dairy farming, etc. Even the fossil fuels like coal and petroleum are the products of biodiversity from the geological past.

Most of the drugs and medicines used in the present times are extracted from different plant parts. Examples of the commonly used drugs derived from plants are given in Table 4.

**Table 4: Common modern drugs obtained from plants**

| Drug | Plant | Use |
|---|---|---|
| Penicillin | Penicillium | Antibiotic and antibacterial |
| Quinine | Cinchona | Antimalarial |
| Atropine | Belladonna | Painkiller |
| Caffeine | Tea,coffee | Stimulant |
| Cocaine | Coca | Analgesic and anaesthetic- painkiller |
| Morphine | Opium | Analgesic -painkiller |
| Menthol | Mint | Rubefacient(reduces pain on local application) |
| Papain | Papaya | Highly digestive |
| Tetracycline | Bacterium | Antibiotic |
| Resepirine | Rauwolfaserpentina | Controls blood pressure |

### 2.3.2 Consumptive value

Consumption value of biodiversity is related to natural products that are consumed directly, i.e., the goods which do not come under normal circulation of trade. It is related to natural products that are used directly for food, fodder, timber, fuel wood, etc. Humans use at least 40,000 species of plants and animals on a daily basis. Many people around the world still depend on wild species for most of their needs like food, shelter and clothing. The tribal people are completely dependent on the forests for their daily needs. Similarly, fishermen in the coastal areas are dependent on the marine resources. The wood derived from the forests has been used from the birth of civilization as fuel.

### 2.3.3 Social values

The lifestyle of the ancient people was closely interwoven with their surroundings. The life of the indigenous people in many parts of the world still revolves around the forests and environment, even in the modem times. Many of them still live in the forests and meet their daily requirements from their surroundings. The biodiversity in different parts of the world has been largely preserved by the traditional societies. Since the indigenous people always protect the forests for their own benefit, the government should formulate plans to involve such people for environmental protection.

### 2.3.4 Ethical and moral values

Every form of life on earth is unique and warrants respect regardless of its worth to human beings; this is the ecosystems right of an organism. Note that every organism has an inherent right to exist regardless of whether it's valuable to human beings or not. Humankind is part of nature and the natural world has a value for human heritage. The wellbeing of all future generations is a social responsibility of the present generations, hence the existence of an organism warrants conservation of the organism

It is based on the principle of '**live and let others live**'. Morality and ethics teach us to preserve all forms of life and not to harm any organism unnecessarily. Some people take pleasure in the hunting of animals. People also sometimes degrade and pollute the environment by their unethical actions.

Through proper education and awareness, the people's conscience against such practices must be raised. We may not be deriving direct benefits from many plants and animals, **but should they be harmed because of this?** Each species has its own utility in the world of biodiversity and has every right to live.

### 2.3.5 Aesthetic value

The beauty of our planet is because of biodiversity, which otherwise would have resembled other barren planets dotted around the universe. Biological diversity adds to the quality of life and provides some of the most beautiful aspects of our existence. Hence, biodiversity is responsible for the beauty of a landscape.

Human beings derive great enjoyment from natural environment. The shapes, structure and colour stimulate our senses and enrich our culture. Wild species enhance our appreciation and enjoyment of the environment through leisure activities. Humans are also attracted towards the biologically rich regions and nobody likes to live or visit a barren place. People go too far off places to enjoy the natural surroundings and wildlife.This type of tourism is referred to as eco-tourism, which has now become a major source of income in many countries. Eco-tourism includes visiting, national parks, wildlife sanctuaries, safaris and trekking in the mountainous and forested areas. In some countries including Ethiopia eco-tourism has now become the major source of foreign currency.

### 2.3.6 Ecological values

Biodiversity maintains the integrity of the environment through maintaining $CO_2/O_2$ balance. It is through biodiversity that sequential balance of $CO_2$ and $O_2$ is maintained. The greenhouse effect is as a result of $CO_2$ accumulation in the atmosphere, ozone layer depletion also occurs overtime making the earth warmer and more prone to natural calamities.

Biological resources are important media in biochemical cycles, without which the cycles are not complete. Absorption and breakdown of pollutants and waste materials through decomposition in food webs and food chains where the flow of energy goes through production, consumption, and decomposition without which breakdown and absorption of materials will not be complete. In an ecosystem, there is no waste as decomposition will take place to purify our environment by transforming the waste to other forms of biodiversity.

Biodiversity has roles in determination and regulation of the natural world climate whether local, regional or micro through influencing temperature, precipitation and air turbulence. Acting as indicators of environmental changes i.e., the greenhouse effect as a result of global warming causes changes in weather seasonality and also affects crops among others. Protective services including protection of human beings from harmful weather conditions by acting as wind breaks, flood barriers among others are examples of ecological values of biodiversity.

### 2.3.7 Ecosystem Services

Biodiversity may be viewed as a description of the world's biosphere. Its interaction with the physical part of our world: soil, rocks, water, air, and the energy from the sun are the ingredients of life on our planet. A well balanced yet unimaginably complex cyclic system of energy, material and information flow among the physical and living parts of the planet has developed over 2-3 billion years. Biodiversity is, at the same time, both the result of these processes and the agent that sustains them.

Biodiversity encompasses more than the diversity of animal and plant species, habitats, ecosystems and landscapes by which we define and view our biosphere; it also provides the basis for all ecological processes that sustain life on earth and human livelihoods. The variation within species also provides the basis for evolution through the adaptation of species to new and changing habitats.

These ecosystem services that all life and all human activities depend on are increasingly used as a key argument for urging closer attention to biodiversity. Economic values on ecosystem services that are sustained and enabled by biodiversity amount to valuation of biodiversity itself. Because biodiversity, in its widest sense is both an enabler as well as the product of life, it provides an excellent measure for assessing the sustainability of human use of natural resources. The status of biodiversity reveals a great deal about the sustainability of human activities, including business.

# 3. TRENDS AND CHALLENGES IN BIODIVERSITY MANAGEMENT

**Biodiversity is in trouble:** there is growing scientific concern about the major and rapid decline in biodiversity around the world. The extinction of each additional species and the loss of variation within species bring the irreversible loss of unique genetic diversity.The scientific community has linked human activities to the accelerated rate of recent and current extinctions.

Human cultural diversity and biodiversity are linked. Indigenous cultures living traditional lifestyles require an intact, functioning ecosystem, and are threatened by the loss of biodiversity and ecosystem goods and services. Human impacts on biodiversity have been accelerating as population growth and consumption rates have increased. Loss of species may mean loss of important but as yet unknown resources for humans.

## 3.1 Threats of biodiversity

Threats to species and ecosystems are the greatest record in recent history and virtually all of them are caused by human mismanagement of biological resources. A threat by definition refers to any process or event whether natural or human induced that is likely to cause adverse effects upon the status or sustainable use of any component of biological diversity.

Over the last decades, human beings have changed global ecosystems faster and more extensively than in any comparable period of time in human history, leading to an unprecedented and on-going loss of biodiversity. The size of key natural ecosystems such as tropical forests or wetlands has already shrunk dramatically, or become increasingly fragmented, with disastrous results for biodiversity. Species are becoming extinct at 1,000 times the typical background extinction rate leading scientists speak about **the sixth wave of extinction** taking place in Earth's history.

Extinction is a natural process. Humans, however, have increased the species extinction rate, and in the future, this rate may be 10 -100 times higher than today. We have changed ecosystems more in the last 50 years than at any other time in human history. Cultivated systems now take up one quarter of the Earth's land surface, and 20% of coral reefs have been destroyed over the last several decades. The causes of ecosystem degradation are stable or increasing, and 60% of ecosystem services assessed are degraded or used unsustainably. More than one quarter of all fish stocks are overharvested.  One quarter of vertebrate species are threatened with extinction to some degree.

The great biologist E. O. Wilson sums up threats of biodiversity with the acronym, ‘HIPPO’ or the HIPPO in the room. ‘H’ is for habitat destruction; ‘I’ for introduction of invasive species; ‘P’ for pollution; ‘P’ for population; and ‘O’ for over-exploitation.

### 3.1.1 Habitat destruction and fragmentation

This is possibly the greatest cause of species decline. Fragmented habitats lead to isolated small populations of species. Small populations are especially vulnerable to genetic in-breeding, random genetic drift, demographic factors and random events from warfare to extreme weather.This results in a loss of genetic variability which leads to a reduction in the reproductive fitness of individuals and the adaptability of populations. As a consequence, there is lower reproduction and higher mortality. Populations become even smaller. The result may be a spiralling vortex to extinction.

### 3.1.2 Introduced and invasive species

Introduced species often become invasive when they breed and out-compete or eat the natives.  Species introduced in an ecosystem will cause changes in the ecosystem. Introduced species are organisms arising in areas/ habitats in which they were previously not native. Such introduced species are usually referred to as biological pollutants. Some of the ecological impacts of the invasion include hybridization, out competition, disruption of original ecosystem, plant pathogenic influences, disease transmission, disruption of foodwebs and extinction. Species may be introduced intentionally for ornamental concerns, agriculture, hunting and spotting activities, for scientific research, trade etc.

### 3.1.3 Pollution

Chemical or thermal pollution is a threat to biodiversity. Species in habitats are increasingly being harmed by industrial activities and pollution from excessive use of agro-chemicals such as DDT, oil spills, acid precipitation etc.

The industrialised ‘west’ has been polluting since the industrial revolution. Now, nearly emerging economies of India and China are following in their footsteps.What are the alternatives, for every country? How far would you go to change your life? A recycled plastic bag? A self-inflicted ban on flying? Breeding?Or not breeding?

### 3.1.4 Population – human population

There is rather a lot of us, 7.4 billion at the present time with projections of an increase and peaking at 9.2 billion by 2050. Not all places have similar population growth rates. The rate is negative in central and eastern Europe and South Africa, for example, but increasing in Latin America, the Middle East and sub-Saharan Africa. We do not consume equally.

The richer nations far outstrip the poorer ones in terms of consumption. We are drawing on nature's capital rather than living off its interest. Our ecological footprint currently exceeds the capacity of Earth resources to support us by 25%.It is therefore vital to control human population which will result in biodiversity conservation.

### 3.1.5 Over-exploitation

This results when individuals of a particular species are taken at a higher rate than can be sustained by the natural reproductive capacity of the population being harvested. This can be through hunting, fishing, trade, food gathering etc. Overharvesting will lead to extinction of the biological resources, eventually leading to loss of species.

For species that are protected by the law and overharvesting occurs, this is known as poaching, if the law allows for harvesting of a resource, this is known as cropping. From tiger medicines to elephant tusks, from forest trees to oceanic fish, we are living beyond our means i.e., consuming the equivalent of what three planets would produce per year.

As summarized by E. O. Wilson the noble savage never existed.  Eden occupied was a slaughterhouse. Paradise found is paradise lost.

## 3.2 Climate Change and Biodiversity

Climate change is of great concern especially when global $CO_2$ increases in the atmosphere resulting to global warming. Most species originate within a very narrow physiological limit; hence nature has a range of tolerance maintained for ecosystem stability. Changes may be gradual or abrupt such that if the limit is exceeded the upper or lower species suffers extinction.

Loss of habitat due to climate change is the leading threat to global biodiversity.  Ecosystems fluctuate around a state of equilibrium. In the long run, however, ecosystems and their components always change when climate changes. Climate change and biodiversity represent a reciprocal issue i.e., climate change degrades biodiversity. Stable, bio-diverse environments are more capable of adapting to climatic shifts. Stable, bio-diverse environments are more capable of mitigating the production of greenhouse gases (for example, carbon sequestration by forests) and thus climate change. Reduction in sources of climate change such as excessive fossil fuel use will help to conserve biodiversity.

Management/conservation of biodiversity such as forest conservation reduced chemical pollution, and other factors not directly related to climate change will minimize impacts of climate change. We may have to help some species adapt to changes in climate. Climate change resulting from, among other things, unsustainable use of fossil fuels which results in loss of biodiversity.

Temperature increase makes certain environments unsuitable to previously indigenous species. Loss of indigenous species allows introduced species to flourish, thus increasing the loss of other indigenous species.Changing composition of environments and loss of species directly affects ecosystem services.

# 4. INTEGRATED BIODIVERSITY MANAGEMENT PLANNING

## 4.1 How Stakeholders Plan for Managing Biodiversity

Biodiversity loss is driven by local, regional, and global factors, so responses are needed at all scales. Responses need to acknowledge multiple stakeholders with different interests. Therefore, responses designed to address biodiversity loss will not be sustainable unless relevant direct and indirect drivers of change are addressed.

Further progress in reducing biodiversity loss will come through greater coherence and synergies among sectoral responses and through more systematic consideration of trade-offs among ecosystem services or between biodiversity conservation and other needs of the society.
Some drivers of biodiversity loss are localized, such as overexploitation. Others are global, such as climate change, while many others operate at a variety of scales, such as the local impacts of invasive species through global trade. Most of the responses assessed here were designed to address the direct drivers of biodiversity loss. However, these drivers are better seen as symptoms of the indirect drivers, such as unsustainable patterns of consumption, demographic change, and globalization.

At the local and regional scale, responses to the drivers may promote both local biodiversity and human well-being by acting on the synergies between maintenance of local biodiversity and provision of key ecosystem services. Responses promoting local management for global biodiversity values depend on local “capture” of the global values in a way that provides both on-going incentives for management and support for local well-being.

The well-being of local people dominates the assessment of many responses, including those relating to protected areas, governance, wild species management, and various responses related to local capture of benefits. Local consideration of global biodiversity recognizes the value of what is unique at a place or what is not yet protected elsewhere. The values of ecosystem services, on the other hand, do not always depend on these unique elements. Effective biodiversity responses recognize both kinds of values.

Developing better indicators of biodiversity would enhance integration among strategies and instruments. For example, existing measures often focus on local biodiversity and do not estimate the marginal gains in regional or global biodiversity values.

While planning for management of biodiversity, stakeholders should think of the following points:

- How do protected areas benefit biodiversity and humans;
- Can economic incentives benefit biodiversity and local communities;
- How can invasive species be addressed;
- What are the key factors of success of conservation actions; and
- How important drivers of biodiversity losses be addressed.

### 4.1.1 How do protected areas benefit biodiversity and humans

Protected areas are an extremely important part of programs to conserve biodiversityand ecosystems, especially for sensitive habitats**.** Recent assessments have shown that at the global and regional scales, the existence of current protected areas, while essential, is not sufficient for conservation of the full range of biodiversity.

Protected areas need to be better located, designed, and managed to deal with problems like lack of representativeness, impacts of human settlement within protected areas, illegal harvesting of plants and animals, unsustainable tourism, impacts of invasive alien species, and vulnerability to global change. Aquatic ecosystems are even less well protected than terrestrial systems, leading to increasing efforts to expand protected areas in these biomes.

Survey of management effectiveness of a sample of nearly 200 protected areas in 34 countries indicated that only 12% were found to have implemented an approved management plan. The assessment concluded that protected area design, legal establishment, boundary demarcation, resource inventory, and objective setting were relatively well addressed. But management planning, monitoring and evaluation, and budgets for security and law enforcement were generally weak among the surveyed areas. Moreover, the “paper park” problem remains, whereby geographic areas may be labelled as some category of protected area but not achieve the promised form of management.

Protected areas (PAs) may contribute to poverty where rural people are excluded from resources that have traditionally supported their well-being. However, PAs can contribute to improved livelihoods when they are managed to benefit local people. Relations with local people should be addressed more effectively through participatory consultation and planning. One possible strategy is to promote the broader use of IUCN protected areas management categories. Success depends on a collaborative management approach between government and stakeholders, an adaptive approach that tests options in the field, comprehensive monitoring that provides information on management success or failure, and empowerment of local communities through an open and transparent system that clarifies access and ownership of resources.

Success of PAs depends on adequate legislation and management, sufficient resources, better integration with the wider region surrounding protected areas, and expanded stakeholder engagement. Moreover, representation and management targets and performance indicators work best when they go beyond measuring the total area apparently protected.

Protected area design and management will need to take into account the impacts of climate change. The impacts of climate change will increase the risk of extinctions of certain species and change the nature of ecosystems. Shifts in species distribution as a result of climate change are well documented.Today's species conservation plans may incorporate adaptation and mitigation aspects for this threat, drawing on existing tools to help assess species' vulnerability to climate change.

Corridors and other habitat design aspects to give flexibility to protected areas are effective precautionary strategies. Improved management of habitat corridors and production ecosystems between protected areas will help biodiversity adapt to changing conditions.

### 4.1.2 Can economic incentives benefit biodiversity and local communities

Transferring rights to own and manage ecosystem services to private individuals gives them a stake in conserving those levels of institutional support. For example, in some countries such as in South Africa, changes in wildlife protection legislation allowed a shift in landownership and a conversion from cattle and sheep farming to profitable game farming, enabling conservation of indigenous wildlife.

Payments to local landowners for ecosystem services show promise of improving the allocation of ecosystem services and are applicable to biodiversity conservation. However, compensating mechanisms addressing the distributive and equitable aspects of these economic instruments may need to be designed in support of such efforts.

Direct payments are often more effective than indirect incentives. Overall, long-term success for these response strategies depends on meeting the economic and social needs of communities whose well-being already depends to varying degrees on biodiversity products and the ecosystem services biodiversity supports. However, direct payments have been criticized for requiring on-going financial commitments to maintain the link between investment and conservation objectives. Furthermore they have led in some instances to community conflict.

Yet many success stories show the effectiveness of direct payments and the transfer of property rights in providing incentives for local communities to conserve biodiversity. Effectiveness of payments in conserving regional biodiversity may be enhanced by new approaches that target payments based on estimated marginal gains i.e., “complementarity”values.

The promotion of “win-win” outcomes has been politically correct at best and naive at worst. Economic incentives that encourage the conservation and sustainable use of biodiversity show considerable promise. However, trade-offs between biodiversity, economic gains, and social needs have to be more realistically acknowledged. The benefits of biodiversity conservation are often widespread, even global in the case of existence values or carbon sequestration, while the costs of restricting access to biodiversity often are concentrated on groups living near biodiversity rich areas.

### 4.1.3 How can invasive species be addressed

Direct management of invasive species will become an important biodiversity conservation response, typically calling for an ecosystem level response if the invasive species has become established. Control or eradication of an invasive species once it is established is often extremely difficult and costly, while prevention and early intervention have been shown to be more successful and cost effective.

Common factors in successful eradication cases include particular biological features of the target species for example poor dispersal ability, early detection/response, sufficient economic resources devoted for a sufficient duration, and widespread support from the relevant agencies and the public. Successful prevention requires increased efforts in the control and regulation of the transportation of invasive species due to international trade.

Chemical control of invasive plant species, sometimes combined with mechanical removal like cutting or pruning, has been useful for controlling at least some invasive plants, but has not proved particularly successful in eradication. In addition to its low efficiency, chemical control can be expensive. Biological control of invasive species has also been attempted, but results are mixed. For example, the introduction of a non-native predatory snail to control the giant African snail in Hawaii led to extinction of many native snails.

Some 160 species of biological agents, mainly insects and fungi, are registered for controlling invasive species, and many of them appear highly effective. However, at least some of the biological agents used are themselves potential invaders. Environmental screening and risk assessment can minimize the likelihood of negative impacts on non-target native species.

Social and economic aspects of the control of invasive species have received less attention, perhaps because of difficulties in estimating these trade-offs. The Global Invasive Species Program is an international response to address the problem. The CBD has adopted guiding principles on invasive alien species  as a basic policy response.

Sustainable use of natural resources is an integral part of any sustainable development program, yet its contribution to conservation remains a highly controversial subject within the conservation community. Conserving species when the management objective is ensuring resource availability to support human livelihoods is frequently unsuccessful. This is because optimal management for natural resource extraction frequently has negative impacts on species targeted for conservation. Therefore, care in establishing positive incentives for conservation and sustainable use is critical to successful biodiversity conservation.

Where the goal is species conservation, and where a specific population has a distinct identity and can be managed directly, species management approaches can be effective. However, managing for a single species is rarely effective when the goal is ecosystem functioning, which is tied to the entire suite of species present in the area. Where human livelihoods depend on single species resources, species management can be effective for example, some fisheries and game species, but where people depend on a range of different wild resources, as is frequently the case, multiple species management is the appropriate approach.

### 4.1.4 What are the key factors of success of conservation actions

Education and communication programs have both informed and changed preferences for biodiversity conservation and have improved implementation of biodiversity responses. Scientific findings and data need to be made available to all of society. A major obstacle for knowing and therefore valuing, preserving, sustainably using, and sharing benefits equitably from the biodiversity of a region is the human and institutional capacity to research a country's biota.

Ecosystem restoration activities are now common in many countries and include actions to restore almost all types of ecosystems, including wetlands, forests, grasslands, estuaries, coral reefs, and mangroves. Restoration will become an increasingly important response as more ecosystems become degraded and as demands for their services continue to grow. Ecosystem restoration, however, is generally far more expensive an option than protecting the original ecosystem, and it is rare that all the biodiversity and services of a system can be restored.

Rather than the "win-win" outcomes promoted by many practitioners of integrated conservation and development projects, conflict is more often the norm, and trade-offs between conservation and development need to be acknowledged. Identifying and then negotiating trade-offs is complex, involving different policy options, different priorities for conservation and development, and different stakeholders. In the case of biodiversity conservation, the challenge is in negotiating these trade-offs, determining levels of acceptable biodiversity loss, and encouraging stakeholder participation. Where trade-offs must be made, decision-makers must consider and make explicit the consequences of all options.

The ecosystem approaches as developed by the CBD and others provide principles for integration across scales and across different responses. Central to the rationale is that the full range of measures is applied in a continuum from strictly protected to human-made ecosystems and that integration can be achieved through both spatial and temporal separation across the landscape, as well as through integration within a site.

Many contributions to overall biodiversity protection are made from productionlandscapes or other lands outside of protected areas, and integration allows these contributions to be credited at the regional planning scale and to increase regional net benefits. However, the ideal of measurable gains from production lands should not reduce the more general efforts to mainstream biodiversity into other sectors; even without formal estimates of complementarity values, mainstreaming policies can be seen as important aspects of integration.

### 4.1.5 How could important drivers of biodiversity loss be addressed

Many of the responses designed with the conservation of biodiversity or ecosystemservice as the primary goal will not be sustainable or sufficient unless indirect and directdrivers of change are addressed. Numerous responses that address direct and indirect drivers would be particularly important for biodiversity and ecosystem services.

The expansion of agriculture will continue to be one of the major drivers of biodiversity loss well into the twenty-first century. In regions where agricultural expansion continues to be a large threat to biodiversity, the development, assessment, and diffusion of technologies that could increase the production of food per unit area sustainably, without harmful trade-offs related to excessive consumption of water or use of nutrients or pesticides, would significantly lessen pressure on biodiversity.

Where agriculture already dominates landscapes, the maintenance of biodiversity within these landscapes is an important component of total biodiversity conservation efforts, and, if managed appropriately, can also contribute to agricultural productivity and sustainability through the ecosystem services that biodiversity provides (such as through pest control, pollination, soil fertility, protection of water courses against soil erosion, and the removal of excessive nutrients).

Climate change may be the dominant direct driver of biodiversity loss and change of ecosystem services globally. Harm to biodiversity will grow with both increasing rates in change in climate and increasing absolute amounts of change. For ecosystem services, some services in some regions may initially benefit from increases in temperature or precipitation expected under climate scenarios, but the balance of evidence indicates that there will be a significant net harmful impact on ecosystem services worldwide if global mean surface temperature increase more than 2˚C above preindustrial levels or faster than 0.2˚C per decade.

## 4.2 Society's Role in Biodiversity Management

"We do not inherit the Earth from our ancestors; we borrow it from our children." Conserving biodiversity is not necessarily about preserving everything currently in existence. We depend on biodiversity and have a responsibility to contribute to biodiversity management and to use biological resources in a sustainable manner.

Government, non-governmental organizations, community groups, academic institutions and individuals use a variety of means to protect biodiversity. Preservation of local natural areas allows the plants and animals that depend on these areas to continue. Restoration of habitat that has been lost can increase the number of different species found in an area.

Zoos and botanical gardens and other facilities can participate in captive breeding with the intent of reintroducing the species when habitat problems have been solved through processes such as ecological restoration. Individual and community contributions to biodiversity conservation and steps towards sustainable living do make a difference. That is, informed consumer choices.

## 4.3 Key considerations in biodiversity planning

Every population of every species is worth conserving. Prioritization is not about selecting which elements of biodiversity deserve conservation attention and which do not, but about deciding which elements need attention first. It is based on the rationale that biodiversity elements do not all have the same conservation needs, nor do they all provide the same contribution to the conservation of global biodiversity.

Prioritization is therefore one of the key issues needed because resources available for conservation efforts are scarce and therefore need to be invested in strategic ways to ensure that our conservation efforts make the greatest contribution to preserving global biodiversity.

### 4.3.1 Principles for setting conservation priorities

Two main variables determine how we prioritize conservation targets and actions: irreplaceability and vulnerability. The irreplaceability (or uniqueness) of a site is the degree to which geographic (or spatial) options for conservation will be lost if that particular site is lost.

A site is completely irreplaceable if it contains one or more species that occur nowhere else. In contrast, when sites contain only species that are widely distributed, many alternatives exist for conserving these species. Sites that hold significant fractions of a species' entire population during particular periods of the year such as migratory bottlenecks and routes are also highly irreplaceable.

Vulnerability (or threat) refers to the likelihood that a site's biodiversity value will be lost in the future. Sites facing low threat will retain options for conservation in the future. Vulnerability may be measured on a site basis likelihood that the species will be locally extirpated from a site or a species-basis (if the species will go globally extinct).

**High irreplaceability + high vulnerability = high conservation urgency**

Protection must occur right now, to prevent imminent and irreversible biodiversity loss.

**Additional principles governing the priority-setting process**

In order to maximize conservation investment, prioritization exercises must evaluate how much each site contributes towards achieving conservation objectives by complementing existing investment. The priority level of each site is thus not simply based on its biological composition but on that of other sites as well, and on the previous conservation decisions. Gap analysis identifies sites that best complement the existing network of protected areas.

**New data**: if new data reveal the existence of previously unknown populations or the absence of a species from sites it previously occupied, or if conditions change (for example, a species goes locally extinct in some sites, or more rarely, colonizes others), the priorities will need to be updated accordingly.

**Accountability**: solutions for conservation planning should be obtained in a transparent way, so that others can understand why and how the result was derived and, if desired, challenge the findings.

**Repeatability:**repeatability ensures that others with the same data and the same set of criteria would derive similar solutions.

Accountability and repeatability are important because protected area networks chosen objectively can be more easily justified and defended, which is particularly crucial when there are many competing interests for the same land.

**Data-driven systematic conservation planning**

Data-driven, systematic analysis is necessary for strategic and sound conservation planning. As with all analytical processes, the quality of the results depends directly on the quality of the input data. The reality is that there are gaps and biases in the data currently available for conservation planning:

Data availability and quality vary tremendously spatially (for example, amongst countries, or even within regions of a country) and between different types of data (such as between different groups such as birds and plants). Often those regions of the world with poorer data are those most in need of conservation planning.

Although strategic investments in acquiring new data can fill crucial gaps in knowledge, conservation planning is often required too urgently to allow time for extensive data collection.

### 4.3.2 Levels for planning biodiversity management

Biodiversity represents a continuum of ecological organization (from genes to populations, to species, to the entire biosphere) that cannot be encapsulated into a single variable. This makes setting targets for protected area planning a non-trivial task. Furthermore, given that conservation planning is a spatial exercise, only biodiversity features that can be mapped are useful.

Although techniques for mapping and measuring ecological and evolutionary processes are progressing, they are still in their infancy; thus, conservation planning has focused mainly on biodiversity pattern (such as concentrations of restricted-range species) rather than process (for example, species movements in response to climate change). Biodiversity features most commonly used in conservation planning are species and broad-scale attributes obtained from data on ecosystems and/or data of abiotic systems.

### Problems with using species richness

Species richness should not be used as the criterion for establishing protected area networks. A site may contain many species, but if all of these are already well protected at other sites, this site remains a lower conservation priority than an area with fewer species of which none are protected by existing networks. Moreover, a site with many widespread species (which can be protected elsewhere) is of less concern than a site containing fewer species that occur nowhere else (i.e., a site of high irreplaceability).

### Environmental surrogates for biodiversity

Maps of habitats, ecosystems or vegetation classes, which utilize abiotic information (e.g., climate, geology, topographic relief) to create subdivisions of environmental space, are now widely available at ~1km resolution globally; however they vary in accuracy. The quality of these data continues to improve as they depend more on direct observation via satellites and are further calibrated.

These data have been used extensively in conservation planning as environmental surrogates for biodiversity, because they are perceived to save time and resources (relative to field surveys) and they generally do not suffer from spatial gaps (i.e., they can be measured across a landscape). Similarly, habitat units derived from a mix of data on vegetation types, climate, geology and topography ecosystem types obtained from satellite imagery, and environmental diversity plotted within a multidimensional environmental space have all been used for conservation planning.

### Existing management units

The best way to ensure that the conservation needs of target species are met is to define the boundaries of each spatial unit based on existing land management units. Because land management units are the scale at which site conservation actually takes place, they make the most relevant conservation planning units.

Where management units do not exist, units that correspond to the habitat of target species should be used instead. This will yield distinct types of planning units (e.g., protected areas, forest fragments, wetlands, etc.) of variable size and will help to promote ownership and action at the national level.

### Errors in priority-setting

Conservation planning based on perfect data is impossible even in the best-known parts of the world. Thus, results are always affected by error, which can be divided into two classes;

**Omission errors (false negatives):** result when conservationists fail to realize that a species occurs in a particular site, where it could be protected. These often result from incomplete information and are particularly associated with point locality data. The less well known a species or a region is, the more likely that the species occurs beyond the places where it has been confirmed.

The risk in using data with a geographic bias in defining conservation priorities is that areas that have been heavily sampled tend to be highlighted as higher priorities than areas with little sampling. Point locality data are thus plagued by false-negatives (or omission errors), in which species are considered to be absent from sites at which they are, in fact, present.

It is tempting to try to 'correct' for sampling effort through statistical modelling, in particular by extrapolating from known species localities to modelled distributions. There are serious dangers, however, in this approach. Models have less statistical power for species with very few records and with small ranges in relation to the resolution of the environmental data, making them less useful and reliable for application to rare or poorly known species, which are often among the most in need of conservation attention.

**Commission errors (false positives):** result when a species is considered adequately protected in a site where it is not actually present. These errors tend to result from data extrapolation. For example, when fitting point data to a grid format, people sometimes assume that cells in between known records are also occupied. They may also result from habitat suitability models, which extrapolate from point localities into un-sampled regions based on environmental similarity.

While extrapolations are predictions of habitat suitable for occupancy, not of actual current occupancy, these models are often interpreted as the latter. Applying such modelled data to gap analyses can potentially result in an overestimate of the species' current coverage by the existing network of protected areas and in the diversion of conservation action towards sites where species do not exist.

**Commission errors should be minimized**

Commission errors are more serious in conservation planning than omission errors. False negatives are precautionary in that they assume that conservation efforts should be aimed at places where we know that species are present. False positives, on the other hand, could lead to a species' extinction because we assume we are conserving it where it does not actually occur. These consequences are particularly vital for species with small ranges and/or globally threatened species.

Omission errors can also result in extinctions if species are lost before their locations are mapped, but correcting for these errors must rely on field data, rather than solely on predictions that can lead to commission errors.

Predicted occurrences, on the other hand, are invaluable in identifying priorities for research.

**Conservation implementation priorities and conservation research priorities**

Usually, biological data tend to be highly biased towards regions of better accessibility (such as near roads or rivers). Consequently, a protected area planning approach aimed at minimizing commission errors tends to identify priority areas in these regions, to the detriment of other, less-studied areas that may be equal or higher priorities.

In the short term, it is important to protect areas that are known to be extremely important. However, it is also critical to fill knowledge gaps and to incorporate information on new priority areas into conservation planning as it becomes available. It is important to distinguish clearly between areas that are priorities for conservation action (those supported by existing data) and areas that are priorities for further exploration (those only suspected to be important).

### 4.3.3 Measuring biodiversity for planning

In spite of many tools and data sources,biodiversityremains difficult to quantify precisely. Species richness (i.e. the number of species in a given area) represents the most important metric that is valuable as a common currency of the diversity of life. However, to fully capture biodiversity, a variety of proxy measures including the species richness of specific taxa, the number of distinct plant functional types (such as grasses, forbs, bushes or trees) or the diversity of distinct gene sequences must be integrated. However, species based measures of biodiversity rarely capture key attributes such as variability, function, quantity, and distribution, all of which provide insight into the roles of biodiversity.

Biodiversity can be measured through the use of quantitative **indicators**, although no single unified approach exists.

It is necessary to measure the abundance of all organisms over space and time, using taxonomy such as the number of species, functional traits such as nitrogen-fixing plants like legumes versus non-nitrogen-fixing plants, and the interactions among species that affect their dynamics and function including predation, parasitism, competition, and facilitation such as pollination, and how strongly such interactions affect ecosystems. Even more important would be to estimate turnover of biodiversity, not just point estimates in space or time. Currently, it is not possible to do this with much accuracy because the data are lacking. Even for the taxonomic component of biodiversity, where information is the best, considerable uncertainty remains about the true extent and changes in taxonomic diversity.

## 4.4 Conservation of biodiversity

Biodiversity conservation is about monitoring, managing, and mainstreaming. It involves a journey from the raw data of scientists to the policy documents of governments. It includes community involvement at grassroots level to legislation and agreements at global, regional, national and local levels. It is underpinned by the rigour of science but driven by human needs for sustainable livelihoods and quality of life as well as by economic, cultural and political factors. People are central to its success or failure. Personal action is as important as collective action.

Biodiversity conservation is implemented in two broad forms. These are Ex-situ conservation and In-situ conservation approaches.

**Ex-situ conservation (captive conservation)**: refers to conservation of components of biodiversity outside their natural habitats,such as in zoos, museums, gene banks, botanic gardens. This method is used for threatened and endangered species to avoid their extinction.

**In-situ conservation:** refers to conservation of ecosystems and natural habitats including maintenance and recovery of viable populations of species in their natural habitats.

### 4.4.1 Biodiversity Management Plan

Biodiversity management plan is a comprehensive document bearing analytical quantitative and qualitative information on: the problems and challenges of biodiversity to be addressed; relevant interventions to address the problems; strategies of implementation including institutional arrangements for management, and monitoring and evaluation systems.

A biodiversity management plan is often intended to monitor changes in biodiversity at the species/community and ecosystem levels. It is concerned mainly with the effectiveness of maintaining the extent and quality of habitat, and of maintaining ecosystem processes. As the maintenance of ecosystem processes directly affects the success of biodiversity conservation, it is desirable that these processes should be monitored.

Two critical components for the success of the biodiversity management plan are: Increased awareness of environmental issues by residents in the area, and promotion of research and cooperative efforts with non-government organizations, universities and conservation institutes.

### 4.4.2 Implementation of biodiversity management interventions

Analysed data on biodiversity management needs allows conservationists to prioritise conservation actions. For example, the IUCN red lists and species according to how threatened they are. Species may be extinct, extinct in the wild, critically endangered, endangered, vulnerable, near threatened, of least concern, data deficient, or not evaluated. Another ranking system, from the Zoological Society of London is the EDGE programme. EDGE classifies species according to their evolutionary distinctiveness and global endangerment. Species and habitats will then be incorporated into global, regional, national and local biodiversity conservation plans.

The contents and features of conservation actions vary enormously. They may include protected area management, community participation and management, communication, education and public awareness, habitat restoration, habitat creation, connecting fragmented habitats, ecosystem resilience, ecosystem scale approaches to mitigate and adapt to the effects of climate change, wildlife crime, overexploitation, wildlife health, control of invasive species, ex-situ conservation breeding, sustainable livelihoods and poverty alleviation, eco-tourism, working in partnership, enforcing legislation and more.

### 4.4.3 Baseline Assessment

A baseline assessment provides information on the situation the project aims to change. It provides a critical reference point for assessing changes and impact, as it establishes a basis for comparing the situation before and after an intervention, and for making inferences as to the effectiveness of the project. Baseline assessments should be conducted before the actual project intervention starts so as to serve as a benchmark for examining what change is triggered by the intervention. A baseline assessment is a crucial element in formative research and planning, and in any monitoring and evaluation framework.

The type of data to be included in the baseline depends on the goals the project aims to achieve, the theory of change underlying the project, and the change indicators that are defined in the monitoring and evaluation framework. Baseline information should be carried out in such a way that the same type of data can be collected after the intervention, in order to compare the results and assess the extent of change, or lack thereof.

Good sources of information for baseline assessments include: Official statistics, existing survey results and quality research reports, journal and newspaper articles.. It may also be necessary to conduct one's own baseline research on specific project issues or methods and tools, particularly if there is limited existing data and information. In this case, baseline research could include a range of strategic planning exercises including formative situation analysis, stakeholder analysis, and resource mapping.

#### 4.4.4 Monitoring

Monitoring is a form of evaluation or assessment, though unlike outcome or impact evaluation, it takes place shortly after an intervention has begun (formative evaluation), throughout the course of an intervention (process evaluation) or midway through the intervention (mid-term evaluation).

Monitoring is not an end in itself. Monitoring allows programmes to determine what is and is not working well, so that adjustments can be made along the way. It allows programmes to assess what is actually happening versus what was planned.

You cannot conserve something if you do not know what it is, where it is, and how it's doing. Scientific monitoring provides the basic species and habitat data that can be analysed to look at trends in the status of species and the overall 'health' of the ecosystems. Moreover, socio-economic, traditional knowledge and cultural information is often integral to the environmental management of particular places, issues and situations

**Monitoring allows programmes to**:

Implement remedial measures to get programmes back on track and remain accountable to the expected results the project is aiming to achieve.

Determine how funds should be distributed across the programme activities.

Collect information that can be used in the evaluation process.

When monitoring activities are not carried out directly by the decision-makers of the programme it is crucial that the findings from those monitoring activities are coordinated and fed back to them.

Information from monitoring activities can also be disseminated to different groups outside of the organization which helps promote transparency and provides an opportunity to obtain feedback from key stakeholders.

There are no standard monitoring tools and methods. These will vary according to the type of intervention and objectives outlined in the programme. Examples of monitoring methods include:

- Activity monitoring reports;
- Record reviews from service provision;
- Exit interviews with clients

Qualitative techniques to measure attitudes, knowledge, skills, behaviour and the experiences of survivors, service providers, and others that might be targeted in the intervention.

A long-term outcome may be the sector and system-wide integration of those policies. It is important to be very clear from the beginning of a project or intervention, what the expected objectives and outcomes will be, and to identify what specific changes are expected for what specific population.

The following sections summarize the monitoring activities to be undertaken as part of the biodiversity management plan.

### A. Habitat mapping

Habitat mapping should be undertaken on an annual basis, and will focus on habitat distribution, and vegetation structure

### B. Habitat distribution

Habitat distribution will be monitored by mapping changes of habitat boundaries. The location of habitat boundaries can show expansion or retreat of crucial habitats, and can be determined through annual surveys/fixed point photography of permanent plots or transects.

### C. Vegetation structure

Vegetation structure will be monitored by the change in the percent of crown cover in the upper canopy level (whether it is tree, shrub, grass, etc.).This is accomplished through standard canopy cover measurement methods, conducted seasonally, or at least annually in the same season. Significant habitat disturbance is generally indicated by changes in canopy cover and dominant species. However, records need to be taken over an extended time period to take into account short-term fluctuations due to factors such as fires and weather patterns.

### D. Wildlife monitoring

The change in the number, composition, and distribution of wildlife species can indicate changes in ecological processes,particularly the ability to support sustainable populations of keystone species. Monitoring of local wildlife will be undertaken through surveys along transects and/or in strategic sites (depending on the type of wildlife being surveyed) on an annual basis. Monitoring of nest boxes, roost boxes and other measures intended to provide habitat opportunities for wildlife, can be used to evaluate the effectiveness of these initiatives.

### E. Rare species

Occurrence records of any rare species encountered in the project area will be kept. These records will include rare species that are encountered both during the formal wildlife monitoring programs and from casual observations.

### F. Indicator events

Natural events, which are related to biodiversity health at the community/ecosystem level, will be recorded and mapped as they occur. Examples of such occurrences include landslides, floods, forest fires and wildlife mortality.

**G. Promoting stewardship ethic**

Community participation in conservation activities from an early stage in the project will sow the seeds of environmental responsibility, and eventually a responsible stewardship ethic that will extend beyond the life of the project. Community involvement in conserving biodiversity resources will develop trust and foster open dialogue between the community and the project.

### 4.4.5 Impact evaluation

Impact evaluation measures the difference between what happened with the programme and what would have happened without it. It answers the question, "How much (if any) of the change observed in the target population occurred because of the programme or intervention?"

Rigorous research designs are needed for this level of evaluation. It is the most complex and intensive type of evaluation, incorporating methods such as random selection, control and comparison groups.

These methods serve to establish causal links or relationships between the activities carried out and the desired outcomes. Identify and isolate any external factors that may influence the desired outcomes.

While impact evaluations may be considered the "gold standard" for monitoring and evaluation, they are challenging and may not be feasible for many reasons, including: They require a significant amount of resources and time, which many organizations may not have.

To be done properly, they also require the collection of data following specific statistical methodology, over a period of time, from a range of control and intervention groups, which may be difficult for some groups.

Impact evaluations may not always be called for, or even appropriate for the needs of most programmes and interventions looking to monitor and evaluate their activities.To measure programme impact, an evaluation is typically conducted at the start (known as a baseline) and again at the end (known as an endline) of a programme. Measurements are also collected from a control group with similar characteristics to the target population, but that is not receiving the intervention so that the two can be compared. Generally, evaluation requires technical expertise and training.

**The ecological baseline reports:** describe the biological diversity conditions prior to commencement of the project. This comprehensive study serves as a benchmark against which management-induced changes can be identified and measured. However, it is important to note that future monitoring generally does not need to update the full data set gathered during the baseline studies.

In most cases, management is concerned with trends rather than absolute values. Absolute values (total number of species,exact densities, etc.) are generally not needed on a day-to-day basis. Changes in relative indices of these parameters (trends) will provide the information that environmental managers need to show progress is being made, or if indicators are falling dangerously close to unacceptable levels.

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