# APPENDIX XII
# EXAMPLES OF ENVIRONMENTAL DAMAGE CALCULATIONS

**Example 1: Environmental damage caused by a hurricane**

The wind, waves, and rain produced by a hurricane have affected an area of a country noted for the wealth of its environmental heritage. The main economic activities of the affected area are fishing and the tourism attracted by its beaches and diving around its coral reefs. The following table presents the identified changes to the environment and the human-made capital that affect the people's well-being.

Table 1

IDENTIFICATION OF CHANGES IN THE ENVIRONMENT AND MAN-MADE CAPITAL AND THE ENVIRONMENTAL GOODS AND SERVICES INVOLVED

| Identified enviromental changes | Enviromental goods and services involved |
|---|---|
| • *Deaths of seabirds and destruction of their habitat (nesting and breeding places)* | • *Wildlife habitat*<br>• *Recreation (tourism)* |
| • *Changes in the quality of the sea water: turbidity, floating sea-grass, faecal contamination from flooded septic tanks* | • *Navigation*<br>• *Fishing*<br>• *Recreation (tourism)* |
| • *Changes to the shoreline: erosion, silt barriers, loss of beaches and beaches littered with debris* | • *Land (property)*<br>• *Recreation (tourism)* |
| • *Damage to sea-grass beds: mechanical damage, excess siltation, smothering and loss of fishing habitats* | • *Fishing*<br>• *Wildlife habitat* |
| • *Mangrove swamps: defoliation and uprooting of plants least tolerant especies exposed to saltwater flooding* | • *Coastal protection*<br>• *Wildlife habitat*<br>• *Fishing* |
| • *Coral reefs: Localized mechanical damage and other impacts (asphyxia and growth of algae)* | • *Coastal protection*<br>• *Recreation (tourism)*<br>• *Fishing*<br>• *Unique ecosystem (existence value)* |
| • *Changes in the sanitation conditions caused by flooding and overflowing of septic tanks and sewer lagoons* | • *Health conditions*<br>• *Recreation (tourism)* |
| **Infrastructure and equipment affected** | |
| • *Tourism and fishing infratructure: Hotels, piers, boats, fishing gear and seawalls* | • *Recreation (tourism)*<br>• *Navigation*<br>• *Fishing* |
| • *Destruction of septic lagoons and tanks* | • *Health conditions*<br>• *Recreation (tourism)* |



Direct damage to environmental assets is measured on the basis of their market value (when there is one) or of the investments in restoration planned by the government and other participants in the affected country. The indirect damage includes the loss of income during the time that the infrastructure and natural capital are being restored (when their recovery is not instantaneous). As will be seen, part of the damage has already been included in the assessments of other sectors (fishing, tourism and infrastructure). The calculations of direct and indirect damage are shown below with a chart explaining the assessment process.

Table 2

ASSESSMENT OF ENVIRONMENTAL DAMAGE

| A. ENVIRONMENTAL DAMAGE NOT ASSESSED IN OTHER SECTORS | |
|---|---|
| **A.1 DIRECT ENVIRONMENTAL DAMAGE** | ***US $000*** |
| **1. Properties lost due erosion of the coast (including beaches)**<br>*Measured at places where there is a market for plots of land. The lost area measures 6,400 $m^2$ at a price of USD 200/$m^2$. Damage is considered to be irreversible or very long-term.* | *1,280* |
| **2. Clean-up of beaches for tourism purposes**<br>*in tourism areas, investment made shortly after the hurricane by the municipal authority (financed by the hotel keepers) to clean up the debris and rests of vegetation. The total cost of USD $ 280,000.* | *280* |
| **3. Damage to the mangrove swamps (partial assessment)**<br>*The priority for the environmental authorities is the recovery of the belt of mangrove swamps that offer greatest protection against the effects of storms . It is estimated that an area of 2,300 hectares of mangrove swamps was damaged. A replanting programme is projeted for the 500 hectares situated in the most vulnerable places whose natural recovery is thought difficult. The cost of replanting is USD $ 4,800 per hectare. The environmental value of the rest of the damaged mangrove swamps is not assessed.* | *2,400* |
| **4. Damage to the coral reef**<br>*A. study of a similar ecosystem in a Caribbean island to appraise the coral reef in the area takes the following environmental services into account: recreation (linked to tourism); fish habitat; coastal protection; maintenance of biodiversity; source of sand for beaches and dunes. The study calculates that the present value of a hectare of coral is between USD $ 90,000 and USD $ 320,000. No option value or existence values are calculated. According to the environmental authority, an area 7,000 m long and 75m wide has been seriously affected, with irreversible damage or very long-term recovery. The value used (simple average) is USD $ 205,000 per hectare.* | *10,762* |
| **5. Direct damage not assessed**<br>*The following direct damage has been identified but not assessed since no restoration measures are planned and there is no information that would make it possible to use another assessment methodology.*<br>*• Destruction of avian habitats:*<br>*• Changes in the quality of the seawater (turbidity, floating seawced); linked with the fishing, tourism, and transportation sectors;* | |
| **TOTAL DIRECT DAMAGE** | ***14,722*** |
| **A-2 INDIRECT ENVIRONMENTAL DAMAGE** | |
| **6. Indirect damage not assessed**<br>*This consists of the environmental services lost during the recovery period of the mangrove* | |
| **TOTAL INDIRECT ENVIRONMENTAL DAMAGE** | ***0*** |
| **A. TOTAL ENVIRONMENTAL DAMAGE** | ***14,722*** |

Table 3

ASSESSED IN OTHER SECTORS, WITH ISOLATION OF COSTS

| B. ENVIRONMENTAL DAMAGE ASSESSED IN OTHER SECTORS | |
|---|---|
| *B.1 DIRECT ENVIRONMENTAL DAMAGE THAT CAN BE ISOLATED FROM OTHER SECTORS* | |
| **7. Restoration of the following infrastructure and equipment:**<br>• **Fhising sector** *(information obtained from the person responsible for the sector). Includes i)equipment and fishing vessels; ii)cold storage facilities; iii)stored fish and seafood*<br>• **Drinking water and sanitation** *(information obtained from the person in charge of infrastructure). Includes damage to the drinking water and drainage systems (pumping stations, storage tanks, septic pits, etc)* | 4,780<br>1,655 |
| **TOTAL DIRECT DAMAGE** | **6,435** |
| *B.2 INDIRECT ENVIRONMENTAL DAMAGE THAT CAN BE ISOLATED FROM OTHER SECTORS* | |
| **8. Changes in environmental goods and services flows during the restoration period of the human-made capital and natural capital:**<br>• **Tourism sector** *(information obtained from the person in charge of the sector). Includes the fall in income due to lower takings from visitors: i)entry fees to marine parks (for diving); ii)lost airport departure taxes used for environmental protection*<br>• **Fishing sector** *(information obtained from the person in charge of the sector) Assessment of the reduction in the catches until they return to normal levels, i.e. the recovery of fishing vessels and equipment and normal sea conditions. Value of lost catches estimated at US$ 4.6 million; costs of production are 75% of revenues.*<br>• **Drinking water and sanitation** *(information obtained from the person in charge of the sector). Includes additional costs for carrying water, chemical treatment, energy consumed by emergency equipment, and prevention campaigns, and lower billing beacause less water is provided* | 935<br>1,150<br>1,138 |
| **TOTAL INDIRECT DAMAGE** | **3,223** |
| **TOTAL ENVIRONMENTAL DAMAGE THAT CAN BE ISOLATED FROM OTHER SECTORS** | **9,658** |

Table 4

ASSESSED IN OTHER SECTORS, WITH NO POSIBILITY FOR ISOALTION OF COSTS

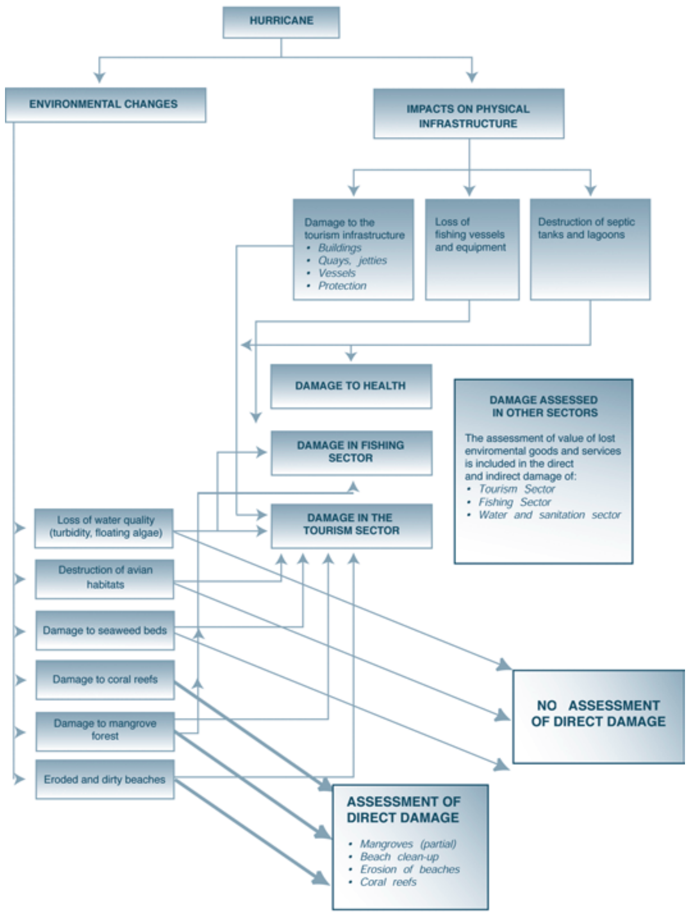
| C. ENVIRONMENTAL DAMAGE ASSESSED IN OTHER SECTORS | |
|---|---|
| C.1 DIRECT ENVIRONMENTAL DAMAGE THAT CANNOT BE ISOLATED FROM OTHER SECTOR | |
| 9. Restoration of the following infrastructure and equipment:<br>• Tourism sector (information obtained from the assessment team responsible for tourism). Includes the cost of replacing i)hotels(building, forniture, equipment, facilities, including a golf courses); ii)gift shops; iii)restaurants; iv)quays and tourist craft; v)sea-walls. Restoration costs add up US$ 62 million. Part of this figure corresponds to the value of the lost environmental services related to the tourims, but it is not easy to estimate it. | N/A |
| C.2 INDIRECT ENVIRONMENTAL DAMAGE THAT CANNOT BE ISOLATED FROM OTHER SECTORS | |
| 10. Changes in environmental goods and services flows during the restoration period of the human-made capital and natural capital:<br>• Tourism sector (information obtained from the person in charge of the sector). Includes the fall in income due to lower takings from visitors to hotels (lower occupancy) and other tourism-related income (restaurants, gift shops, transportation, etc.). Its estimation adds up US$18 million. Part of this damage are the lost environmental services related to tourism during the restoration period. | N/A |

The following table summarizes the environmental damage assessment:

| (US$000) | Not assessed in other sector | Assessed in other sectors |
|---|---|---|
| Isolated from other sectors | 14 722 | 9 658 |
| Not isolated from other sectors | | Not estimated<br>80 000 |

**Figure 1**

PROCESS FOR ECONOMIC ASSESSMENT OF ENVIRONMENTAL DAMAGE



The complete assessment of environmental damage includes, therefore, the damage (both direct and indirect) assessed by the sectoral specialists and that assessed by the environmental specialist.

**Example 2: Assessment of damage to the environmental services provided by forests**

This example concentrates on the assessment of damage to the environmental services provided by forests, since this is one of the most likely effects of an extreme event. The event has been simplified to show only this damage, and there is no analysis of links to other sectors.

An extreme event has affected a region in a country in the following way:

- Primary forest: 3 200 hectares destroyed. Most of the area cannot be recovered or is recoverable in the very long term.
- Secondary forest: 6 100 hectares destroyed. Most of the area cannot be recovered or is recoverable in the very long term.
- Shade coffee plantations: 7 200 hectares affected, of which 60% (4 320 hectares) is considered incapable of recovery. The remaining 2 880 hectares might recover over a period of five years.



The country's government has introduced a scheme whereby landowners who conserve the forests will be paid for environmental services. This payment will be made for 20 years. The environmental services and annual monetary values included under this scheme areas follows: [28]

Table 5
VALUE OF THE FOREST ENVIRONMENTAL SERVICES

| Environmental Service | Primary forest ( USD/ha/year) | Secondary forest ( USD/ha/year) |
|---|---|---|
| *Carbon fixing* | 38 | 29 |
| *Water protection* | 5 | 3 |
| *Biodiversity protection* | 10 | 6 |
| *Recreation (natural beauty)* | 5 | 3 |
| **Total** | **58** | **41** |

**28** The World Bank uses the figure of 20 dollars per ton of carbon emitted as an estimate of the damage caused by carbon dioxide emissions. This figure represents the current value of the damage to economic assets and the fall in human well-being for the time the polluting unit is in the atmosphere. There is still no agreement as to the carbon sequestration capacity per type of vegetation.

The shade coffee plantations are agroforest systems that provide agricultural products while conserving the ability to provide typical forest environmental services. An environmental assessment study of the area has taken into account the provision of one good (firewood) and three environmental services (protection of water production and flood control; soil stabilization and conservation; and maintenance of biodiversity). The study does not take  into account the environmental service of carbon fixing because the branches cut in the annual pruning are burned.

There is an estimated timber production of 14 m3/ha/year with a value per $m^3$ of 56 dollars/ha/year. The value of the other three environmental services is 21dollars/ha/year. The total value therefore is 77 dollars/ha/year.

Table 6

ASSESSMENT OF ENVIRONMENTAL DAMAGE

| DIRECT ENVIRONMENTAL DAMAGE | USD$ 000 |
|---|---|
| **1. Loss of environmental services provided by primary forests.**<br>*The method used to assess the value of the loss of the 3,200 hectares of forest is baed on the government's decision to pay for the conservation of forests (i.e. there is a market for environmental services).*<br>*By using the formula below with a discount rate of 7 per cent (that used by the government to evaluate its investment projects), the income from conservation over the next 20 years is expressed at its present value.*<br>$VP = +\sum_{t=0}^{20} \frac{58}{(1.07)^t}$<br>*The present value of the future income flows is USD 672/ha. For 3,200 ha., this comes to* | 2,150 |
| **2. Loss of environmental services provided by secondary forests.**<br>*This is calculated in the same way as the previous example, but the value of the annual payment per hectare is changed as shown in the following formula.*<br>$VP = +\sum_{t=0}^{20} \frac{41}{(1.07)^t}$<br>*The present value of the future income flows is USD 475/ha. For 6,100 ha., this comes to* | 2,897 |
| **3. Loss of environmental services provided by shade coffee plantations**<br>*In this case, it is considered that the value of the land has already been included in the farming sector assessment, although it ought to be taken into account in an extended assessment of environmental damage. The value of the environmental services taken into account is calculated for the non-recoverable area (4,320 ha) as in the previous case. The same formula is used as in the previous cases, and the value of the annual benefit per hectare is introduced*<br>$VP = +\sum_{t=0}^{20} \frac{77}{(1.07)^t}$<br>*The present value of the future income flows is USD 893/ha. For 4,320 ha., this comes to* | 3,858 |
| **Total direct environmental damage** | **8,905** |
| **IN DIRECT ENVIRONMENTAL DAMAGE** | |
| **4. Loss of environmental services provided by shade coffee plantations during rehabilitation period**<br>*There is a loss of environmental services during the recovery period of the 2,880 hectares of plantations that are capable of recovery (it is considered that the necessary investment is included as direct damage in the farming sector assessment, although it ought to be included in an extended assessment of environmental damage). For calculation purposes it is considered that the production of firewood and environmental services recover lineally over five years. Therefore,*<br>$VID = 2{,}880^{*} [77 + 77^{*}0.8/(1.07) + 77^{*}0.6/(1.07)^2 + 77^{*}0.4/(1.07)^3 + 77^{*}0.2/(1.07)^4]$ | 610 |
| **Total indirect environmental damage** | **610** |
| **Total enviromental damage** | **9,515** |

## APPENDIX XIII

## LIFE ZONE SYSTEMS

The relationship between climate and vegetation has been recognized for many years, eventually leading researchers create a worldwide environmental classification system for geographically defining various habitats and natural biotas. Physical environmental factors (soils, nutrients, climate patterns, lighting, seasonality, humidity) that constitute a region's constant or cyclical characteristics are determinants in the development or presence of natural ecosystems that biologically define the area in question. These environmental parameters are the basic reference points for L.R. Holdrige's method of classifying life zones. This system recognizes discrete natural units so that they can be easily distinguished in the field, whether they consist of indigenous vegetation or forms that have been greatly altered. By employing universal parameters that can be easily measured with the same precision in any region and fed into the same model using identical formats, it is applicable to the entire globe.

The application of this system offers the following advantages:

1. Achieving a useful cartographic expression of diverse plant categories or formations that make up a region, country or continent in all of its latitudinal, and altitudinal, climatic, soil and hydrographic variations;
2. Determining the quality and potential of ecosystem servcies in a specific area (e. g., water production or absorption of carbon dioxide).
3. Forecasting the potential environmental impact of any human development or major natural events;
4. Choosing the areas that would be most conducive to farming, forestry or livestock activities (land use planning);
5. Identifying naturally existing communities with an eye toward stressing the importance of their conservation; and
6. Predicting bio-geographical scenarios in response to global climatic changes.



The four main analytical elements in the life zone system (Holdridge, 1979) are heat factors expressed in terms of biotemperature; the use of logarithmic increases in mean annual biotemperature and precipitation to express significant change in natural vegetation units; the ratio between biotemperature and potential evapotranspiration (humidity), on the one hand and the humidity and real evapotranspiration, on the other; and the ratio between evapotranspiration and biological productivity (Tosi, 1997), which is intimately related to environmental services.

In short, the life zone system reflects the relationship between the physical environment and all biota as expressed on three levels:

- Level 1: Bioclimate or life zone;
- Level 2: Vegetation association or ecosystems; and
- Level 3: Successional state (vegetation cover).

The system is thus based on the idea that it is possible to objectively define groups of ecosystems or plant associations on the basis of clear relationships with specific temperature, precipitation and humidity conditions. Holdridge referred to these as life zones, understood to be a group of natural associations, which are divided and subdivided accordingly, regardless of whether each group includes a chain of varying landscape or environmental units that may range from swampland to watershed. Life zones are also equally balanced between the three leading climatic principles of heat, precipitation and humidity, while recognizing that these associations may vary according to the altitudinal variations within a single region. This method of classification allows for recognition of the multiplicity of potential ecosystems or vegetable associations to be found within each of the world's 120 life zones or bio-climates. Vegetable association have been broken down into the following categories:

- One climatic association

- Three atmospheric associations

    Temperature associations (hot, cold)
    Humidity associations (arid, humid)

- Five soil associations

    Humidity associations (arid, semi-arid, humid)
    Fertility associations (fertile, sterile)



- Water associations

Furthermore, each of these systems includes a wide range of potential successional stages from a climactic or ideal state to those marked by extreme disturbances of a natural or anthropogenic nature. In this manner, all levels of vegetation corresponding to each of the successional states can be found in a broad array of conditions defined in physiognomic rather than in floristic terms.

### Verifying System Validation

The life zone system has been validated through extensive mapping of tropical and subtropical regions with comparisons between similar areas based on limited meteorological data and observations on the relationship between climate, vegetation and patterns of land use. All of the countries of Central America, as well as Bolivia, Colombia, the Dominican Republic, Ecuador, Haiti, Jamaica, Paraguay, Peru, Puerto Rico, Santa Lucia and Venezuela have been environmentally mapped based on the life zone system. In addition, a preliminary macro-scale or partial mapping has been done of Australia, Brazil, Mexico, Mozambique, Nigeria, Thailand, Timor, Papua New Guinea and the United States. In most countries, these maps are accompanied by supplementary descriptive and explanatory texts.

**Life zone definition based on climatic data**

According to this system, life zones are defined based on mean annual readings of temperature (biotemperature), precipitation, humidity and meters of elevation above sea level. These are defined as follows:

- Biotemperature: mean annual temperature in centigrade conducive to plant life (between 0 and 30°C);
- Precipitation: the mean volume of any form of precipitation (rain, snow, sleet) in millimeters; and
- Humidity: the ratio between temperature and precipitation, independent of other sources of humidity. The best formula is called the potential evapotranspiration factor (in millimeters), which is achieved by multiplying the biotemperature by factor 58.93.

The second and third levels of life zones

Holdridge conceived of life zones defined by parameters applicable to the entire globe, such as biotemperature, precipitation and humidity. Nevertheless, specific environmental factors play a major part in defining the ecosystems of specific local landscapes. These conditions are the framework for defining a second subdivision that includes soil type, precipitation patterns, soil humidity patterns, the prevalence of strong (damp or dry) winds and the frequency of heavy fog. The presence or absence of any of the above factors moves the area in question left or right, or higher or lower, on the Holdridge Life Zone Model.



The variety of the floristic composition and the structure and physionomy of the vegetation of a region or country generally tends to narrow as one moves to higher elevations along the same latitudes, relative to a wet tropical rainforest with a sub-alpine landscape near the equator. A similar divergence can be seen with precipitation levels and seasonality in an arid tropical forest versus a very humid tropical forest at the same latitudes.

Within a life zone or formation, limiting factors can condition or make possible the development of many associations: mangroves, rocky costal zones, lagoons, dry steppe, windy hills and a range of other systems.

The system recognizes four basic associations (and possible combinations thereof): climatic, soil, atmospheric and moisture conditions. Climatic associations occur when precipitation and monthly distribution such as biotemperature are normal for the life zone, there are no atmospheric aberrations such as strong winds or frequent fog cover and the soil is typical for the zone. Soil associations appear when conditions are more or less favorable in relation to those for a normal (zonal) soil for the corresponding life zone. Atmospheric associations are those in which the weather varies from the norm in that area. Moisture associations involve all forms of wetlands (whether saltwater, brackish or freshwater) but logically exclude deep bodies of water.

The broad, climatically defined life zones are further subdivided into associations based on local environmental conditions and actual vegetation cover or land use. Generally speaking, the associations tend to make the vegetation appear more arid or humid than normal for such a life zone. For example, an association of fertile soil with supplemental water from a Tropical Rainforest has a metabolism similar to that of a Very Humid Tropical Rainforest; similary an area designated as an Arid Tropical Forrest might appear to be a Very Arid Tropical Forrest owing to a monsoon climate pattern with a vertisol soil that is wet in the rainy season and dry and cracked in the dry season.

The third level of the system contemplates provisional changes to ecosystems resulting from natural succession introduced by humans or animals. Life zone systems catalogue those changes as part of the successional state, and owing to their very short life span they are handled as part of land use.

One must be very careful with regard to apparent disparities between local vegetation and the corresponding life zone designation, which occasionally refers to the original vegetation of the climatic association. By the time the field survey is conducted, the area may have experienced some successional change or alteration of the climatic association. However, such a concern only arises when the system is not being applied properly. For example, wherever human activity has altered plant life, the nomenclature of the life zone should project the potential (or ideal) vegetation assuming that conditions would allow for a full recovery through a natural process of environmental succession.



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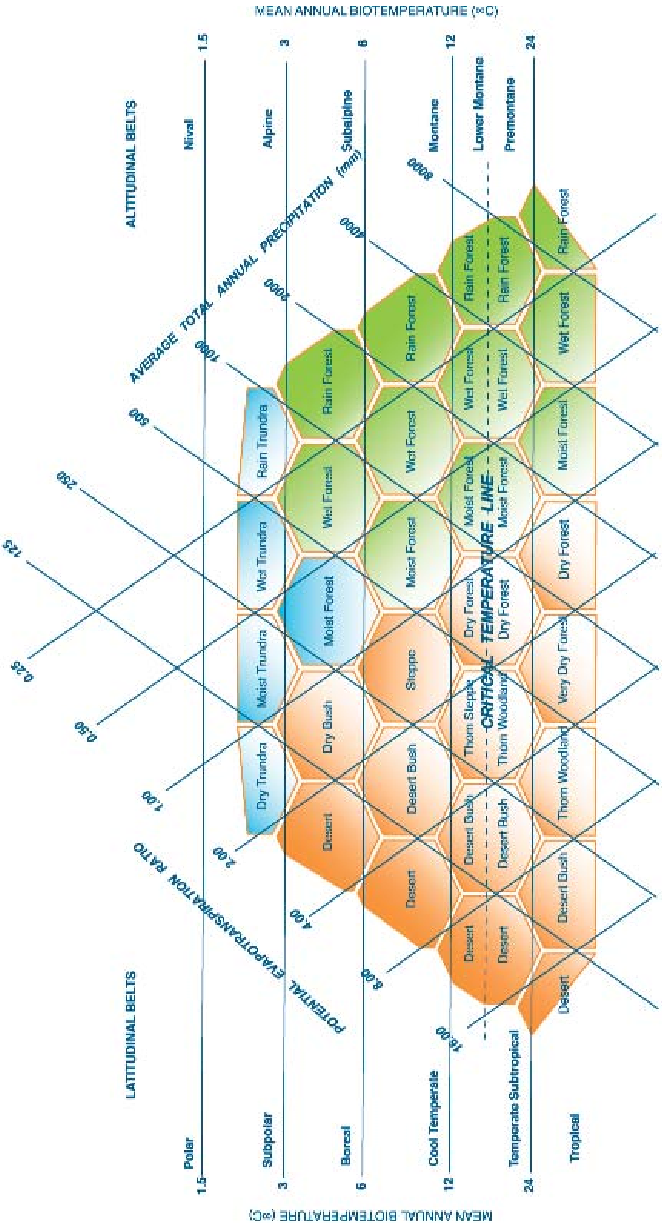
HOLDRIGE LIFE ZONES OF THE WORLD




Source: Tropical Science Center, San José, Costa Rica.