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PROPOSALS TO REFOREST THE EARTH

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1 - INTRODUCTION

The world forests destruction is one of today's major concerns. During the 1990s the world has lost more than 9 million hectares of forests each year. Among the problems related to deforestation are the timber stocks depletion, grave flooding, soil accelerated destruction, progressive desertification, and land productivity diminution.

These problems have reached disastrous proportions in many countries. The lack of firewood negatively affects more than 1 billion human beings around the world. The fast deforestation consequences can be seen on Haiti, where the continuos arable land decrease resulted in smaller crops, while the population never ceased to grow. It is doubtless a recipe for disaster.

If the society attitude towards the forests will not change, most of the natural forests will vanish until the end of the 21^{st} century. Most of Earth's plants and animals will vanish with them, since about 70 percent of the living beings live in function of the forests.

Additionally, the destruction of these forests will create an energetic crisis for at least 2 billion people, that will not have enough timber for cooking or heating. In their desperate search for timber, they will destroy more forests, what will increase the erosion, causing climatic changes, desertification of even more land, and generalized famine.

People living in developed countries will equally suffer if the forest area will not grow in the same proportion than the economy. Even old growth forests absorb about 0.5 ton of CO_2 per hectare per year, and new forests can absorb up to 30 ton of CO_2 per hectare per year. Therefore, their contribution for the mitigation of the human impacts over the atmosphere is extremely important.

Carbon absorption and timber are only some of the forest services. Forest can also provide food, medications and water, as seen on this book's chapter 3. The Proposals to Reforest the Earth also regards other important issues over forests, like their natural regeneration, management and planting. This publication's main purpose is to make people understand that we not only can live from the forests, but also that we must do it in order to avoid our own extinction.

Forests are renewable resources, rich and resistant ecosystems that when sustainably explored can provide us all goods and services we need, at the same time conserving the planet biodiversity and stabilizing the environment for the future generations.

2 – MAIN ISSUES REGARDING FORESTS

2.1 – Forest Cover

Forest is the land covered with trees and shrubs. Its minimum area is of 0.01 ha, with a minimum tree cover of 30%, and a minimum tree height of 2.5 meter. There are more than 600 forest types occurring worldwide, and these were transformed into global ecological zones, as seen on table 2.01.

Table 2.01 – Forest Cover by Ecologic Zone

Ecologic Zone	*Total Area (Million ha)*	*Forest Area (Million ha)*	*Forest Cover*
Tropical	**5,830**	**2,020**	**35%**
Rain forest	1,468	1,013	69%
Moist	1,117	346	31%
Dry	755	483	64%
Shrub	839	59	7%
Desert	1,192	0	0%
Mountain	459	119	26%
Subtropical	**2,282**	**372**	**16%**
Humid	471	146	31%
Dry	156	70	45%
Steppe	491	44	9%
Desert	674	13	2%
Mountain	490	98	20%
Temperate	**2,782**	**511**	**18%**
Oceanic	182	46	25%
Continental	726	247	34%
Steppe	593	24	4%
Desert	552	6	1%

Ecologic Zone	*Total Area (Million ha)*	*Forest Area (Million ha)*	*Forest Cover*
Mountain	729	190	26%
Boreal	**1,904**	**993**	**52%**
Coniferous	865	571	66%
Tundra	407	106	26%
Mountain	632	316	50%
Polar	**564**	**11**	**2%**
TOTAL	**13,362**	**3,907**	**29%**

Source: FAO, 2001

From the world total area of 13.4 billion hectares, less than 4 billion are covered with forest (29%). This percentage changes from one ecologic zone to another. As an average, the ecologic zone with the best forest cover is the boreal, with 52% of its area covered with forests. This is because boreal areas are generally not converted to other uses, such as agriculture or pasture. Item 5 brings a description for each ecologic zone.

2.2 – Deforestation

The clearing of forests across the Earth has been occurring on large scale for many centuries. This process, known as deforestation, involves the clear cut, burning and damaging of forests, converting that land to other uses, such as pastureland or cropland. The loss of forests is more profound than the merely destruction of beautiful areas. If the current rate of deforestation continues, most of the world's natural forests will vanish within 100 years, causing unknown effects on global climate and eliminating the majority of plant and animal species of the planet.

Deforestation occurs in many ways. Most of the clearing is done for agricultural purposes - grazing cattle, planting crops. Poor farmers chop down a small area (typically of a few hectares) and burn the tree trunks, in a process called “slash and burn” agriculture. Intensive agriculture occurs on a much larger scale, sometimes deforesting several square kilometers at a time. Large cattle pastures often replace forests.

The causes of deforestation are very complex. Illegal loggers open roads to selectively harvest (a process different from the selective management – see item 4.5) valuable species of trees. Then, capitalized individuals or firms use these roads to clear-cut the forest and convert it to pasture or agriculture.

Deforestation by peasant farmers is often done to raise crops for self-subsistence. Most of the population living in tropical countries, where most of the deforestation take place nowadays (see table 2.02) is very poor, and farming is a basic way of life for a large part of the population. In Brazil, for example, the average annual earnings per person is US$ 2,830, compared to US$ 35,400 per person in the United States. In Nigeria, another poor country with large deforestation rates, the average annual earnings per person is US$ 300 (World Bank, 2004). Farmers in these countries do not have the money to buy necessities and must raise crops for food and to sell.

Figure 2.01 - Clearing Forests for Use in Agriculture

Source: The University of Georgia

There are other reasons for deforestation, such as urbanization or to construct dams, which flood large areas. Yet, these latter cases constitute only a very small part of the total deforestation (Urquhart et al., 2004).

It is estimated that about 9,4 million hectares forest were eradicated each year during the 1990s (FAO, 2001). The rate of deforestation varies from region to region.

Table 2.02 – Changes in Forest Cover (1990 – 2000)

AREA	Total Forest 1990 (1,000 ha)	Total Forest 2000 (1,000 ha)	Annual Change (1,000 ha)	Annual Change Rate (%)
Afica	702,502	649,866	-5,262	- 0.78
Asia (Excl. Russia)	551,448	547,793	-364	- 0.07
Oceania	201,271	197,623	-365	- 0.18
Europe (incl. Russia)	1,030,475	1,039,251	881	0.08
North and Central America	555,002	549,304	-570	-0.10
South America	922,731	885,618	-3,711	-0.41
TOTAL	**3,963,429**	**3,869,455**	**-9,391**	**-0.22**

Source: FAO, 2001

The African continent presents the highest annual forest cover change rate (-0.78% per year), and also the largest annual forest cover change area (-5,3 million hectares per year). This represented about 56% of the world total deforestation during the 1990s. The second area with the largest annual deforestation rate was South America (-0.41% per year), or about 40% of the world total deforestation during the 1990s. These are the world poorest areas.

Deforestation increases the amount of carbon dioxide (CO_2) and other trace gases in the atmosphere. When a forest is cut and burned to establish cropland and pastures, the carbon that was stored in the tree trunks joins with oxygen and is released into the atmosphere as CO_2.

The loss of forests has a profound effect on the global carbon cycle. From 1850 to 1990, deforestation worldwide released 122 billion metric tons of carbon into the atmosphere, with the current rate being approximately 1.6 billion metric tons per year. In comparison, fossil fuel burning (coal, oil, and gas) releases about 6 billion metric tons per year, so it is clear that deforestation makes a significant contribution to the increasing CO_2 in the atmosphere (about 21%). Releasing CO_2 into the atmosphere enhances the greenhouse effect, contributing to an increase in global temperatures (Urquhart et al., 2004) with still unclear effects.

Deforestation also affects the local climate of an area by reducing the evaporative cooling that takes place from both soil and plant life. Recent research suggests that about half of the precipitation that falls in a forest is a result of its moist, green canopy. Evaporation and evapo-transpiration processes from the trees and plants return large quantities of water to the local atmosphere, promoting the formation of clouds and precipitation. The lost of forest cover in a specific area means less local evaporation, making more of the Sun's energy able to warm the surface and, consequently, the air above, leading to a rise in temperatures and drying out that specific region.

Worldwide, 5 to 80 million species of plants and animals comprise the biodiversity of planet Earth. Tropical rain forests, covering less than 8% of the total dry surface of the Earth, hold over half of all these species. Of the tens of millions of species believed to live on planet Earth, scientists have only identified about 1.5 million of them, and even fewer of the species have been studied in depth (Urquhart et al., 2004).

Many of the rain forest plants and animals can only be found in small areas, because they require a special habitat in which to live. This makes them very vulnerable to deforestation. If their habitat is destroyed, they may become extinct. Every day, species are disappearing from the tropical rain forests as they are cleared. No one knows the exact rate of extinction, but estimates indicate that up to 137 species disappear worldwide each day (Urquhart et al., 2004).

2.3 – Illegal Logging

Illegal acts are a major threat to the forest resources all around the world. Illegal forest acts have substantial negative economic, social, and environmental impacts, are common in both developing and industrialized nations, and occur in all major forest types - boreal, temperate, subtropical and tropical. They do not stop at illegal logging; rather, they include the entire market chain from illegal transport to industrial processing and trade operations, all the way down the line to markets (Contreras-Hermosilla, 2001).

2.3.1 - Magnitude of Illegal Activities

Though there has been no comprehensive regional assessment of illegal forest activities, research focused on individual countries, crossborder activities, and actions taken by transnational forest corporations paints a picture of widespread corruption and crime.

Examples of illegal practices in the forestry and forest industries sector: (i) illegal occupation of forest land; (ii) converting public forested land for agriculture or cattle ranching by families, communities or private corporations; (iii) encouraging landless peasants to occupy forested areas, thus forcing governments to grant land ownership rights, which are then purchased by corporations; (iv) logging in protected and prohibited areas, and outside concession boundaries; (v) obtaining logging concessions through bribes; (vi) duplication of felling licenses; (vii) logging of protected species; (viii) girdling or ring-barking to kill trees so that they can be "legally" logged; (ix) removing under/oversized trees from public forests; (x) extracting more than authorized amounts of timber; (xi) smuggling timber; (xii) transporting illegally harvested timber; (xiii) exporting and importing tree species banned under international law; (xiv) exporting and importing timber in contravention of national bans; (xv) declaring artificially high purchase prices for inputs, such as equipment or services from related companies; (xvi) inflating debt repayment to avoid taxes; (xvii) under-grading, under-valuing, under-measuring, and misclassification of species for export or for the local market; (xviii) operating without a processing license; (xix) ignoring environmental, social, and labor laws and regulations; (xx) using illegally-obtained wood in industrial processing.

The situation in Indonesia illustrates the problems of many countries. In 1997/1998, illegal timber harvesting was approximately 33 million cubic meters, exceeding the official production of 29.5 million cubic meters. The estimated cost to the government was $3.5 billion per year - one-third of the potential timber harvesting revenue. During the mid-1990s, 84 percent of timber concessionaires did not follow the law and in some cases illegal logging was even taking place in some of Indonesia's most important national parks. Still another assessment exposed that as much as 40 percent of the large paper industry's wood supplies came from undocumented sources.

Illegal forest activities in this area of the world often spill over national borders. For example, a study commissioned by the World Wildlife Fund concluded that most of the timber exports from various countries in Asia were illegal. Substantial logging trade has been documented between Cambodia and Vietnam, despite both countries' prohibitions on such trade. Similar illegal timber trade activities take place between Myanmar and China. In 1995 Myanmar reported that it exported about 276,000 fewer cubic meters of logs than importing countries declared they received. This could be equivalent to an undeclared $86 million, which would be almost half of Myanmar's forest export revenues that year. The large illegal flow of logs from the Russian Far East to China carries major local and international importance.

Russia's Institute for Economic Research estimates that at least 20 percent of the value of timber trade from the Russian Far East to Japan, China, and South Korea, the three main export markets, is illegal. In 1999 the Primorski region alone illegally exported some 300,000 cubic meters, with a value of about US$ 24 million. Nearly 40 to 50 percent of Russian timber is sold to Pacific Rim countries under dumping prices and faked contracts.

In the last few years aggressive transnational forest corporations often have expanded their operations in developing countries. This has brought a surge in illegal activity as many of these corporations reputedly have little respect for the laws of host countries. These corporations ignore the prescriptions of forest management plans, obtain timber concessions by bribing public officials, engage in transfer pricing and employ other illegal practices - often in collusion with government officials.

The research done on illegal forestry activities in the Asia Pacific Rim may understate the magnitude of illegal acts. In many cases, local officials are reluctant to report illegal acts because they fear reprisals from criminals or because they are directly involved in the illegal schemes. Companies often conceal their extractions through complex methods of documentary fraud and corruption of officials. In many countries a large proportion of the exploitation of forests is part of the "shadow" economy. Thus, a proportion of forest illegal acts either remains undetected or is even recorded as legal.

In every Asia Pacific country, diverse groups are involved in a variety of illegal activities. Examples of illegal acts include unauthorized exploitation of public and private lands, illegal logging in protected or environmentally sensitive areas, logging of protected species, woodland arson, illegal transport of wood and other forest products, smuggling, transfer pricing and other fraudulent accounting practices, and illegal industrial processing.

Synergies may be created involving various actors. For example, some corporations excuse their logging of prohibited species because illegal loggers, coming into the concession areas after they are opened for exploitation, would steal them anyway. Some illegal acts are the unintended consequences of faulty laws. An imperfect legal framework induces or even forces some actors to operate outside the law. For example, ownership of forestlands is often a matter of contention between official government claims and those of local communities, especially indigenous ones because many forest laws unfairly criminalize ancestral use. These laws often deprive indigenous communities of the legitimate rights they have held for generations, leaving them with no option but to act in ways considered “illegal” by the state. Recently these conflicts have become more acute due to the growing interest in developing markets for the environmental services forests provide. This has brought new attention to property rights issues. Many governments, local organizations, and private sector actors are just beginning to consider questions regarding who owns forest’s ability to provide carbon, biodiversity and water services, who should pay for the production of these services, and how dominant cultural, legal, and regulatory mechanisms could be reformed to protect these interests and rights.

The interest in determining what is legal or illegal has thus acquired new relevance. Companies or individuals may extract timber from public or private forestlands without authorization, log protected species, log in excess of prescribed volumes in timber concessions, or log outside concession areas.

Since many forest management plans allow for “sanitary” cuts (extracting over mature trees, trees infected by pests or killed by fires, etc.) loggers may abuse this reason illegally to extract large volumes of valuable trees. Surreptitious girdling of trees to kill them may take place to force their exploitation. Some unscrupulous logging interests sponsor poor individuals to enter forests can cut down trees illegally for them.

Illegal activities do not stop at the forest. They travel down the line to include operations related to transportation of forest products in national and international trade. Individuals and corporations may transport timber without permits or smuggle products across international borders. Timber smuggling is often induced by restrictions to logging imposed in one of the trading countries.

Some corporations inflate the price of imported inputs, such as machinery, and deflate prices and volumes of their exports to reduce nominal profits and their tax liability with the host country and then illegally transfer funds abroad. These illegal practices are facilitated when enterprises are vertically integrated, i.e., when they are exporting to or importing from other branches of the same company thus making it easier to manipulate accounts.

In countries where law enforcement is weak, illegal and highly mobile sawmills often buy illegal logs from local small-scale operators - thus evading taxes and environmental laws. In other cases large industrial installations, such as pulp and paper complexes, may not follow water pollution and other emission control rules.

Frequently operations are carried out in ways that obscure economic links and the details of operations thus making it more difficult for law enforcers to trace illegal activities. For example, some transnational companies operate as subcontractors to various national concessionaire firms created by them. Concessionaires appear as different entities thus circumventing laws that may limit the size of timber concessions given to a single company. Companies may incur disproportionate debt or mismanage company operations for the benefit of a few. Some can get away with this because their investments are so large that eventually major creditors or the government itself will come to their rescue. Technically no laws may have been broken. Financial frauds are disguised as corporate mismanagement.

Forest resources are also vulnerable to illegal activities in other sectors of economic activities. For example, mineral and oil resource often lie under forests and illegal operation to extract these minerals have caused enormous damage to forest in many parts of the world.

Though illegal forestry activities involving only private parties does occur, in almost every case corruption is involved. Corrupt deeds are defined as illegal, intentional, and surreptitious actions involving public officials. This differentiation between illegal acts in general and corrupt activities may seem inconsequential, but acts involving corruption deserve special attention for a couple of reasons. The fundamental reason is that those actions undermine the apparatus of government. This is critical in a sector that generates many social and environmental impacts requiring strong and "clean" intervention from the state. If the government itself voluntarily breaks the law, there is little hope that other actors, such as communities and private corporations, will adhere to the legal framework. It is one thing to have a committed government trying to impose the law and perhaps failing because of lack of resources, and it is another to have a state participating in breaking its own law.

Few dispute that sound governance is impossible in an environment of illegality. However, some argue that corrupt activities contribute to economic efficiency because they allow investors and entrepreneurs to avoid immensely complex - and sometimes absurd - bureaucratic regulations. There is no empirical evidence to support the often cited argument that corruption is "the grease of the development process" (Contreras-Hermosilla, 2001).

2.3.2 - Consequences of Forest Crime

Illegal forest activities have generated a host of negative impacts on the economy, the poor, and the quality of forest management. Economic impact. Forest crime leads to wrong decisions and poor allocation of scarce economic resources, thus undercutting economic development. Though there are no comprehensive assessments of the effects of illegal acts on the economy of the forest sector, macro and global evaluations reveal that illegal practices in general produce several negative economic effects.

There is no reason to believe that effects in the forestry sector would be at variance with these findings. Reasons that illegal forestry activities impair economic efficiency include lower propensity to invest in sustainable forestry. Where the rule of law is weak, investment risks tend to be higher. Higher levels of risk make investors demand higher and faster financial returns, thus discouraging investments in long-term forest management. For example, squatters' invasion of forestlands may spur loggers to harvest the best timber resources as fast as possible - with little thought given to long-term sustainability of the resource. In addition, other costs, such as bribes, can be very high.

Second, when illegal options are easily accessible, they render a higher profit. As a consequence, concessionaires are reluctant to invest in sustainable forest management practices if they can steal with impunity from a concession area or adjacent areas.

Finally, profits from illegal forest operations tend to be sent abroad, thus negating a host country's investments in productive operations.

Funds invested in forestry may be in less desirable options. In part this may be due to the fact that decisions are being made by unprincipled organizations. Responsible foreign investors may shy away from countries where illegalities are common. But this same environment may attract unscrupulous corporations.

Similarly, government decisions influenced by bribes will only coincide by chance with actions that benefit the country's priorities the most. For example, equipment for forest administration may be chosen because of corrupt deals not because it was well suited to the conditions of the country.

Forestry administrations, particularly in developing countries, operate under a permanent shortage of funds. Tax evasion diminishes government income that could be used to promote better forest management.

International donors, such as the World Bank and the International Monetary Fund, are less likely to initiate forest projects and programs in countries where law enforcement is weak. Donors have been known to withdraw financial and technical support from ongoing projects in such countries.

Many of the world's poorest are dependent on forest resources, are forest dwellers, and have legitimate - yet not legally sanctioned - claims to forest resources. They suffer because of a faulty legal system. In other cases, the law may be adequate but actors living in poverty may be willing or compelled to act in criminal ways. Some may benefit but often gains are short lived. For example, initially, landless peasants invading public or private lands benefit from poor law enforcement.

However, the same environment that allows this to happen generates a host of other effects that will eventually hurt the poor. First, if poor law enforcement is systemic and economic growth is impaired as a result, the poor are likely to suffer the most. When economic expansion is slow, the state is not inclined to provide public services such as training and subsidies for the poor. In addition, powerful economic interests are able to capture parts of the state.

The very poor are unable to negotiate large operations and can't pay substantial bribes to benefit from corrupt deals. Thus, the capture of the state by economic and political interests is likely to lead to greater inequality. And, given their lack of political influence, the poor may be asked to pay proportionally more than the rich do in order to obtain government services. In some cases, public officials abusing their power are able to extract money from the disadvantaged for access to forest goods and services - such as fuelwood or hunting - that are granted to them by law.

Moreover, the proliferation of illegal logging activities usually affects the poor negatively because those activities often take place in areas that are vital for the subsistence of the poor. Illegal activities reduce the quality of forests or result in outright deforestation. This deprives local populations of important resources, including agricultural implements, construction materials, medicines, and fuelwood. In addition, food supply is reduced for rural communities that depend on forests for a substantial part of their nutrition needs. Sources of local income and employment also are likely to be lost in the long term. Benefits to the poor, if any, tend to be transitory.

Forest crimes decrease the quality of forest management. Forests produce a number of non-timber goods and services - such as carbon sequestration, aesthetic and religious values, biodiversity, and soil and water protection - that are only just beginning to be transacted in markets around the world. Absent established market prices, the private sector will not produce these goods and services in sufficient amounts.

However, because these are important to society, most countries establish laws, rules, and incentives aimed at sustainable forest management that require operators to manage forests in ways designed to ensure their renewal. While sustainable forest management can be profitable, unsustainable practices are almost invariably even more profitable. Therefore, when governments are unable or unwilling to enforce the law, operators evade sustainable forest management regulations simply because costs can be avoided.

Furthermore, illegal logging and trade depress the market value of forest products. This has two connected effects. First, cheap resources tend to be used in wasteful ways, which creates rapid liquidation and impairs the production of plentiful future harvests.

Second, market incentives that would encourage more sustainable forest management are reduced to very low levels.

Only after comprehending the seriousness of this harm can stakeholders begin to engage in the massive effort required to develop and put into operation plans to combat such practices. Any such effort must start with a general outline of strategies. Situations will vary, but there are three basic steps that proponents of sustainable forest management can take to enhance forest law enforcement: (i) assessing the probabilities of success in improving governance in the forestry sector; (ii) developing a policy framework governing the management of the forestry sector; and (iii) implementing prevention, detection and suppression actions (Contreras-Hermosilla, 2001).

2.3.3 - Conclusion

Illegal activities are a main threat to forestry resources all around the world. A wide variety of harmful acts, including illegal logging, illegal trade, arson, take place in all forest types and regions. Such illegal forest activities have generated a host of negative impacts on the economy, indigenous and other local communities, and the quality of forest management.

It is in the interest of all of the stockholders - from local communities to national politicians to logging companies to international donors - to work together to ensure the preservation of natural forests by identifying and implementing an agreed upon and mutually reinforcing set of actions (Contreras-Hermosilla, 2001).

2.4 – Desertification

2.4.1 – General Aspects

Desertification is one of most serious environmental and social-economic problems in the world. Desertification brought about environmental deterioration and land degradation, which caused heavy losses for the economy of several countries. According to research and practices conduced for more than 20 years, it is considered that the desertification is land degradation mainly resulted from the interaction between excessive human activities and vulnerable environment. The causes leading the land to be desertified may be of varied description, but the two most important factors can be recognized. They are called “natural factor” and “human factor”. The combined forces of these factors are the major cause of desertification, and the human factor is more important than the natural one (Wang et al., 2001) .

Figure 2.02 - Soil Erosion Following Row-Crop Agriculture on Converted Forest Lands

Source: The University of Georgia

Desertification can be noticed in several places of the world, and in all of them the above actors took place. In the Mediterranean area, the noticeable human landscape modification started about 10,000 years ago. Fire, grazing pressure, shifting agriculture, wood cutting for fuel and overcutting in the forest can be indicated as important degradation and/or selection factors in the Mediterranean Basin countries.

In some areas, desert fringes form a gradual transition from a dry to a more humid environment, making it difficult to define the desert border. These transition zones have very fragile, delicately balanced ecosystems. Desert fringes often are a mosaic of microclimates. Small hollows support vegetation that picks up heat from the hot winds and protects the land from the prevailing winds. After rainfall the vegetated areas are distinctly cooler than the surroundings. In these marginal areas, human activity may stress the ecosystem beyond its tolerance limit, resulting in degradation of the land. By pounding the soil with their hooves, livestock compact the substrate, increase the proportion of fine material, and reduce the percolation rate of the soil, thus encouraging erosion by wind and water. Grazing and the collection of firewood reduces or eliminates plants that help to bind the soil.

Figure 2.03 – Collection of Firewood in a Desert Fringe

Source: Worldisround

This degradation of formerly productive land – desertification- is a complex process. It involves multiple causes, and it proceeds at varying rates in different climates. Desertification may intensify a general climatic trend toward greater aridity, or it may initiate a change in local climate.

Desertification does not occur in linear, easily mappable patterns. Deserts advance erratically, forming patches on their borders. Areas far from natural deserts can degrade quickly to barren soil, rock, or sand through poor land management. The presence of a nearby desert has no direct relationship to desertification. Unfortunately, an area undergoing desertification is brought to public attention only after the process is well underway. Often little or no data are available to indicate the previous state of the ecosystem or the rate of degradation (USGS, 2004).

2.4.2 – Issues

Desertification, or land degradation, is recognized as an environmental and social economic issue, and attracts attentions from all over the world. Most of the areas subject to the desertification have suffered from high pressure of population and intensive human impacts. In China, the main types of desertification can be classified as: (i) sandy desertification, caused by wind erosion, (ii) land degradation, by water erosion; (iii) soil salinization and other land degradation, caused by engineering construction of residential areas, communications, coal mining and oil fields (Wang et al., 2001).

Desertification became well known in the 1930's, when parts of the Great Plains in the United States turned into the "Dust Bowl" as a result of drought and poor practices in farming, although the term itself was not used until almost 1950. During the dust bowl period, millions of people were forced to abandon their farms and livelihoods. Greatly improved methods of agriculture and land and water management in the Great Plains have prevented that disaster from recurring, but desertification presently affects millions of people in almost every continent.

Increased population and livestock pressure on marginal lands has accelerated desertification. In some areas, nomads moving to less arid areas disrupt the local ecosystem and increase the rate of erosion of the land. Nomads are trying to escape the desert, but because of their land-use practices, they are bringing the desert with them.

It is a misconception that droughts cause desertification. Droughts are common in arid and semiarid lands. Well-managed lands can recover from drought when the rains return. Continued land abuse during droughts, however, increases land degradation. By 1973, the drought that began in 1968 in the Sahel of West Africa and the land-use practices there had caused the deaths of more than 100,000 people and 12 million cattle, as well as the disruption of social organizations from villages to the national level.

While desertification has received tremendous publicity by the political and news media, there are still many things not known about the degradation of productive lands and the expansion of deserts. In 1988, it was pointed out in an important scientific paper that the desertification problem and processes are not clearly defined. There is no consensus among researchers as to the specific causes, extent, or degree of desertification. Contrary to many popular reports, desertification is actually a subtle and complex process of deterioration that may often be reversible (USGS, 2004).

2.4.3 - Global Monitoring

In the last 25 years, satellites have begun to provide the global monitoring necessary for improving our understanding of desertification. Landsat images of the same area, taken several years apart but during the same point in the growing season, may indicate changes in the susceptibility of land to desertification. Studies using Landsat data help demonstrate the impact of people and animals on the Earth. However, other types of remote-sensing systems, land-monitoring networks, and global data bases of field observations are needed before the process and problems of desertification will be completely understood.

2.4.4 - Local Remedies

At the local level, individuals and governments can help to reclaim and protect their lands. Placement of straw grids, each up to a square meter in area, decrease the surface wind velocity. Shrubs and trees planted within the grids are protected by the straw until they take root. In areas where some water is available for irrigation, shrubs planted on the lower one-third of a dune's windward side will stabilize the dune. This vegetation decreases the wind velocity near the base of the dune and prevents much of the sand from moving. Higher velocity winds at the top of the dune level it off and trees can be planted atop these flattened surfaces.

Oases and farmlands in windy regions can be protected by planting tree fences or grass belts. Sand that manages to pass through the grass belts can be caught in strips of trees planted as wind breaks 50 to 100 meters apart adjacent to the belts. Small plots of trees may also be scattered inside oases to stabilize the area. On a much larger scale, a "Green Wall," which will eventually stretch more than 5,700 kilometers in length, even longer than the famous Great Wall, is being planted in northeastern China to protect "sandy lands"- deserts created by human activity.

More efficient use of existing water resources and control of salinization are other effective tools for improving arid land conditions. New ways are being sought to use surface-water resources such as rain water harvesting or irrigating with seasonal runoff from adjacent highlands. New ways also being sought to find and tap groundwater resources and to develop more effective ways of irrigating arid and semiarid lands.

Research on the reclamation of deserts also is focusing on discovering proper crop rotation to protect the fragile soil, on understanding how sand-fixing plants can be adapted to local environments, and on how grazing lands and water resources can be developed effectively without being overused.

If we are to stop and reverse the degradation of arid and semiarid lands, we must understand how and why the rates of climate change, population growth, and food production adversely affect these environments. The most effective intervention can come only from the wise use of the best earth-science information available (USGS, 2004).

3 – FOREST BENEFITS

For many countries, forests represent an important resource base for economic development. If managed wisely, the forest has the capacity to provide a perpetual stream of income and subsistence products, while supporting other economic activities (such as fisheries and agriculture) through its ecological services and functions.

Forestland may be utilized in many different ways. It can be used for commercial timber extraction, it may be used for commercial purposes such as oil palm or rubber plantations, it may be used for traditional subsistence activities (for example, traditional agricultural practices such as agroforestry and shifting cultivation, and/or for the extraction of non-timber forest products or it may be afforded various levels of protection through the establishment of a Protected Area, a National Park or Wildlife Sanctuary.

How best to manage forests has become a growing concern for policy makers, interest groups and the public due to: the increasing scarcity of virgin forest land; greater awareness and understanding of the social and economic implications of destructive forest practices; and, a growing realization that the significant opportunities for economic development based on forestry activities should not be wasted.

Greater attempts are now being made to rationalize the decision making process with respect to the use of forestland. If the returns from forest land are to be maximized over the long term, then the forest needs to be managed sustainably (i.e., the production of goods and services needs to be balanced with the conservation of the resource base).

In order to make sustainable forest management decisions, more reliable information on the environmental, social, and economic value of forests in their own right and relative to other land uses is urgently needed.

A problem has been that traditional project evaluation procedures do not incorporate the full range of environmental and social costs associated with different forestland use options. Due to this omission, decisions on forestland use have been biased in favor of development options, some of which have been shown to be economically unjustifiable once the relevant environmental costs are accounted for. Table 3.01 shows the most important forest benefits.

Table 3.01 – Most Important Forest Benefits

Use Values			***Non Use Values***
Direct Value	***Indirect Value***	***Option Value***	
Sustainable timber Non-timber forest products Recreation and tourism Medicine Plant genetics Education Human habitat	Watershed Protection Nutrient cycling Air pollution reduction Micro-Climatic Functions Carbon store Biodiversity	Future use as per direct value and/or indirect value	Existence value Cultural heritage Biodiversity

Source: Bann, 2003

3.1 - Direct Use Values

Direct use values are values derived from direct use or interaction with a forest's resources and services. They involve both commercial, subsistence, leisure, or other activities associated with a resource. Subsistence activities are often crucially important to rural populations.

Timber is the most recognized economic product from forests. However, forests are the source of many non-timber forest products (NTFP) including: fuelwood; extractives such as bark, dyes, fibbers, gums, incense, latexes, oils, resins, shellac, tanning compounds and waxes; parts of plants and animals for medicinal, ceremonial or decorative purposes; and, food such as bush meat, flowers, fruits, honey, nuts, leaves, seeds and spices.

Most NTFP are consumed locally (i.e., nationally). Nevertheless, they constitute a valuable resource, and their commercial value per hectare of land can exceed that of wood products. Certain NTFP have considerable international markets as well. Rattan, latex, palm oil, cocoa, vanilla, nuts, spices, gum and ornamental plants are commodities for which markets do exist and are expanding in developed countries.

Ecotourism within forests is an emerging economic activity with tremendous potential to generate foreign exchange. Local residents also derive recreational benefits from visiting forest reserves, but their Willingness to Pay (WTP) for this activity is generally lower than that of international travelers (Bann, 2003).

3.1.1 - Timber

Timber extracted from the forest is typically marketed, and therefore market prices can be used for valuation purposes. Market prices are usually available for roundwood delivered at the processing plant or point of export. Total value is derived by applying the price for a unit of timber to the estimated quantities that could be sustainably harvested from the area of forest under consideration.

A number of issues need to be covered when using market prices to value timber. The costs of harvesting and transporting the timber must be deducted from the market price to arrive at the net value of standing timber in the forest (Bann, 2003).

3.1.2 - Non-Timber Forest Products

The term Non-Timber Forest Products (NTFP) may be defined as the variety of physical goods, other than timber, that are derived from forests and that are used either for subsistence purposes or traded or sold. NTFP include plants and plant based products (fruits, latexes and medicines) as well as animals and animal based products. Table 3.02 summarizes the various NTFP categories.

Table 3.02 - Characterization of Non-Timber Forest Products

Category	*Example*
Food	Fish Fruit Edible oils Edible plants Honey
Medicinal products	
Fuel	Fuelwood Charcoal
Structural Materials	Rattan Bamboo Wood poles Various fibbers
Animal products	Honey Feathers Other decorative wildlife products Ornamental plants

Source: Bann, 2003

Traditionally, forest value has been based on timber production, while NTFP values have been largely neglected, if not ignored. The omission of NTFP benefits from the analysis means that the forest resource is undervalued. This can result in unsustainable paths for timber extraction or to the conversion of forest land to alternative land uses, since both of these options appear financially more attractive.

Greater attention is now being paid to the importance and value of NTFP. A number of economic studies have been undertaken in order to measure, in monetary terms, the value of NTFP. These studies have demonstrated that the real (or potential) magnitude of NTFP in many cases is substantial. A study in the Amazon forest indicated that the economic value of NTFP was in fact bigger than that of the timber in the long run. Other studies have shown that NTFP are important sources of fuelwood, building materials, fodder, food and income to the rural people. A number of NTFP (e.g., rattan, bamboo, resins and medicinal plants) have shown potential economic value for further research and development. It has also been highlighted that higher economic values can be derived if forest management emphasizes the production of both timber and NTFP (Bann, 2003).

3.1.3 - Tourism and Recreation

When information on the number of visitors to a site and the cost of either entrance fees or permits is available, it can be used to estimate a minimum level of benefits from park use. However, information on the demand for the recreational services of the forest is usually not available from markets, because many forest areas are accessible to the public free of charge.

When market prices are not readily available, the assessment of forest-based recreation values requires the application of the Travel Cost Method (TCM) or Contingent Valuation Method (CVM). Both of these WTP techniques estimate demand curves and consumer surplus to forest users. A limitation of TCM is that it captures only part of the value to the user (i.e., it does not account for option and existence values). A concern with CVM is the assumption that people's stated assessment of what they would be WTP accurately reflects what they would actually spend to enjoy that recreational experience. There has been limited experience to date of trying to apply either method to recreational use in forest areas due to their considerable data requirements.

In certain cases, even when price data are available these may be unreliable or insufficient for research purposes. In such circumstances, a non-market valuation technique has to be applied. For example, Tobias and Mendelsohn (1991) used the travel costs method to estimate the value of Monteverde Cloud Forest Reserve in Costa Rica for ecotourism. While revenue data for the reserve were available, the authors felt that peoples WTP for the amenities of the reserve far exceeded the amount actually charged to enter the reserve. This hypothesis was upheld by the application of the TCM, which allowed a more complete assessment of consumer surplus (Bann, 2003).

3.1.4 - Research and Education Benefits

Protected forest areas can be used as research and education facilities. Valuation of forest research and education benefits could be based on specific expenditures within the park. Although such expenditures do not represent economic values per se, they do indicate a minimum WTP to take advantage of the park resources.

Furthermore, foreigner researchers may add to the overall tourism statistics for a country and bring in foreign exchange, while some projects provide employment and training opportunities for locals.

While revenues from people who go to the park to learn about nature would be included in tourism benefits, an additional but non-quantifiable value would be the effect of education on the future actions of visitors. Environmental sensitivity gained by visiting a park would tend to promote greater awareness of the importance of natural resources and encourage conservation. This benefits could be measured by a survey inquiring about visitor's knowledge and opinions before and after their visit (Bann, 2003).

3.2 – Indirect Use Values

Indirect use value relates to the indirect support and protection provided to economic activity and property by the forest's natural functions, or regulatory environmental services. For example, the watershed protection function of a forest may have indirect use value through controlling sedimentation and flood drainage that affect downstream agriculture, fishing, water supplies and other economic activities. The micro-climate function of some forests may also have indirect use value through the support of neighboring agricultural areas.

If the environmental functions and services provided by the forest are disturbed, then there will be a corresponding change in the value of production or consumption of the activity and property that is protected or supported by the forest. As indirect values cannot, typically, be directly or indirectly inferred from observed human or market behavior, they are often difficult to value.

3.2.1 - Watershed Effects

Forests serve important watershed functions. When forested mountain slopes are denuded, forest soils lose their water retention capacity and most rainfall disappears rapidly as surface runoff which can result in excessive flooding along riverbeds. Damage from widespread flooding can include: crop damage; loss of livestock and other animals; damage to human dwellings, infrastructure and equipment; displacement of people; and, the spread of disease.

Forests also protect against soil erosion due to surface water runoff and wind. If an area is deforested this soil retention capacity is reduced, allowing the erosion of fertile topsoil. This reduces the productivity of the land and can result in the siltation of riverbeds and reservoirs downstream, thereby affecting hydroelectric projects, fisheries and agriculture.

Forests also play a role in providing fresh water supply. The destruction of watersheds can therefore be devastating, especially to rural poor communities that rely on natural resources for their basic requirements (Bann, 2003).

The hydrological services of forests, chiefly water quality and water flow, are among the most valuable of the many ecosystem services from forests. An ecosystem approach to watershed management seeks to achieve water management objectives by conserving forest and wetland habitats, creating buffer zones along rivers and streams, shifting away from farming and road-building on steep slopes, and avoiding agricultural chemical use in sensitive areas.

The scope for using financial incentives to encourage the conservation of forest watersheds is potentially huge for at least two reasons. First, the global market for water is immense and second, investments in sustainable watershed management may be substantially cheaper than investments in new water supply and treatment facilities. It is estimated that the majority of the world’s population live downstream of forested watersheds and therefore are susceptible to the costs of watershed degradation.

Further, at least 13 percent of the world’s land area is needed to protect water supplies for the global population — an area that will grow with the population. By investing approximately $1 billion in land protection and conservation practices New York City hopes to avoid spending $4-6 billion on filtration and treatment plants. In South Africa, restoring native vegetation produces water at a fraction of the cost of water delivered through diversion or reservoir projects (Johnson et al. 2000).

- **Flow Regulation**

A forest intercepts rainfall and, with a generally large capacity for water absorption and retention, may convert irregular precipitation into a more even flow of water from a catchment area. The more complex structure of the forest ground surface and underlying soil allows more efficient soil infiltration compared to a deforested watershed. By slowing the rate of runoff, forests can help to minimize flooding in smaller watersheds. A forest may also act as a slow-release reservoir, increasing dry-season base flow from a catchment.

- **Reduced Soil Erosion**

Interception of rain and snowfall by forest canopies means that less water falls on the ground compared to a deforested watershed. Understory forest vegetation and leaf litter protect the soil from the impact of rain that does fall through the canopy. Extensive root systems help hold soil more firmly in place and resist landslides compared to clear-cut or heavily disturbed watersheds. Sedimentation levels in waterways of forested watersheds are generally lower than in nearby agricultural or urbanized watersheds, but the degree depends on soil types, topography, and climate (Johnson et al. 2000).

Soil erosion could also be measured by the cost of replacement approach (i.e., the cost of fertilizer required to restore nutrients lost due to soil erosion). The replacement cost method is also useful for estimating flood protection and water regulatory services supplied by the forested watershed which provides natural barrages (e.g., the costs of building flood prevention structures to prevent such damage).

Another example is that soil erosion can result in sedimentation of downstream reservoirs. Sedimentation in reservoirs reduces the water storage capacity of the reservoir, impacting its function as a supply of water for agriculture irrigation and power generation. To estimate the loss in reservoir benefits associated with increased sedimentation, data on annual erosion rate in the watershed, channel and bedload erosion, and the sedimentation delivery rates are needed. The base case would first estimate the effects of existing erosion rates. With increased loss of forest cover, erosion and sedimentation would increase. Costs associated with this increased rate of erosion are the effects on downstream structures and water users affected by the increased sedimentation. Increased costs associated with the increased erosion and sedimentation rates could then be used to value the forest's watershed function of the forest (Bann, 2003).

- **Maintenance of Water Quality**

Rain falling on a forest is intercepted and filtered through a mass of soil and roots. As a result, water flowing from an undisturbed catchment area is generally high-quality. Disturbance to the catchment and changes in land use can lead to sedimentation and nutrient pollution. This can affect water availability and associated benefits, such as fisheries. The quality of water for human consumption, agricultural use and industrial use also can be affected (Powell et al. 2002). For example, streams in agricultural areas in temperate regions typically have nitrate levels 10 times higher than streams in nearby forested watersheds (Johnson et al. 2000).

- **Water Table Regulation**

Forests can play an important role in water table regulation. Over time, equilibrium develops between vegetation and the water table. Deforesting a catchment may lead to greater infiltration high in the catchment and rising water tables lower down. This may bring salt water nearer to the surface and affect crops and water quality. Conversely, in other watersheds, water table replenishment may be disrupted. Deforestation can lead to falling water tables if denuded land becomes heavily eroded or compacted and water runs off before it can infiltrate (Powell et al. 2002).

- **Precipitation**

Forests may influence precipitation at a large regional scale. The distribution of forests is a consequence of climate and soil conditions, and vice-versa. Evidences suggest that large-scale deforestation has reduced rainfall in China and some climate models indicate extensive forest losses in the Amazon and Central Africa could lead to a drier climate. Therefore, forestation and reforestation are effective strategies to increase rainfall.

The conservation of ecosystems is often seen as a cost to society rather than as an investment that sustains nature and human livelihoods. For example, natural forest and wetland ecosystems filter and purify water while absorbing rain and snow melt for gradual release. When these ecosystems become degraded, large investments in water treatment plants, dams, and flood control structures may be needed to replace these lost ecosystem services. Despite the economic value of these services, ecosystem protection is chronically under-funded. By understanding the financial value of these services and investing in their conservation it may be possible to save money spent to replace lost services and to increase investments in sustainable forest management.

3.2.2 - Biodiversity

Forests provide some of the most biodiversity-rich ecosystems on earth and are believed to provide habitat for an estimated 90 percent of threatened and endangered species. Forests house myriad examples of genetic diversity within individual species. Similarly, ecosystems within forests adapt to local and landscape-level variations in the environment. Ecosystems become resilient to environmental disturbance and stress by maintaining diversity on all levels.

Forest cover plays an important and complex role in sustaining aquatic productivity. Trees shade waterways and moderate water temperatures. Woody debris provides fish with habitat while leaves and decaying wood provide nutrients to a wide array of aquatic organisms (Johnson et al. 2000).

Biodiversity includes direct and indirect use values, option and existence value. The valuation of preferences for biodiversity is perhaps the most challenging issue in the context of economic valuation.

“Biological diversity” (biodiversity) is an umbrella term used to describe the number, variety and variability of living organisms in a given assemblage. Biodiversity may be described in terms of genes, species and ecosystems, relating to the three fundamental and hierarchically-related levels of biological organizations. It therefore embraces the whole of “Life on Earth”. Declines in biodiversity includes all those changes which will reduce or simplify biological heterogeneity, from individuals or regions.

It is hard to use the term biodiversity for valuation. Diversity valuation requires some idea of WTP for the range of species and habitats. In reality, what economic studies are normally measuring is the economic value of biological resources rather than biodiversity.

Biological resources area more anthropocentric term for biota such as forest, wetlands and marine habitats. They are simply those components of biodiversity which maintain current or potential human uses. This anthropocentric view of biological resources is much more convenient for economic analysis compared to alternative value paradigms such as intrinsic values (values in themselves and, nominally unrelated to human use). Intrinsic values are relevant to conservation decisions, but they generally cannot be measured. Studies of biological resources may capture diversity values; for example, studies valuing habitat may capture perceptions of biodiversity (i.e., valuations may be high simply because the area is known to be rich in diversity) but such effects are difficult to assess.

There are other reasons why it is difficult to put a monetary estimate on biodiversity. The lack of consensus on the rate of biodiversity loss and biodiversity indicators, and of any baseline measurements of biodiversity also has important implications for economic valuation. Fundamental to any monetary measure of value is some index or set of indices of biodiversity change.

The projected loss of species over the next century might be as high as 20%-50% of the world's total which represents a rate between 1,000-10,000 times the historical rate of extinction. The implications of species depletion on the functioning of vital ecosystems are not clear. Possible worst case scenarios involve the existence of depletion thresholds and associated system collapse. Such outcomes clearly indicate the interaction between the environment and the economy. More immediately, the loss of biological resources might be apparent in decline in cultural diversity, indices of which are provided in diet, medicine, language and social structure.

- **Valuing Biodiversity**

Contingent valuation approaches are perhaps the most promising in terms of valuing biodiversity. Individuals can be presented with different ranges of species and habitats to see which they prefer. Information is obviously crucial for the success of such approaches. Many scientists believe that biodiversity is fundamental to human well-being while others argue that the functions of diversity are simply unknown. As such, individuals may not be well informed of the potential value of biodiversity.

WTP studies relating to the conservation of biodiversity per se have not yet been attempted in the developing country context. In developed countries, direct questioning on biodiversity preferences has focused on the preservation of well-known or charismatic species and ecosystems. The few attempts that have been made to elicit preferences for less familiar biodiversity have encountered response difficulties when the subject good is difficult to explain or unknown to respondents, or where respondents lack experience of making similar transactions. In any event, contingent valuation studies on the WTP for biodiversity protection do not provide information on the inherent value of biological diversity and are likely to underestimate economic value.

Travel cost and discrete choice studies might also be used for diversity valuation if it is possible to look at choices between alternatives that vary in their degree of diversity.

Even if the intrinsic value of biodiversity cannot be measured, there is still a very good reason for measuring the direct use values of conservation: biodiversity will be more prone to loss when direct use values are not appreciated.

There are many sustainable use values of habitat, such as ecotourism, and the collection of medicinal plants and non-timber forest products which might be valued. In addition, surveys measuring the foregone local use benefit as a result of designating a protected area, or tourists' willingness to pay for park maintenance provide some estimate of conservation values Such conservation studies may include incidental diversity benefits if subjects (biological resources studied) are considered central to the system as a whole. There is then considerable scope for at least securing minimum values for biological diversity through the use of approaches focused on market values.

Methodologies for estimating the economic value of medicinal plants and plant genetic resources for agriculture are presented in more detail as follows (Bann, 2003).

- **The Economic Value of Medicinal Plants**

The potential returns from commercial drugs derived from plant species is one strong argument for identifying and preserving the world's biodiversity (particularly of species rich ecosystems such as forests).

About 25% of all Western prescription drugs and 75% of developing world drugs are based on plants and plant derivatives. The pharmaceutical industry based on natural forest related drugs is estimated to generate about US$ 43 million in annual revenues. Clearly, medicinal plants are relevant to use value arguments for conserving biological resources. How far they have relevance in justifying conservation of biodiversity as such is more problematic.

Quantitative assessment of the medicinal benefits of plant species are highly speculative. Their value typically lies in undiscovered species of unknown uses that might have potential commercial value in the future. A difficulty then in valuing the potential returns from such species is that of assigning values to properties or products that have not yet been identified.

A further consideration is that because of the potentially significant global importance of uniquely rich forest systems, the issue seems to be as much about what other, wealthier, countries are prepared to contribute to conserve biodiversity, as it is about their values within and for the countries where these resources occur. Valuation of such global values are at present highly speculative (Bann, 2003). Table 3.03 brings some values of plant-based pharmaceutical products.

Table 3.03 - Some Values of Plant-based Pharmaceutical (US$ Billion)*

Item	*USA*	*OECD*	*World*
Market value of trade in medicinal plants	5.7 (1980)	17.2 (1981)	24.4 (1980)
Market or fixed value of plant-based drugs on prescription	11.7 (1985); 15.5 (1990)	35.1 (1985)	49.8 (1985)
Market value of prescription and over-the-counter plant based drugs	19.8 (1985)	59.4 (1985)	84.3 (1985)

*Bracketed number refer to year to which estimate relates
Source: Bann, 2003

- **The Value of Plant Genetic Resources for Agriculture**

Genetic and species diversity can be of great benefit to agriculture in offering the possibility for plant improvements and increases in yield, and as a form of “natural insurance” against yield unpredictability of homogenized systems. In terms of assessing the benefits of conserving species-rich forest lands, the question arises whether such functions are maximized as a result of in situ recombination, in farms or in the wild. Related to this question, as for medicinal plants, is the issue of the distribution of benefits resulting from the global adoption of new agricultural varieties originating in developing countries.

Measurements of the benefits of germplasm diversity to crop development are a difficult task. Genetic resources are rarely traded in markets and common landraces based on wild species are often the product of generations of informal and formal innovations by international research centers. Identifying the contribution of an original landrace to the success of a particular modern variety is therefore extremely difficult. Furthermore, the base materials used for breeding are themselves the result of a production process which includes labor and on-farm technology. Attributing the returns to respective complementary inputs with any accuracy, including a return to all historical intellectual inputs, is highly improbable.

Netting out human and technological contributions to agricultural production is complex, since an accurate picture of the contribution of genetic resources requires assessment of the net incremental yield value at every stage of recombination. Information on parentage and genealogy of many common landraces is available at agricultural research centers. However, an accurate catalogue of yield effects of successive breeding stages and the necessary input cost information is not (Bann, 2003).

3.2.3 - Micro Climatic Functions

In principle, the value of forest in terms of micro climate, climate, and the atmosphere could be assessed through the effects on production (or preventive expenditure costs) resulting from climatic and atmospheric changes associated with alterations in the extent or composition of forests. In practice, the relationship between forest changes and atmospheric change is as yet imperfectly understood. For example, it is known that transpiration from forest accounts for a substantial part of the recycling of moisture back into the atmosphere; but empirical evidence as to the impact of disruption of this flow through forest removal is limited and inconclusive. Therefore, valuation of the micro climate benefits of forests is rather speculative.

However, it may be possible to measure the local and immediate effects of forest removal. A falloff in crop yields on adjacent lands, for example, could be assessed in terms of the costs of compensatory inputs of fertilizer, or of the investment in windbreaks that prove necessary to offset the loss of protection previously afforded by the forest.

3.2.4 - Carbon Storage

All forests store carbon. Consequently, clearing and burning of forest releases carbon dioxide into the atmosphere which will contribute to the greenhouse effect and to global warming. Valuing the benefit of the carbon storage function of forests is complicated for a number of reasons:

(i) it is not clear what share of the total emissions of carbon is due to deforestation and how much is due to other sources (primarily fossil fuel use).

(ii)there are a variety of ways in which carbon dioxide emissions could be curbed or reduced (e.g., replacing the forest with carbon dioxide-absorbing plantations or crops, or establishing compensatory fast growing plantations elsewhere). The value of retaining or managing forests as a carbon store would need to be compared to the efficiency of alternate forms of carbon capture or storage, and with the opportunity cost of not exploiting other forest values such as timber.

(iii)the scientific evidence on climate change and the likely impacts of rising carbon dioxide levels in different parts of the world is not yet clearly understood.

Notwithstanding these issues, methodologies for valuing the carbon storage function of forests and some estimates of this value are available.

A methodology for deriving carbon credits, or credits that should be ascribed to an intact forest is summarized below.

To derive a carbon credit, the following must be known: (i) the net carbon released into the atmosphere when forests are converted; and, (ii) the economic value of one ton of carbon released.

- **Estimating Carbon Released Through Forest Land Conversion**

One important consideration is that carbon is released at different rates according to the method of forest clearance and the subsequent use of the land.

If the forest is burned, CO_2 is immediately released into the atmosphere, while some remaining carbon is locked in ash and charcoal. This charcoal and ash will typically decay over a 10-20 months, releasing most of its carbon into the atmosphere. Studies on tropical forests indicate that significant amounts of cleared vegetation become lumber, slash, charcoal and ash. The proportion differs for closed and open forest; generally the smaller stature and drier climate of open forests means that a higher proportion of vegetation is burned.

If forest land is converted to pasture or permanent agriculture, then carbon will be stored in the biomass of the grass grown or crops planted. If secondary forest is allowed to grow, carbon will be accumulated, and maximum biomass density is attained relatively quickly.

Table 3.04 presents the net carbon store of land which has been converted from forests (closed primary, closed secondary, or open forests) to shifting cultivation, permanent agriculture, or pasture. The negative figures indicate emissions of carbon. For example, when closed primary forest is converted to shifting agriculture an estimated 204 tC/ha are lost. The greatest loss of carbon occurs when land use is changed from primary closed forest to permanent agriculture. The data suggests that allowing for the carbon fixed by subsequent land uses, carbon released from the deforestation of secondary and primary forest is around 100-200 tC/ha.

Table 3.04 - Changes in Carbon with Land Use Conversion (tC/ha)*

Original Use	*Original C*	*Shifting Agriculture*	*Permanent Agriculture*	*Pasture*
Closed Primary	283	-204	-220	-220
Closed Secondary	194	-106	-152	-122
Open Primary	115	-36	-52	-52

* Shifting cultivation represents carbon in biomass and soils in second year of shifting cultivation.
Source: Bann, 2003

It should be noted that the above estimates represent the "once and for all change" in carbon storage as a result of land use conversion. Further refinement would require estimating the present value of the carbon releases by discounting future releases of carbon (i.e., if not all the carbon is released in the initial burning of the forest, subsequent burnings and the associated quantities of carbon released over time would need to be accounted for) (Bann, 2003).

- **Estimating the Economic Value of One Ton of Carbon**

The carbon released from burning forest contributes to global warming. There are several estimates of the minimum economic damage caused by global warming (not including catastrophic events). One suggests a central value of US$ 20 of damage for every ton of carbon released between 1991-2000. Another estimates the damage from a rise in sea level due to global warming at US$13 per ton of carbon.

Taking US$20 as an estimate of damage and applying this figure to the data in Table 3.04, the cost of global warming damage as a result of converting an open forest to agriculture or pasture is estimated at US$600 - US$ 1,000 per hectare. Similarly, conversion of closed secondary forest would cause damage of US$ 1,000 - US$ 3,000 per hectare; and conversion of primary forest to agriculture US$ 4,000 - US$ 4,400 per hectare. These figures allow for carbon fixation in the subsequent land use.

These damage estimates (carbon credits) can be compared to the development benefits of land conversion. For example, it is reported a value of US$ 300 per hectare of forest land in the Brazilian Amazon. In this case, carbon credit values are two to fifteen times the price of land. These carbon credits also compare favorably with the value of forest land for timber. In Indonesia for example, estimates are US$ 2,000 - US$ 2,500 per hectare

3.2.5 - Soil Nutrient Cycling

Some studies have used the replacement cost approach to value the soil nutrient cycle function of forests. For example, the benefit of naturally-occurring soil nutrient cycling by examining the costs of replacing such nutrients with commercially available plant fertilizer.

It is suggested that the social costs associated with the leaching of nutrients due to the conversion of forest pasture in the Eastern Amazon can be valued at US$ 3,480 per hectare per decade. In this case, one of the benefits provided by intact forest is measured in terms of the cost of replacing the nutrients lost through conversion and subsequent ranching activities.

In the eastern Amazon case the net present values for ranching (for a comparable period of time as the nutrient loss) are estimated to vary from US$ 5/ha to US$ 541/ha, depending on the size of the ranch and the management regime employed. Such a discrepancy between the value of production realized under ranching and the social costs of nutrient leaching may indicate the need for reassessment of the assumption that the level of benefits is being reproduced exactly by replacement activity.

3.2.6 – Urban Values

Many important decisions in cities are based on careful cost and benefit analysis of options. Yet the values of trees and plants in our urban centers are often overlooked. Urban forests are a significant and increasingly valuable asset of the urban environment. Scientists have measured the tremendous returns that trees provide for people in cities. A complete assessment of both benefits and costs is challenging. Nonetheless, full understanding of this information is valuable if decision-makers wish to make cost effective policy and budget decisions. Investments in the planting and care of trees represent long term commitments of scarce dollars; improper plantings will increase costs and reduce benefits. Adequate resources for both planning and management of urban green is necessary if cities wish to optimize the values and benefits of the urban forest (University of Washington, 1998).

- **Environmental and Energy Savings**

City-wide, the amount and quality of trees influence both biological and physical urban environments. Plants, if strategically placed and cared for, can become a “living technology,” a key part of the urban infrastructure that contributes to more livable urban places.

A 8 meter tree reduces annual heating and cooling costs of a typical residence by 8 to 12%, producing an average US$10 savings per household. Also, buildings and paving in city centers create a heat island effect. A mature tree canopy reduces air temperatures by about 5 to 10°C, influencing the internal temperatures of nearby buildings.

A typical person consumes about 175 Kg of oxygen per year. A healthy tree, say a 10 meter tall Ash tree, can produce about 118 Kg of oxygen annually – two trees supply the oxygen needs of a person each year. Also, cooler air temperatures created by tree canopies reduce smog levels by up to 6%, producing savings in air clean-up campaigns.

Finally, a mature tree absorbs from 55 to 110 Kg of the small particles and gases of air pollution. In the city of Sacramento, United States, for instance, this represents a value of US$ 28.7 million.

The canopy of a street tree intercepts rain, reducing the amount of water that will fall on pavement and then must be removed by a stormwater drainage system. In one study, 10 meter tall street trees intercepted rainfall, reducing stormwater runoff by 121 liters. Savings are possible since cities can install surface water management systems that handle smaller amounts of runoff (University of Washington, 1998).

- **Financial Values**

Weyerhauser surveyed real estate appraisers, and 86% of them agreed that landscaping added to the dollar value of commercial real estate. About 92% also agreed that landscaping enhances the sales appeal of commercial real estate.

One study looked at 30 variables - architecture and urban design - of potential importance in determining office occupancy rates. Results suggest that landscape amenities have the highest correlation with occupancy rates, higher even than direct access to arterial routes.

House prices are also influenced by the presence of trees. Developers can maximize profits by retaining existing trees or replanting an urban forest after construction is completed.

Several studies have analyzed the effects of trees on actual sales prices of residential properties. Homes with equivalent features – area, number of bathrooms, location - are evaluated. In one area a 6% increase in value was associated with the presence of trees; an increase of 3.5 to 4.5% was reported in another study.

A team of researchers compared tree size and public valuations of homes. Tree size did not affect the judgments of price for low price homes, but did affect values of more costly houses. For more expensive homes, small and medium-sized trees enhanced the public’s perception of real estate value.

Using a scale model of a land parcel, researchers found that there was a 30% difference in appraised value based on the amount and variation of tree cover. Taking into account the potential value of a house built on the site, the value increase would be close to 5%.

Businesses work hard to offer products and services that meet their customers’ needs. The presentation or image of shops and business districts is also important. Trees help create a positive environment that attracts and welcomes consumers.

In a survey of one southern community, 74% of the public preferred to patronize commercial establishments whose structures and parking lots are beautified with trees and other landscaping (University of Washington, 1998).

3.3 - Option Value

Option value is a type of use value in that it relates to future use of the forest. Option value arises because individuals may value the option to be able to use a forest some time in the future. Thus there is an additional premium placed on preserving a forest system and its resources and functions for future use, particularly if one is uncertain about the future value but believe it may be high, and if current exploitation or conversion may be irreversible.

For example, forest resources may be underutilized today but may have a high future value in terms of scientific, educational, commercial and other economic uses. Similarly, the environmental regulatory functions of the forest ecosystem may become increasingly important over time as economic activities develop and spread in the region.

A special category of option values are bequest values, which result from individuals placing a high value on the conservation of forests for future generations to use. The motive is the desire to pass something on to one's descendants. Bequest values may be particularly high among the local populations currently using or inhabiting a forest in that they would like to pass on to their heirs and future generations their life and culture that has co-evolved in conjunction with the forest.

Option and bequest value is difficult to assess as it involves some assumptions concerning future incomes and preferences, as well as technological change (Bann, 2003).

3.4 - Non-Use Value

Non-use values are derived neither from current direct nor indirect use of the forest. There are individuals who do not use the forest but nevertheless wish to see it preserved in their own right. These intrinsic values are often referred to as existence values. Existence value is derived from the pure pleasure in something's existence, unrelated to whether the person concerned will ever be able to benefit directly or indirectly from it. Existence values are difficult to measure as they involve subjective valuations by individuals unrelated to either their own or others use, whether current or future. However, several economic studies have shown the existence value of forests to constitute a significant percentage of total economic value (Bann, 2003).

3.5 - Case Study: Nigeria, Shelterbelts and Farm Forestry

This study is a cost benefit analysis of the tree planting program already underway in the arid zone of northern Nigeria. Unsustainable use of fuelwood in the area (used by 90% of the population for cooking) is leading to a sharp decline in farm tree stocks, increased encroachment by farmers on public reserves, and the non-sustainable harvesting of trees in the more humid southern belt. These activities are reducing soil fertility through gully erosion, loss of top soil, surface evaporation, reduced soil moisture, and the use of dung and residues for fuel rather than fertilizer.

The two main components of the forestation project are shelter belts and farm forestry. Shelterbelts consist of lines of trees (usually *Azadirachta indica*) arranged in 6 to 8 rows up to 10 km long. Farm forestry is undertaken by farmers on their own land, and typically 15-20 trees/ha are planted with the aim of providing useful products (fodder, fruit, fuel, shelter) for the household.

The analysis compares the financial and economic returns to shelterbelt and farm forestry projects to a 'without project' base case. The benefits from forestation include halting declines in soil fertility, increasing soil fertility as a result of improved moisture retention and nutrient recycling, increased outputs of livestock products, and the value of tree products.

The benefits of livestock and tree products are valued directly by multiplying increase in quantity by the market price to derive their financial value and then adjusting this to reflect the economic value as appropriate. The value of wood and fruit from the new trees is estimated to be US$ 22 per hectare for the shelter belts and US$ 7 per hectare for the farm forestry, net of labor costs.

Estimation of the environmental benefits of the rural forestation program are undertaken using the production function approach. The two main steps to this approach are discussed as follows (Bann, 2003).

- **Estimating the Effect of the Forestation Program on Soil Fertility**

Estimates of the changes in soil fertility due to the forestation program were difficult to make due to insufficient data on soil fertility and on the direct and indirect impact of tree stock decline on soil erosion. Through discussions with agronomists and other soil experts, a rate of soil fertility decline of between 1%-2% per year was adopted in the analysis. These rates are applied to the gross value of farm output but not to costs (costs could increase over time if it becomes harder to work the land).

Following a review of the international research on the topic, it is assumed that the shelterbelts would increase the net yield of crops in the area by 15%-25%. The main mechanisms for this would be increased soil moisture retention and reduced crop losses from wind due to reduced wind speeds. For farm forestry, the increased yield is taken to be a more modest 5%-10%.

In the with project case the decline in soil fertility is gradually stemmed and soil fertility is enhanced as the forestation program begins to take effect (after 7-10 years for shelterbelts and 7-15 years for farm forestry). These “with project” benefits are compared with the assumed trend “without”, which is a decline in soil fertility of 0%-2% per annum. This decline would be halted after 8 years with the project.

The benefits derived from changes in soil fertility are calculated by estimating the value of the changes in agricultural output. The estimates of financial and economic values of crop output under the three systems are made from traditional agricultural cultivation on a typical three-hectare farm, using information from local surveys undertaken during preparation of rural development projects and border price information from World Bank data.

The main investment costs of the program included in the analysis are:

(i) fencing and planting expenses -- $150/ha for shelterbelts and $40/ha for farm forestry;

(ii) the opportunity cost of the farm land occupied by trees, taken to be proportional to the area taken up by the trees -- 12% for shelterbelts, 2% for farm forestry;

(iii) other farm forestry costs (e.g., setting up seedling nurseries, distributional facilities and an extension network).

- **Results**

For shelterbelts, a base rate IRR (Internal Rate of Return) of about 15% was estimated. Sensitivity analysis on yield costs, and underlying erosion produced a IRR within the range of

13%-17%, while a consideration of the wood benefits only showed an IRR of 4.7%. The base case for the farm forestry program was an IRR of 19%, with a range of 15%-22% in the sensitivity tests. The IRR for wood and fruit benefits was 7.4%.

The timing of benefits is significant to the results. After Year 17, net farmer income without the shelterbelt program declines to zero and it is assumed that the land is abandoned at this point. However, for the first 9 years of the shelterbelt program, gross farmer income with the project is less than 'without', because of the effect of taking land out of production to plant the trees.

Traditional Cost Benefit Analysis (CBA) typically does not provide an economic justification for planting trees. This is because the environmental benefits are normally omitted and trees grow so slowly their benefits arise a long time into the future. Applying conventional discount rates to their stream of benefits tends to yield a low economic rate of return. As a result, forestation schemes are usually undertaken in response to tax incentives, or are subject to special low discount rates (exceptions include rapidly growing species and trees planted for social and amenity purposes).

However, an environmental CBA can show very different results if it attempts to place economic values on the full range of forest benefits excluded in traditional CBA (e.g., indirect benefits of shade, windbreaks and soil retention). The above study was one of the first to demonstrate that forestation can be justified according to conventional cost benefit criteria when the wider non-timber benefits of the forest are considered, despite the lags involved in the appearance of benefits. Merely considering wood benefits would not justify proceeding with the scheme.

The study is also an example of using the production function approach to estimate tree planting's soil fertility maintenance function. The estimates are based on a number of assumptions sensitive to local conditions and project parameters. These cannot be uncritically transferred from elsewhere and the study indicates what kind of information needs to be collected for appraisal purposes, and the importance of such analysis to the final results.

4 - METHODS

4.1 – Forestation and Reforestation

According to the Clean Development Mechanism (CDM), forestation is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources; reforestation is the direct human-induced conversion of non-forested land to forested land through planting, seeding or human-induced promotion of natural seed sources, on land that was forested until 50 years ago but that has been converted to non-forested land.

Forest is a minimum area of land of 0.01 hectare with tree crown cover of more than 30 per cent with trees with the potential to reach a minimum height of 4 meters at maturity in that site. A forest may consist either of closed forest formations, where trees of various storeys and undergrowth cover a high proportion of the ground, or open forest.

4.1.1 - Function and Place of Trees and Shrubs

- **Introduction**

Trees and shrubs play a vital role in maintaining an ecological balance and improving the livelihood of people. If this role is to be developed and expanded, the function and place of trees and shrubs in the rural landscape must be analyzed and understood.

- **Function of Trees and Shrubs**

− *Overview*

Trees and shrubs can act as soil stabilizers and prevent water and soil erosion. Woody vegetation protects the soil better and lasts longer than annual plants. Its roots deepen and improve the soil, and the shade it provides facilitates ecosystem metabolism. These functions are essential for ensuring the soil stability and the continuity of agricultural activities.

They are an important source of forage for livestock and wildlife at a time when herbaceous fodder is not available. A number of multi-purpose trees and shrubs are ideal for protecting and improving the soil, while providing a high fodder yield in the dry months without impairing agricultural production in the rainy season.

They are a source of wood products, including fuelwood, poles, and lumber. Fuelwood is almost the only domestic fuel in most poor countries, not only in the rural areas but in some urbanized areas as well. Wood is also used as a construction material.

They are a source of foodstuff for the population. Many fruits, leaves, young shoots, and roots provide valuable food in the dry season and, therefore, comprise an important reserve for emergencies.

They are a source of non-woody products. Many trees and shrubs yield products which are important for everyday use by the inhabitants, for industry, and at times, for export. For example, a variety of tree and shrub species are characterized by a high content of tannin (utilized by the leather industry) in their bark or fruit. Other trees and shrubs yield fibers, dyes, and pharmaceuticals. The pollen of many trees and shrubs is used for honey production (beekeeping).

Due to unrestricted cutting of wood of vegetation, overgrazing by livestock, and cultivation of unsuitable lands, many arid zones have an inadequate forest cover and, therefore, inadequate timber, fuelwood, and fodder resources.

Development programs in arid regions should include a forestry component. This component should not be seen separately but must be integrated with agriculture and animal husbandry to optimize land use. The elements for such integration are explained in the following items (FAO, 1989).

− *Fuelwood*

Forest plantations are often proposed for the production of fuelwood. The production of fuelwood can be crucial to people, because over 50 percent of the wood removed from the world's forests is used for fuel and 90 percent of the inhabitants of developing countries rely on it for their domestic needs; these people simply cannot afford other sources of energy.

Fuelwood is a marketable commodity that is transported over long distances. Demands for fuelwood and charcoal are increasing, and wood is likely to continue to be an important source of domestic fuel and fuel for small-scale industrial use in rural and urban areas. Most of the fuelwood still comes from natural forests and woodlands that are being cut down and destroyed at alarming rates. However, fuelwood can also be grown on an intensive and sustained scale in forest plantations.

Scarcity of fuelwood can create further problems. People frequently turn to the next available fuel, such as agricultural residues and dung, instead of using these materials to maintain the soil fertility of agricultural land. Furthermore, a change in availability of fuelwood will often affect the health and nutrition of a whole family, which will use more fast-cooking foods and have less money for food as fuel prices increase. Also, fuelwood scarcities affect several aspects of family life, as more time must be spent in fuel gathering at the expense of more productive work.

To meet the increasing demand for fuelwood, land must be set aside to secure a production base, either as well-managed natural stands or in forest plantations. Large-scale fuelwood plantations may be required to supply urban areas, including industrial operations. For rural areas, which are under less population pressure, small-scale forestry activities may be sufficient to meet the demand for fuelwood. It is this latter type of plantation which is usually required in arid zones (FAO, 1989).

– *Fodder*

A significant role of woody vegetation in arid zones is its contribution to a pastoral economy by providing arboreal fodder. The protein from ligneous vegetation during the dry season constitutes an essential element in the animal diet. Among the various sources of feed (concentrates, cereals, and annual fodder crops), woody vegetation is generally the cheapest and the one on which the majority of the livestock rely.

The role of woody vegetation in fodder production can be examined in three situations:

(i) Normal Scarcity Situations: During the dry season (when grass and forte vegetation is not available), only trees and shrubs can provide the necessary feed for livestock; this is a traditional use of the woody vegetation in arid regions. When such vegetation is not available, the production of livestock can be seriously affected, as people do not normally have the resources to acquire other types of feed for their animals. The creation of fodder resources for scarcity situations is, therefore, a vital activity for maintaining the production of animals. Overall fodder resources can be enhanced by managing existing woody vegetation for increased fodder production or by creating additional fodder resources through tree and shrub plantations.

(ii)Emergency Situations: Rainfall in arid zones is not only variable during the year, but there is considerable annual variation and, at times, extended periods of drought. Under this situation, trees and shrubs assume greater importance in the form of emergency fodder reserves for livestock, since ligneous vegetation is better able to survive extended periods of drought than annual plants.

(iii)Contribution to the Feed Budget: The most intensive method of fodder production may be the creation of year-long forage plantations on convenient sites to improve animal production. Forage species can be grown in pure stands, harvested in a controlled way, and then fed to livestock. Where grasses are grown, livestock could be moved between the different areas of production to enable optimal use of both types of forage. Another possibility is to establish two-storied pastures, with suitable browse species over an understorey of grasses or fortes and legumes (FAO, 1989).

– *Improvement in Agricultural Production*

The productivity of agricultural land in arid zones is inherently low and the risk of failure is high. This is due not only to the minimal and unreliable rainfall, but to the effect of wind and water erosion and low soil fertility, as described below:

(i) Wind Erosion: In most of the arid zones, wind erosion is a serious problem. The destruction of the vegetative cover exposes the soil to the desiccative effects of hot, dry wind, resulting in dust storms, the formation of sand dunes, and other forms of severe wind erosion. Winds are not only responsible for the transport of soil particles, but through their desiccating effect, they prevent the growth and development of food and animal production. In irrigated agriculture, wind, by increasing evaporation, facilitates the upward movement of salts and their subsequent concentration in the rooting zones of agricultural crops. Particles of dust and sand carried by wind can be deposited in irrigation channels and drainage ditches, increasing the maintenance costs of irrigation. Such damage can be diminished by the establishment of windbreaks and shelterbelts.

(ii) Water Erosion: Erosion by water is an important phenomenon in most of the arid zones; this type of erosion is the result of the susceptibility of the soil to high rainfall intensities, and the frequent destruction of the vegetative cover. When these conditions occur, considerable amounts of soil are washed down from catchment areas. Roads are damaged, lowlands are flooded, and streams are filled with muddy water. Some of this sediment-laden water accumulates in reservoirs or is transported to lakes or the sea. The loss of water through runoff and the ensuing soil erosion can be controlled by adopting preventive soil conservation measures. The role of vegetation in reducing siltation of dams, regulating stream flow and preventing floods and soil erosion is invaluable.

Figure 4.01 - A Watershed Protected Against Erosion by a Dense Vegetation Cover

(iii)Soil Fertility: Agricultural production in arid zones is frequently hindered by poor soil fertility. However, the importance of soil fertility is often overlooked; water shortage is considered the principal constraint. Whereas the conventional method to improve soil fertility commonly consists of repeated application of mineral fertilizers, this problem may also be solved through the systematic use of soil-improving species (FAO, 1989).

- **Place of Trees and Shrubs in Rural Landscapes**

To grow trees or shrubs (in any form) is a forestry practice; forestry, in turn, is a land use exercise. Pressure on land for agriculture is high in arid zones, so high that land unsuitable for agriculture is sometimes used in a desperate effort to grow agricultural crops. As a result, forestry can be relegated to lands which are too poor for plant growth.

There is a generally-held misconception that forestry is best suited to poor sites. However, it must be realized that forestry, like agriculture, places demands on the land to reach satisfying production levels. Two basic requirements are needed: (i) trees and shrubs should not be confined to areas designated as "marginal", and (ii) forestry should be integrated in the overall land use.

There are several ways to plant trees and shrubs in the rural landscape, including:

(i) Trees in rows (windbreaks and shelterbelts) to protect crops and pastures against wind and desiccation.

(ii)Trees intermingled with agricultural crops to protect the crops and to reconstitute and enrich the soil.

(iii)Trees and shrubs grown during the fallow period to enrich the soil, and to provide fuel, fodder, and secondary forest products.

(iv)Linear plantations along roads and waterways to protect infrastructures and adjacent fields, and to provide shade and contribute to the production of fuelwood, fodder and non-woody products.

(v)Woodlots established under rain-fed or irrigated conditions to make the best use of unused land, and to contribute to needed wood supplies.

(vi)Intensive management of natural forests and woodlands to maintain a stable environment and yield essential products traditionally used by the local population.

(vii)Areas threatened by sand dune encroachment can be stabilized by making use of trees and shrubs.

Within the above, it is possible to select the most appropriate combination of land uses to: (i) improve agricultural and livestock production; (ii) stabilize and enrich the environment; (iii) meet essential needs for fuelwood, farm timber and non-wood products for the rural population.

The introduction of trees and shrubs into rural landscapes can improve the living conditions and the rural economy, and contribute to rural development (FAO, 1989).

- **Combined Production Systems**

In combined production systems, agriculture, livestock production, forestry, and combinations thereof are practiced on the same piece of land, either in rotation, simultaneously, or spatially. Such combinations, also called "agroforestry", can involve agricultural crop production or animal husbandry, within which trees or shrubs play a significant role. The basic aim of agroforestry is to attain ecological stability and, at the same time, to provide maximum short-term and long-term benefits to the user of the land.

Agroforestry in rotation involves the alternation of agriculture, livestock production, and/or forestry practices through time on the same piece of land. When combinations of these land uses are implemented at the same time on the same piece of land, agroforestry is considered to be practiced simultaneously. Where the land use practices are placed side-by-side, as they are in the case of windbreaks and shelterbelts, agroforestry is spatially practiced. All three practices are legitimate types of agroforestry, and each should be followed where most appropriate.

Depending on the land use, three "types" of agroforestry can be distinguished; namely:

(i) Agrisilviculture: where the land use is agriculture and forestry production.

(ii)Silvipasture: when the land use is forestry and animal husbandry.

(iii)Agrosilvipasture: where the land use is agriculture, forestry, and animal husbandry.

The elements for each type are outlined in the following items (FAO, 1989).

− *Agrisilviculture*

Agrisilviculture is a land use system where both agricultural crops and forest products are produced, simultaneously or sequentially. This form of land use represents an improvement on the traditional system of "shifting cultivation", a method of cyclical agricultural cultivation in which farmers cut some or all of the tree crop, burn it, and raise agricultural crops for one or more years before moving on to another site and repeating the process.

Agrisilviculture is ecologically sound, provided that the fallow period is long enough to allow the trees to restore soil fertility. To shorten the fallow, trees or shrubs can be planted or sown instead of allowing the forest to establish itself by natural regeneration when the shifting cultivator abandons the land (FAO, 1989).

− *Silvipasture*

Silvipasture, practiced when the land use is primarily the growing of forest products and the raising of livestock through grazing, involves controlled grazing of forest vegetation. Arid zones are generally livestock raising areas, where silvipasture is a dominant land use system. The vegetative resources of these vast low-yield areas are frequently best utilized through grazing. Under this system, the main source of fodder for livestock consists of natural vegetation, including grasses and other forage plants, and trees and shrubs.

At times, silvipasture involves the controlled grazing of forest vegetation, but it must be realized that there is a limit to the number of cattle the land can support. Proper management of the vegetation resources to prevent overgrazing is vitally important. Sometimes, introducing trees and shrubs in natural grasslands can be feasible, since a combination of trees, shrubs, and grasses offers optimal benefits. Individual trees on grazing lands offer the additional benefit of providing shade and shelter for the animals. Animals droppings that collect under these trees can be of further benefit in enriching soil fertility.

Figure 4.02 - Trees for Shade for Animals

To avoid problems of overgrazing, an effort must be made to equate the number of grazing animals to the carrying capacity of the land. Efforts to improve the grazing land's capability should be introduced at the same time, although there is no point in undertaking improvements where livestock numbers cannot be controlled.

Because periods of drought are impossible to predict and will always occur, silvipastoral systems must have a "built-in" component to handle a drought, such as the establishment of fodder-producing trees and shrubs (FAO, 1989).

− *Agrisilvipasture*

As the name indicates, this land use system is a combination of agricultural and silvipastoral practices. The land use can be a mixture of agriculture and livestock raising, relying heavily on fodder from tree and shrub species. Agrisilvipasture should be practiced in areas that can support agriculture. Quite often, agrisilvipasture can take place in a valley, where agriculture is practiced on the valley floor and silvipasture is employed on the forest-covered slopes around the valley. Agrisilvipasture also can be practiced on the same piece of land, but not always at the same time. In some cases, fields in which trees or shrubs are growing can be farmed only during certain periods of the year, and grazed during other periods (FAO, 1989).

4.1.2 - Techniques of Nursery Operations

Nurseries are places where seedlings are raised for planting purposes. In the nursery the young seedlings are tended from sowing to develop in such a way as to be able to endure the hard field conditions. Whether local or introduced species, nursery seedlings are found to have better survival than seeds sown directly in the field or through natural regeneration. So nursery seedlings become the planting material for plantations, whether these plantations are for production, protection or amenity. Nurseries are of two types:

(i) Temporary Nurseries: These are established in or near the planting site. Once the seedlings for planting are raised, the nursery becomes part of the planted site. There are sometimes called "flying nurseries".

Figure 4.03 - A Temporary Nursery

(ii)Permanent Nurseries: These can be large or small depending on the objective and the number of seedlings raised annually. Small nurseries contain less than 100,000 seedlings at a time while large nurseries contain more than this number. In all cases permanent nurseries must be well-designed, properly sited and with adequate water supply.

Seedling production is a major expense of forestation/reforestation projects, and every effort should be made to produce good quality seedlings at a reasonable cost. To this end mastering the techniques of nursery operations is essential. This chapter will review the various operations involved in the production of seedlings (FAO, 1989).

Figure 4.04 - A Permanent Nursery

- **Choice of Site for the Nursery**

When the site of the nursery is to be selected, four questions arise:

(i) What is the type of the nursery? Is it temporary or permanent?

(ii)What is the size of the nursery? Is it large with 100,000 seedlings per year and more, or is it small with 50,000 seedling capacity per year or less.

(iii)Seedling demand. How big is the seedling demand? For example, a nursery surrounded by several development projects may demand huge amounts of different seedlings every year, whereas a nursery for small community woodlots may have a low annual seedling production.

(iv)Transport or distance from the nursery to places of seedling demand.

When these questions are answered, the nursery is sited where: (i) Good water supply source is available, e.g. near a river or a well. Because water is very crucial to the nursery, this is a determining factor. (ii) Good soil source is available; as soil is bulky, it is needed in great quantities. Site soil must be at least free from salinity and alkalinity. (iii) Also the site must be well drained to avoid waterlogging and be fairly safe from flood hazards. (iv) Shelter against prevailing winds: sites which have a natural shelter by vegetation or any other formation are preferred to exposed sites. If the site is exposed then it must be sheltered artificially. (v) The site must have good access roads to places of seedling demand. This will ensure that seedlings can reach the site in good condition. Bad roads and long journeys reduce seedling survival to a great extent. (vi) The nursery must be sited where labor is available or can be easily obtained and accommodated. Nursery work is labor-intensive and placing nurseries far away from habitation centers will be very costly (FAO, 1989).

- **Design of the Nursery**

Having decided on the site and size of the nursery, the site is carefully leveled, fenced, and shelter from the prevailing wind is established.

The nursery must be well designed. The nursery is divided into a suitable number of blocks. These blocks contain adequate roads among them. Blocks are normally labeled by letters, e.g. A,

B. C, etc. or by Roman numbers: block I, block II, block III, etc. Roads between the blocks should be wide enough to provide space for on-loading and offloading and contain turning space with a minimum width of 5 meters.

Each block is further divided into 4-8 sections with paths among them. Sections are labeled by their respective block label followed by a small letter, e.g. Section Ia denotes the first section from the left hand corner of block I.

Each section is further divided into beds. The bed is the smallest unit in the nursery design. Beds are normally one meter wide and their length may vary from 6-10 meters. Beds may be sunk in the ground at a depth of 30-35 cm below general ground level. In this case they may be laid with concrete, stone or bricks.

Also beds may be designed slightly higher than the general ground surface. In this case, the beds are surrounded by stakes, bricks or stones. In every case drainage in these beds is very important for seedling development and for nursery hygiene.

Beds are labeled by their blocks and section followed by Arabic figures, e.g. bed No. Ia1 denotes the first bed in section (a) of block I. Beds are separated by paths one meter wide to facilitate work and transport of seedlings by hand or wheelbarrow, watering and tending of seedlings.

In addition to these, the nursery design should contain adequate space for soil mixing (at least 5 x 5 meters). It should also contain a separate area for making compost. This is better placed slightly away from the nursery beds.

– *Size of the Nursery*

The size of the nursery area stacked with containers and the total nursery area will vary with the diameter of the containers. For example, for containers with a diameter of 5 centimeters, 240 square meters of beds are required. To estimate the total nursery area, the area of seedbeds is multiplied by 2.5, to include road and service areas, and 100 square meters are added (for paths), based on the production of 2,000 seedlings per square meter of seedbed. Therefore, in general: the total nursery area = (2.5 x area of seedbed) + 100 square meters and, for this example: the total nursery area = (2.5 x 240) + 100 square meters (FAO, 1989).

– *Nursery Water Supply*

Two aspects should be emphasized: (a) water quality; and (b) daily water requirement.

(i) Water Quality: It must be slightly acidic with a pH less than 7, with dissolved salts less than 550 parts/million, and with a conductivity less than 0.8 mho/cm. Generally fairly sweet and clear.

(ii) Water Quantity: Adequate water of the above description should be supplied daily to the nursery.

The amount of water applied (at any one time) will vary with the weather conditions, the soil infiltration rate, and the size of the plant. During the period of germination, frequent light watering is required to keep the seedbeds moist, but not saturated. As plants become larger, the total quantity of water applied is increased and the frequency of application is reduced.

As a guide to estimate the quantity of water to apply in one month, the following calculation can be made: water quantity = water loss factor x E x area of seedbed where: water loss factor = values between 1.2 and 1.4, averaging 1.3 (E = monthly evaporation).

For example, assuming a water loss factor of 1.3, for a monthly evapotranspiration (E) of 0.2 meter and a seedbed area of 10,000 square meters, the water requirement for one month is: water quantity = 1.3 x 0.2 x 10,000 = 2,600 cubic meters

Watering can be either by hand or through irrigation. Hand watering with cans, hoses fitted with spray-nozzles, or knapsack mist sprayers are methods used by small nurseries. For watering containers or seedbeds in which seeds have been sown, a fine droplet size is essential. Otherwise, the seeds can be washed out of the ground or the seed covering material can be washed away and the soil surface will be consolidated. Therefore, hand watering of the seedbeds is commonly done with a gardener's watering can or a knapsack pressure sprayer fitted with a fine mist-producing nozzle (FAO, 1989).

- **Collection, Handling, Storage and Pre-Treatment of Seeds**

− *Seed Quality*

Seeds are either collected by the forester or obtained from a known seed source in the country or abroad. In the latter case, the seed must be of good quality: (i) it must be clean from dirt, debris and chaff; (ii) it must be free from pests and pathogens; (iii) it must have a high percentage of germination; (iv) it must be accompanied by a note, carrying the scientific name of the species, place of collection, date of collection, number of seeds/unit weight and whether any treatment has been applied (FAO, 1989).

− *Seed Collection*

To ensure good seed quality, fruit collection must be made from trees having the desirable characters. Such trees are labeled and their locality recorded on a map.

The phonology of these trees should be observed as to when they would flower, set fruit, and have mature fruits. Does fruiting take place every year, every two years? Are there any factors affecting fruit production? e.g. drought, defoliation by insects, etc.

(i) Nature of fruit: dehiscent or intact. Does it remain on the tree or fall to the ground?

(ii)Hazards to the fruits: collected by humans, animals, insects, pathogens, blown by wind?

(iii)Collection time and method: well developed and mature fruits contain good seeds. So the collection time is when fruits are fully matured. Fruits are either collected from the tree by beating the tree with a stick, or shaking the crown with a long hook, or by climbing. Some fruits fall to the ground and they are collected. In such a case, the place of collection is cleaned beforehand.

(iv)Treatment of fruits: Collected fruits are cleaned, sprayed against insects and spread on a clean sheet to dry (FAO, 1989).

Figure 4.05 Collection of Seeds

– *Seed Extraction*

This is the process of separating the seeds from the fruit. Therefore, the method of extraction varies with the type of fruit. For example, *Acacia seyal* and *Acacia senegal* legumes dehisce once they are completely dry and a gentle shaking is sufficient to extract the seeds, while *Prosopis* spp. seeds are difficult to extract. The fruit is first pounded to remove the pulpy material, then the remaining part of the fruit is treated with dilute hot hydrochloric acid for 30 minutes; then washed and dried and then pounded again to get rid of the thin cover over the seed. *Eucalyptus* seeds are extracted very easily when fruits become brown on top; they are collected and put in clean open tins to dry, once dried the fruits open, shedding the seeds and chaff. *Hyphaene thebaica* seeds are extracted by sawing-off the shell (FAO, 1989).

– *Seed Drying*

Once seeds are extracted, they are cleaned of chaff and dirt and dried in the sun or in an oven. If seeds are stored wet, molds and pathogens may spoil them (FAO, 1989).

– *Seed Storage*

Seeds, whether bought or collected, must be stored in a proper way until needed. Dry seeds can be safely stored in air-tight polythene bags at room temperature.

When seeds are stored they are normally labeled, given a number and placed in an air-tight bag inside a closed tin. A single tin may contain several bags and a card register system is used to indicate in which tin seeds are stored and how much is left after using a given quantity (FAO, 1989).

– *Seed Viability*

Some seeds lose their viability in a short period, e.g. *Azadirachta indica* seeds lose viability in about 6 months. Therefore it is important to test seeds which are stored to determine their germination percentage and it is useless to store any seeds that fall below 40% germination unless they are very rare or very expensive. The viability can be tested by:

(i) Germination test: Filter paper method - where seeds are small, about 100 seeds are germinated in a petri-dish over a filter paper. Silt test - 100 seeds are sown in a container with silt soil.

(ii)Tetrazonium chloride test: This is a chemical that imparts color to living tissue. The seed is cut and the liquid is smeared onto the cut surface to find whether the embryo is alive (FAO, 1989).

– *Number of Seeds per Unit Weight*

It is very important to know the number of seeds per gram or kilogram. Because seeds are ordered by weight, unless one knows how many seeds there are per unit weight, one may order too few or too many seeds.

The number of seeds/unit weight for any species is determined by taking about ten random samples of seeds having the same weight, counting the number of each sample and obtaining the mean (FAO, 1989).

- **Seedling Production**

There are many operations involved in seedling production. The most essential ones are described as follows:

– *Nursery Soil Mixtures*

Nursery potting soil should have the following characteristics:

(i) it must be light;

(ii)it must be cohesive;

(iii)it must have good water retention capacity;

(iv)it must have high organic matter;

(v)it must be fairly fertile or made so by the addition of 2 kg NPK/M3 of soil.

In the majority of countries with arid conditions, a mixture of one part sand, one part clay, and one part animal manure would be adequate. This is called 1:1:1 mixture. In the Sahel region, the mixture is formed of one part sand, one part manure and two parts soil. If river alluvium is available, it can be used directly.

– *Nursery Soil Treatment*

Potting soil must be acidic (i.e. pH6). If it happens to be alkaline, it can be acidified by a solution of 2% sulfuric acid. Sometimes nursery soil has to be sterilized against pathogens by use of a 40% solution of formaldehyde applied as 80 cc per 5 liters of water and applied to the soil 7 to 10 days before sowing the seeds. Soil fumigation is also a treatment against fungi by methyl bromide gas.

– *Filling the Pots/Pot Size*

Polythene pots of different sizes are now used for raising nursery plants. This does not preclude the use of other containers like boxes, half tins, earth pots, etc. The pots are filled with nursery soil, taking care to have no voids by shaking and knocking regularly. The pots are filled, leaving a small space at the top, and stacked side by side on nursery beds.

Figure 4.06 - Different Kind of Containers Used for Raising Nursery Stock

Source: FAO, 1989

It is very important to determine the pot size because: large pots require more soil, take a lot of labor to fill and transport; they occupy a large nursery space and require more water in contrast to small pots. But they produce large plants in a short time. The general rule is that "the harsher the planting site, the larger the pot should be".

A comparison between the smallest containers (diameter 5 centimeters, height 15 centimeters) and the largest (diameter 15 centimeters, height 25 centimeters) is quite eloquent. To fill 100,000 small containers, 28 cubic meters of soil are needed; whereas 442 cubic meters of soil are needed for filling 100,000 of the largest containers (16 times more).

– *Pretreatment of Seed*

Some tree and shrub seeds are ready for sowing as soon as they are collected; others pass through a dormant stage, during which time the embryo completes its development. Often, a pre-treatment is used to hasten germination or to obtain a more even germination. The methods of pre-treatment vary with the different types of dormancy of tree and shrub seeds. The main types of dormancy are:

(i) Exogenous dormancy: associated with the properties of the pericarp or the seed coat (mechanical, physical, or chemical).

(ii) Endogenous dormancy: determined by the properties of the embryo or the endosperm (morphological or physiological).

(iii) Combined exogenous and endogenous dormancy.

In general, the most frequently encountered type of dormancy in arid zones is exogenous dormancy. Some of the more commonly used methods of attempting to overcome this type of dormancy are described below.

(a) Mechanical treatment: A small number of seeds can be scarified by scratching each seed with sandpaper, by cutting each seed with a knife, or by sandpapering the end of the seed that is opposite the radicle until the cotyledon is seen. With large quantities of seed, mechanical scarification can be achieved by pounding the seeds with sand, or by rubbing the seeds over an abrasive slab. A variety of other methods of scarification are also available.

(b) Soaking in cold water: For a number of tree and shrub species soaking their seeds in cold water for from one to several days is sufficient to ensure germination. The improvement in germination is caused by the softening of the seed coat and the ensuring of adequate water absorption by the living tissues. When long soaking periods are used, it is recommended that the water be changed at intervals. Usually, it is important to sow the seed immediately after soaking without drying, because drying generally reduces the viability of the seed.

(c) Soaking in hot or boiling water: The seeds of many leguminous species have extremely tough outer coats, which can delay germination for months or years after sowing, unless subjected to pre-treatment by immersion in hot or boiling water. The seed is immersed in two to three times its volume of boiling water, and allowed to soak from 1 to 10 minutes, or until the water is cold. The gummy mucilaginous exudations from the seed coat are then washed off by stirring in several lots of clean water.

(d) Acid treatments: Soaking in solutions of acid is frequently used in the case of seeds with hard seed coats. Concentrated sulfuric acid (98 per cent) is the chemical used most generally. Most commonly, soaking times vary from 15 to 30 minutes. After soaking, the seed must be washed immediately in clean water. Tests should be made to determine the optimum period of treatment for each tree or shrub species, and even for different provenances, since overexposure to solutions of acid can easily damage the seed.

(e) Seed inoculation: Legume trees have root nodules which harbor nitrogen-fixing bacteria. When seeds are planted outside their natural range, the soil should be inoculated with crushed nodules from natural stands. Some inoculum are available on the market which can be mixed with the seeds before germination.

(f) Other treatments: For a number of salt bushes and shrubs, washing seeds in cold water for one to two hours is sufficient to remove salt from the seeds and improve germination.

– *Sowing of Seeds*

Having determined the soil mixture, kind and size of container, one would proceed to sow the seeds.

(i) Type of sowing: When the containers are beds or boxes, seeds can be sown by broadcasting or in lines. When the containers are pots, then it is pit sowing.

(ii)Depth of sowing: Seeds are sown at a depth of 1-3 times their diameter. When seeds are sown at this depth adequate moisture and optimum temperature will hasten their germination. Excessively deep sowing will impair seedling emergence. Small seeds like those of Eucalyptus are mixed with fine soil before sowing to facilitate uniform distribution of seeds and to avoid seed waste by dense sowing. To economize in sowing Eucalyptus seeds, the seeds are mixed with fine sand in the ratio of 2 sand: 1 seed. This mixture is placed in a container while a small brush is first dipped in water, then dipped in the sand/seed mixture and then brushed gently onto 4-5 nursery pots containing soil. This was found to give a maximum number of 4-5 seedlings per pot.

(iii)Ideal sowing time: This is determined by the period required to raise a plantable seedling of the desired size. For example, if it takes four months in the nursery to raise plantable seedlings of *Eucalyptus microtheca*, to be planted in June, then the ideal sowing date for that species and locality is the first of February. Similarly, for planting in October, the ideal sowing date is the first of June.

– *Watering Plants in the Nursery*

After sowing, seed beds should be watered using a fine nozzle spray, producing almost a mist. This will-guard against removing and washing away fine seeds. Hand watering, whether by a container or with a hose, is the best method of watering. Watering is done frequently until seeds germinate.

– *Pricking out of Seedlings*

When seedlings raised in beds and boxes reach the 2-leaf stage, they are carefully picked up using a sharp stick and carefully replanted in pots or other beds. This is a very delicate process which is now avoided by sowing the seeds directly in pots and thinning the excess seedlings leaving only one good seedling per pot.

– *Care of Nursery Stock*

The production of good quality seedlings will depend on how well the following activities have been executed in its nursery:

(i) Weeding: Weeds compete for water and soil nutrients. They also block the circulation of air and may harbor insects and disease organisms. Where weeds are permitted to grow in the seedbeds, seedlings will be of poor quality; therefore weed competition must be eliminated. The methods of ensuring a minimum of weeds in the nursery are: prevention, eradication and control. Prevention is the practical method. It is accomplished by making sure that weeds are not carelessly introduced in the nursery. Eradication is the complete removal of weeds and their seeds from the nursery. Control is the process of limiting weed dissemination. Eradication and control are generally carried out as one operation in the nursery.

(ii)Root pruning: Some of the tree and shrub species best adapted to arid zone environments are characterized by a strong taproot. However, when raised in a container, the development of the taproot becomes constricted; it can emerge from the bottom and will grow into the soil of the bed beneath if it is not cut. The purpose of root pruning is not only to prevent the development of a long taproot, but to encourage the growth of a fibrous lateral root system in the pot or bed. Root pruning can be done by drawing a piano wire between the base of the containers and the bed surface so as to cut through the descending roots. Alternatively, it can be done by lifting the pots and snapping off the roots. The timing and frequency of the pruning must be adjusted to the speed with which the roots grow and emerge from the bottom of the containers.

(iii)Control of Damping-off: Damping-off is a common and serious disease in many forest nurseries. It can occur either in seed beds or in containers after transplanting. Damping-off is a pre-emergent and seedling disease caused by various fungi. Some of these fungi attack the seed just as germination starts, whereas others infect the newly germinated seedlings. Affected seedlings topple over, as though broken at the ground line, or remain erect and dry up. A watery-appearing constriction of the stem at the ground line is generally visible evidence of the disease. Damping-off is favored by high humidity, damp soil surface, heavy soil, cloudy weather, an excess of shade, a dense stand of seedlings, and alkaline conditions. One of the best preventive measures for damping-off is to maintain a dry soil surface through cultivation, to reduce the sowing density, and to thin the seedlings to create better aeration at the ground line. The need for soil fumigation is minimized in nurseries where fresh soil mixtures are prepared annually.

(iv)Hardening-off: Seedlings continue under nursery care while they develop for 2-3 months. Then the good ones will be selected and placed in separate beds. They are given less water and exposed to the sun gradually to condition them for planting in the site. This hard treatment is called hardening-off. Seedlings will develop a dark green colour and look healthier in the open than under nursery shade.

− *Vegetative Propagation*

Not all trees and shrubs used in planting programs are produced from seed. Species whose propagation by seed is difficult can often be reproduced by vegetative propagation. Nursery stock that is obtained by vegetative propagation includes stumps, cuttings, and sets.

"Stump" is a term applied to nursery stock of broad-leaved species which has been subjected to drastic pruning of both the roots and the shoot. The top is generally cut back to 2 centimeters and the root to about 22 centimeters. Stump planting is suitable for "taproot-dominated" species. Frequently, stumped plants are used in sand dune stabilization plantations. Stumps are normally covered with wet sacks or layers of large leaves during transit to the planting site.

Cuttings and sets are also commonly used as planting stock. A "cutting" is a short length cut from a young living stem or branch for propagating; a cutting produces a whole plant when planted in the field. A rooted cutting is one that has been rooted in the nursery prior to field planting. "Sets" are long, relatively thin, stem cuttings or whole branches.

− *Size and Quality of Planting Stock*

There is a considerable range in what is considered the desired size of tree or shrub seedlings for planting. The optimum size varies, depending on whether the seedlings are bare-rooted or containerized, on the tree or shrub species to be planted, and on the characteristics of the planting site.

In general, it is agreed that plants with a well-proportioned root-to-shoot ratio represent good planting stock, but it is difficult to define an "optimum" root-to-shoot ratio. A root-to-shoot ratio based on weight might give a more accurate measure of balance. Stem diameter and height are other criteria for evaluating planting stock that might allow the setting of minimum acceptable limits. Experience indicates that medium-sized stock, between 15 and 40 centimeters, with a woody root collar, have a better survival rate that do smaller plants.

The maximum size for planting potted stock is largely determined by the size of the container. The larger the container, the larger the plant that can be grown in it; but the period of growth is limited to that free of harmful root restriction. Excessively tall plants can be lessened in the ground or blown over, and root development might be restricted or inadequate to cope with the high transpiration demand of a large top.

− *Preparation of seedlings for the planting site*

Seedlings of plantable size are first graded. The grading of planting stock depends, to a large extent, on local experience and the establishment of local standards. The main objectives of a grading system for planting stock are:

(i) To eliminate culls, seedlings with damaged or diseased tops or roots.

(ii)To eliminate seedlings below minimum standards of size and root development.

(iii)To segregate the seedlings that exceed the minimum standards into two or more quality classes.

– *Transport of Seedlings to the Planting site*

Packing of container-raised plants for transport presents few problems. They are put in trays and loaded into vehicles. The tins which have been used for seedling trays can be used for transporting container plants. Sometimes wooden trays are used, but these are heavy.

Often, plants are damaged during transport to the planting site. Therefore, adequate care must be taken to avoid mishandling of plants during loading and unloading from vehicles. Something that is often forgotten is that plants require protection during transportation, as the air-flow can cause drying. It also is important that the containers are packed tightly, so that they cannot move. Special shelves for stacking pots or trays can be added to the vehicle platform (each layer of trays being placed on a shelf, with one shelf about 50 centimeters above the other). When possible, plants should be transported in the planting season on cool, cloudy, or even rainy days to prevent desiccation during transport.

Shipping schedules should be planned to avoid delays and to allow proper disposition of the plants immediately upon arrival. Normally, plants should arrive one day ahead of planting; where shade and watering facilities are available, supplies can be brought several days in advance. As soon as the plants arrive at the planting site, they must be watered and, if necessary, heeled-in in a cool, moist, shaded place until they are needed for planting.

– *Organization of Seedling Production*

Seedling production must be organized in such a way that plantable seedlings of good quality are produced in time. As time of planting is critical in arid countries - except when irrigation is applied - the organization becomes very important. All the processes which have been described earlier must be done perfectly and in time. These include (i) seeds and their treatment; (ii) soil mixture; (iii) filling of pots; (iv) sowing; (v) watering; (vi) pricking out; (vii) weeding; (viii) root pruning; (ix) provision of shade and shelter; (x) cutting; (xi) hardening off; and (xii) transport to the planting site.

Only the number which can be planted in one day should be removed from the nursery to the site. According to the planting program seedlings are hardened off and transported. The number of plants raised originally in the nursery is about 20% more than that planted in the field. This is to make up for culling and a reserve for replacing dead plants.

Administration is also very important in nursery work to ensure that:

(i) nursery activities (jobs) are done correctly;

(ii)these activities are done in time;

(iii)labor requirement is available (man-days) for performing the work; and

(iv)materials/tools and equipment required to do the work are suitable.

This requires a nurseryman having a fair knowledge of labor productivity, nursery technique and prices of materials. Records of nursery seedling production as well as costs of materials and labor are kept to show the economics of nursery work.

Labor and material requirements depend on the size of the nursery.

Forms showing cost of tasks, e.g. seed collection, filling of pots with soil, sieving, mixing and preparing nursery soil, should be designed and filled in regularly.

4.1.3 - Site Reconnaissance

The more information there is available about the site conditions in the area being considered for tree planting, the better are the chances of selecting the tree species best suited to the area. Information most commonly included in site reconnaissance is:

(i) Climate: temperature, rainfall (amount and distribution), relative humidity, and wind.

(ii)Soil: depth of soil and its capacity to retain moisture, texture, structure, parent material, pH, degree of compaction, and drainage.

(iii)Topography: important for its modifying effects on both climate and soil.

(iv)Vegetation: composition and ecological characteristics of natural and (when present) introduced vegetation. On areas which have not been degraded by man, the vegetation can provide an indication of the site. Unfortunately, over much of the arid world, the vegetation has been so disturbed that it is no longer a reliable indicator of potential planting sites; in these situations, site selection should be based on soil surveys.

(v)Other biotic factors: past history and present land use influences on the site, including fire, domestic livestock and wild animals, insects and diseases.

(vi)Watertable levels: a knowledge of the depth and variation of the watertable levels in the wet and dry seasons is valuable and can be crucial in determining the tree and shrub species that can be grown. Watertable levels can be estimated from observations in wells or by borings made for this purpose.

(vii)Availability of supplementary water sources: ponds, lakes, streams, and other water sources.

(viii)Distance from nursery.

Apart from the above biophysical information, socio-economic factors also play an important role. Among these factors are: (i) the availability of labour; (ii) motivation of the local population; (iii) the distance of the forest plantation to the market and consumer centers; (iv) land ownership and tenure (FAO, 1989).

4.1.4 - Selection of the Planting Site

Where to plant is generally a collective decision made by policy makers, foresters, and the planting crews, based on information obtained in the site reconnaissance. The key is to select the site that, when planted, will lead to the establishment of a successful forest plantation. Often, the choice of the planting site is limited to lands which are not suited for agriculture or livestock production; when this is the case, the site reconnaissance information gains importance.

The boundaries of the planting site, once the area has been chosen, should be marked with boundary posts. When there is a danger of trespassing and damage by grazing animals, a boundary fence should be established. Fencing is costly and, therefore, should only be built when other means of protection are not effective. Once a forest plantation is well established and the trees are sufficiently tall, the fences can be removed and reused at another planting site.

When roads and other passageways traverse the planting site, they should also be contained with fences.

In many instances, tree and shrub planting is undertaken to protect fragile sites from degradation. However, in some situations, the fragile sites should not be planted; it may be better not to disturb the soil in these areas. Where gullies have been severely degraded by erosion, protective measures other than the planting of vegetation (such as building small checkdams) may be necessary. With time the planted species will start reproducing, naturally colonizing these fragile sites. The colonization will be faster if pioneer species are planted nearby these fragile sites (FAO, 1989).

4.1.5 - Species Selection

When the best possible information has been collected on the characteristics of the site to be planted, the next step is the selection of the tree or shrub species to plant. The aim is to choose species which are suited to the site, will remain healthy throughout the anticipated rotation, will produce acceptable growth and yield, and will meet the objectives of the plantation (fuelwood production, protection, etc.).

For a successful planting, performance data may have to be extrapolated from one locality to another. Results from a locality where a tree or shrub species is growing naturally strictly apply only to that locality. Their application in another locality involves the assumption of site comparability, an assumption which may or may not be justified. When reliable information shows a close similarity between the site to be planted and that on which the species is already successful, it is generally possible to proceed to large-scale planting with confidence.

In practice, the above data are seldom available, and planting on the new site becomes (in effect) experimental and should proceed on a small scale; when this occurs, detailed performance records should be maintained throughout the experimental planting period.

The selection of tree or shrub species through the use of analogous climates is important as a first step; but this must be amplified by an evaluation of localized factors which can be more important (for example, soil, slope, and biotic factors). However, the ability to match closely a planting site and a natural habitat may not preclude the need for species trials, since climatological or ecological matching may not reveal the adaptability of a species. It cannot be emphasized too strongly that, without such trials, the choice of tree or shrub species is (in most cases) a risky business. Since planting in arid environments is normally an expensive undertaking, large-scale failures which result from the wrong choice of species or failure to test them can prove costly (FAO, 1989).

4.1.6 - Preparation of the Planting Site

When the tree or shrub seedlings arrive from the nursery, the site should have been prepared to ensure that planting can proceed without delay. Arid zone conditions frequently demand more intensive and thorough site preparation than is necessary for planting programmes in moister climates (FAO, 1989).

- **Objectives of Site Preparation**

Among the objectives of site preparation in arid zones are to:

(i) Remove competing vegetation from the site.

(ii)Create conditions that will enable the soil to catch and absorb as much rainfall as possible. Surface runoff should be reduced to increase the moisture in the soil.

(iii)Provide good rooting conditions for the planting, including a sufficient volume of rootable soil. Hardpans must be eliminated.

(iv)Create conditions where danger from fire and pests is minimized.

Site preparation is directed toward giving the seedlings a good start with rapid early growth. In general, the methods used to achieve site preparation will vary with the type of vegetation, amount and distribution of rainfall, presence or absence of impermeable layers in the soil, the need for protection from desiccating winds, and scale of the planting operations. Additionally, the value of the tree or shrub crop to be grown is important in determining the amount of expense that may be justified in plantation establishment (FAO, 1989).

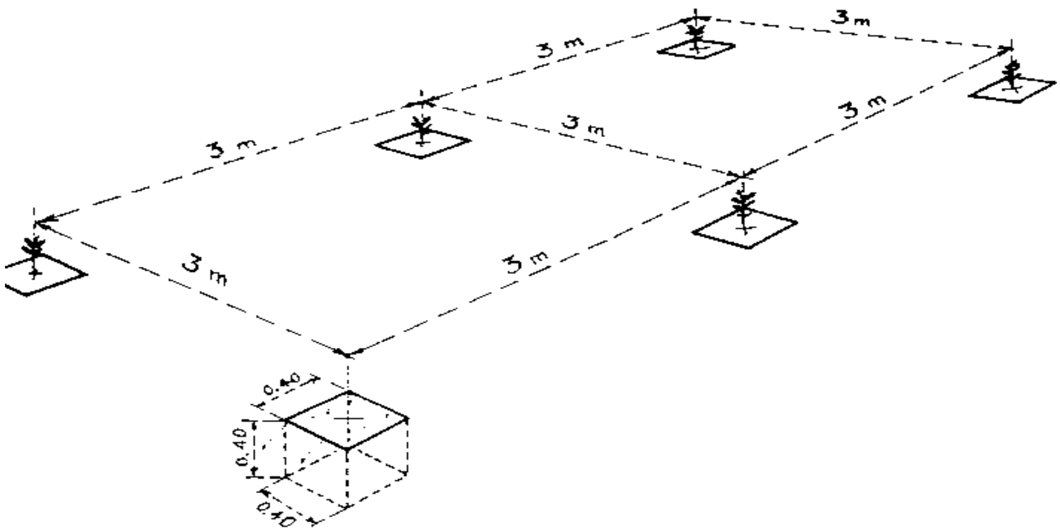
- **Methods of Site Preparation**

In general, preparation of the site by hand is possible and economical only for relatively small-scale projects, where the labor of clearing the competing vegetation and working the soil is not too time-consuming. Under certain conditions, animal-drawn ploughs and harrows can also be economical for small-scale operations.

Mechanical soil preparation, used increasingly in large-scale planting programs, has become a common practice in many areas; often, this is because the supply of labor and the time available for ground preparation are too limited to permit large-scale projects to be undertaken by hand. Some operations, such as deep subsoiling and the breaking up of hardpans, can only be done by machines.

Whatever method of site preparation is used, a planting pit (of an appropriate size) should be prepared. The objective of creating planting pits is to aerate and loosen the soil in which the plants will grow. When these planting pits are prepared, they should not be left empty with the excavated soil lying on the ground, but refilled immediately, otherwise sun and wind will dry out the soil completely.

Figure 4.07 - Planting Holes 0.4 m x 0.4 m x 0.4 m at a Density of 3 m x 3 m



Source: FAO, 1989

Soil preparation can be carried out in patches, strips, or by complete cultivation. Complete cultivation is necessary for tree and shrub species which are intolerant of competition from grass, forte, and woody growth. Sometimes, spot preparation may be sufficient, but the spots should be large (for example, 1 to 1.5 meters in diameter). Also, it is important that the work be done thoroughly.

Other methods of soil preparation by hand are the ash-bed method, tie-ridging, contour trenching and terracing, and the "steppe" method.

The ash-bed technique consists of piling the debris from harvesting or clearing the land into long lines or stacks. After drying, the debris is burned and vegetation is planted in the ash patches. Sometimes, the lines or stacks of debris are covered with "clods" to obtain a more intense heat when burning. Advantages of this method are that the burning kills the competing vegetation, the area remains free of this vegetation for an appreciable period, and the ash provides a useful fertilizer for the planted trees or shrubs.

The tie-ridging technique involves the cultivation of the entire area and the establishment of ridges at specified intervals. The main ridges, aligned along the contours, are joined by smaller ridges at right-angles to create a series of more-or-less square basins which retain rainwater and prevent erosion. The ridges are generally 3 meters apart. The trees and shrubs are planted on the ridges. This method is suitable for flat or gently sloping ground and can be combined with an agricultural crop during the initial years of plantation establishment.

Trenching techniques along the contours are used in site preparation in hilly country. The trenches can be (i) continuous, (ii) divided by cross banks, or (iii) consist of short discontinuous lengths, arranged so that the gaps between the trenches in one row are opposite those in the next row; in this latter instance, runoff from rainfall is caught. Trenches are formed manually or mechanically. On gently sloping ground, the herring-bone technique can be used.

Terraces, which are wider and flatter than trenches, can be either manually or mechanically formed on the side of a hill by digging soil from the uphill side and depositing it on the downhill side. Usually, the bottom of the terrace is made to slope into the hillside. The purpose of terracing is to retard and collect water runoff between the terraces. Because of the improved soil moisture conditions, the terrace provides improved conditions for plant growth. Planting is done on the ridge of soil, at the base of the ridge, or in patches at the bottom of the trench, according to moisture conditions. Terraces are used widely on moderate to severe slopes. Terraces can be 2 to 3 meters or several hundred meters in length. If short, they can be staggered on the hillside wherever convenient. Sometimes, crescent-shaped terraces are constructed with the two tips of the crescent pointing uphill.

The "steppe method of site preparation is designed to promote growth of trees and shrubs in extremely dry areas. In this method, the surface of the soil is modified by breaking-up and stirring the deep layers of the soil with rooters, rippers, or large discs, and then building widely-spaced, parallel ridges following the contour. Ridges are built with the topsoil, and trees or shrubs are planted on the lower half of the ridges facing the slope; here, the depth of moist soil is greatest, due to accumulation of water after rain. The purpose of the "steppe" method is to maintain a reserve of moisture in the deep layers of the soil. Spacing between ridges is greater with lower rainfall, as the catchment area between the ridges is increased (FAO, 1989).

4.1.7 - Time of Planting

The planting season generally coincides with the rainy season; usually, planting is started as soon as a specified quantity of rain has fallen. This amount of precipitation must be judged on the basis of local knowledge. Planting can also be initiated when the soil is wet to a specified depth (approximately 20 centimeters).

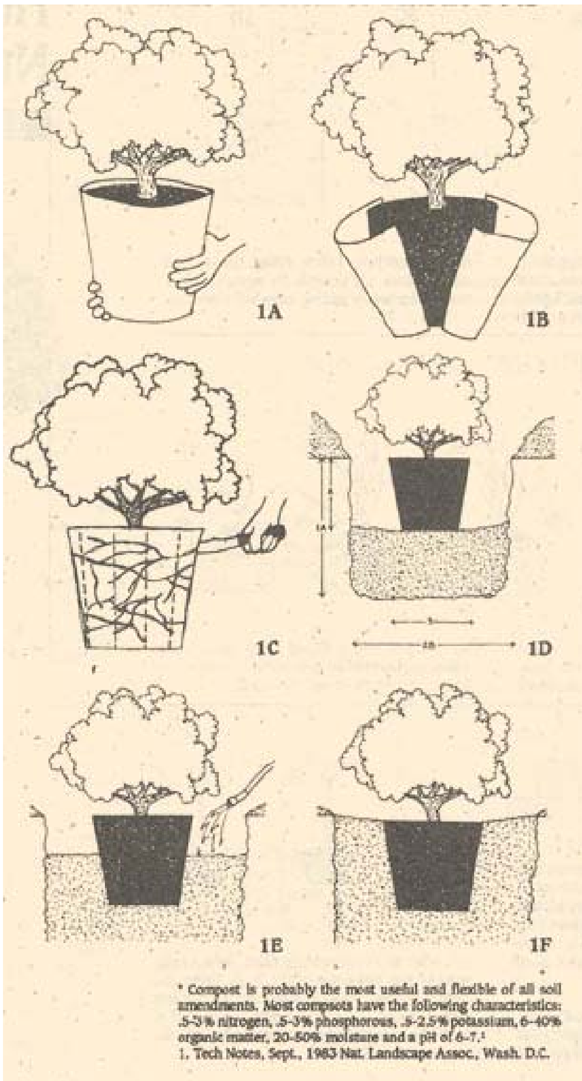
A common mistake is to start planting too soon. On the other hand, if planting is started too late, it may be difficult to complete a large planting program in the scheduled time, and the plants will lose the maximum benefit of rains after planting; this can be a serious matter where the rainfall is low and erratic (FAO, 1989).

4.1.8 - Planting of Containerized Stock

Planting of containerized stock is usually done in holes that are large enough to take the containers or the root-balls when the plants are removed from the containers. It is essential that the surrounding soil is firmed down around the plant immediately after planting to avoid the formation of air gaps which can lead to root desiccation.

A good practice for the preparation of planting holes is to surround the planting pit with a small ridge (15 to 20 centimeters in height) of soil, to obtain a small basin (about 80 centimeters in diameter). This is especially helpful when the plants are watered individually after planting. The small prepared basin can also be covered with a plastic sheet (held in place on the ground with stones or earth), with an opening in the center for the plant. The plastic sheet impedes evaporation of ground water from the planting hole; also, dew collects on its surface and runs to the central opening of the sheet to irrigate the roots. Through conservation of soil moisture, plastic films facilitate more rapid establishment and growth of trees and shrubs during the initial, and most critical years. Another benefit of opaque plastic films is that they inhibit weed growth by reducing light penetration. With the suppression of weeds in the immediate vicinity of the plants, labor also can be saved.

Figure 4.08 – Tree Planting



A threat to newly-planted trees in arid zones is the high rate of transpiration. Unless the plants can establish themselves quickly and compensate for the transpiration by taking water through their root systems, they will wilt soon after planting. This explains why even a single watering immediately after planting can be useful. In general, containerized seedlings have a distinct advantage over barerooted seedlings, in that the earthball surrounding the roots provides protection during transport and enables the plant to establish itself quickly and easily.

The restriction of lateral root extension, a result of using containers, can cause root malformation, coiling, and spiraling. In extreme cases, the coiling can lead to strangulation of the roots and the death of the plant. In other situations, it may reduce wind-firmness or lead to stunted growth. Unfortunately, the symptoms may not become apparent until 4 to 5 years after planting.

To reduce the damage of root malformation in containerized plants, a common practice is to remove the container from the soil cylinder before planting and make two or three vertical incisions to a depth of one centimeter with a knife to cut "strangler" roots. As a further precaution, the bottom 0.5 to 1 centimeter of the soil cylinder can be sliced off. Care must be used to ensure that the soil does not disintegrate and expose the roots to desiccation (FAO, 1989).

4.1.9 - Spacing of Plantings

The amount of water available to a tree or shrub in a plantation is proportional to the stand density. When irrigation or mechanical cultivation is practiced, it is necessary to adjust spacing to the width of the machinery used and to ensure that plants are placed in straight rows. Actual spacing varies with species, site, and the purpose of the forest plantation. In fuelwood plantations, for example, one might prefer closer spacings than employed in other kinds of plantations. Seldom can a spacing of less than 3 x 3 meters be applied, however.

The number of trees per hectare, according to the spacing between the lines in a plantation and the spacing of plants within a line, is given in. For example, with a spacing between lines of 3 meters and a spacing of plants within a line of 3 meters, a planting density of 1,110 trees per hectare will be required.

Table 4.01 - Number of Trees per Hectare According to Spacing

Spacing Between Lines	Spacing of Plants in the Lines								
	2.0 m	**2.5 m**	**3.0 m**	**3.5 m**	**4.0 m**	**4.5 m**	**5.0 m**	**5.5 m**	**6.0 m**
2.0 m	2,500	2,000	1,670	1,430	1,250	1,110	1,000	909	833
2.5 m	2,000	1,600	1,300	1,140	1,000	888	800	727	667
3.0 m	1,670	1,300	1,110	952	833	747	667	606	555
3.5 m	1,430	1,140	952	816	714	635	571	548	476
4.0 m	1,250	1,000	833	714	625	555	500	454	416
4.5 m	1,110	888	747	635	555	493	444	404	370
5.0 m	1,000	800	667	571	500	444	400	363	333
5.5 m	909	727	606	548	454	404	363	330	303
6.0 m	833	667	555	476	416	370	333	303	277

Source: FAO, 1989

4.1.10 - Maintenance of the Plantation

Once a plantation has been established, the work should not be considered finished. It will be necessary, for example, to protect the plantation against weather, fire, insects and fungi, and animals. A variety of cultural treatments also may be required to meet the purpose of the plantation (FAO, 1989).

- **Protection**

− *Weather Phenomena*

The occurrence of damaging weather phenomena is usually unpredictable. Little can be done to protect forest plantations against the damage caused by weather, except to grow tree and shrub species known to be resistant to the detrimental effects of local weather patterns, or locating the stands of trees or shrubs in sheltered areas. Some tree and shrub species are more windfirm than others, or are less prone to crowns and branches breaking off in high winds. Other species are more tolerant to salt spray and, therefore, can be used for planting in belts along exposed seaward flanks to give protection to other less tolerant species forming the main plantation. Thin-barked species are more susceptible to damage and to subsequent attacks by insects or fungi than are other species (FAO, 1989).

– *Fire*

Damage by fire imposes a serious threat to plantations. The fire risk is generally high in the dryer climatic regions; but, even in relatively moist or high rainfall areas, there may be warm and dry spells when the fire risk is high. Fire risk should be a major consideration from the early stages of plantation development.

Fires can originate from natural causes, such as lightning, but many occur as a result of the activities of man. Plantation fires can start from fires spreading from farmland on the perimeter, from the activities of hunters, or from burning by herdsman to improve livestock grazing. There have been instances of deliberate burning to create employment (in the fire suppression and subsequent replanting) or to show disapproval of forest policies. It is not possible to prevent a climatic build-up of fire hazard conditions, but much can be done to minimize the risk of fire through public education and involving local people in forestry.

A main principle in protecting forest plantations against fire is that, where there is insufficient combustible material to allow a ground fire to develop, there is little or no fire risk. Dangerous and damaging plantation fires can only develop when fire is able to occur at ground level.

In many parts of the world, annual or periodic burning of vegetation is commonly practiced to improve grazing conditions, to reduce the build-up of fuels, or to improve soil fertility through accumulation of ash (FAO, 1989).

– *Insects and Fungi*

Most insects and fungi are selective of the host species. In their natural environment, trees and shrubs normally attain a state of equilibrium with indigenous pests. However, when exotic trees and shrubs are planted, exotic pests can also be introduced. Quite often, these exotic pests readily adapt themselves to the conditions of their new habitat. In general, the risk of damage from pests is higher when the plants are physiologically weakened from planting on unsuitable sites, improper site preparation, inefficient planting, adverse climatic conditions, or neglect of weeding and other maintenance operations. But even healthy trees and shrubs are attacked at times. For many insects and fungi, no control measures are available; when this is the case, the best precaution is to plant tree and shrub species or varieties known to be resistant to the pests.

The main precautions to be taken in guarding against possible future damage from insects and fungi are to plant tree or shrub species that are suitable to the climatic and soil conditions of the site, and to make surveys of indigenous pests to ensure that none are among the known forms to which the selected species is susceptible; but this is seldom easy, especially in view of the gaps in available knowledge on site requirements and susceptibility of exotic species to insects and fungi. To obtain this needed information, carefully controlled experiments should be initiated before developing large-scale planting programs.

Care taken in establishment and maintenance operations during the early years of a plantation (resulting in healthy vigorous young trees or shrubs) can help to make a plantation more resistant to insects and fungi. However, when evidence of pest attack appears, it should be investigated promptly and the cause identified. Various control measures are available; these may be silvicultural, chemical, biological, or mechanical.

Silvicultural measures include well timed, careful thinnings after establishment of the forest plantation. Through thinning, poor and suppressed stems are eliminated, maintaining the plantation in a thrifty and vigorous growing condition. In young plantations, prompt removal and destruction of infested trees and shrubs can be effective in preventing the spread of the pest attacks to the rest of the plantation. Where a threat of infection is known to exist, planting of tree or shrub mixed species also can be considered a silvicultural control measure.

One disadvantage of mixed plantings is that subsequent forest management can be complicated; however, this may be avoided, at least partially, by planting alternate blocks or wide belts with different tree or shrub species, forming barriers to the spread of a pest or disease from the initial point of infection.

Insects and fungi can often be checked by applications of appropriate chemical insecticides or fungicides. Usually, these chemicals are available as liquids (or wettable powder), dusts, or smokes. Spraying with hand-operated spray guns or portable mist-blowers is frequently used to control attacks in young plantations; with canopy closure, aerial spraying and dusting or smoking can be more effective and cheaper. Only previously tested and environmentally sound insecticides and fungicides should be prescribed for use.

Biological control of insects has been employed with success in some situations; in most instances, the introduction of a parasite to control the insects is required. The greatest success in biological control is usually achieved after the problem has grown to epidemic proportions.

Mechanical control, either by physically removing and destroying the pests or by eliminating the alternative hosts, can be effective (FAO, 1989).

– *Wild Animals*

Damage to forest plantations by wild animals mainly takes the form of tree browsing or de-barking. In general, there are three orders of wild animals responsible for damage: rodents (rats, mice, and moles and squirrels); lagomophs (hares and rabbits); and artiodactyls (deer, antelopes, pigs and buffaloes). The principal methods of controlling damage by wild animals involves the use of fences, hedges or ditches, trapping and removal, and poison baits (FAO, 1989).

– *Domestic Animals*

In some countries, grazing or browsing by sheep, goats and cattle can be a menace to young plantations. At times, hedges and fences are used to prevent intrusion by domestic animals. Where fencing costs are high, trespass by livestock can be controlled by guards.

In many dry areas, grazing by goats is a traditional land use. Extensive enclosures of forest plantations can impose drastic changes in the habits and economies of the rural communities affected. In such situations, it would be unwise to initiate planting programs unless alternative means of livelihood can be provided beforehand; generally, this requires the integration of community development schemes (for example, improved agriculture or animal husbandry, better communications, schools, or medical welfare) and increased opportunities for employment by the development of rural industries (such as forestation programs and rural forest industries) (FAO, 1989).

- **Cultural Treatments**

Cultural operations are required to promote the conditions that are favorable to the survival and subsequent growth and yield of the trees or shrubs in the plantation. In most forest plantations, cultural operations are concerned with preventing the trees and shrubs from being suppressed by competing vegetation; quite often, this treatment is called weeding. Other cultural treatments are thinning to achieve a desired spacing among the trees or shrubs, and the periodic watering of the plants (FAO, 1989).

– *Weeding*

Weeding is a cultural operation that eliminates or suppresses undesirable vegetation which, if no action were taken, would impair the growth of the plantation crop. This undesirable vegetation competes with trees and shrubs for light, water, and nutrients; weeding increases the availability of all or the most critical of these elements to the trees and shrubs. A primary objective of weeding is to promote growth and development of the plantation crop, while keeping the costs of the operation within acceptable limits.

A main factor affecting the intensity and duration of weeding treatments is the relationship between the tree or shrub crop and the weeds. On some sites, the plantation crop eventually grows through the weeds, dominates the site, and becomes established; on such sites, the function of weeding is to increase crop uniformity and speed up the process of establishment and growth. On other sites, the type or density of the weed growth is such that, in the early stage of a forest plantation, it may suppress and kill some or all of the planted trees or shrubs; in such areas, the main purpose of weeding is to reduce mortality and maintain an adequate stocking of trees or shrubs.

The methods of weeding involve either suppression or elimination of the competing vegetation. Suppression of weeds consists of physically beating down or crushing them, or cutting the weeds back at or above ground level. Weed elimination can be achieved by killing the weeds, destroying the whole plant either by cultivation or by the use of chemicals. Weeding may be total or partial (FAO, 1989).

– *Thinning*

Thinning of forest plantations, particularly those established for wood production, may be required to obtain the desired spacing between the trees. In general, this spacing is a compromise between a "wide" spacing to reduce planting costs and inter-tree competition in times of drought, and a "close" spacing to attain early canopy closure, the suppression of weeds, the reduction of weeding costs, and natural pruning of branches through shading.

In "first-rotation" forest plantations, the thinning objective is frequently to adjust the initial spacing among plants, so that the size and type of tree or shrub required is attained on a short rotation, without secondary thinning treatments. Where a tree or shrub of larger size and higher quality is required, closer than final spacing is often prescribed in an initial thinning; usually, some form of secondary thinning is necessary as a subsequent treatment. The element of selection in thinning should ensure that the increment growth of the final crop is concentrated on the best stems.

Regardless of the purpose of the thinning operation, it should follow closely the timing and spacing requirements that are outlined in a prescribed thinning schedule for the area (FAO, 1989).

− *Watering*

Often, forest plantations in arid regions need at least periodic watering during the first growing season to obtain a satisfactory survival rate. Watering should begin after the cessation of rains, when the moisture content of the soil has fallen to near the wilting coefficient; then watering should be repeated at intervals until the onset of the next rainy season. Before each watering, the area around the tree should be cleared of weeds, and a shallow basin should be made around the stem of each tree or shrub to collect as much water as possible.

Watering can be an expensive operation, especially on terrain too steep or too rough for the passage of tank vehicles. Pack animals may be required to carry drums of water to the plantation site. Watering can be uneconomic for large forest plantations, particularly when the source of water is a long distance from the plantation, but it may be justified in the case of small plantations or for establishing roadside avenues.

In some instances, regular cultivation and weeding, especially during the first growing season, are sufficient measures to conserve soil moisture for satisfactory survival of the plants, eliminating the need for watering (FAO, 1989).

4.1.11 - Harvesting Operations

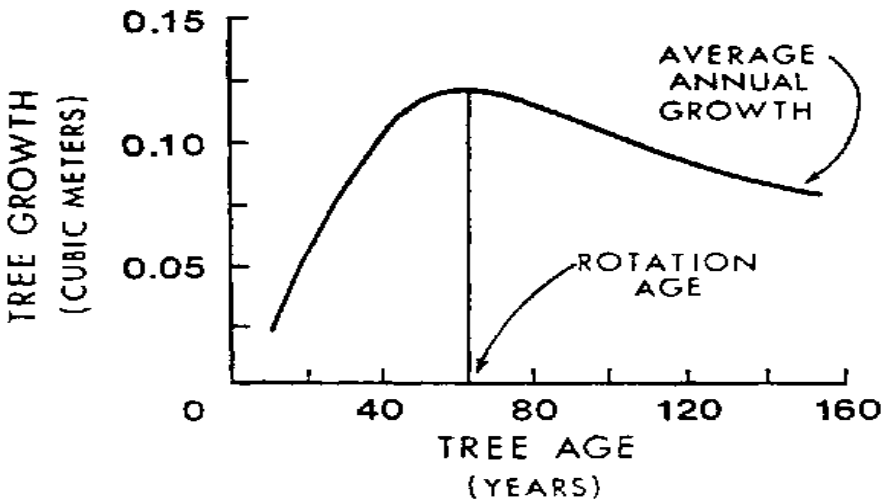
For forest plantations that are established for purposes of wood production, trees and shrubs are harvested once they attain the "optimum size" for the wood product wanted. From a biological standpoint, trees and shrubs should not be cut until they have at least grown to the minimum size required for production utilization. Beyond attaining the minimum size, the question of when to harvest must still be answered, however.

Quite often, the average annual growth rates of a forest plantation can be used as a guide in determining when to harvest wood. In general, the average annual growth (usually measured in m^3/ha/year) of trees and shrubs increases slowly during the initial years of plantation establishment, reaches a maximum, and then falls more gradually. Trees and shrubs usually should not be allowed to grow beyond the point of maximum average annual growth, which is the age of maximum productivity; foresters call this the "rotation" age of the forest plantation.

To determine the average annual growth rate of a forest plantation at a point-in-time, the volume and age of the trees or shrubs must be estimated; then the average annual growth (at the specified point-in-time) is determined by dividing the standing volume by the corresponding age. Again, careful measurements of volumes and known ages are necessary for this determination.

Figure 4.09 - Relationship Between Tree Age and Tree Growth, Indicating the Rotation Age

Source: FAO, 1989



Economic considerations also help to determine when to harvest trees and shrubs for wood products. When based solely on market factors, the time to harvest is when the profit is maximized. Profit is maximized when the returns generated from harvesting and selling the wood minus the costs of harvesting and (when required) processing the wood into the desired products is the greatest.

The methods of felling trees and shrubs, cutting the stems and branchwood into the desired lengths, and removing the wood from the plantation site should be chosen to minimize degradation of the site. Axes, saws, wedges and sledges may be all that are necessary to fell the trees and shrubs and cut them into the desired lengths. Power-chainsaws are used in many instances; while their use makes harvesting easier, their high cost of operation can make then uneconomical.

Once the trees and shrubs are felled and cut into desired lengths, they must be carried or pulled to loading points for transport to processing sites or directly to a market place. When stem lengths are too heavy to carry, a simple drag or sled can be employed to move them, using an available power source, such as a domestic animal or a tractor. When residual trees or shrubs are left in the forest plantation, the harvesting operation should be carried out to prevent damage to this standing resource.

It is important that the methods of harvesting should be selected to "match" the skills of the people who will harvest the trees or shrubs. Once again, advanced planning will be necessary to ensure that the labor and required equipment will be available for use at the needed time.

4.2 - Irrigated Forest Plantations

Irrigated forest plantations can be established for the commercial production of fuelwood, posts, construction lumber, and fodder, as well as to recover desert areas. The use of irrigation practices also allows the use of more exacting fast-growing tree and shrub species. In many instances, the availability of wood from irrigated plantations will lessen the destruction of the natural vegetation.

In desert zones, irrigated forest plantations can be achieved using: (i) a dependable and permanent water supply; (ii) an intermittent water supply.

4.2.1 - Irrigation with Permanent Water Supply

Depending upon the amount of water which can be made available from a dependable water supply (well, dam, river, etc.), permanent irrigation systems can be established. Different designs of permanent irrigation systems can be chosen, depending on the prevailing conditions. Three types of such systems are reviewed in the following sections: gravity systems, sprinkler systems and localized systems.

- **Gravity Systems**

Gravity irrigation systems are characterized by the manner in which the irrigation stream is controlled by the soil surface. Four types can be distinguished: surface flooding, border check, basin and furrow irrigation.

– *Surface Flooding*

This system resembles the inundation that sometimes takes place on flat lands along rivers and it is the simplest form of permanent irrigation. On gently sloping land that requires little preparation, surface flooding is easy to implement. In essence, water is released from main ditches and allowed to spread over the surface. However simple, this method generally has been inadequate for tree and shrub crops, as it is difficult to obtain uniform distribution of the water. Also, there is a risk that the root system of the plants can become deprived of oxygen because of waterlogging.

– *Border Check*

In this method, parallel earth ridges guide the flowing water as it moves down the slope over the strips which vary from 3 to 30 meters in width and can be more than 100 meters in length. A relatively large flow of water is needed. The land should have a uniform moderate slope parallel to the checks. Careful land preparation is necessary to ensure stability of the ground. The method is suited to medium-textured, deep, permeable soils. On sandy soils, infiltration would be excessive unless the strips are short. Slow percolation renders it unsuitable for heavy soils. A drainage ditch should be sited at the end of the strip to carry away any excess water. Design involves achieving an optimum balance between soil type; slope, width, and length of strips; and water flow so that the desired depth of water will be applied uniformly to the compartment without excessive percolation at the input end. In agroforestry applications, it could be ideal because the trees could be grown along the check, the width of which could be sufficient for one or two rows of trees.

– *Basin Irrigation*

This is a system in which the field or compartment is divided into small units each of which has a level surface. The basins are filled with water which is all allowed to infiltrate, any excess being drained off. When leaching salts from the soil, the depth of water can be maintained for considerable periods by allowing continuous flow into the basins. The method entails relatively high labor inputs.

– *Furrow Irrigation*

This is a common method to distribute irrigation water. Furrows are built from the main feeder channel in parallel lines spaced at regular intervals to permit the wetting of the tree rooting zone. The width of the furrows and their spacing depend, in large part, upon the permeability of the soil. The heavier the soil, the larger and the wider apart the furrows must be; the opposite applies in more porous soils. The method requires relatively high labor inputs and a high degree of skill and experience in directing water from supply channels into the furrows and controlling its flow. A disadvantage of the system is that tree roots tend to develop linearly along the furrow; trees tend to lean across the furrows and windthrow sometimes occurs later in the rotation. Unevenness of furrow levels and distribution of water can develop when soil conditions are not uniform. Regular maintenance of the furrows is important.

- **Sprinkler Systems**

Sprinkler systems are most applicable in areas of irregular topography where land grading is not feasible, in irregularly sloped areas, or when rapid application of relatively small quantities of water is desired. Applications to forestry are somewhat limited by crop height and costs, but such systems are applicable in the early establishment phase of forest plantation crops.

All sprinkler systems have in common a source of water under pressure, a system of pipelines to deliver water to the point of delivery, and nozzles through which the water is distributed.

The advantages of sprinkler systems are that they are applicable to areas of irregular topography and shape without leveling; they can be used in areas of high watertable or where there is a hard pan near the surface, without increasing soil salinity. The amount and rate of water application are easily controlled so that runoff and deep percolation can be avoided. This gives them advantages in areas of high permeability. They can utilize a small, continuous supply of water better than gravity methods; water is distributed evenly if it is not too greatly affected by wind; they do not require land for water channels, ditches, and borders, thus saving land and the maintenance costs and inconveniences of open distribution systems.

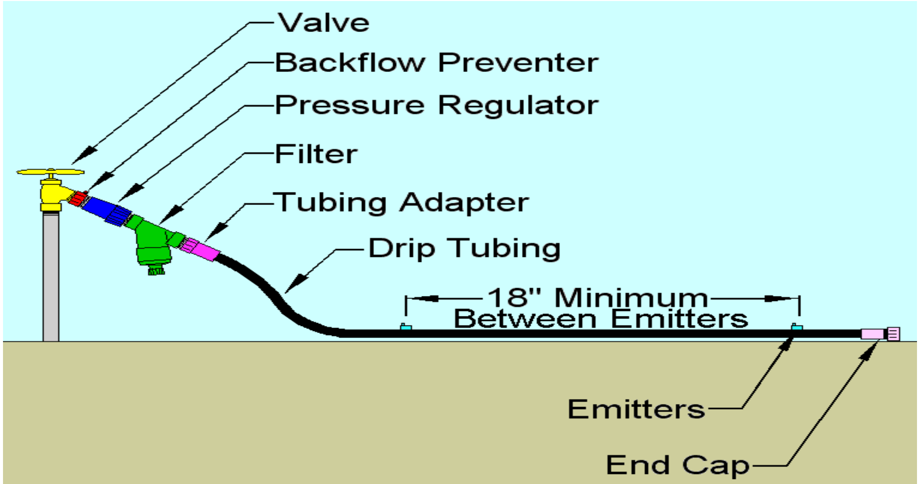
- **Localized Systems**

Localized irrigation systems, an umbrella term for trickle, drip, drop, or sip irrigation methods, are among those that cause wetting of only part of the soil, i.e. that at the base of and surrounding the root system of the plant. They are characterized by slow and low rates of application of water to the plant rooting zone through distribution pipes and orifices or nozzles organized either under or above the soil surface.

The basic components include a pressurized supply of water, a control head, a main line with laterals, and distributors.

Figure 4.10 - Drip System of Irrigation

* 18” = 46 cm



Source: Landscape Irrigation Tutorials

To create the appropriate pressure in the water supply usually requires a pump and storage tanks or reservoir. The control head is usually sited at the highest point in the field and connected to the water supply. The advantages of localized irrigation systems include the facts that, within limits, they can accommodate undulating ground, are relatively easy to manage, have relatively low labor costs, and are simple to operate. The principal problem of localized irrigation systems is the susceptibility of the smaller pipes and the distributors to clogging by sand, silt, organic matter, algae, bacterial slimes, and precipitation of nutrients, colloidal materials, or lime. Root system size or spread and depth being a function of the volume of water applied at each irrigation, root development can be restricted through inadequate watering. Also, trees can die very rapidly if water is withheld for even a short period: thus the water supply must be reliable.

Figure 4.11 - Field Application of the Drip System

Source: University of Edinburgh

4.2.2 - Irrigation With an Intermittent Water Supply: Rainwater Harvesting

Rainwater harvesting as a means of providing water seasonally, over longer periods, has been used in arid areas for thousands of years to grow agricultural crops and trees for fruit, amenity, and other purposes. Rainwater harvesting essentially involves two components: (i) a catchment or collector area, usually prepared in some manner to improve runoff efficiency, and (ii) a smaller water storage area in which crop or tree plants are grown or where water is stored in small tanks or other structures for future use.

In the case of tree planting, rainwater is used directly without storage requirement. Four techniques are particularly relevant:

(i) runoff farming;

(ii)desert strip-farming;

(iii)contour terrace farming, and;

(iv)flood water spreading.

- **Runoff Farming**

Watersheds are divided into several micro-watersheds depending upon the area needed for each tree. The collection area for each micro-watershed may range from 20 to 1000 square meters, depending upon the area precipitation and tree water requirements. Micro-catchment procedures are used in complex terrain where other water harvesting techniques may be difficult to apply.

In a typical situation, a series of well-designed micro-watersheds with appropriate dimensions are prepared. At the lowest point, a basin is dug about 40 centimeters deep and a tree is planted. The depression collects and stores the runoff from the rest of the micro-watershed that feeds the plant. At the root zone, soil should be at least 1.5 meters deep. Diagonal distances between the lowest corner to the farthest contributing corner should be between 5 and 30 meters.

This technique is particularly successful in years of normal precipitation. In dry years, most annual crops will fail. It is therefore advisable to select drought-resistant plants for use with this system.

- **Desert Strip-Farming**

Although only a very small percentage of the rainfall reaches major stream channels in arid and semi-arid regions, considerable runoff occurs on many of the gently sloping watershed areas. Desert strip-farming makes use of this water by employing a series of terraces that shed water onto a neighboring strip of productive soil.

Depending upon the topography, soil characteristics, and climatic conditions of the site, two types of micro-watersheds can be used: (i) one-sided micro-watershed for moderately permeable soils and natural land slope greater than 6 per cent, and (ii) two-sided micro-watershed for highly permeable soils with natural land slope less than 4 per cent.

- **Contour Terrace**

The purpose of terracing is to retard and collect all runoff between the terraces. If the runoff is properly managed, enough water can be added to the soil of the terrace to improve tree growth significantly. Terraces are essential on steep slopes where all woody vegetation has been destroyed and is not likely to be reestablished before severe erosion occurs. Terraces should be large enough to hold or carry the heaviest ten-year rain.

Contour planting consists of placing long, low barriers perpendicular to the gradients, along contour lines which intercept and retain runoff and silt. The barriers can be of stone, logs, earth or hedge.

- **Floodwater Spreading**

In arid regions, rainfall usually falls during short, intense storms. The water swiftly drains away into washes and gullies and is lost to the region. Sometimes floods occur, often in areas untouched by the storm. Waterspreading is a practice of deliberately diverting the floodwaters from their natural courses and spreading them over adjacent floodplains or detaining them on valley floors. The wet floodplains or valley floors are then used to grow tree or forage crops.

Site selection is the key to success in floodwater farming. Three principal types of sites are preferred: (i) slopes below escarpments, (ii) alluvial deltas, or (iii) floodplains.

While potential sites are found in many arid and semi-arid regions, waterspreading systems require careful design and engineering to withstand flood waters. They must be selected so as to optimize topography, soil type, and vegetation.

4.3 – Forest Enrichment

Forest enrichment is a technique for promoting artificial regeneration in which seedlings of preferred trees are planted in the under storey of existing forests or among scattered trees and shrubs, and given preferential treatment to encourage their growth. This technique is a complement to what was seen on items 4.1 and 4.2.

The main planting system used is enrichment line planting, which involves opening 2 meter-wide lines every 10 meter through the forest matrix and planting seedlings every 5 meter along the lines. Lines are opened in an East-West direction. Planting holes are approximately 10 cm in diameter and 20 cm deep. Rock phosphate fertilizer is applied in each planting hole.

Weeding is carried out when necessary, up to 4 rounds a year during the initial 3 years after planting. Figures of labor requirement for each activity of the project are recorded to enable studies of planting efficiency in different sites.

Two months after each plot is planted, 100% of the planted area is surveyed to assess initial survival of seedlings. During this survey, a visual assessment of the degree of canopy cover above each seedling is carried out, classifying it as open, half-open or closed canopy. Rainfall patterns (total monthly rainfall and number of dry days during the first month following planting) are correlated to initial mortality.

The initial phase of the project aims to test different strategies and systems, thus planting is organized in the form of large trial plots testing a range of variables. One such trial can test the effect of the width of planting lines on growth of the seedlings of a specie. Lines of 1.5, 2.0 and 3.0 m width are opened (3 replicates for each width), and approximately 73 seedlings are planted in each line. The width of planting lines are measured at the ground level, and any vegetation apart from trees or seedlings found within the lines are removed. The percentage canopy cover above each planted seedling is measured using a hemispherical canopy densiometer. Height of seedlings is measured one year after planting.

Lack of plot maintenance during the initial years may contribute substantially to poor performance. For instance, most seedling damage and mortality occurs during seedling stage until plants reach 3 meter in height

Seedlings are particularly susceptible to damage by insect borers, browsing mammals, competing vegetation, and physiological stress caused by drought or other factors. It is therefore essential that maintenance of plots is carried out during this initial phase. Subsequent silvicultural treatments such as liberation thinning are also required to maintain growth rates (Moura-Costa et al., 1992).

4.4 – Natural Regeneration

4.4.1 - Overview

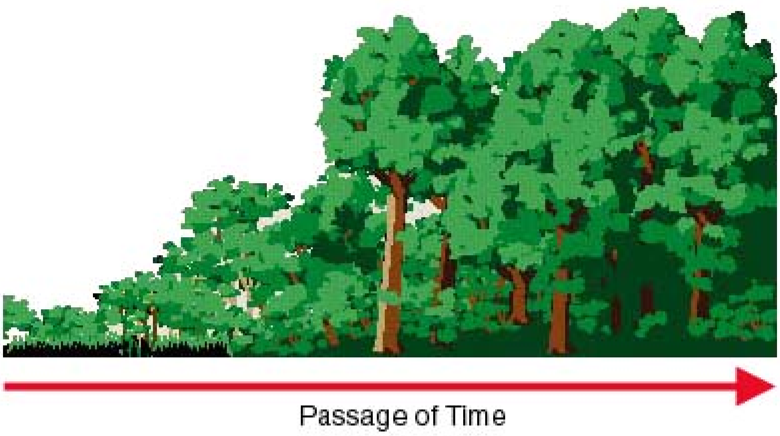
In ecology, succession refers to the replacement of one biological community by another. Succession can be primary or secondary.

Primary succession occurs on essentially new substrata: bare rock or soil that has never been colonized before. Examples would be sand dunes and lava flows. Secondary succession occurs on land which has been colonized before, but has been disturbed back to some earlier state. Examples would include a drained reservoir, cleared forest, or ploughed field.

Succession begins with arrival of the pioneer species and leads eventually to establishment of a climax community. In primary successions, pioneer species are typically hardy plants that survive under harsh conditions. On sand dunes, marram grass has deep roots to tap into the water table, rhizomes to bind the soil, and leaves that reduce water loss through transpiration. On lava flows the first plants to colonize are adapted to survive in thin or no soils and possibly little water.

The pioneer plants add organic matter to the soil, and help bind soil particles together, eventually allowing other species to colonize the area. This process slowly enhances the soil quality, enabling a sequence of other species assemblages to survive until a climax community is established. Climax communities are usually some form of woodland.

Figure 4.12 - Ecologic Succession



Source: Willamette University

4.4.2 - Secondary Succession

- **Overview**

The forest natural regeneration is based on the ecologic succession. Ecologic succession is the ecosystem development, which involves modifications in the structure of species and community processes along time.

When this succession occurs according to changes determinate by the community itself, it is called "autogenic". If the change factor is external, it is called "allogenic". The forest natural regeneration that takes place after natural or anthropogenic events constitutes a dynamic, progressive and continuous mechanism of vegetation restoration that tends to recompose the area original forest cover. This continuous process of germination, installation, growth, reproduction, substitution and death of the plants is denominated "vegetation dynamics", and can be observed in the successional process (linear dynamics) as well as in climax forest formations, with the forest expansion and substitution of dead individuals.

In the beginning of the process, the plants migration until a certain place and their fixation depends on the site capacity, with the plants establishment occurring in the sequence. Its called "ecesis". The first species development is configured as an apparently random mix. However, this is not the case, since there was a natural selection for the germination. Among the plants that have the same ecologic potential, the first ones to arrive, the ones that occur in the vicinity and the ones with developed dissemination mechanisms are favored.

Already in the first succession stage, site conditions determinate if the future forest composition will comport a large number of species or only a few specialized ones. In uncovered areas, generally resulting from abandoned agriculture or pasture land, the neighboring vegetation determinate the succession initial stages.

Natural succession occurring after a forest opening is characterized by alterations in the environmental characteristics, such as light, moisture and temperature. Forests self-renovate themselves through this healing mechanism of disturbed areas (openings).

In places previously occupied by forest communities, and that suffered great anthropic disturbance, the successional process is denominated "secondary succession". Secondary vegetation is a collection of plant associations that appear immediately after the forest removal, or just after the agriculture or pasture land abandonment.

This process is different than the primary succession because it presents well defined successional stages, composed by a reduced number of dominant species. Species adapted to more extreme edaphic conditions, such as mountain tops, marshes, river banks and rocky terrain gather a set of characteristics very close to those classified as pioneer inside openings.

In secondary formations, the pioneer species may both come from the openings pioneer species' group and from the group of species adapted to edaphic restrictions. This species origin difference for the secondary forest formation is of fundamental importance, once that the succession may only take place with the arrival of individuals to the abandoned area, including individuals of species that compose the subsequent stages.

The structural characteristics of secondary formations, arising from anthropogenic disturbance, depend on a number of factors. The main factors are (i) soil fertility, (ii) regional climate, and (iii) proximity of established forests. The intensity of the soil physical and chemical degradation, consequence of the area intensive use, may determinate an increase in the number of successional stages, or the regeneration process stabilization.

A secondary succession is characterized by a set of complex processes, where the soil conditions, micro-climate, flora and fauna biodiversity evolve concomitantly.

- **Secondary Succession Stages**

Successional stages are characterized by the predominance of biologic types that determinate the vegetation physiognomy. The collection of transformations that happen with the secondary vegetation is denominated "successional series". After passing by a series of intermediary stages, these communities converge into forests similar to the original floristic diversity.

– *Pioneer Stage*

The Pioneer stage marks the beginning of the succession process. It is generally characterized by the presence of herbaceous plants, even more in areas abandoned after years of consecutive cultivation. This initial perennial vegetation still cannot maintain interaction levels capable of attracting fauna that could propagate plant species, being the wind the main vector capable of guaranteeing the arrival of new pioneer species.

– *Shrub Stage*

In the following stage in the succession process, it is verified the appearance of the first shrubs. This stage takes place after five years or more of abandonment of the land, lasting for until 10 years.

The flora-fauna and fauna-fauna interaction level starts to intensify from this stage on. The soil is by then with a larger quantity of organic matter, and it maintains larvae of insects and worms. The small humus organic layer can shelter little rodents, and the shrubs attract herbivorous and nectivorous insects. Some of the shrubs have its flowers adapted to the pollination by insects, producing nectar in abundance, while its seeds are transported by the wind.

– *Small Trees Stage*

This stage is characterized by the substitution of the shrubs by small trees, that install themselves in a very aggressive form. These small trees are characterized by sparse tree crowns, allowing a non-uniform shading. Some present a great capacity to attract nesting birds. When these small species of trees achieve an age of about 15 years, larger species of trees, shade tolerant, start to install themselves in an intensive form.

– *Pioneer Arboreal Stage*

In this succession stage, it is observed the dominance of species of trees with more that 15 meters high. The communities are fairly uniform in relation to the dominant trees height. Woody plants predominate, without emergent individuals. The trees have wide crowns, occurring in high intensity, what promotes a very shaded and moist micro-climate inside the forest community, allowing the installation of other shrub and tree species.

Advanced arboreal stage pioneer species appear on this stage, still in the intermediary storey. The transition between the pioneer arboreal stage and the advanced arboreal stage is constituted by a number of intermediary phases, that are generally hard to be distinguished. In the beginning of the transition a number of arboreal species only occur as young individuals in the intermediary storey. After a while these species start developing themselves in a fast manner, changing the forest interior.

– *Advanced Pioneer Stage*

It is also denominated secondary forest. During this stage, which takes place 30 to 50 years after the land abandonment, there exists a truly forest environment under all physiognomic aspects, very similar to the original forest. This phase is characterized by an heterogeneous vegetation, with two well defined arboreal storeys, and a third one in formation. The dominant trees achieve an average height between 10 and 20 meters, reaching 25 meters depending on the site conditions. A well developed and well distributed herbaceous-shrub storey can also be found.

4.5 – Sustainable Forest Management

4.5.1 – Overview

Sustainable Forest Management aims to ensure that the goods and services derived from the forest meet present-day needs while at the same time securing their continued availability and contribution to long-term development. In its broadest sense, forest management encompasses the administrative, legal, technical, economic, social and environmental aspects of the conservation and use of forests. It implies various degrees of deliberate human intervention, ranging from actions aimed at safeguarding and maintaining the forest ecosystem and its functions, to favoring specific socially or economically valuable species or groups of species for the improved production of goods and services. However, it is extremely useful to be familiar with the renewal process of ecosystems and the reproduction mechanism of woody and herbaceous species in order to successfully embark upon sustainable forest management.

Unfortunately, many of the world’s forests and woodlands, especially in the tropics and subtropics, are still not managed in accordance with the Forest Principles adopted at the United Nations Conference on Environment and Development (UNCED, 1992). Many developing countries have inadequate funding and human resources for the preparation, implementation and monitoring of forest management plans, and lack mechanisms to ensure the participation and involvement of all stakeholders in forest planning and development. Where forest management plans exist, they are frequently limited to ensuring sustained production of wood, without due concern for non-wood products and services or social and environmental values (see item 3). In addition, many countries lack appropriate forest legislation, regulation and incentives to promote sustainable forest management practices.

In the sequence are shown the most used forest management techniques. The most modern and therefore indicated technique is the selection system, approached in the end of this section.

4.5.2 – Techniques

- **Clearcut System**

In a clearcut system the stand overstorey is generally removed in one harvest. New even-aged stands are regenerated after harvest within the previously cleared block.

The clearcut system is still used in places such as North America. It incorporates all of the advantages associated with managing an entire stand uniformly through time. Generally, this system is used to replace old stands with a new vigorous stand as quickly as possible. Sometimes, these old stands are starting to break up and are highly susceptible to damaging agents. In North America the public is pressuring forest managers to alter this approach to old stands. Old-growth forests are viewed by some as having special intrinsic values, in spite of deteriorating timber and ground forage cover values. Such a situation is unprecedented in forestry and provides foresters a challenge in developing silvicultural systems.

Figure 4.13 – Clearcut Evolution

Source: British Columbia Ministry of Forests, 2004

Numerous growth and yield models and tools are available to help managers design clearcut systems to produce certain volumes of specific timber products. Stand-tending operations, such as thinning, pruning, and fertilization, can easily be incorporated into the system to meet these specific objectives.

The clearcut system advantages are:

(i) Allow for establishment of a more uniform crop (includes the benefits of uniformity and even-aged management).

(ii)Allow for easier and efficient operations, because it is the simplest method to use.

(iii)May have lower costs for forestry activities including: planning, layout, supervision, harvesting, site preparation, and intermediate treatments. Harvesting may be less expensive due to the higher volume per hectare removal.

(iv)May more easily accommodate highly specialized equipment designed for harvesting and site preparation.

(v)Avoid damage to regeneration since felling and extraction are done before establishment.

(vi)May provide a means to most rapidly achieve a free growing plantation when combined with plantation forestry techniques and fast-growing shade-intolerant species. Note: Often shade-intolerant species are more desirable due to their growth and yield and wood quality considerations.

(vii)May allow for easier control of insect and disease problems

(viii)May more easily allow for amelioration of site/soil through site preparation (although it may be argued that amelioration may not be necessary if another silvicultural system is used).

(ix)Enhance worker safety because most or all trees are removed.

The clearcut system disadvantages are:

(i) Sometimes negatively perceived as being systems that fight against nature, regardless of the ecological conditions, by encouraging uniformity, especially when agricultural techniques, such as site preparation and planting, are used.

(ii)May not be suited to wildlife species where overhead cover or more structurally diverse habitats are required at a stand level.

(iii)May expose the site to erosion, particularly if soils are compacted and moisture inputs are high on steep slopes with significant amounts of exposed fine-textured soils.

(iv)May increase mass wasting hazard on steep slopes with fine soil and high moisture inputs or with smooth geologic bedding planes that are parallel to the ground surface.

(v)May exacerbate adverse environmental conditions for regeneration such as microclimate (frost, drying winds, extreme temperatures), soil moisture and perhaps nutrients, competing vegetation, predators (insects/animals). This adverse situation is only created on extreme sites where trees are very difficult to re-establish.

(vi)May prevent full growth and yield potential of individual trees (as in single tree selection management). During a significant portion of the rotation the growing space is not fully occupied by crop trees.

(vii)May not be considered visually pleasing.

(viii)Not well suited to shade-tolerant species that grow slowly in the juvenile stages, even if they are planted. Pioneer vegetation may have a great advantage and overtop these trees (British Columbia Ministry of Forests, 2004).

– *Strip Clearcut*

Strip clearcuts are used to harvest a stand over a period of three to seven years by removing several strips rather than harvesting the entire stand at once. Strip clearcutting was developed to take advantage of natural seeding from the leave-strips. In a pure sense, strip clearcut systems have mostly been used on a few site types.

A major concern associated with strip clearcuts is wind damage because the leave-strips expose much more edge for a short period than does one large clearcut. To avoid excessive windthrow, leave-strips should be at least 40 m wide, open only at one end, and harvested as soon as adjacent cleared strips are regenerated, thus minimizing exposure time. Also, boundaries of strips should be carefully located in healthy stands on deep, well-drained soils. Strip clearcuts can be designed in an alternate or progressive fashion.

Advantages of strip clearcut system over block clearcut system:

(i) Relies mostly on natural regeneration thereby possibly reducing regeneration costs.

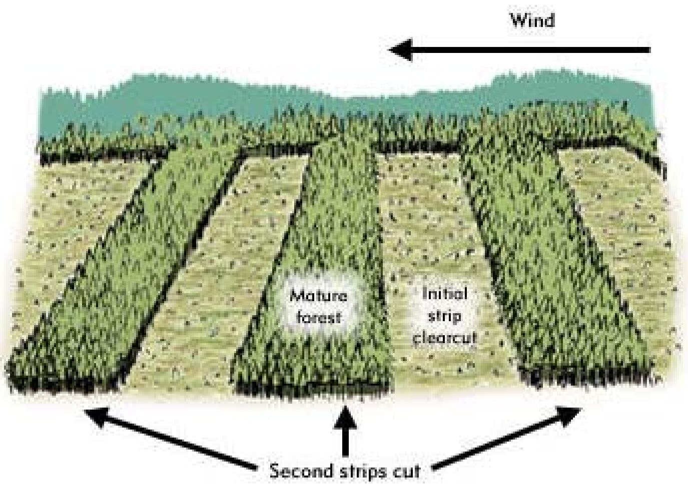
(ii)May have less impact on visual and other resource values (temporary benefit) because strips are smaller in scale than other clearcut systems (British Columbia Ministry of Forests, 2004).

– *Alternate Strip Clearcut*

In alternate strip clearcut systems the cutting unit is cut in two stages. The initial cut produces long narrow clearcuts with leave-strips in between. Often leave-strips are narrower than first-pass strips because the leave-strips are cut once the regeneration is established in first-pass strips. The second-pass cuts will therefore need planting, but this requirement can be minimized.

Figure 4.14 – Alternate Strip Clearcut

Source: British Columbia Ministry of Forests, 2004



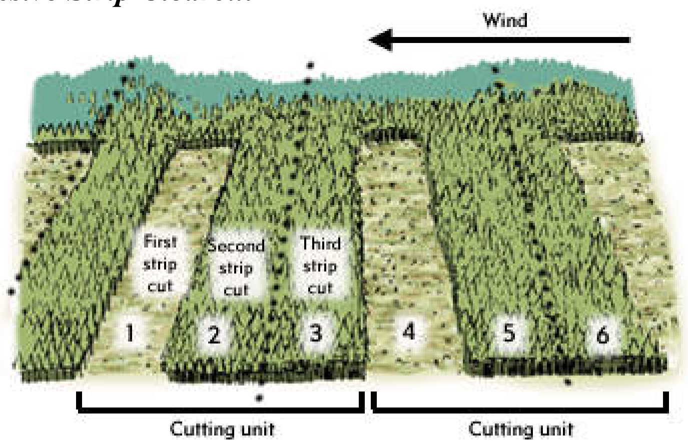
Strip clearcuts, alternate or otherwise, are best oriented at right angles to prevailing winds. The width of the strips will depend on seedfall distances for the preferred species, wind hazard, and other factors (British Columbia Ministry of Forests, 2004).

– *Progressive Strip Clearcut*

The progressive strip clearcut system accomplishes the same objectives, in essentially the same manner, as the alternate strip clearcut but in three or more passes rather than in two.

Progressive strip clearcuts have two advantages over alternate strip clearcuts: (i) the strips are progressively cut into the prevailing wind, reducing the exposed edge and windthrow; (ii) less area in the final pass needs planting (British Columbia Ministry of Forests, 2004).

Figure 4.15 – Progressive Strip Clearcut



Source: British Columbia Ministry of Forests, 2004

– *Block Clearcut Systems*

In block clearcut systems, natural regeneration from adjacent forest is not necessarily relied upon; instead, other considerations dictate block size and shape. These considerations include non-timber management objectives, forest type boundaries, terrain features, windthrow risk, and the limitations of the harvesting equipment to be used.

Advantages of block clearcut system over strip clearcut system:

(i) Allows more flexibility to meet site-specific circumstances because some planting is often used and therefore boundaries can be determined using considerations other than seed dispersal.

(ii)Larger units may make administration, planning, layout, and execution of activities less costly.

(iii)Greater flexibility to deal with large-scale catastrophic events, like fire, insects, and disease (British Columbia Ministry of Forests, 2004).

- **Seed Tree System**

In a seed tree system the entire cutting unit is managed as it is with clearcut systems. However, for a designated time period, those trees selected for supplying seed are not harvested. Trees are generally left just to supply seed for the next crop; therefore, the best phenotypes should be selected to try to encourage desirable genetic traits.

A classic seed tree system depends on natural regeneration, although the seed trees may not be relied upon entirely and some planting may occur under seed trees, often at reduced stocking levels. Usually, the seed trees are harvested in a "removal cut" once regeneration is established.

Figure 4.16 – Seed Tree

Source: British Columbia Ministry of Forests, 2004

The seed tree system advantages are similar to clearcutting, except:

(i) Lower regeneration costs if natural regeneration is easy to secure.

(ii)Better manipulation of species and genetics than with other partial cutting systems when natural regeneration is relied on (more choice for leave-trees).

(iii)Resolves issue of regeneration for species that are difficult to regenerate artificially.

(iv)Aesthetically better than clearcuts where the number and arrangement of leave-trees is visually pleasing.

(v)May be advantageous for wildlife, especially species that use large living or dead trees for habitat depends on the size, species, and vigor of the leave-trees and their duration on the site.

(vi)May have some growth and yield advantages since seed trees will grow while regeneration is being established.

The seed tree system disadvantages are:

(i) Of all silvicultural systems involving partial cutting, exposes leave-trees to the most wind. Should not be used with species, sites, or stand types with a high wind hazard. Losses should be expected on high hazard sites (will depend on individual tree characteristics).

(ii)Higher harvesting costs, compared with clearcut systems, if seed trees are removed (two-stage harvest). Also, silviculture costs may be higher if regeneration damage is excessive during seed tree removal.

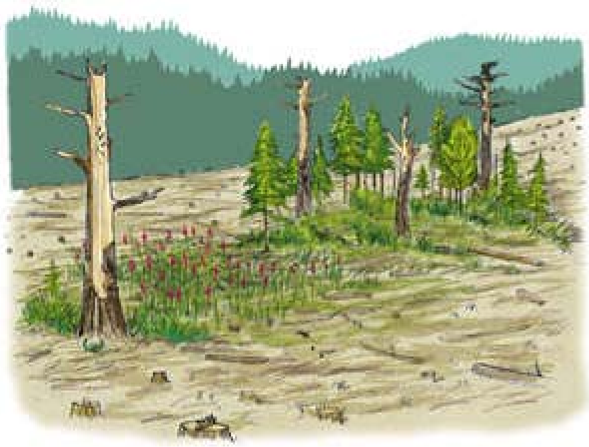
(iii)May not have an advantage over clearcutting in situations where maintaining a moderate crown cover is desirable (for aesthetics, recreation, water, wildlife, soil, or microsite objectives).

(iv)May generate lower harvest volume than with clearcut systems if seed trees are not removed (British Columbia Ministry of Forests, 2004).

– *Seed Tree System with Reserves*

When a block is managed as a seed tree system, but selected trees are reserved from removal cutting to meet long-term objectives not related to regeneration, such a silvicultural system is called a seed tree with reserves. These reserve trees are usually left to satisfy non-timber resource objectives such as visual landscape management and special wildlife habitats.

Figure 4.17 – Reserves



Source: British Columbia Ministry of Forests, 2004

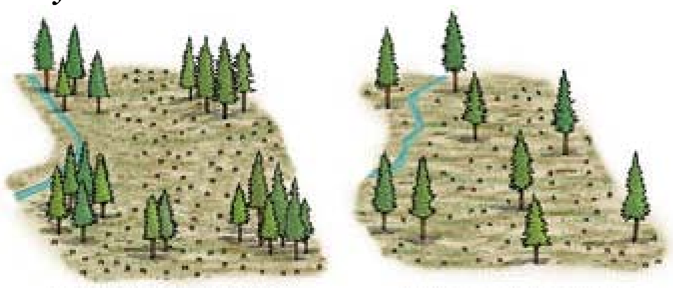
Reserves are individual trees or groups of trees retained during harvest, or other forest management operations, to provide non-timber values such as wildlife habitat, aesthetics, and biodiversity. Reserve trees are generally left for a rotation or more. However, the reserves left after the initial harvest can be replaced with new reserves from the regenerated stand, once the new stand provides the structural attributes associated with older forests such as large wildlife trees, coarse woody debris, and canopy gaps.

Reserves are most often associated with the silvicultural system clearcut with reserves. However, as you can see in the previous case study, reserves are required to be used with all silvicultural systems to ensure the protection of wildlife trees, an undisturbed forest floor, coarse woody debris, and other important stand-level attributes (British Columbia Ministry of Forests, 2004).

– *Uniform Seed Tree System*

In uniform seed tree systems, individual trees are more or less uniformly distributed throughout the block. This system is the most common seed tree system used in Canada. Often more trees are left than the number required to meet regeneration requirements. This provides an economic opportunity for a removal cut or can satisfy other resource objectives, such as wildlife habitat (British Columbia Ministry of Forests, 2004).

Figure 4.18 – Seed Tree Systems



Source: British Columbia Ministry of Forests, 2004

– *Grouped Seed Tree System*

In a grouped seed tree system, seed trees are left in the block in small patches. These patches may be arranged in irregular groups or in strips. Generally, seedfall distance is a major consideration for determining distances between patches or groups of seed trees, although non-timber objectives may also play a part.

The advantages of grouped seed tree system over uniform seed tree system are:

(i) Easier to protect from harvest damage.

(ii)Easier to harvest in final cut.

(iii)May be more windfirm if initial stand was irregular (clumpy) and an entire clump is left or, if clump is left in a protected area.

(iv)May make it easier to achieve other non-timber objectives (e.g., maintaining wildlife trees).

The advantages of uniform seed tree system over grouped seed tree system are that it is easier to choose the species and individual trees with the best characteristics for seed production, windfirmness, genetics, or any other criteria related to timber production or other resource objectives (British Columbia Ministry of Forests, 2004).

- **Shelterwood System**

In a shelterwood system the old stand is removed in a series of cuttings to promote the establishment of an essentially even-aged new stand under the shelter of the old one. Stand tending treatments are conducted to facilitate future harvesting in this manner.

The primary intent of this system is to protect and shelter the developing regeneration. Although shelterwood systems produce natural regeneration, some trees may be planted to diversify the species mix and bolster stocking. The central feature of shelterwoods is that the overstorey leave-trees are now left on-site to protect the regenerating understorey until the understorey no longer requires the protection. At some point the overstorey may start to actually inhibit proper development of the understorey trees through crown expansion and shading, although this will depend on the density of overstorey trees and the species being managed.

Criteria for leave-trees in seed tree and shelterwood systems:

(i) larger, dominant trees

(ii)windfirm trees

(iii)desirable species

(iv)desirable physical characteristics

Shelterwoods are implemented by using a series of harvesting entries, each with specific objectives and characteristics. To fully understand the shelterwood system, it is important to understand the nature and intent of these harvesting entries.

(i) Preparatory cuts: One or several preparatory cuts may improve the vigor of prospective seed-bearing trees such that they can produce a healthy cone crop and be windfirm. Most preparatory cutting is concentrated in the lower canopy classes; in effect, this harvest is similar to a low commercial thinning. If leave-trees can respond and improve growth and vigor, this often overlooked treatment may contribute the most to a successful shelterwood system. It can also provide harvestable volume from stands previously considered too young for harvesting.

(ii)Establishment cut, seeding cut, or regeneration cut: This cutting, which may be the first cutting in some stands, is intended to provide growing space for the regeneration to establish and to provide shelter for the young developing seedlings.

(iii)Removal cut(s): Once regeneration is established, stocking is acceptable, and shelter is no longer required, the sheltering overstorey is usually removed. If left too long the sheltering overstorey may hinder the developing regeneration, through excessive competition for light, moisture and/or nutrients. For shade-tolerant species it may be desirable to remove the overstorey gradually with several removal cuttings over a period of time. Shelterwood systems tend to promote even-aged stands because the cutting and regeneration period is still concentrated near the end of one rotation and the beginning of the next.

(iv)Salvage cut: This non-uniform commercial thinning removes windthrow, diseases, killed trees, etc.

Figure 4.19 – Leave Tree

Source: British Columbia Ministry of Forests, 2004

It is often made the mistake of naming a silvicultural system based on its appearance after harvesting. While the names of the systems may encourage some focus on harvesting patterns (i.e., clearcut), the real difference between the systems is in the intent that each has for regeneration and stand development.

While it is tempting to set arbitrary densities that will differentiate between seed tree and shelterwood systems at the regeneration or seed cut phase, such categories may in fact lose sight of the intent of the systems. If the leave-trees are to be maintained just for their seed, the system should be called a seed tree system. If the intent is to also provide shelter, the system should be called a shelterwood. There is no magic number of trees left on a site that differentiates a shelterwood from a seed tree system because shelter requirements are determined by climatic features within the subzone and by species-specific regeneration requirements.

The need for shelter should be the focus for the forester trying to determine leave-tree densities and distribution. For example, if cooler seedbed temperatures are required for germination, the amount of shade and corresponding residual overstorey trees will be species dependent. In some cases retaining 20-25% of the basal area may be sufficient to provide such shelter. If the overstorey is needed to maintain moisture levels in the seedbed, moderately high numbers of sheltering trees may be needed (30% or more of the original basal area). Note: leave-tree densities are species and stand-specific. If shelter is required to protect the regeneration from frost damage, high levels of overstorey retention may also be needed. Retention levels must be tailored to stand and site conditions.

For some species, poor seed production may encourage high residual densities of leave-trees, even in seed tree systems. However, for hardy pioneer species, shelterwoods on severe sites may appear quite open. For this reason, one may not be able to distinguish between a shelterwood and seed tree system by appearance alone.

If the leave-trees were maintained for their seed alone, the system should be called a seed tree system; if the intent is to also provide shelter, the system should be called a shelterwood.

The shelterwood system advantages are:

(i) Protect new regeneration that is sensitive to frost, drought, and cold winds. Such protection is not found in clearcuts, except in small cuts.

(ii)May more efficiently use the productive growing space since the sheltering overstorey will add growth as regeneration establishes. Generally trees not capable of further increases in volume and value are cut first to make room for regeneration.

(iii)May provide some protection of soil from erosion and mass wasting since precipitation inputs to soil may be reduced via interception and evapotranspiration. This effect will depend on many factors including the amount of overhead cover, skid trail density and location, and the amount of site disturbance.

(iv)Usually preferred aesthetically to clearcuts and seed tree systems through the regeneration phase.

(v)May be more beneficial for wildlife, recreation, or water objectives where significant overhead cover is desired. However, this will depend on leave-tree characteristics and their duration on-site.

The shelterwood system disadvantages are:

(i) Require more skill and time to secure regeneration than with clearcutting or seed tree systems.

(ii)Work is less concentrated, so harvesting and associated planning will be more costly.

(iii)Potential to damage young trees through the removal cut, although this risk can be reduced by careful planning and system design.

(iv)Cutting rates and regeneration establishment and growth may be more difficult to regulate and control than with clearcutting and seed tree systems. This could complicate sustained yield goals.

(v)Major problems can develop with some diseases which easily spread from the overstorey to the regeneration.

(vi)May be more difficult to conduct silviculture treatments like site preparation and vegetation control (British Columbia Ministry of Forests, 2004).

– *Uniform Shelterwood Systems*

In uniform shelterwood systems, treatments are applied uniformly over the same stand: this is the standard type of shelterwood. The uniform system is the system that most often relies on a series of preparatory cuttings (thinnings) to ready the stand for the regeneration/establishment cutting by encouraging crown expansion, and promoting windfirmness and cone production.

In Europe the practice of making preparatory cuttings 2-10 years before the regeneration cutting has generally been replaced by a schedule of preparation thinnings throughout the life of the stand to better encourage the crown expansion and windfirmness required for the establishment cutting.

Figure 4.20 – Uniform Shelterwood System

Source: British Columbia Ministry of Forests, 2004

The uniform shelterwood system advantages are:

(i) Felling is simpler than in most shelterwood systems.

(ii)Produces regular, even-aged stands with uniform, straight stems.

The uniform shelterwood system disadvantages are:

(i) May damage regeneration during harvesting of overstorey during removal cuttings.

(ii)Vulnerable to windthrow where hazard is high and overstorey is susceptible. Future crops will also be susceptible due to regularity and uniformity.

– *Strip Shelterwood System*

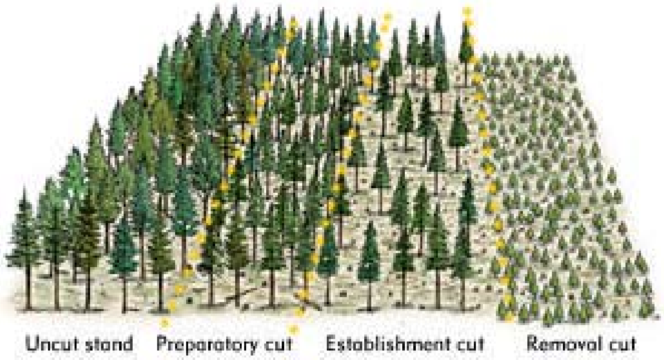
Harvesting entries in a strip shelterwood are made in relatively narrow strips that advance progressively through a portion of the block over the regeneration period. In this way initial harvesting occurs in the stand as uniformly staggered linear strips. Future harvesting strips are added beside the initial strips and progress into the wind until the entire block is harvested, usually within a normal even-aged regeneration period (10-25 years). Harvesting in each strip may occur gradually and include a preparatory, regeneration and removal cut, following in sequence, or strips may be oriented to use the side shade from adjacent forest.

Strip shelterwoods evolved in Europe to provide some protection from windthrow. Establishment cuts (preceded possibly by preparatory cuts) and removal cuts are made in narrow strips running perpendicular to, and advancing progressively against, the prevailing wind direction.

Strip shelterwood does not necessarily cause any greater range of age between the individuals of the new stand than does application uniformly over the entire area since the period of regeneration is the same in the two cases.

Figure 4.21 – Strip Shelterwood System

Source: British Columbia Ministry of Forests, 2004



The strip shelterwood system advantages are:

(i) May adjust conditions of shelter and seedling microsite within systematically arranged transition zones along the leading edge of strips.

(ii)May provide side protection in a specific direction against wind and sun.

(iii)Can provide side protection from sun, which is generally more effective than overhead cover on sites subject to drought and radiation frost.

(iv)Allows for extract of harvested timber through the mature forest and avoid residual damage in areas of tall regeneration.

(v)May easily plan and execute harvesting, regeneration, and tending operations in a systematic, logical fashion.

(vi)May easily control the progress of regeneration and growth and determine the impact on yield.

(vii)May have advantages for biodiversity and aesthetics through variation in sizes of trees and diversity of small habitats near one another.

The strip shelterwood system disadvantages are:

(i) Requires a specialized and rigid layout.

(ii)Requires careful design to gain aesthetic benefits since straight lines may not be considered natural (British Columbia Ministry of Forests, 2004).

– *Group Shelterwood System*

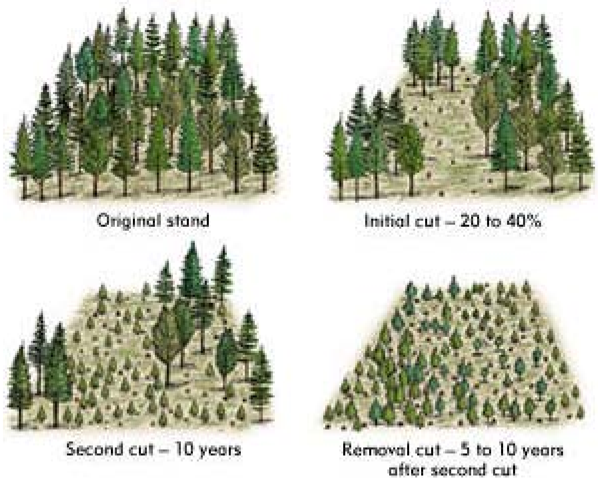
In the simplest form of the group shelterwood system, small gaps (one to two tree lengths in diameter) are created in the stand. The adjacent trees can shelter the new regeneration growing in the gaps. For example, these openings may comprise 20-40% of the stand area during a given entry. Further cuts expand existing openings or create new openings.

The regeneration period for the cutting unit is still concentrated at the beginning of the rotation over 20-30 years, creating an even-aged stand.

The beech forest of Sihlwald in Zurich, Switzerland, was classically managed for over 400 years under a group shelterwood system. In the early 1900s this forest inspired Gifford Pinchot, the first chief forester of the US Forest Service. In 1989, public pressure forced city officials to limit cutting to commercial thinning.

Figure 4.22 – Group Shelterwood System

Source: British Columbia Ministry of Forests, 2004



A German variation (*Gruppenschirmschlag*) mixes the simple group and the strip shelterwood systems. This system uses existing gaps with advance regeneration by initiating a regeneration cutting in a ring around the existing gaps. Additional gaps may be created, each followed by a regeneration-cut ring, once regeneration is established. The regeneration-cut ring continues to expand in successive passes, with removal cuttings following it, once regeneration is established. Eventually, the shelterwood expands to occupy the whole stand.

Woodflow and skid trail networks must be laid out carefully ahead of time to minimize damage to developing regeneration. In windy areas, exposed stand edges should be anchored by windfirm trees and cutting should be modified to progress into the wind as much as possible.

The strip and group system combines elements of the two approaches. First, small groups are opened within a strip to encourage advanced patches of regeneration. After the regeneration has started, the groups are then opened wider and a uniform regeneration felling is made between the groups. A third entry to further widen the groups may occur before the removal cut, providing for regeneration of species mixes, including shade-intolerant species.

The strip and group shelterwood system were developed chiefly in Bavaria, Germany, by H. von Huber, chief of the Bavarian Forest Service. It is now widely used in central Europe.

There is likely to be more injury to reproduction from removal of the old forest in the group than in the strip shelterwood method, because of the more irregular way in which old forest is intermingled with young growth.

The group shelterwood system advantages are:

(i) May provide suitable light conditions for all tree species in a particular biogeoclimatic subzone.

(ii)May have advantages for biodiversity and aesthetics through variation in sizes of trees and diversity of small habitats near one another.

(iii)Young stands may develop more naturally than in uniform systems (in forest types where small-scale "gap disturbance regimes" are common).

(iv)Can be used as group openings to concentrate and plan the pattern of small openings, thereby meeting more closely the management objectives (e.g.,release and use advance natural regeneration, maximize habitat, water, or aesthetic benefits).

(v)May protect against snow breakage and sliding on steeper slopes due to the irregular nature of the regeneration.

(vi)Felling is directed away from gaps with regeneration, thereby avoiding damage to regeneration in early stages.

The group shelterwood system disadvantages are:

(i) Regulation and control of cutting and regeneration, is more time consuming due to small scattered centers of regeneration.

(ii) Regeneration must be able to tolerate exposure to open conditions on north edges as gaps enlarge.

(iii) Planting may be necessary in the simple versions.

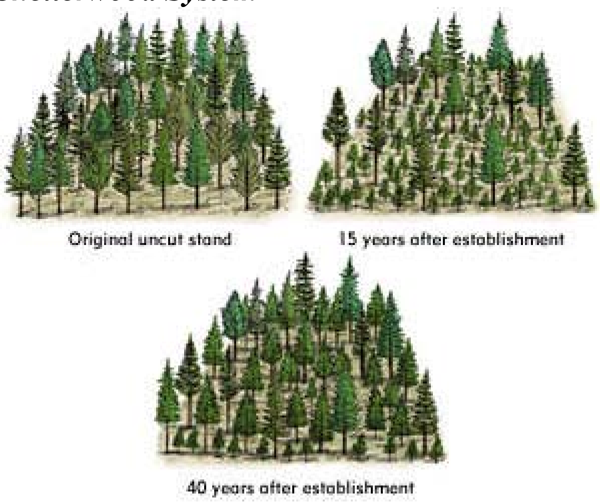
(iv) Requires dense extraction network to offset scattering of activities. However, excessive roading may be mitigated or even eliminated through careful planning (British Columbia Ministry of Forests, 2004).

– *Irregular Shelterwood System*

Irregular shelterwoods are defined by timing of regeneration establishment not by spatial arrangement. The regeneration period for the stand is extended so long that the new stand is not really even-aged. Although the regeneration period may extend up to 50 years over the whole cutting unit, the stand does not have three or more age classes, as in an uneven-aged stand. Therefore, the stand structural objective is between the even-aged and uneven-aged structure.

This system may be executed the same way as a shelterwood with reserves if the overstorey is retained for the entire rotation. The difference is that with an irregular shelterwood, the seedbed is receptive to regeneration for a long time and the intent is to continue to procure regeneration for much longer than the normal regeneration period.

Figure 4.23 – Irregular Shelterwood System



Source: British Columbia Ministry of Forests, 2004

"Irregular" refers to the subsequent variation in tree heights in the new stand. This system tends to draw on elements from other systems, notably group and single tree selection. While our example shows retained leave-trees scattered individually through a block, felling in groups is common. The groups are expanded slowly outward until they coalesce at the end of the regeneration period (50 years or longer). The irregular shelterwood system is very versatile and can be applied in uniform, strip, or group spatial variations (i.e., irregular group or irregular strip shelterwood).

This irregular shelterwood system is usually used to promote structural diversity while maintaining the simplicity of even-aged management. Objectives for aesthetics, wildlife, biodiversity, or hydrological green-up may be compatible with this system.

Of all the classical silvicultural systems, some form of the group systems and the irregular shelterwood system have the best potential for geriatric silvicultural prescriptions in over-mature ecosystems. The irregular shelterwood is the most recent silvicultural system to have been developed, and has replaced all the others except the selection system.

The irregular shelterwood system advantages are:

(i) Very flexible system.

(ii)Best possible use of each small site.

(iii)Highly diverse forest structure with potential advantages for wildlife, biodiversity, recreation, and aesthetics objectives.

The irregular shelterwood system disadvantages are:

(i) Planning and execution made difficult with scattered activities.

(ii)Requires dense extraction network to offset scattering of activities. However, excessive roading may be mitigated or even eliminated through careful planning.

(iii)Requires a high level of skill in planning and execution.

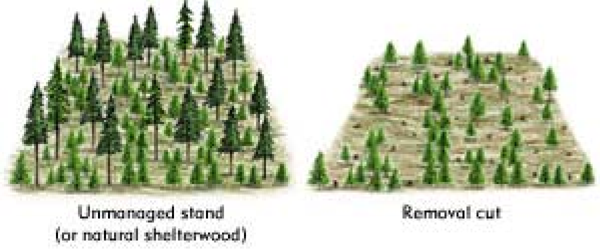
(iv)Favors shade-tolerant species unless opening size is large enough to promote shade-intolerant species (British Columbia Ministry of Forests, 2004).

− *Natural Shelterwood System*

Often associated with clearcutting and called "overstorey removal," this system may better be called a shelterwood because the regeneration is established naturally under the shelter of an overstorey.

Some foresters express concern over labeling what will look like a regenerated clearcut a type of shelterwood. This concern relates to the difference between harvesting patterns, which are short term, and silvicultural systems, which are long term. All shelterwoods or seed tree systems will look like regenerated clearcuts after removal cutting, unless some "reserve trees" have been retained.

Figure 4.24 – Natural Shelterwood System



Source: British Columbia Ministry of Forests, 2004

By definition, a natural shelterwood may only be used once when some unmanaged stands come under management. However, these types of stands may be quite suitable for continued management using a shelterwood system over subsequent rotations.

The natural shelterwood system advantages are that it saves planting costs and time. A 10- to 15-year-old stand may already be established after harvest, significantly shortening the regeneration delay period.

The natural shelterwood system disadvantages are:

(i) Requires a well-stocked, acceptable understorey.

(ii)Requires a vigorous, acceptable regeneration in the understorey that will be able to release and grow to a merchantable size. It is generally considered necessary to have 2 times the target stocking to allow for harvesting damage.

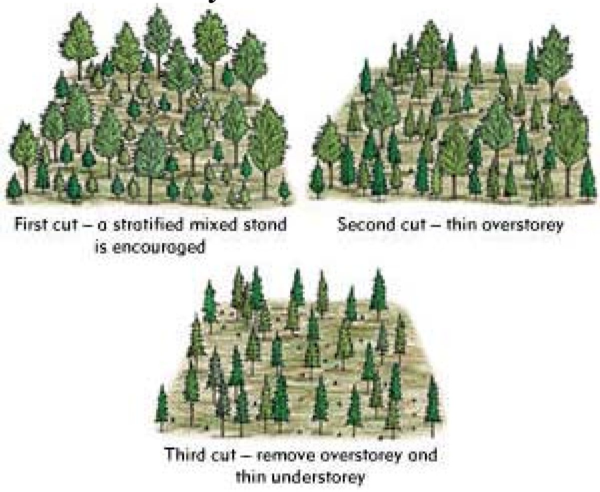
(iii)Must be economically possible to harvest the overstorey and save the regeneration.

(iv)May require some quality slashing or spacing after harvesting and some fill planting (British Columbia Ministry of Forests, 2004).

– *Nurse-Tree Shelterwood System*

These systems encourage development of two stories in a stand, each containing a different species or mix of species. With these systems, intolerant, seral species tend to make up the overstorey with tolerant, climax species making up the understorey.

Figure 4.25 – Nurse-Tree Shelterwood System



Source: British Columbia Ministry of Forests, 2004

The nurse-tree shelterwood system may be used to maintain a component of shade-tolerant species on sites where these species require protection, or on cleared sites where desired tolerant species grow too slowly to compete successfully with other vegetation in the open.

Establishment of a hardy, shade-intolerant, exposure-tolerant species as a nurse-crop may precede establishment of the more sensitive, shade-tolerant species. The understorey of shade-tolerant trees may be established either naturally or artificially. However, a proper understanding of natural succession dynamics and species requirements is essential for success.

The nurse-tree shelterwood system advantages are:

(i) May logistically fit with natural succession and therefore works with, rather than against, succession.

(ii)Overstorey provides protective cover for establishment of species.

(iii)May allow for "heavy" thinning of overstorey, without excessive reduction to growing space occupancy, to get early returns at a mid-point in the rotation.

The nurse-tree shelterwood system disadvantages are:

(i) Can considerably damage understorey when overstorey is thinned or harvested. The understorey can be protected by careful harvesting and planning of the road network. Also, the understorey can be thinned to allow future overstorey fellings to fall into gaps.

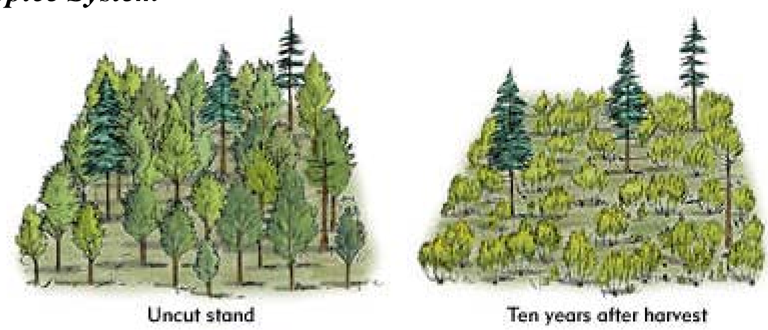
(ii)Must establish a stratified stand with different species in each layer. This may require planting for one or both layers. Combinations of other systems may preclude this requirement and still allow for a stratified species mixture (British Columbia Ministry of Forests, 2004).

- **Coppice System**

The coppice system is an even-aged silvicultural system for which the main regeneration method is vegetative sprouting of either suckers (from the existing root systems of cut trees) or shoots (from cut stumps). This system is limited to hardwood species management. In areas with shade-intolerant commercial hardwood tree species, opening sizes for the coppice system are generally larger than one hectare.

While clearcut, seed tree, shelterwood, and selection systems have often been referred to as high forest systems because regeneration generally originates from seed (even if planting occurs), the coppice system has been referred to as a low forest system due to reliance on vegetative reproduction. In Europe seed-origin hardwoods are sometimes interspersed in a stand and grown over regular rotations with coppice crops produced in between. This system, coppice with standards, works particularly well when the hardwood species are shade-tolerant. Coppice with standards can be more appealing for maintaining non-timber resource values.

Figure 4.26 – Coppice System



Source: British Columbia Ministry of Forests, 2004

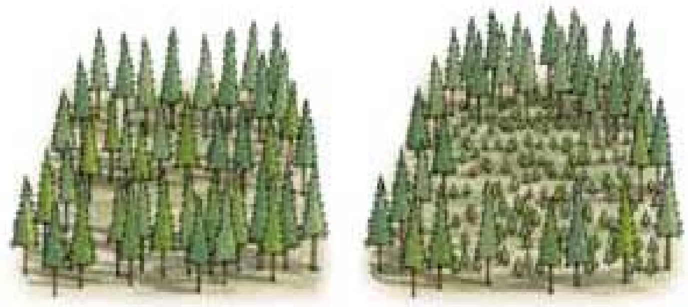
Coppice systems were used in Europe by the Romans and during the Middle Ages mostly to provide firewood for fuel (British Columbia Ministry of Forests, 2004).

- **Patch Cut System**

The patch cut system involves removal of an entire stand of trees less than one hectare in size from an area. Each patch cut is managed as a distinct even-aged opening. If an area contains several patch cuts, each opening is still managed as a distinct opening. Regeneration is obtained either by artificial or natural regeneration, or a combination of the two.

As mentioned earlier, this system is a clearcut variant. However, these very small openings have characteristics that differ from a typical clearcut.

Figure 4.27 – Patch Cut System



Source: British Columbia Ministry of Forests, 2004

The patch cut system is a type of clearcut silvicultural system that promotes natural regeneration in small openings. All definitions of patch cuts include the concept of small openings that will be managed as individual stand units, unlike the openings created in a group selection or group shelterwood situation (British Columbia Ministry of Forests, 2004).

- **Retention Silvicultural System**

Retention system means a silvicultural system that retains individual trees or groups of trees to:

(i) maintain structural diversity over the area of the cutblock for at least one rotation

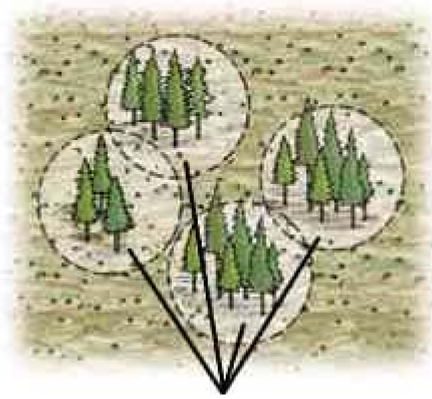
(ii)leave more than half the total area of the cutblock within one tree height from the base of a tree or group of trees, whether or not the tree or group of trees is inside the cutblock.

(iii)Retention can be dispersed throughout a cutblock as single trees or aggregated groups of trees.

The proportion of an opening that is influenced by the surrounding trees differentiates a clearcut from a retention system. Clearcutting is the harvesting of all trees in a single cut from an area of forest large enough so that the “forest influence” is removed from the majority of the harvested area. In practice, seldom will any spot within a retention system opening be more than two tree heights away from standing trees. This will result in more than half of the opening being influenced by surrounding trees.

In the retention system the retained is planned, not the removed. Retention areas should be designed to provide late successional structures to enrich diversity, enhance habitat connectivity over the landscape, and supply refuges for survival and dispersal of species after harvesting.

Figure 4.28 – Area under Forest Influence



Source: British Columbia Ministry of Forests, 2004

Retention objectives are unique to the individual area or landscape unit. These objectives must be clearly expressed in the operational plan for the area.

Figure 4.29 – Retention Systems

Source: British Columbia Ministry of Forests, 2004

The retention system advantages are:

(i) Follows nature's model by retaining part of the forest after harvesting.

(ii)Retains structural features - snags, large woody debris, live trees of varying sizes, and canopy layers - as habitat for a wide variety of organisms.

(iii)Retention structures can be dispersed throughout a cutblock (individual trees or small groups) or aggregated (clumps or patches) depending on the objectives.

(iv)Can mitigate factors such as visual viewscapes and wildlife habitat that might constrain amounts of timber available.

(v)May be advantageous for wildlife that require large living and dead trees for habitat.

(vi)May be well suited to shade-tolerant species or species requiring a shaded environment for establishment.

(vii)Lower regeneration costs if natural regeneration is easy to achieve.

(viii)May allow for establishment of species that are hard to regenerate artificially if retention of some advanced regeneration is possible.

The retention system disadvantages are:

(i) Pioneer vegetation may have a great advantage and may inhibit and overtop regeneration.

(ii)Site preparation and some vegetation management activities may be restricted or more difficult.

(iii)Work is less concentrated, so harvesting and/or associated planning will be more costly.

(iv)Requires more worker skill to achieve goals and involves more training at extra cost.

(v)Increases risk of exposed residual trees to windthrow.

(vi)Some diseases can easily spread from the retained overstorey to regeneration.

(vii)May require more roads unless layout is carefully done (British Columbia Ministry of Forests, 2004).

- **Selection System**

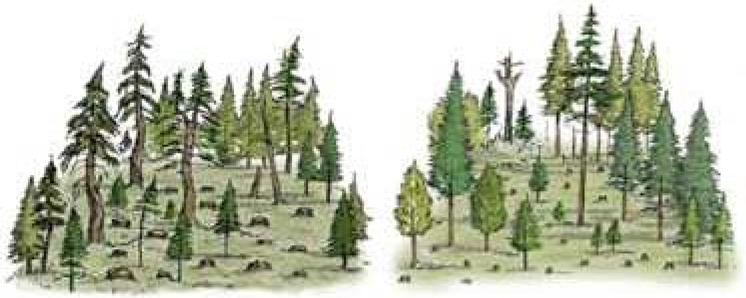
In the selection system, the only uneven-aged system, mature trees are removed either as single scattered individuals or in small groups at relatively short intervals, repeated indefinitely, where an uneven-aged stand is maintained. Regeneration should occur throughout the life of the stand with pulses following harvest entries.

This system depends on recruitment of trees into successive age classes over time and the predictable yield from merchantable age classes. Yield will be obtained by thinning clumps, harvesting individual trees, or by harvesting whole groups of the most mature age class to create small openings scattered throughout the stand.

People often confuse the term selective logging with selection system. Selective logging is an illegal logging practice, where the largest, highest quality trees from a stand are removed. Selective logging amounted to mere exploitation, requiring little or no silvicultural skill. This style of cutting does not provide for regulated sustained yield and often results in overstocked stands with a deteriorated gene pool. From a long-term management perspective this approach to harvesting is similar to shooting the top three finishers in a horse race and putting the last place horses out to stud. The term selective logging should not be used in silvicultural terminology due to its association with these crude practices.

As Swiss foresters tried to transfer German clearcut/even-aged approaches to Switzerland, they encountered problems due to differences in climate, terrain and land tenure. Karl Gayer and Arnold Engler encouraged a more "natural system" in the late 1800s. In 1920, Henri Boilley built on the work of French forester Adolph Gurnaud to develop the "check method," the precursor to the modern selection system.

Figure 4.30 – Selective System



Source: British Columbia Ministry of Forests, 2004

The selection system advantages are:

(i) Well suited to uneven-aged stands that cannot easily be converted to even-aged without wasting considerable growing stock.

(ii)Fulfills management objectives that require maintenance of some large trees on-site for aesthetic and/or wildlife habitat reasons.

(iii)Desirable on sites where climatic conditions are seldom conducive to regeneration and growth is too slow to justify cost of planting. Trees on-site produce seed whenever circumstances allow.

(iv)Can make the best possible use of the site since the system is both flexible and intensive.

(v)May have advantages for small landowners who wish to harvest smaller yields over more frequent intervals while minimizing initial development/regeneration costs.

(vi)May be more flexible in reacting to changes in markets that influence management objectives for tree size and quality.

(vii)May provide some soil protection through the presence of a continual, variable canopy. Soil damage, however, can still be influenced by the nature and extent of roading, and the maintenance of roads. Note: With ground-based harvesting, this system may require extensive roading.

(viii)May provide some protection from fire once the stand structure is established due to the broken irregular structure that may disrupt rapid spread through the upper canopy.

(ix)Tend to minimize snow and wind damage. This is not necessarily the case if attempts are made to convert even-aged stands to uneven-aged stands using group selection or other methods.

(x)May allow for merchantable volume gains, by capturing mortality from frequent harvesting entries and from continuous stocking.

The selection system disadvantages are:

(i) Considerable silvicultural skill is required in planning and executing of selection systems.

(ii)Felling and extraction must be done with extreme skill and care.

(iii)Costs are often increased in planning and execution.

(iv)Tend to favor the most shade-tolerant species for the site when single tree selection systems are used. (May not be advantageous if shade-intolerant species are preferred.) However, shade tolerance is relative and depends on the species and subzones.

(v)Highgrading is a potential problem.

(vi)Stands often regarded as uneven-aged and more or less balanced when they are not. This assumption is made because a wide range of diameter classes or mixed species may be present.

(vii)May incorrectly assume that the allowable harvesting rate is equal to the periodic annual increment. Stands resulting from highgrading will have a predominance of middle-aged trees If these stands are cut at a rate determined by periodic annual increment, the average diameter will decline for every cutting cycle and the trees available will decrease.

(viii)Stands often undercut. Quantitative guides are needed to prevent stands from being overcrowded with middle-aged trees.

(ix)The "balanced uneven-aged structure" may become the major goal instead of a means of attaining objectives. This may lead to reckless cutting of age classes with desirable, but surplus, trees and careful retention of poor trees in sparse diameter classes. This blind adherence to diameter distribution may interfere with resource objectives.

(x)May be difficult to handle disease problems.

(xi)While harvest volumes per unit area are low, harvesting is spread over more of the land base at a given time, with more frequent entries on the same unit of land. This continuous harvesting may not be perceived favorably by the public.

(xii)Increased site degradation is possible when using certain harvesting methods on specific sites.

(xiii)The risk of damage to the remaining trees is present during each harvest entry (British Columbia Ministry of Forests, 2004).

– *Single Tree Selection System*

Single tree selection removes individual trees of all size classes more or less uniformly throughout the stand to maintain an uneven-aged stand and achieve other stand structural objectives. While it is easier to apply such a system to a stand that is naturally close to the uneven-aged condition, single tree selection systems are prescribed for even-aged stands, although numerous preparatory cuttings must be made to create a stand structure where the system can truly be applied.

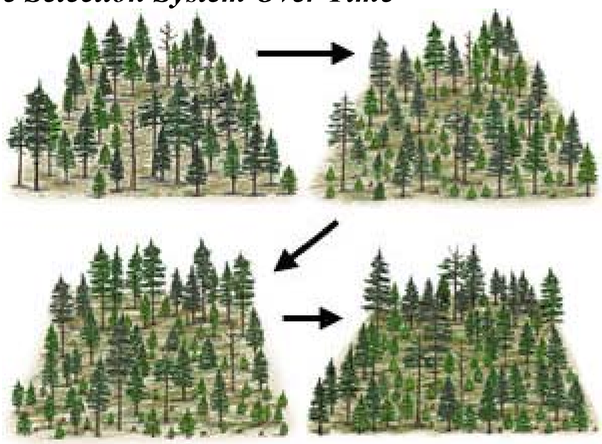
Once the uneven-aged structure approximates the balanced condition, the single tree selection system generally produces a complex mixture of small, even-aged clumps which are thinned over time to theoretically produce one mature tree. In theory these clumps should yield at least one mature tree of the specified maximum diameter, although in practice these clumps are often larger.

New regeneration develops in small scattered openings created theoretically in small gaps with an area equivalent to the crown spread of a single mature tree. In practice these gaps are often larger, created through the removal of several mature trees. Since regeneration is always being recruited and larger mature trees are scattered, or in very small groups, these stands appear quite open, with many gaps. The system is generally used for the most tolerant species in an area. Using the single tree selection system to encourage species mixtures requires effort, especially where some less tolerant seral species are desired. Such stands must be opened considerably for this system to work.

Since these stands are a confusing jumble of age classes, regulation of these stands tends to be complex. Usually guidelines for residual stocking, maximum diameter, diameter distribution and cutting cycle are used during each entry. It is dangerous attempting to create mini, sustained yield units at the stand level. It is suggested that foresters should instead focus on maintaining a continuous stock of larger trees, without excessive concern about perfectly balancing age classes.

Close monitoring and periodic remeasurement to follow selection stands through their cutting cycles are suggested, since these parameters can be adjusted to fit the biological reality with the management objectives. All authors encourage foresters to never forget the basic tenets for successful single tree selection: to provide sufficient gaps for regeneration and to maintain vigor throughout the stand.

Figure 4.31 – Single Tree Selection System Over Time



Source: British Columbia Ministry of Forests, 2004

However, it is recommend using all of the classic selection parameters as interim guidelines.

The single tree selection system advantages are:

(i) Generally better than group selection if discernible openings are to be minimized.

(ii)May be better than group selection at reducing wind, snow and, in some cases, fire damage.

The single tree selection system disadvantages are:

(i) Crown closure of adjacent trees may occur before the regeneration in the small openings can occupy a place in the canopy. This risk makes frequent assessment and light cuttings necessary. Also, the growth and branching characteristics of the overstorey trees should be considered before developing a prescription.

(ii)More difficult to protect regeneration and immature age classes than with group selection as operations are scattered and mixed into a mosaic of treatment units.

(iii)Logging may be more difficult and costly than with group selection. Very large trees or difficult terrain further increase difficulty. best for light equipment and suitable terrain where permanent skid trails or skidding corridors can be used on a continuous basis suited to either ground-based or light cable systems.

(iv)More complicated to manage regulation, planning, and layout for single tree selection than group selection.

(v)May be more difficult to meet environmental regulations when managing for wildlife trees because frequent harvesting entries are made throughout most of the stand (British Columbia Ministry of Forests, 2004).

− *Group Selection System*

Group selection systems also promote uneven-aged stands with clumps of even-aged trees well distributed throughout the cutting unit. Unlike single tree selection, however, these even-aged groups are large enough to accommodate some shade-intolerant seral species in addition to more tolerant climax species. Small gaps or openings are created on short intervals to develop into a mosaic of at least three or more age classes throughout the stand.

The choice of group or single tree selection must consider the resource management objectives at all levels and the existing stand and site conditions. Because of stand-level advantages, group selection or any other system cannot be viewed as a panacea in areas with many conflicting management objectives. The implications of using a broad application of one silvicultural system over a large area could be serious for one or more management objectives.

Figure 4.32 – Group Selection System

Source: British Columbia Ministry of Forests, 2004

Basically the group selection system is easier to administer and treat than single tree selection. The simplest types of group selection systems create definite gaps in the forest canopy. These systems fit ecologically with "gap-regenerated" stands, which tend to be common in some unmanaged stand types. If gaps are large enough, the entire spectrum of local vegetation may regenerate within them. This may encourage a diverse habitat for wildlife and promote biodiversity.

Such a stand can be regulated using simple area management techniques, although diligent stratification and mapping would be required. However, if groups are quite small and the age classes numerous, the stand may best be regulated as a single tree selection with intensive marking and the full range of uneven-aged parameters.

Some authors suggest that group selection systems may have openings as small as that created through the removal of two or three trees, up to as large as several tree lengths across. However, single tree selection system, where opening size approximates that created through the removal of a single mature tree, is rarely applied on the ground. Instead, single tree selection often removes clumps of several mature trees, potentially confusing it with this definition of group selection. Also, some authors speak of group/single tree selection combinations and patch selection systems, where single tree selection is combined with small fixed-area patches at widely scattered locations.

The array of terms used for uneven-aged systems can become quite confusing. Therefore, it is perhaps simpler to recognize a continuum of group or clump sizes between single tree selection and group selection. Use of the terms may vary among managers depending on the species they manage and the ecology of their sites. At the margin between the two systems the name chosen to describe them probably does not matter too much. It is appropriate to call selection systems single tree selection when the group openings created are so tiny that simple area based regulation is impractical and the classic uneven-aged parameters must be used.

At the other end of the group-size question, a group selection with 5 hectare openings to harvest a 200 hectare stand stretches the definition of group selection too far. Authors worldwide agree that a group becomes a clearcut ecologically when most of the opening (greater than 50%) starts to have the same environmental regime as a large clearcut. The opening size will depend on the biological requirement of the preferred tree species and other resource objectives. However, if the openings become larger then several tree lengths, they may approach the clearcut environment. Ecological considerations related to the influence of the stand edges would depend on aspect, slope, and other terrain features which may influence the angle of solar radiation and wind flow.

The Advantages of group selection system over single tree selection system are:

(i) Easier to plan, control, and therefore reduce costs of harvesting, site preparation, planting, and intermediate treatments.

(ii)Trees develop in clearly defined even-aged aggregations, with associated advantages for form.

(iii)May benefit some wildlife and increase diversity of stand species due to increased heterogeneity, with increased edge effect and maintenance of good cover in the same stand.

(iv)May satisfy regeneration requirements for a greater range of species.

(v)May be better able to meet environmental requirements when managing for wildlife trees.

The disadvantage of group selection system over single tree selection system can be increased edge between young and mature trees may create problems such as:

(i) large edge trees compete for light (and moisture on dry sites) and may shed snow on to the regeneration encouraging damage

(ii)more windthrow may be encouraged, depending on size of openings and wind hazard and risks

(iii)insects and diseases could be spread to the regeneration

(iv)more browsing damage to regeneration may be encouraged (British Columbia Ministry of Forests, 2004).

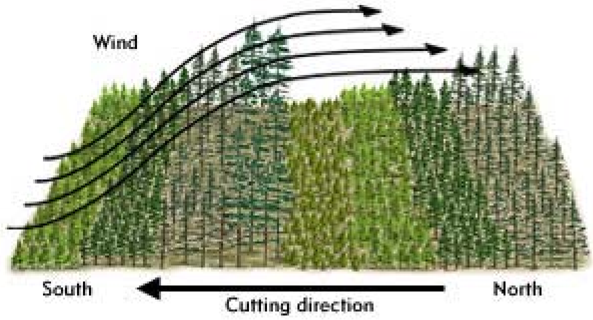
– *Strip Selection System*

The strip selection system manages age classes in regular strips rather than unspecified group shapes. This system was developed to provide advantages for managing windthrow. As with other systems using strips, the strips should be oriented perpendicular to the prevailing wind. If cutting proceeds systematically against the wind, the stand develops an aerodynamic shape, with further advantages for wind protection.

Again, this system differs from the strip shelterwood system in that the strips are removed over three or more passes to give a truly uneven-aged stand and their removal occurs much more slowly. The cutting period between passes will be 15-30 years, depending on the number of passes, and a regular rotation is needed to complete all passes.

As in the strip shelterwood system, the strip width in the strip selection is sufficiently narrow to create an environment that differs substantially from a clearcut and produces strips that are too small to qualify as individual stand units. Because they have the advantage of one long dimension, strips tend to be narrower than groups. Where mature tree heights are 30-35 m, strips widths of 15-50 m will be used, depending on orientation and objectives. These systems are well suited to small skyline systems.

Figure 4.33 – Strip Selection System



Source: British Columbia Ministry of Forests, 2004

The strip selection advantages are:

(i) Timber is scattered throughout the stand and often must be harvested across areas of regeneration in both single tree and group selection. This problem may be avoided by concentrating each age class in a long narrow strip.

(ii)May progressively develop a complete set of age classes across the landscape.

(iii)Similar to strip shelterwood.

(iv)Enables transport of logs through next strip to be harvested.

(v)Road location and consideration of harvesting patterns ahead of time is very important.

(vi)Will want to progress into the most dangerous winds, or towards the south if harvesting allows.

(vii)If wind protection wanted, resulting stand has an "aerodynamic effect."

(viii)May get an increased water yield from snow-melt in both strip and group systems.

The strip selection disadvantages are:

(i) More time consuming to implement.

(ii)May be less aesthetically pleasing than group selection depending on scale, viewpoint, and viewing distances.

5 – SPECIES TO BE PLANTED

5.1 – Africa

The African continent has a land area of about 3 billion hectares. From that, about 24% are covered with forests (774 million hectares). Almost all forests are located in the tropical ecological domain, and Africa has about one-quarter of all tropical rain forests. Only 1 percent of the forest area is classified as forest plantations. Table 6.01 shows the forest cover of each African ecologic zone.

Table 5.01 - Forest Area by Ecologic Zone - Africa (Million Hectares)

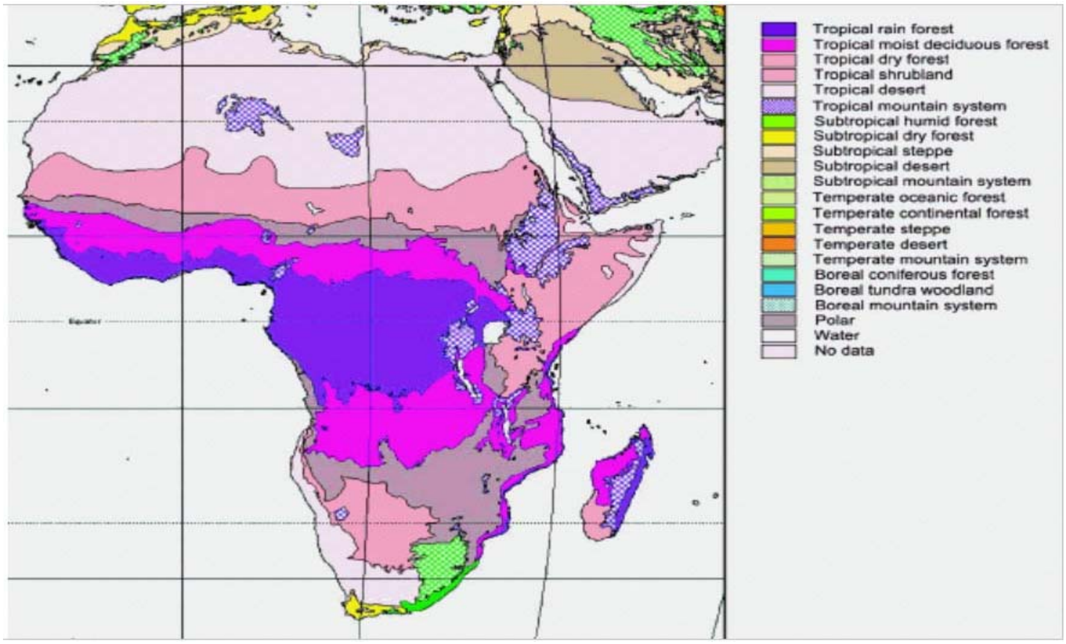
Ecologic Zone	*Total Area*	*Forest Cover*	*Forest Area*
Tropical	**2,898**	**21%**	**598**
Rain forest	409	57%	233
Moist	473	31%	147
Dry	370	48%	178
Shrub	601	4%	24
Desert	898	0%	0
Mountain	147	11%	16
Subtropical	**133**	**7%**	**10**
Humid	8	16%	1
Dry	35	19%	7
Steppe	48	0%	0
Mountain	42	4%	2
Total	**3,031**	**457%**	**608**

Source: FAO, 2001

The net change of forest area is the highest among the world's regions, with an annual net loss, based on country reports, estimated at -5.3 million hectares annually, corresponding to -0.78 percent annually. Figure 5.01 shows the African ecologic zones distribution.

Figure 5.01 – African Ecologic Zones

Source: FAO, 2001



5.1.1 - Tropical Rain Forest

This zone covers the central part of Africa on both sides of the equator as well as the southeastern coast. The climate is more or less tropical. Rainfall ranges from 1,000 mm to more than 2,000 mm per year. If there is a dry season, it does not exceed three to four months and always occurs in winter. Temperature is always high, generally more than 20°C, except in the mountains.

The greater part of the zone was formerly covered with rain forests and swamp forests. Today, little undisturbed rain forest remains and secondary grassland and various stages of forest regrowth are extensive. Compared to the rain forests of South America and Asia, African forests are relatively poor floristically.

The most extensive formation is the Guineo-Congolian lowland rain forest, concentrated in the Congo Basin. It is a tall, dense forest, more than 30 m high with emergents up to 60 m and several strata. Some species are deciduous but the forest as a whole is evergreen or semi-evergreen.

The rain forest of Madagascar is 25 to 30 m tall, without large emergent trees but very rich in species. It is evergreen and grows up to 800 to 1,000 m altitude.

In Africa, this ecologic zone has a total area of about 409 million hectares, from which 233 million hectares are now covered with forest (57%).

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abrus canescens
Acanthus latisepalus
Acioa lujae
Acioa pallescens
Acioa staudtii
Acridocarpus longifolius
Adhatoda bolomboense
Adhatoda buchholzii
Afzelia africana
Afzelia bella

Afzelia bipindensis
Afzelia pachyloba
Afzelia quanzensis
Aganope impressa
Aidia micrantha
Aidia ochroleuca
Albizia adianthifolia
Albizia ferruginea
Albizia gummifera
Albizia laurentii
Alchornea cordifolia
Alchornea floribunda
Alchornea hirtella
Allexis cauliflora
Allophylus africanus
Alsodeiopsis poggei
Alstonia boonei
Alstonia congensis
Alstonia gilletii
Aneulophus africanus
Angylocalyx oligophyllus
Aningeria altissima
Aningeria robusta
Anonidium floribundum
Anonidium mannii
Anthocleista liebrechtsiana
Anthocleista schweinfurthii
Anthocleista vogelii
Anthonotha gilletii
Anthonotha macrophylla
Antiaris africana
Antiaris welwitschii
Antidesma laciniatum
Antidesma membranaceum
Antidesma rufescens
Antidesma venosum
Antidesma vogelianum
Aphanocalyx djumaensis
Aptandra zenkeri
Argomuellera macrophylla
Artabotrys crassipetalus
Artabotrys thomsonii
Atractogyne gabonii
Aucoumea klaineana
Augouardia letestui
Baikiaea fragrantissima
Baikiaea insignis
Baikiaea robynsii
Baillonella toxisperma
Baissea axillaris

Baissea baillonii
Baissea leonensis
Balanites wilsoniana
Baphia buettneri
Baphia dewevrei
Baphia leptostemma
Baphia maxima
Barteria nigritiana
Bauhinia tomentosa
Beilschmiedia congolana
Beilschmiedia dinklagei
Beilschmiedia gabonensis
Beilschmiedia klainei
Beilschmiedia letouzeyi
Beilschmiedia mannii
Berlinia auriculata
Berlinia bracteosa
Berlinia bruneelii
Berlinia confusa
Berlinia grandiflora
Bertiera aethiopica
Bertiera batesii
Bertiera breviflora
Bertiera globiceps
Bertiera iturensis
Bertiera letouzeyi
Bertiera loraria
Bertiera racemosa
Bixa orellana
Blighia welwitschii
Bombax buonopozense
Bombax rhodognaphalon
Borreria latifolia
Borreria pusilla
Bosqueiopsis gilletii
Brachystegia laurentii
Brachystegia mildbreadii
Brazzeia congoensis
Brenania brieyi
Bridelia ferruginea
Bridelia grandis
Bridelia micrantha
Burkea africana
Caesalpinia welwitschiana
Calliandra surinamensis
Caloncoba glauca
Caloncoba welwitschii
Calophyllum inophyllum
Calpocalyx klainei
Calpocalyx ngouniensis

Camoensia brevicalyx
Camptostylus mannii
Campylospermum calanthum
Campylospermum dybovskii
Campylospermum elongatum
Cananga odorata
Canarium buettneri
Canarium edule
Canarium manfeldianum
Canarium odontophyllum
Canarium schweinfurthii
Canthium mannii
Canthium multiflorum
Carapa procera
Carpolobia alba
Carpolobia lutea
Casearia barteri
Cassia alata
Cassia kirkii
Cassia mannia
Cassia mimosoides
Cassia obtusifolia
Cassipourea congoensis
Cathormion altissimum
Cathormion obliquifoliatum
Ceiba thonningii
Celtis adolfi-friderici
Celtis gomphophylla
Celtis mildbreadii
Celtis tessmannii
Centroplacus glaucinus
Cephaelis peduncularis
Chaetocarpus africanus
Chassalia corallifera
Chlorophora excelsa
Chlorophora regia
Chrysobalanus icaco
Chrysophyllum perpulchrum
Cissus barbeyana
Cissus barteri
Cissus dewevrei
Cissus diffusiflora
Cissus dinklagei
Cissus ruginosicarpa
Cleistanthus bipindensis
Cleistanthus ripicola
Cleistopholis glauca
Cleistopholis patens
Cleistopholis staudtii
Clerodendrum buettneri

Clerodendrum capitatum
Coelocaryon preussii
Coffea eketensis
Coffea liberica
Cola acuminata
Cola chlamydantha
Cola digitata
Cola ficifolia
Cola gigantea
Cola lizae
Cola mahoundensis
Cola tsandensis
Colletoecema dewevrei
Combretum cuspidatum
Combretum mannii
Combretum paniculatum
Combretum paradoxum
Combretum pecoense
Combretum platypterum
Combretum rabiense
Combretum racemosum
Commitheca liebrechtsiana
Conceveiba macrostachys
Connarus griffonianus
Copaifera mildbraedii
Copaifera salikounda
Cordia abyssinica
Cordia africana
Cordia gilletii
Cordia millenii
Cordia platythyrsa
Corynanthe mayumbensis
Coula edulis
Craibia atlantica
Craibia laurentii
Craterispermum schweinfurthii
Crossopteryx febrifuga
Crotalaria axillaris
Crotalaria ochroleuca
Crotalaria pallida
Croton mubango
Croton sylvaticus
Crotonogyne manniana
Crotonogyne parvifolia
Crotonogyne poggei
Crudia gabonensis
Crudia harmsiana
Cryptosepalum pellegrinianum
Cryptosepalum staudtii
Cuervea isangiensis

Cuviera calycosa
Cuviera longiflora
Cyathea camerooniana
Cyathogyne viridis
Cyclocotyla congensis
Cynometra alexandri
Cynometra ananta
Cynometra mannii
Cynometra schlechteri
Cyrtogonone argentea
Dacryodes buettneri
Dacryodes igaganga
Dacryodes klaineana
Dacryodes normandii
Dacryodes yangambiensis
Dalbergia melanoxylon
Dalbergia olongifolia
Dalbergia rufa
Dalhousiea africana
Daniella soyauxii
Daniellia klainei
Daniellia ogea
Daniellia pynaertii
Daniellia thurifera
Dasylepis brevipedicellatus
Desbordesia glaucescens
Desbordesia glauscens
Desmodium ramosissimum
Desmodium scorpiurus
Desmodium velutinum
Dialium densiflorum
Dialium dinklagei
Dialium guineense
Dialium lopense
Dialium pachyphyllum
Dialium soyauxii
Dialium zenkeri
Dichaetanthera africana
Dichapetalum madagascariense
Dichostemma glaucescens
Dicranolepis disticha
Dictyandra arborescens
Dictyophleba ochracea
Didelotia africana
Didelotia idae
Didelotia letouzeyi
Diospyros abyssinica
Diospyros boala
Diospyros conocarpa
Diospyros crassiflora

Diospyros dendo
Diospyros gabunensis
Diospyros heterotricha
Diospyros iturensis
Diospyros kamerunensis
Diospyros mannii
Diospyros melocarpa
Diospyros piscatoria
Diospyros polystemon
Diospyros pseudomespilus
Diospyros soyauxii
Diospyros suaveolens
Diospyros viridicans
Diospyros zenkeri
Discoglypremna caloneura
Donella ogowensis
Dorstenia barteri
Dracaena camerooniana
Dracaena mannii
Drypetes arborescens
Drypetes aylmeri
Drypetes gilgiana
Duboscia macrocarpa
Duparquetia orchidacea
Duvigneaudia inopinata
Echinocarpus dasycarpus
Echinocarpus hemsleyanus
Elaeis guineensis
Enantia chlorantha
Entada gigas
Entandrophragma angolense
Entandrophragma candollei
Eribroma oblonga
Eriocoelum microspermum
Eriosema glomeratum
Erismadelphus exsul
Erythrina tholloniana
Erythrina vogelii
Erythrococca atrovirens
Eugenia congolensis
Euonymus congolensis
Euphorbia thymifolia
Euphorbia venenifica
Eurypetalum batesii
Exellia scammopetala
Fagara macrophylla
Fagaropsis angolensis
Ficus asperifolia
Ficus barteri
Ficus bubu

Ficus conraui
Ficus cyathistipuloides
Ficus dicranostyla
Ficus kimuenzensis
Ficus ovata
Ficus polita
Ficus subsagittifolia
Ficus sur
Ficus tremula
Ficus variifolia
Ficus wildemaniana
Fillaeopsis discophora
Funtumia africana
Gaertnera paniculata
Gambeya africana
Gambeya lacourtiana
Gambeya subnuda
Garcinia afzelii
Garcinia conrauana
Garcinia epunctata
Garcinia gnetoides
Garcinia kola
Garcinia mannii
Garcinia ovalifolia
Garcinia punctata
Garcinia smeathmannii
Gardenia imperialis
Geophila afzelii
Gilbertiodendron dewevrei
Gilbertiodendron grandistipulatum
Gilbertiodendron preussii
Gilbertiodendron stipulaceum
Gilletiodendron pierreanum
Glyphaea brevis
Grewia barombiensis
Grewia coriacea
Grewia pinnatifida
Griffonia physocarpa
Guarea cedrata
Guarea laurentii
Guarea thompsonii
Guibourtia demeusei
Guibourtia ehie
Guibourtia pellegriniana
Guibourtia tesmannii
Hallea ciliata
Hallea rubrostipulata
Hallea stipulosa
Hannoa klaineana
Haplocoelum intermedium

Haplormosia monophylla
Harungana madagascariensis
Heinsia crinita
Heisteria parvifolia
Hexalobus crispiflorus
Hippocratea myriantha
Holarrhena floribunda
Holoptelea grandis
Homalium abdessammadii
Homalium africanum
Homalium buchholzii
Homalium letestui
Homalium neurophyllum
Homalium sarcopetalum
Hoslundia oppositifolia
Hugonia gabunensis
Hugonia obtusifolia
Hugonia platysepala
Hybanthus enneaspermus
Hylodendron gabunense
Hymenocardia ulmoides
Hymenostegia klainei
Hymenostegia pellegrinii
Hypodaphnis zenkeri
Icacina mannii
Indigofera conjugata
Indigofera welwitschii
Irvingia gabonensis
Irvingia grandifolia
Irvingia smithii
Ixora hippoperifera
Jatropha gossypiifolia
Julbernardia brieyi
Julbernardia seretii
Khaya anthotheca
Khaya grandifolia
Khaya ivorensis
Kigelia moosa
Klaineanthus gaboniae
Klainedoxa busgenii
Klainedoxa gabonensis
Landolphia dewevrei
Landolphia glabra
Landolphia heudelotii
Landolphia incerta
Landolphia jumellei
Landolphia mannii
Landolphia owariensis
Landolphia reticulata
Landolphia subrepanda

Lannea antiscorbutica
Lannea welwitschii
Lantana camara
Lasianthera africana
Leea guineensis
Leonardendron gabunense
Leptactina arnoldiana
Leptactina leopoldi-secundi
Leptoderris brachyptera
Leptoderris congolensis
Leptoderris fasciculata
Leptoderris hypargyrea
Leptonychia echinocarpa
Letestua durissima
Leucaena leucocephala
Leucomphalos capparideus
Licania elaeosperma
Lindackeria dentata
Lingelsheimia longepedicellata
Linociera mannii
Lippia multiflora
Loeseneriella apiculata
Lonchocarpus griffonianus
Lophira alata
Lophira alata
Lovoa brownii
Lovoa swynnertonii
Lovoa trichilioides
Ludwigia stenorraphe
Macaranga barteri
Macaranga gabunica
Macaranga monandra
Macaranga schweinfurthii
Macaranga spinosa
Maesa lanceolata
Maesobotrya dusenii
Maesobotrya floribunda
Maesobotrya pynaertii
Maesopsis eminii
Magnistipula butayei
Magnistipula zenkeri
Malouetia bequaertii
Mammea africana
Manilkara fouilloyana
Manilkara obovata
Manniophyton fulvum
Mansonia altissima
Maprounea membranacea
Maranthes aubrevillei
Maranthes gabunensis

Maranthes glabra
Mareya micrantha
Mareyopsis longifolia
Margaritaria discoidea
Markhamia tomentosa
Martretia quadricornis
Massularia acuminata
Memecylon myrianthum
Mezoneuron angolense
Michelsonia microphylla
Micrococca mercurialis
Microdesmis afrodecandra
Microdesmis puberula
Milicia excelsa
Milicia excelsa
Millettia barteri
Millettia conraui
Millettia eetveldeana
Millettia laurentii
Millettia laurentii
Millettia macroura
Millettia mannii
Millettia sanagana
Millettia versicolor
Millettia warneckei
Mimosa pellita
Mimosa pigra
Mitracarpus scaber
Mitragyna ciliata
Mitragyne stipulosa
Monanthotaxis congoensis
Monanthotaxis declina
Monanthotaxis letestui
Monodora angolensis
Monopetalanthus coriaceus
Monopetalanthus durandii
Monopetalanthus heidinii
Monopetalanthus heitzii
Monopetalanthus letestui
Morelia senegalensis
Morelia senegalensis
Morinda lucida
Morus lactea
Morus mesozygia
Mostuea brunonis
Musanga cecropioides
Mussaenda polita
Mussaenda tenuiflora
Myrianthus arboreus
Napoleonaea gabonensis

Napoleonaea imperialis
Napoleonaea leonensis
Napoleonaea vogelii
Nauclea diderrichii
Nauclea diderrichii
Nauclea gilletii
Nauclea vanderguchtii
Neochevalierodendron stephanii
Neostenanthera robsonii
Nesogordonia papaverifera
Nesogordonia papaverifera
Newbouldia laevis
Newtonia buchananii
Newtonia leucocarpa
Ochna afzelii
Ochna multiflora
Ochthocosmus congolensis
Ochthocosmus sessiliflorus
Ocotea gabonensis
Ocotea usambarensis
Octoknema affinis
Octolepis decalepis
Oddoniodendron micranthum
Olax gambecola
Olax mannii
Olax wildemanii
Oldenlandia corymbosa
Oldenlandia lancifolia
Omphalocarpum procerum
Oncoba brachyanthera
Oncoba spinosa
Ongokea gore
Opilia congolana
Orthopichonia barteri
Ostryocarpus riparius
Otomeria elatior
Otomeria guineensis
Otomeria micrantha
Ouratea arnoldiana
Ouratea dusenii
Ouratea flava
Ouratea latepedunculata
Ouratea myrioneura
Oxyanthus schumannianus
Oxyanthus speciosus
Oxyanthus unilocularis
Pachypodanthium staudtii
Pachystela brevipes
Pancovia laurentii
Panda oleosa

Pandanus butayei
Pandanus candelabrum
Paraberlinia bifoliata
Paramacrolobium coeruleum
Parinari congensis
Parkia bicolor
Paropsia grewioides
Pauridiantha callicarpoides
Pauridiantha dewevrei
Pauridiantha efferata
Pauridiantha floribunda
Pausinystalia johimbe
Pausinystalia macroceras
Pavetta brachycalyx
Pavetta cellulosa
Pavetta lasioclada
Pavetta nitidula
Pavetta plumosa
Pavetta viridiloba
Pellegriniodendron diphyllum
Pentabrachion reticulatum
Pentaclethra eetveldiana
Pentaclethra eetveldiana
Pentaclethra macrophylla
Pentadesma butyracea
Pentadesma butyracea
Pentadesma grandifolia
Pentadesma lebrunii
Pericopsis angolensis
Pericopsis elata
Petersianthus macrocarpus
Phoenix reclinata
Phyllanthus acidus
Phyllanthus diandrus
Phyllanthus nigericus
Phyllanthus polyanthus
Phyllanthus reticulatus
Phyllanthus urinaria
Pinacopodium congolense
Piper umbellatum
Piptadeniastrum africanum
Plagiosiphon gabonensis
Plagiostyles africana
Podococcus barteri
Polyalthia suaveolens
Polycoryne fernandensis
Popowia klainii
Porterandia annulata
Porterandia cladantha
Pouchetia baumanniana

Pouchetia gilletii
Prionostemma fimbriata
Pseudomussaenda stenocarpa
Pseudoprosopis gilletii
Pseudosabicea batesii
Pseudosabicea floribunda
Pseudosabicea mildbraedii
Pseudospondias microcarpa
Psidium guineense
Psilanthus lebrunianus
Psorospermum tenuifolium
Psychotria calva
Psychotria djumaensis
Psychotria gilletii
Psychotria kimuenzae
Psychotria peduncularis
Psychotria venosa
Psydrax arnoldiana
Pteleopsis hylodendron
Pterocarpus soyauxii
Pterygota bequaertii
Pterygota macrocarpa
Ptychopetalum petiolatum
Pycnanthus angolensis
Pycnobotrya nitida
Pycnocoma cornuta
Pyrenacantha klaineana
Quassia africana
Quassia undulata
Quisqualis hensii
Raphia sese
Raphiostylis ferruginea
Rauvolfia mannii
Rauvolfia vomitoria
Ravenala madagascariensis
Rhabdophyllum arnoldianum
Rhabdophyllum calophyllum
Rhodognaphalon brevicuspe
Rhodognaphalon lukayense
Rhodognaphalon schumannianum
Rhopalopilia pallens
Ricinodendron heudelotii
Rinorea elliotii
Rinorea ilicifolia
Rinorea parviflora
Rinorea preussii
Ritchiea capparoides
Rothmannia octomera
Rothmannia whitfieldii
Rungia grandis

Rutidea pavettoides
Rytigynia rubra
Sabicea efulenensis
Sabicea fulva
Sabicea mollis
Sacosperma paniculatum
Salacia alata
Salacia callensii
Salacia cornifolia
Salacia dusenii
Salacia elegans
Salacia klainei
Salacia mannii
Salacia mayumbensis
Salacia nitida
Salacia staudtiana
Salacia whytei
Samanea leptophylla
Santiria trimera
Sapium cornutum
Sapium ellipticum
Sauvagesia erecta
Scaphopetalum blackii
Scaphopetalum thonneri
Schumanniophyton magnificum
Schwenckia americana
Sclerosperma mannii
Scorodophloeus zenkeri
Scottellia coriacea
Scytopetalum klaineanum
Sideroxylon mayombense
Sindoropsis letestui
Solanum nigrum
Sorindeia africana
Sorindeia claessensii
Sorindeia gilletii
Sorindeia juglandifolia
Sorindeia mayumbensis
Sorindeia sparanoi
Sorindeia warneckei
Sorindeia zenkeri
Spathodea campanulata
Spondias mombin
Stachytarpheta cayennensis
Staudtia gabonensis
Staudtia kamerunensis
Sterculia rhinopetala
Sterculia tragacantha
Strombosia grandifolia
Strombosia pustulata

Strombosia zenkeri
Strombosiopsis tetrandra
Strophanthus preussii
Strychnos angolensis
Strychnos congolana
Strychnos densiflora
Strychnos longicaudata
Strychnos malacoclados
Strychnos ngouniensis
Strychnos ternata
Strychnos variabilis
Swartzia fistuloides
Symphonia globulifera
Synsepalum dulcificum
Synsepalum stipulatum
Syzygium guineense
Tabernaemontana crassa
Tabernanthe iboga
Tarenna conferta
Tarenna eketensis
Tarenna lasiorachis
Tarenna laurentii
Tarenna pallidula
Teclea verdooniana
Tephrosia purpurea
Terminalia ivorensis
Terminalia superba
Tessmannia africana
Tessmannia anomala
Tessmannia dewildemanniana
Tessmannia lescrauwaetii
Testulea gabonensis
Tetraberlinia bifoliolata
Tetraberlinia tubmaniana
Tetrapleura tetraptera
Tetrorchidium didymostemon
Thecacoris annobonae
Thecacoris stenopetala
Thomandersia butayei
Thomandersia laurentii
Tieghemella africana
Tieghemella heckelii
Treculia africana
Treculia obovoidea
Trema guineensis
Trema orientalis
Tricalysia anomala
Tricalysia anomalura
Tricalysia concolor
Tricalysia coriacea

Tricalysia macrophylla
Tricalysia oligoneura
Tricalysia pallens
Trichilia gilgiana
Trichilia gilletii
Trichilia monadelpha
Trichilia prieuriana
Trichilia welwitschii
Trichoscypha acuminata
Trichoscypha atropurpurea
Trichoscypha gossweileri
Trichoscypha laxiflora
Trichoscypha oba
Trichoscypha oddonii
Trichoscypha patens
Trichostachys aurea
Trilepisium madagascariense
Triplochiton scleroxylon
Triumfetta cordifolia
Tulestea tomentosa
Turraea cabrae
Turraeanthus africana
Uapaca guineensis
Uapaca heudelotii
Uapaca kirkiana
Uapaca paludosa
Uapaca togoensis
Uapaca vanhouttei
Uncaria africana
Uraria picta
Uvaria comperei
Uvaria klainei
Uvaria lastourvillensis
Uvaria ngounyensis
Uvaria psorosperma
Uvaria scabrida
Uvariastrum pierreanum
Vahadenia laurentii
Vangueriopsis rubiginosa
Vepris louisii
Vernonia brazzavillensis
Vernonia conferta
Vigna gracilis
Vigna multinervis
Vismia guineensis
Vismia rubescens
Vitex ciliata
Vitex congolensis
Vitex doniana
Vitex pachyphylla

Vitex rivularis
Voacanga africana
Voacanga chalotiana
Voacanga thouarsii
Xylopia acutiflora
Xylopia aethiopica
Xylopia hypolampra
Xylopia parviflora
Xylopia pynaertii
Xylopia quintassii
Xylopia rubescens
Xylopia wilwerthii
Zanthoxylum gilletii
Zeyherella longepedicellata
Zornia latifolia

5.1.2 - Tropical Mangrove

African mangroves extend along the muddy, sheltered coasts of the Gulf of Guinea, from Angola to Senegal, and also along the sheltered coasts of the Indian Ocean.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acrostichum aureum
Anopyxis klaineana
Avicennia africana
Avicennia marina
Avicennia nitida
Laguncularia racemosa
Rhizophora harrisonii
Rhizophora mangle
Rhizophora mucronata
Rizhophora racemosa
Sonneratia alba

5.1.3 - Tropical Moist Deciduous Forest

This zone lies on the Great African Plateau to the south of the Guineo-Congolian Basin, mostly at an altitude of 900 to 1,000 m but in some places up to 1,500 m, as well as along the southeastern coast of Africa and in the central part of Madagascar. The dry season is always pronounced, lasting up to six months. There is a single rainy season, in summer, but there is pronounced regional variation. Annual rainfall for the zone varies between 800 and 1,500 mm, but can reach 2,000 mm locally.

Dry evergreen forest is widely distributed on Kalahari sands. Semi-evergreen forest of the Guineo-Congolian type is mainly confined to Angola. On the eastern coastal plain, forest is the climax but has been largely replaced by wooded grassland and cultivation. Everywhere else the most characteristic vegetation is woodland - wetter Zambezian miombo woodland to the south and Sudanian woodland to the north.

In Madagascar, the primary vegetation is a dry deciduous forest or thicket, but the most extensive vegetation is now secondary grassland. Nevertheless, some areas of forest remain, especially along the coast, on sandy soils and on calcareous plateaus.

In Africa, this ecologic zone has a total area of about 473 million hectares, from which 147 million hectares are now covered with forest (31%).

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia amythethophylla
Acacia dudgeoni
Acacia galpinii
Acacia gourmaensis
Acacia kirkii
Acacia nigrescens
Acacia nilotica
Acacia polycantha
Acacia sieberiana
Acacia tortilis
Acalypha allenii
Acanthospermum hispidum
Accophylus africanus
Adansonia digitata
Adenia gumifera
Afromomum biauriculatum
Afzelia africana
Afzelia bella
Afzelia bipindensis
Afzelia cuanzensis
Afzelia pachyloba
Afzelia quanzensis
Albizia adainthifolia
Albizia antunesiana
Albizia ferruginea
Albizia versicolor
Albizia zygia
Allophylus africanus
Aloe greatheadii
Aloe milne-redheadii
Aloe nuttii
Amaranthus hybridus
Amblygonocarpus andogensis
Andropogon gayanus
Androstachys johnsonii
Aningeria robusta
Anisophyllea boehmii
Annona senegalensis
Annona stenophylla
Ansellia africana
Anthephora elongata
Anthocleista schweiinfurthii
Antiaris africana
Antiaris welwitschii
Antidesma membranaceum

Antidesma venosum
Apodytes dimidiata
Arachis hypogaea
Ascolepsis protea
Aspidotis schimperi
Azanza garckeana
Bacium obovatum
Baikea plurijuga
Baikiaea plurijuga
Baissea wulfhorstii
Balanites aegyptiaca
Baphia bangweolensis
Baphia massaiensis
Bauhinia petersiana
Becium cameronii
Bequaertiodendron magalismontanum
Berchemia discolor
Berchemia zeyheri
Berlinia giorgii
Bersama abyssinica
Bidens pilosa
Boerhavia diffusa
Bombax flammeum
Bombax rhodognaphalon
Boophane disticha
Borassus aethiopum
Boscia cauliflora
Brachystegia bakeriana
Brachystegia boehmii
Brachystegia bussei
Brachystegia floribunda
Brachystegia glaberrima
Brachystegia gossweileri
Brachystegia longifolia
Brachystegia microphylla
Brachystegia puberula
Brachystegia speciformis
Brachystegia taxifolia
Brachystegia utilis
Brachystegia wangermeeana
Bridelia cathartica
Bridelia ferruginea
Bridelia micrantha
Buchnera henriquesii
Buddleja loricata
Buddleja salvifolia
Bulbine abyssinica
Bulbostylis hensii
Burkea africana
Byrsocarpus orientalis

Cananga odorata
Canthium lactescens
Cassia siamea
Celtis adolfi-friderici
Celtis kraussiana
Celtis tessmannii
Chanaechrista mimosoides
Chlorophora excelsa
Chlorophora regia
Chlorophytum imperata
Chlorophytum pilosissimum
Chrysophyllum bangweolense
Clematopsis scabiosifolia
Colophospermum mopane
Combret zeyheri
Combretum adenogonium
Combretum celastroides
Combretum imbebe
Combretum laxiflorum
Combretum molle
Combretum platypetallum
Combretum psidioides
Commelina africana
Conyza sumatrensis
Copaifera soyauxii
Cordia abyssinica
Cordia africana
Cordia chrysocarpa
Cordia millenii
Cordia platythyrsa
Cordyla africana
Craibia affinis
Crassocephalum sarcobasis
Craterispermum schweinfurthii
Craterosiphon quarrei
Crossopteryx febrifuga
Crotalaria acuminatissima
Croton leuconeurus
Cryptosepalum exfoliatum
Cryptosepalum maraviese
Cryptosepalum pseudotaxus
Cussonia angolensis
Cussonia arborea
Cymbopogoon densiflorus
Cynodon dactylon
Cynometra alexandri
Cyperus mwinilungensis
Cyperus tenuinervis
Cyperus zambesiacus
Cyphostemma junceum

Dalbergia acutifoliolata
Dalbergia melanoxylon
Dalbergia nitidula
Dalbergia sericea
Dalbergia sissoo
Daniellia klainei
Daniellia ogea
Daniellia thurifera
Dialium englerianum
Dichrostachys cinerea
Dicoma angustifolia
Digitaria gazensis
Diospyros batocana
Diospyros lycioides
Diospyros mespiliformis
Diospyros pseudomespilus
Diospyros virgata
Diospyrus kirkii
Diplorhynchus condylocarpon
Disa walleri
Disperis katangensis
Dolichos gululu
Dolichos kilimanscharica
Dolichos trinervatus
Dombeya rotundifolia
Dracaena camerooniana
Dracaena usambarensis
Dryopteris athamantica
Ekebergia benguelensis
Ekebergia capensis
Elephantopus scaber
Eleusine cocoana
Entada abyssinica
Entandrophragma angolense
Entandrophragma candollei
Entandrophragma caudatum
Entandrophragma delevoyi
Epaltes gariepina
Eriosema engleri
Eriosema psoraleoides
Eriosperum abyssinicum
Erythrina abyssinica
Erythrophleum africanum
Euclea racemosa
Eulophia latilabris
Eulophia parvula
Fagaropsis angolensis
Faidherbia albida
Faurea saligna
Faurea speciosa

Ficus epiphytes
Ficus fischeri
Ficus glumosa
Ficus ovata
Ficus sansibarica
Ficus stuhlmannii
Ficus sur
Ficus sycomorus
Ficus thonningii
Fiscus epiphytes
Fiscus fisheri
Flacourtia indica
Galdiolus natalensis
Garcinia buchananii
Garcinia huillensis
Garcinia smeatttthmanii
Gardenia imperialis
Gardenia ternifolia
Gisekia africana
Gossweilerodendron balsamiferum
Grewia falcistipula
Guarea cedrata
Guarea thompsonii
Guibourtia coleosperma
Harungana madascarariensis
Heteromorpha trifoliata
Hexalobus monopetalus
Hygophila pilosa
Hymenocardia acida
Hyparrhenia filipendula
Hyphaene peteriana
Indigofera sutherlandoides
Ipomoea verbascoidea
Isoberlinia angolensis
Isoberlinia doka
Jasminum streptopus
Jatropha curcas
Julbernadia globiflora
Julbernardia paniculata
Keetia gueinzii
Khaya anthotheca
Khaya ivorensis
Khaya nyasica
Klainedoxa gabonensis
Landolphia parvifolia
Lannea asummetica
Lannea discolor
Lannea edulis
Lantana camara
Launea rarifloia

Leonotis nepetifloia
Lepidagathis microchila
Leptactina benguelensis
Leptactina liebrechtsiana
Leucaena leucocephala
Lippia multiflora
Lonchocarpus capassa
Lonchocarpus nelsii
Lophira lanceolata
Loudetia simplex
Lovoa brownii
Lovoa swynnertonii
Lovoa trichiliodes
Lucosidea sericea
Magnistipula sapinii
Mangifera indica
Manihot cassava
Manihot glaziovii
Maprounea africana
Maranthes polyandra
Markhamia obtusifolia
Marquesia acuminate
Marquesia macroura
Memecylon flavorvirens
Memecylon sapinii
Milicia excelsa
Monocymbium ceresiforme
Monotes glaber
Monotes katangensis
Monotes kerstingii
Morus alba
Morus lactea
Morus mesozygia
Mucuna poggei
Multidentia crassa
Myrsine africana
Nephrolepsis undulata
Nesogordonia papaverifera
Newtonia buchananii
Nicolasia pedunculata
Nidorella resedifloia
Ochna afzelii
Ochna manikensis
Ochna multiflora
Ochna pulchra
Ochna schweinfurthiana
Ocium canum
Ocotea usambarensis
Olax abtusifolia
Oldfieldia dacrylophylla

Olea europea
Olea welwitschii
Oxygonum sinatum
Oxystima oxyphyllum
Oxytenanthera abyssinica
Ozoroa insignis
Pachycarpus lineolatus
Paralepistemon shirensis
Parinari capensis
Parinari curatellifolia
Parinari excelsa
Paropsia brazzeana
Pavetta schumanniana
Pavonia urens
Peltophorum africanum
Pericopsis angolensis
Phoenix reclinata
Phragmites mauritianus
Phyllanthus muelleranus
Phyllocosmus lemaireanus
Phytolaca dondecandra
Piliostigma thonningii
Platysepalum vanderystii
Plectranthastrum rosmarinifolium
Plectranthus esculentus
Protea angolensis
Protea baumii
Protea madiensis
Protea petiolaris
Protea welwitschii
Pseudolachnostylis maprouneifolia
Psidium guajava
Psorospermum febrifugum
Psydrax livida
Psydrax mutimushii
Pteleopsis anisoptera
Pteridiumm aquilinum
Pterocarpus angolensis
Pterocarpus antunesii
Pycnanthus angolensis
Pygeum africanum
Pygmaeothamnus zeyheri
Rauvolfia caffra
Rhamnus prinoides
Rhus kirkii
Rhynchosia resinosa
Ricinodendron heudelotii
Ricinodendron rautanenii
Ricinus communis
Rothmannia englerana

Rothmannia fischerii
Rothmannia whitfieldii
Rytigynia welwitschii
Salix subserrata
Sapium ellipticum
Sapium oblongifolium
Sarcocephalus latifolius
Satyrium kitimboensis
Schrebera trichoclada
Scleria bulbifera
Sclerocarya birrea
Scorodophloeus zenkeri
Securidaca longepedunculata
Senna singueana
Sesbania sesban
Setaria sphacelata
Setaris megaphylla
Smilax kraussiana
Sopubia simplex
Sphenostylis erecta
Spirostachys africana
Steganotaenia araliacea
Sterculia quinqueloba
Sterculia subviolcea
Strobilanthopsis linifolia
Strophanthus welwitschii
Strychnos cocculoides
Strychnos innocua
Strychnos pungens
Strychnos spinosa
Stryshnos pungens
Swartzia madagascarensis
Syzygium cordatum
Syzygium guineense
Tabernaemontana angolensis
Tacca involucrata
Tamarindus indica
Teclea nobilis
Tephrosia lupinifolia
Tephrosia vogelli
Terminalia brachystemma
Terminalia glauscens
Terminalia mollis
Terminalia sericea
Thonningia sanguinea
Tieghemella africana
Tieghemella heckelii
Trachypogon spicatus
Treculia africana
Tribulus terrestris

Tricalysia angolensis
Tricalysia pallens
Trichilia emetica
Tristachya superba
Uapaca kirkiana
Uapaca nitida
Uapaca sansibarica
Uapaca togoensis
Urginea altissima
Vangueria infausta
Vapaca guineensis
Vapaca kirkiana
Vapaca nitida
Vapaca pilosa
Vapaca sansibarica
Veronia glaberrima
Veronia glabra
Vitex fischeri
Vitex madiensis
Vitex mombassae
Ximia caffra
Xylopia aethiopica
Xylopia odoratissima
Zanha africana
Ziziphus muaritiana
Ziziphus mucronata
Zornia glochidiata
Zyzygium guineense

5.1.3 - Tropical Dry Forest, Tropical Shrubland and Tropical Desert

Farther from the equator and the wet southeastern coast, rainfall decreases and the dry season is always long six to seven months. Rainfall varies between 500 and 1,000 mm. Temperature is always high, with the mean temperature of the coldest month about 20°C. Similar conditions are found in Ghana (Accra) and Angola (Cabinda).

Woodland is the predominant vegetation type under these drier conditions. In the Zambezian region there is drier miombo, mopane woodland or Sudanian woodland in the southern valleys and depressions and scrub woodland in the southern lowlands. Where cultivation is possible, most of the land is bush fallow. Near Accra, Ghana, some patches of dry semi-evergreen forest remain. In Cabinda, Angola, the prevalent vegetation is wooded grassland. A conspicuous tree of this zone is the Baobab, with its bizarre big trunk.

In Africa, the tropical dry forest ecologic zone has a total area of about 370 million hectares, from which 178 million hectares are now covered with forest (48%).

The tropical shrubland ecologic zone of Africa covers about 601 million hectares of the continent. Only 4% of this zone is forested (24 million hectares). In the Sahelian zone, the Kalahari and the southwestern part of Madagascar, rainfall becomes lower while temperatures are still high. Rainfall is always less than 1,000 mm and reaches scarcely 200 mm in the drier parts. The mean temperature of the coldest month is generally more than 20°C, except in the Kalahari where temperatures are lower (to 10°C). Even though Somalia lies across the Equator the climate is semi-arid to arid, with annual rainfall between 400 and 750 mm and very high temperatures.

In these very dry areas, spontaneous vegetation is generally pseudo-steppe, scrub woodland or thicket. In the Sahelian zone, wooded grassland is located in the south and semi-desert grassland in the north. Somalia has predominately deciduous shrubland and thicket. In the Kalahari, stunted scrub woodland and shrub pseudo-steppe forms the landscape. In Madagascar, some dry deciduous forest still occurs in the northern part of the zone but the most characteristic vegetation type in the western part is deciduous thicket with Didiereaceae.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Acacia abyssinica
Acacia adenocalyx
Acacia albida
Acacia amythethophylla
Acacia arenaria
Acacia ataxacantha
Acacia benthamii
Acacia borleae
Acacia burkei
Acacia caffra
Acacia campylacantha
Acacia chariessa
Acacia cinerea
Acacia davyi
Acacia detinens
Acacia dulcis
Acacia eriocarpa
Acacia erioloba
Acacia erubescens
Acacia exuvialis
Acacia farnesiana
Acacia fleckii
Acacia galpinii
Acacia gerrardii
Acacia giraffae
Acacia goetzii
Acacia grandicornuta
Acacia hebeclada
Acacia hereroensis
Acacia hermannii
Acacia horrida
Acacia karroo
Acacia kirkii
Acacia laeta
Acacia leuderitzii
Acacia macrostachya
Acacia macrothyrsa
Acacia mellifera
Acacia mizera
Acacia montis-usti

Acacia natalitia
Acacia nebrownii
Acacia nigrescens
Acacia nilotica
Acacia pentagona
Acacia permixta
Acacia polyacantha
Acacia reficiens
Acacia rehmanniana
Acacia robusta
Acacia robynsiana
Acacia rogersii
Acacia rovumae
Acacia schweinfurthii
Acacia scorpioides
Acacia senegal
Acacia seyal
Acacia sieberiana
Acacia stuhlmannii
Acacia suma
Acacia tortilis
Acacia welwitschii
Acacia xanthophloea
Acrocarpus fraxinifolius
Adansonia digitata
Adenolobus pechuelii
Afzelia africana
Afzelia quanzensis
Albizia adianthifolia
Albizia amara
Albizia anthelmintica
Albizia antunesiana
Albizia brevifolia
Albizia chevalieri
Albizia chirindensis
Albizia fastigiata
Albizia forbesii
Albizia glaberrima
Albizia gummifera
Albizia harveyi
Albizia mossambicensis
Albizia petersiana
Albizia rhodesica
Albizia schimperiana
Albizia sericocephala
Albizia tanganyicensis
Albizia versicolor
Albizia zimmermannii
Allophyllus africana
Amblygonocarpus andongenis

Amblygonocarpus obtusangulus
Amblygonocarpus schweinfurthii
Aningeria robusta
Anogeissus leiocarpus
Anthocleista oubanguiensis
Arbus canascens
Aristogeitonia monophylla
Baikiaea plurijuga
Balanites aegyptiaca
Bauhinia fassoglensis
Bauhinia galpinii
Bauhinia macrantha
Bauhinia petersiana
Bauhinia punctata
Bauhinia thonningii
Bauhinia tomentosa
Bauhinia variegata
Berlinia eminii
Bombax costatum
Borassus aethiopium
Boscia albitrunca
Boscia angustifolia
Boscia corymbosa
Boscia filipes
Boscia foetida
Boscia grandiflora
Boscia indica
Boscia matabelensis
Boscia mossambicensis
Boscia rehmanniana
Boscia salicifolia
Boscia senegalensis
Boscia ustifolia
Bosqueia phoberos
Boswellia dalzielii
Brachylaena huillensis
Brachystegia allenii
Brachystegia boehmii
Brachystegia glaucescens
Brachystegia manga
Brachystegia microphylla
Brachystegia randii
Brachystegia spiciformis
Brachystegia tamarindoides
Brachystegia torrei
Brachystegia utilis
Brachystegia woodiana
Buddleja saligna
Burkea africana
Butyrospermum parkii

Buxus obtusifolia
Cadaba farinosa
Caesalpinia decapetala
Callitris columellaris
Callitris endlicheri
Callitris whytei
Calophospermum mopane
Calyptrothea taiensis
Canthium burtii
Canthium captum
Canthium frangula
Canthium glaucum
Canthium inerme
Canthium kilifiensis
Canthium kuntzeanum
Canthium lactescens
Canthium mundianum
Canthium ngonii
Canthium oligocarpum
Canthium pauciflorum
Canthium pseudorandii
Canthium pseudoverticillatum
Canthium racemulosum
Canthium randii
Canthium robynsianum
Canthium setiflorum
Canthium swynnertonii
Canthium ventosum
Cantuffa exosa
Capparis corumbosa
Capparis tomentosa
Cardiogyne africana
Cassia abbreviata
Cassia absus
Cassia afrofistula
Cassia arachoides
Cassia bicapsularis
Cassia biensis
Cassia coluteoides
Cassia didymobotrya
Cassia falcinella
Cassia fenarolii
Cassia floribunda
Cassia goratensis
Cassia gracilior
Cassia granitica
Cassia hirsuta
Cassia hochstetteri
Cassia italica
Cassia kirkii

Cassia mimosoides
Cassia obtusifolia
Cassia occidentalis
Cassia orbbreviata
Cassia parva
Cassia petersiana
Cassia polytricha
Cassia quarrei
Cassia rotundifolia
Cassia sieberiana
Cassia singueana
Cassia wittei
Cassia zambesica
Cassiopourea mollis
Cassytha filiformis
Cassytha pondoensis
Catophractes alexandri
Celtis africana
Celtis durandii
Celtis gomphophylla
Celtis integrifolia
Celtis kraussiana
Celtis mildbraedii
Celtis rhamnifolia
Chaetachme aristata
Chamaecrista absus
Chamaecrista biensis
Chamaecrista dimidiata
Chamaecrista falcinella
Chamaecrista fenarolii
Chamaecrista gracilior
Chamaecrista kirkii
Chamaecrista mimosoides
Chamaecrista parva
Chamaecrista polytricha
Chamaecrista rotundifolia
Chamaecrista stricta
Chamaecrista wittei
Chamaecrista zambesica
Chionanthus battiscombei
Chionanthus foveolatus
Chlorophora excelsa
Cissus quadrangularis
Colophospermum mopane
Combretum aculeatum
Combretum apiculatum
Combretum erythrophyllum
Combretum glutinosum
Combretum lecardii
Commiphora africana

Commiphora angolensis
Commiphora caerulea
Commiphora edulis
Commiphora glandulosa
Commiphora karibensis
Commiphora marlothii
Commiphora merkeri
Commiphora mollis
Commiphora mossambicensis
Commiphora neglecta
Commiphora pyracanthoides
Commiphora schimperi
Commiphora stuhlmanni
Commiphora tenuipetiolata
Commiphora ugogensis
Commiphora viminea
Commiphora zanzibarica
Conocarpus lancifolius
Copaifera coleosperma
Copaifera mopane
Cordeauxia edulis
Cordia abyssinica
Cordia africana
Cordia millenii
Cordia platythyrsa
Courbonia decumbens
Courbonia glauca
Croton gratissimus
Cryptocarya liebertiana
Cryptocarya transvaalensis
Cryptosepalum maraviense
Cupressus torulosa
Dalbergia melanoxylon
Daniellia oliveri
Dekindtia africana
Delonix elata
Dialium englerianum
Dialium simsii
Dichrostachys cinerea
Dichrostachys glomerata
Diospyros abyssinica
Diospyros batocana
Diospyros ferrea
Diospyros hoyleana
Diospyros kirkii
Diospyros loureiriana
Diospyros lycioides
Diospyros mespiliformis
Diospyros natalensis
Diospyros nummularia

Diospyros quiloensis
Diospyros sabiensis
Diospyros senensis
Diospyros squarrosa
Diospyros usambarensis
Diospyros whyteana
Dombeya rotundifolia
Dombeya shumpangae
Dorstenia benguellensis
Dorstenia buchananii
Dorstenia cuspidata
Dorstenia psilurus
Ehretia rigida
Ekebergia arborea
Ekebergia benguelensis
Ekebergia capensis
Ekebergia meyeri
Elephantorrhiza burchellii
Elephantorrhiza burkei
Elephantorrhiza elephantina
Elephantorrhiza goetzii
Elephantorrhiza rubescens
Elephantorrhiza suffruticosa
Ellipanthus hemandradenioides
Entada abyssinica
Entada arenaria
Entada chrysostachys
Entada nana
Entada pursaetha
Entada rheedei
Entandrophragma caudatum
Erythrina obyssinica
Erythrophleum africanum
Erythrophleum guineense
Erythrophleum pubistamineum
Erythrophleum suaveolens
Euclea crispa
Euclea divinorum
Euclea eylesii
Euclea kellau
Euclea lanceolata
Euclea linearis
Euclea macrophylla
Euclea multiflora
Euclea natalensis
Euclea racemosa
Euclea schimperi
Euclea undulata
Eugenia angolensis
Eugenia capensis

Eugenia chirindensis
Eugenia cordata
Eugenia malangensis
Eugenia natalitia
Eugenia nyassensis
Eugenia owariensis
Euphorbia guerichiana
Fagaropsis angolensis
Faidherbia albida
Fernandoa magnifica
Ficus abutilifolia
Ficus bubu
Ficus burkei
Ficus bussei
Ficus caffra
Ficus capensis
Ficus capreifolia
Ficus chirindensis
Ficus cordata
Ficus craterostoma
Ficus exasperata
Ficus fischeri
Ficus glumosa
Ficus ingens
Ficus kirkii
Ficus lutea
Ficus natalensis
Ficus nigropunctata
Ficus ottoniifolia
Ficus polita
Ficus pretoriae
Ficus rehmannii
Ficus salicifolia
Ficus sansibarica
Ficus scassellatii
Ficus smutsii
Ficus soldanella
Ficus sonderi
Ficus stuhlmannii
Ficus subcalcarata
Ficus sur
Ficus sycomorus
Ficus tettensis
Ficus thonningii
Ficus vallis-choudae
Ficus verruculosa
Ficus vogelii
Ficus zambesiaca
Gardenia ternifolia
Gleditsia triacanthos

Grewia bicolor
Grewia burtii
Grewia flava
Grewia platyclada
Guibourtia coleosperma
Guibourtia conjugata
Hardwickia mopane
Heeria paniculosa
Heeria reticulata
Hoffmannseggia burchellii
Hoffmannseggia rubroviolacea
Hyphaene thebaica
Intsia quanzensis
Isoberlinia doka
Isoberlinia globiflora
Jasminum abyssinicum
Jasminum brachyscyphum
Jasminum fluminense
Jasminum mauritianum
Jasminum meyeri-johannis
Jasminum multipartitum
Jasminum multipartitum
Jasminum oleicarpum
Jasminum stenolobum
Jasminum streptopus
Julbernardia globiflora
Juniperus procera
Khaya anthotheca
Khaya nyasica
Khaya senegalensis
Kigelia africana
Kigelia africana
Kigelia pinnata
Lannea barteri
Lannea discolor
Lannea edulis
Lannea humilis
Lannea humilis
Lannea schweinfurthii
Lannea stuhlmannii
Lasiodiscus mildbraedii
Linociera battiscombei
Linociera foveolata
Lonchocarpus laxiflorus
Lophira alata
Lovoa brownii
Lovoa swynnertonii
Maba mualala
Maclura africana
Maerua angolensis

Maerua angolensis
Maerua arenicola
Maerua buxifolia
Maerua cafra
Maerua decumbens
Maerua edulis
Maerua friesii
Maerua juncea
Maerua kirkii
Maerua nervosa
Maerua parvifolia
Maerua prittwitzii
Maerua pubescens
Maerua rhodesiana
Maerua salicifolia
Maerua triphylla
Markhamia acuminata
Markhamia lanata
Markhamia obtusifolia
Markhamia obtusifolia
Markhamia zanzibarica
Markhamia zanzibarica
Milicia excelsa
Millettia thonningii
Mimosa asperata
Mimosa pigra
Mitragyna inermis
Monotes engleri
Monotes glaber
Monotes hypoleucus
Monotes katangensis
Monotes kerstingii
Morus alba
Morus indica
Morus lactea
Morus mesozygia
Nauclea latifolia
Neptunia oleracea
Nesogordonia holtzii
Newtonia buchananii
Newtonia hildebrandtii
Ocotea kenyensis
Ocotea usambarensis
Ocotea viridis
Olea africana
Olea capensis
Olea chimanimani
Olea chrysophylla
Olea europaea
Olea europaea

Olea hochstetteri
Olea laurifolia
Olea macrocarpa
Olea welwitschii
Ozoroa insignis
Ozoroa longipetiolata
Ozoroa nitida
Ozoroa obovata
Ozoroa paniculosa
Ozoroa reticulata
Ozoroa sphaerocarpa
Pahudia quangensis
Pappea capensis
Parkia biglobosa
Parkinsonia aculeata
Peltophorum africanum
Perlebia galpinii
Peudocedrela kotschyi
Piliostigma refuscens
Piliostigma reticulata
Piliostigma thonningii
Piptadenia buchananii
Piptadenia hildebrandtii
Podocarpus latifolius
Podocarpus milanjianus
Podranea brycei
Premna angolensis
Premna chrysoclada
Prosopis africana
Prosopis cineraria
Pseudocedrela caudata
Pteleopsis tetraptera
Pterocarpus erinaceus
Pterocarpus lucens
Pterolobium exosum
Pterolobium lacerans
Pterolobium stellatum
Rhigozum brevispinosum
Rhigozum obovatum
Rhigozum virgatum
Rhigozum zambesiacum
Rhus amerina
Rhus chirindensis
Rhus commiphoroides
Rhus culminum
Rhus dentata
Rhus gueinzii
Rhus kirkii
Rhus lancea
Rhus legatii

Rhus leptodictya
Rhus longipes
Rhus lucens
Rhus lucida
Rhus magalismontana
Rhus natalensis
Rhus oblanceolata
Rhus pentheri
Rhus pyroides
Rhus quartiniana
Rhus tenuinervis
Rhus tenuipes
Rhus tomentosa
Rhus transvaalensis
Rhus trifoliolata
Rhus tumulicola
Rhus undulate
Rhus vulgaris
Rhus wildii
Royena pallens
Royena sericea
Salvadora persica
Sapium bussei
Schotia brachypetala
Schotia capitata
Schrebera alata
Schrebera argyrotricha
Schrebera gilgiana
Schrebera mazoensis
Schrebera trichoclada
Sclerocarya birrea
Sclerocarya caffra
Senna bicapsularis
Senna didymobotrya
Senna hirsuta
Senna italica
Senna obtusifolia
Senna occidentalis
Senna pendula
Senna petersiana
Senna septemtrionalis
Senna siamea
Senna singueana
Sopubia ramosa
Sterculia africana
Sterculia setigera
Stereospermum kunthianum
Streblus usambarensis
Swartzia madagascariensis
Syzygium cordatum

Syzygium guineense
Syzygium intermedium
Syzygium masukuense
Syzygium owariense
Tamarindus indica
Tamarix usneoides
Tarchonanthus camphoratus
Tarchonanthus minor
Tecoma brycei
Terminalia laxiflora
Terminalia macroptera
Terminalia sericea
Terminalia stuhlmanni
Tetrapleura andongensis
Trema guineensis
Trema orientalis
Tricalysia okelensis
Trichilia capitata
Trichilia chirindensis
Trichilia dregeana
Trichilia emetica
Trichilia natalensis
Trichoscypha ulugurensis
Trilepisium madagascariense
Turraea eylesii
Turraea fischeri
Turraea floribunda
Turraea nilotica
Turraea obtusifolia
Turraea randii
Turraea zambesica
Tylosema fassoglense
Uapaca togoensis
Vepris glomerata
Vitex cuneata
Widdringtonia cupressoides
Widdringtonia nodiflora
Widdringtonia whytei
Xylia torreana
Ziziphus mauritiana
Ziziphus mucronata

5.1.4 - Tropical Mountain Systems

The main mountain systems are the Cameroon highlands, the mountains of Kenya, the Kivu ridge and the Ethiopian highlands. Some lower and isolated hills occur, such as the Fouta Djalon, Jos and Mandara Plateaus in West Africa, Hoggar in the Sahara and Windhoek Mountain in southern Africa. Madagascar has a high central range.

The climate is similar to that of the surrounding lowlands but with lower temperatures and, often, higher rainfall. Above 800 to 1,200 m, temperature decreases and vegetation changes, defining submontane, montane and high-elevation ecofloristic zones.

The vegetation is extremely diverse and varies with climate. On most mountains the lowermost vegetation is forest. Between the lowland forest and the rather different (in physiognomy and flora) montane forest, there is a submontane transition zone. In many places, however, fire and cultivation have destroyed the vegetation of this transition zone. Montane forest, generally above 1,500 to 2,000 m, is lower in structure than lowland and submontane forests. At the upper part of the montane level is an Ericaceous belt followed, above 3,000 m, by alpine vegetation.

In western Africa, on the Kivu ridge or the wetter slopes of the Ethiopian highlands and East African mountains, the trees of the upper stratum are 25 to 45 m tall with middle and lower layers. Bamboo forest or thicket occurs between 2,300 and 3,000 m on most of the high mountains in East Africa and sporadically on some of the mountains of Cameroon.

In Madagascar, the original vegetation in the mountains was moist montane forest, sclerophyllous montane forest on the eastern slopes and drier forest on the western slopes. These forests have been replaced over extensive areas by secondary grassland. In other areas shrubland and thicket is the prevalent vegetation.

In Africa, this ecologic zone has a total area of about 147 million hectares, from which only 11% are covered with forest (16 million hectares).

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia gerrardii
Acacia laeta
Acacia scorpiodes
Afzelia cuanzensis
Albizia schimperiana
Aningeria adolfi-friederici
Aningeria robusta
Anticharis glandulosa
Arundinaria alpina
Chrysophyllum gorungosanum
Cola greenwayi
Convolvulus fatmensis
Cordia abyssinica
Cordia africana
Cordia millenii
Cordia platythyrsa
Cordia rochii
Croton macrostachyus
Cupressus depreziana
Dalbergia melanoxylon
Diospyros abyssinica
Drypetes gerrardii
Ficus ingens
Juniperus procera
Lovoa brownii
Lovoa swynnertonii
Lupinus pilosus
Moringa stenopetala

Myrtus nivellei
Newtonia buchananii
Ocotea kenyensis
Ocotea usambarensis
Olea capensis
Olea lapperrini
Podocarpus falcatus
Podocarpus latifolius
Prunus africana
Silene kiliani
Syzigium guineense
Teclea nobilis
Trianthema pentandra
Uapaca bojeri
Xymalos monospora

5.1.5 - Subtropical Humid Forest

This zone is restricted to a narrow zone along the east coast of southern Africa, roughly between 25° and 34°S. It has moderately high and well-distributed rainfall and, except in the extreme south, is frost free. Annual rainfall is 800 to 1,200 mm and the mean temperature of the coldest month is 7° to 15°C. Mean annual temperatures diminish from 22°C in the north to 17°C in the south. Further inland, climate changes rapidly over short distances.

In most of the zone the natural vegetation is evergreen or semi-evergreen forest, the most luxuriant stands approaching rain forest stature and structure. The canopy varies in height from 10 to 30 m. About 120 species occur, although more than 30 are not usually present in any one stand. Today, where the original vegetation has not been completely replaced, land cover often consists of a mosaic of forest, scrub forest, bushland, thicket and secondary grasslands. Where rainfall is too low to support forest, the most widespread climax vegetation is evergreen and semi-evergreen bushland and thicket.

In Africa, this ecologic zone has a total area of about 8 million hectares, from which only 16% are covered with forest (1 million hectares).

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Atalaya natalensis
Anastrabe integerrima
Beilschmiedia natalensis
Brachylaena uniflora
Cola natalensis
Commiphora harveyi
Cordia caffra
Diospyros inhacaensis
Manilkara concolor

5.1.6 - Subtropical Dry Forest and Subtropical Steppe

The African subtropical dry forest zone includes parts of North Africa and South Africa with a Mediterranean climate. There is a pronounced dry season in summer. Most of the rainfall (400 to 1,000 mm per year) occurs in winter although in the eastern regions of South Africa it is more evenly distributed (subtropical humid). The annual temperature varies but the mean temperature of the coldest month, in the lowlands, is always more than 7°C. In northern Africa, the climax vegetation is forest in the most humid parts. In many places, as a result of degradation by overgrazing, these forests have been replaced by scrub. In South Africa, the prevalent vegetation of this zone is fynbos, sclerophyllous shrublands 1 to 4 m high. This ecologic zone has an area of about 35 million hectares, but only 7 million are covered with forest (19%).

The subtropical steppe zone of Africa is a transitional belt that lies in the Marrakech and Agadir Basins in Morocco and the lower inland plateaus in Algeria and Tunisia. Rainfall varies from 200 to 500 mm with a long dry hot season of 6 to 11 months. The mean temperature of the coldest month is always more than 7°C. Vegetation in this zone is a tree pseudo-steppe. In Morocco (Sous), the typical vegetation type forest. The subtropical steppe zone of Africa covers an area of 48 million hectares, with almost none forest cover.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Acacia gummifera
Acacia nilotica
Acacia tortilis raddiana
Alnus glutinosa
Argania spinosa
Argania sideroxylon
Bauhinia galpinii
Canthium inerme
Ceratonia siliqua
Euphorbia resinifera
Juniperus phoenicia
Leucadendron argentum
Pinus halepensis
Pinus pinaster
Pistacia atlantica
Pistacia lentiscus
Prosopis cineraria
Prosopis farcta
Quercus afares
Quercus coccifera
Quercus faginea
Quercus ilex
Quercus robur
Quercus suber
Tamarix africana
Tamarix aphylla
Tamarix boveana
Tamarix parviflora
Taxus baccata
Tetraclinis articulata
Ziziphus lotus

5.1.7 - Subtropical Mountain Systems

In northern Africa, the Atlas Mountains dominate the landscape and extend over 3,000 km. Their altitude reaches 1,500 m in Tunisia, 2,500 m in Algeria and 4,165 m in Morocco. The Rif Atlas experiences a humid climate because of proximity to the Atlantic Ocean. Rainfall approaches 1,000 mm, with a short summer drought. Further inland, the dry season is always pronounced and the climate becomes semi-arid to the south.

In South Africa, the largest highland area is the Highveld region, more than 1,000 m in altitude, bordered by the Drakensberg, reaching more than 3,000 m. The mountain ranges in the Cape region also belong to this ecological zone. The climate is humid with a tropical regime. Rainfall varies from 500 to 1,100 mm with a short winter dry season. Winter temperatures are only somewhat low, more than 7°C up to 1,500 m. In the northern Atlas Ranges, the lower slopes are covered by mixed forest. Above 1,600 m this forest gives way a conifer dominated forest.

In southern Africa an evergreen montane forest grows on the Drakensberg slopes. In the Cape region, a forest with conditions resembling those of temperate forest grows on the slopes of the Outeniekwaberge, facing the sea. In Africa, there are 42 million hectares belonging to this ecologic zone, from which only 2 million ha covered with forest (4%).

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies numidica
Cedrus atlantica
Juniperus thurifera
Olea capensis
Pinus halepensis
Pinus pinaster
Quercus ilex

5.2 – Asia (Excl. Russia)

Asia as a whole contains about 601 million ha of forests which corresponds to 14% of the world total. Asian forests amount to 0.2 ha per capita, which is low compared to the world average. Most forests are located in the tropical ecological domain and Asia has about 21% of all tropical rain forests. Table 5.02 shows the forest cover of each Asian ecologic zone.

Table 5.02 - Forest Area per Ecologic Zone - Asia (Million Hectares)

Ecologic Zone	*Total Area*	*Forest Cover*	*Forest Area*
Tropical	**1,079**	**34%**	**365**
Rain forest	303	55%	167
Moist	141	36%	51
Dry	146	65%	95
Shrub	121	10%	12
Desert	280	0%	0
Mountain	88	46%	40
Subtropical	**838**	**16%**	**138**
Humid	208	36%	75
Dry	13	34%	4

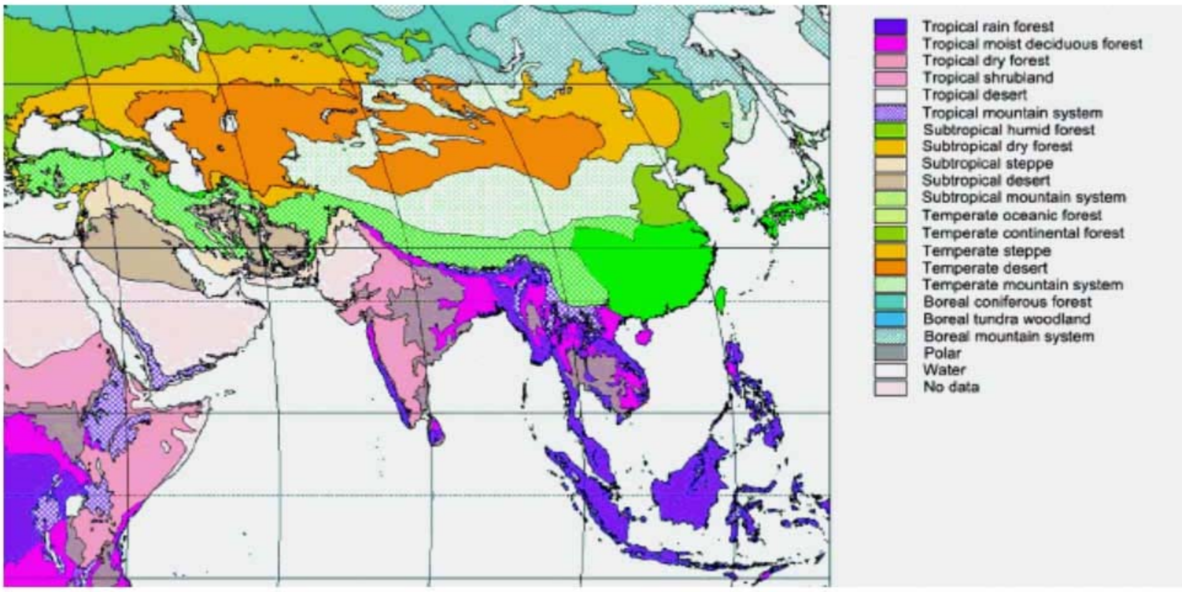
Ecologic Zone	***Total Area***	***Forest Cover***	***Forest Area***
Steppe	116	2%	2
Desert	150	0%	0
Mountain	351	16%	56
Temperate	**1,226**	**7%**	**84**
Continental	130	31%	40
Steppe	210	5%	11
Desert	468	0%	0
Mountain	418	8%	33
Boreal	**17**	**84%**	**14**
Coniferous	16	85%	14
Mountain	1	76%	1
TOTAL	**3,160**	**19%**	**601**

Source: FAO, 2001

Subtropical forests are extensive and Asia has more subtropical mountain forests than any other region and more than one third of the world total. More than 60 percent of the world's forest plantations are located in Asia. The net change of forest area is relatively low, with an annual net loss, based on country reports, estimated at 364,000 ha, corresponding to 0.2 percent annually. Figure 5.02 shows the Asian ecologic zones distribution.

Figure 5.02 – Asian Ecologic Zones

Source: FAO, 2001



5.2.1 - Tropical Rain Forest

This zone covers the southwestern coasts of India and Sri Lanka, Myanmar and the eastern Himalayan foothills, the coastal lowlands of Southeast Asia, the Philippines and most of the Malay Archipelago.

The western coasts of the Asian continent are very wet owing to monsoonal rains. Viet Nam and the Philippines deviate from this pattern and their eastern coasts are wet. Across the zone, annual rainfall is everywhere more than 1,000 mm and often more than 2,000 mm. There is no dry season in the equatorial regions. Everywhere else there is a short dry season, generally one to four months. Temperatures are always high.

In the wettest parts of this extensive zone the prevailing vegetation type is dense moist evergreen forest. A striking characteristic is the occurrence of Dipterocarpaceae only to the west of Wallace's Line. In the drier parts of the area, mainly in eastern Indonesia and the Himalayan foothills, semi-deciduous or moist deciduous forests occur.

The lushest rain forests are found in the Malay Archipelago, harbouring a very rich flora. Over half (220) of the world's flowering plant families are represented as well as about one-quarter of the genera (2,400), of which about 40 percent are endemic. Of 25,000 to 30,000 species, about one-third are trees of more than 10 cm in diameter. Dipterocarpaceae, which are particularly diverse in genera and species, dominate rain forests west of the Wallace Line. They contribute many (Sumatra, Malaysia), most (Borneo) or all (Philippines) of the top canopy giant trees. In Asia, this ecologic zone covers 303 million hectares, from which 167 million are forested (55%).

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia leucophloca
Acalypha caturus
Acer niveum
Actinodaphne glomerata
Actinodaphne macrophylla
Actinodaphne pruinosa
Adenanthera pavonina
Adenanthera tamarindifolia
Adina fagifolia
Adina minutiflora

Adinandra dumosa
Adinandra sarcosanthera
Aetoxylon sympetalum
Afzelia javanica
Agathis alba
Agathis beccarii
Agathis borneensis
Agathis dammara
Agathis hammii
Agathis loranthifolia
Agelaea borneensis
Agelaea trinervis
Aglaia borneensis
Aglaia dookko
Aglaia edulis
Aglaia eusideroxylon
Aglaia ganggo
Aglaia korthalsii
Aglaia lawii
Aglaia macrocarpa
Aglaia maingayi
Aglaia minahassae
Aglaia odoratissima
Aglaia palembanica
Aglaia rubiginosa
Agrostistachys longifolia
Alangium javanicum
Alangium ridleyi
Albizzia chinensis
Albizzia falcataria
Alphonsea cylindrica
Alphonsea elliptica
Alphonsoa javanica
Alphyllus zizyphoides
Alseodaphne bancana
Alstonia angustifolia
Alstonia ranvolfia
Alstonia sumatrana
Altingia excelsa
Alverites moluccana
Amoora rubiginosa
Anacolosa frutescens
Ancistrocladus tectorius
Anisophyllea disticha
Anisoptera costata
Anisoptera grossivenia
Anisoptera marginata
Anthocephalus cadamba
Anthocephalus macrophyllum
Anthochephalus cadamba

Antiaris toxicaria
Antidesma celebicum
Antidesma cuspidatum
Antidesma stipulare
Aporusa antennifera
Aporusa falcifera
Aporusa frutescens
Aporusa granularis
Aporusa lagenocarpa
Aporusa nervosa
Aporusa subcaudata
Aquilaria malaccensis
Araucaria cunninghamii
Archidendron borneense
Archidendron havilandii
Archidendron microcarpum
Ardisia macrophylla
Ardisia monticola
Ardisia rumphii
Areca vestiaria
Arenga pinnata
Aromadendron elegans
Artabotrys roseus
Artabotrys suaveolens
Artocarpus anisophyllea
Artocarpus dadah
Artocarpus dasyphyllus
Artocarpus elasticus
Artocarpus fulvicortex
Artocarpus integer
Artocarpus kemando
Artocarpus lanceifolius
Artocarpus nitidus
Artocarpus odoratisimus
Artocarpus rigidus
Artocarpus rufescens
Artocarpus teysmanii
Atuna racemosa
Averrhoa bilimbi
Azadirachta excelsa
Azadirachta indica
Baccaurea angulata
Baccaurea bracteata
Baccaurea kunstleri
Baccaurea lanceolata
Baccaurea latifolia
Baccaurea macrocarpa
Baccaurea minor
Baccaurea parviflora
Baccaurea racemosa

Baccaurea stipulata
Baccaurea sumatrana
Baccaurea tempoi
Baillanodendron malayanum
Barringtonia acutangula
Barringtonia asiatica
Barringtonia lanceolata
Barringtonia reticulata
Beilschmiedia glabra
Beilschmiedia longipedicellata
Beilschmiedia madang
Beilschmiedia micrantha
Beilschmiedia splendens
Beilschmiedia weiringa
Berrya cordifolia
Bhesa paniculata
Bhesa robusta
Bischeffia javanica
Blumeodendron calophyllum
Blumeodendron kurzii
Blumeodendron tokbari
Bombax valetonii
Bouea gandaria
Bouea macrophylla
Bouea oppositifolia
Brackenridgea hookeri
Breynia cernua
Buchacania amboinensis
Buchanania arborescens
Buchlandia tricuspis
Calamus manan
Callicarpa pentandra
Calophyllum austrocoriaceum
Calophyllum biflorum
Calophyllum calaba
Calophyllum gracilipes
Calophyllum inophyllum
Calophyllum molle
Calophyllum nodosum
Calophyllum pulcherrimum
Calophyllum rigidum
Calophyllum rubiginosum
Calophyllum soulattri
Calophyllum tetrapterum
Camnosperma auriculata
Camnosperma macrophylla
Cananga odorata
Canarium apertum
Canarium asperum
Canarium hirsutum

Canarium megalanthum
Canarium pilosum
Canarium vriesanum
Canthium glabrum
Cantleya corniculata
Cantleya corniculata
Capparis micracantha
Carallia brachiata
Caryota mitis
Casearia capitellata
Castanopsis acuminatissima
Castanopsis argentea
Castanopsis borneensis
Castanopsis buruana
Castanopsis javanica
Castanopsis motleyana
Castanopsis rhamnifolia
Castanopsis sumatrana
Casuarina equisetifolia
Casuarina junghuhniana
Casuarina nobilis
Celtis latifolia
Chaetocarpus castanocarpus
Chionanthus cuspidatus
Chionanthus lucens
Chionanthus montana
Chisocheton kingii
Chrysophyllum roxburghii
Chukrasia tabularis
Cinnamomum javanicum
Cinnamomum parthenoxylon
Cinnamomum rhynchophyllum
Cinnamomum zeylanicum
Citrus celebica
Clausena excavata
Clerodendrum minahassae
Cocos nucifera
Combretocarpus retundatus
Connarus minor
Cordia mysea
Cordia subcordata
Coscinium fenestratum
Cotylelobium flavum
Cotylelobium malayanum
Cotylelobium melanoxylon
Crateva nurlava
Cratoxylon arborescena
Cratoxylon celebicum
Cratoxylon formosum
Croton argyratus

Crypteronia griffithii
Cryptocarya bicolor
Cryptocarya ceasia
Cryptocarya celebica
Cryptocarya crassinervia
Cryptocarya diversifolia
Cryptocarya ferrea
Cryptocarya nitens
Ctenolophon parvifolius
Cyathocalyx havilandii
Cyathocalyx magnigica
Dacrydium elatum
Dacrydium junghunii
Dacryodes costata
Dacryodes incurvata
Dacryodes laxa
Dacryodes rostrata
Dacryodes rugosa
Dactylocladus stenotachys
Dalbergia discolor
Dalbergia parviflora
Dalbergia sissoides
Dehaasia cuneata
Dendrocalamus asper
Dendrocnide microstigma
Deplanchea bancana
Desmodium umbellatum
Dialium indicum
Dialium kunstleri
Dialium platysepalum
Dialium wallichii
Dillenia excelsa
Dillenia ochreata
Dillenia sumatrana
Diospyros argentea
Diospyros bantamensis
Diospyros buxifolia
Diospyros celebica
Diospyros confertiflora
Diospyros diepenhorstii
Diospyros javanica
Diospyros korthalsiana
Diospyros lanceifolia
Diospyros maingayi
Diospyros maritima
Diospyros minahasae
Diospyros pilosanthera
Diospyros rumphii
Diospyros sumatrana
Diospyros yeobi

Diploknema oligomera
Dipterocarpus alatus
Dipterocarpus borneensis
Dipterocarpus grandiflorus
Dipterocarpus indicus
Dipterocarpus kunstleri
Dipterocarpus stellatus
Dipterocarpus sublamellati
Dipterocarpus trinervis
Distylium stellare
Dracontomelon dao
Dracontomelon mangiferum
Drimycarpus luridus
Dryobalanops aromatica
Dryobalanops beccariana
Dryobalanops camphora
Dryobalanops fusca
Dryobalanops kayanensis
Dryobalanops keithii
Dryobalanops lanceolata
Dryobalanops oblongifolia
Dryobalanops oocarpa
Dryobalanops rappa
Drypetes kikir
Drypetes laevis
Drypetes longifolia
Drypetes microphylla
Duabanga moluccana
Durio acutifolius
Durio carinatus
Durio griffithii
Durio lanceolatus
Durio oxleyanus
Durio zibethinus
Dyera costulata
Dysoxylum acutangulum
Dysoxylum arborescens
Dysoxylum cauliflorum
Dysoxylum mollissimum
Ehretia acuminata
Elaeocarpus floribundus
Elaeocarpus longipetiolatus
Elaeocarpus pedunculatus
Elaeocarpus petiolatus
Elaeocarpus sphaericus
Elaeocarpus stipularis
Elateriospermum tapos
Elattostachys zippeliana
Elmerrilla celebica
Elmerrilla ovalis

Endiandra coriacea
Endospermum malaccense
Engelhardia spicata
Enkleia malaccensis
Erythroxylon cuneatum
Eucalyptopsis papuana
Eucalyptus deglupta
Eucalyptus platyphylla
Eugenia accuminatissima
Eugenia acheriana
Eugenia bankensii
Eugenia cumini
Eugenia cuprea
Eugenia fastigata
Eugenia filiformis
Eugenia glauca
Eugenia grandis
Eugenia lineata
Eugenia palawanense
Eugenia polyantha
Eugenia rugosa
Eugenia sandakanensis
Eugenia spicata
Eugenia tawahense
Euodia minahasae
Euonumys javanicus
Eurycoma longifolia
Eusideroxylon zwageri
Euthemis leucocarpa
Evodia speciosa
Excoecaria agallocha
Fagraea gigantea
Fagraea racemosa
Fahrenheitia pendula
Ficus altissima
Ficus ampelas
Ficus annulata
Ficus aurata
Ficus auriculata
Ficus beccarii
Ficus benjamina
Ficus binnendykii
Ficus bracheata
Ficus callicarpides
Ficus callophylla
Ficus caulocarpa
Ficus chrysolepis
Ficus consociata
Ficus cordulata
Ficus crassiramea

Ficus cucurbitina
Ficus curtipes
Ficus delosyce
Ficus deltoidea
Ficus disticha
Ficus drupacea
Ficus dubia
Ficus excavata
Ficus fistulosa
Ficus forstenii
Ficus geocharis
Ficus glandulifera
Ficus globosa
Ficus grossularoides
Ficus gul
Ficus hemsleyana
Ficus heteropleura
Ficus hispida
Ficus indica
Ficus kerkhovenii
Ficus lanata
Ficus lowii
Ficus magnoleaefolia
Ficus microcarpa
Ficus minahassea
Ficus obscura
Ficus palungensis
Ficus paracamptophylla
Ficus parietalis
Ficus pellucido-punctata
Ficus pisocarpa
Ficus pubinervis
Ficus punctata
Ficus recurva
Ficus retusa
Ficus ribes
Ficus ruginerva
Ficus sagittata
Ficus saxophilla
Ficus schwartzii
Ficus septica
Ficus sinuata
Ficus spathulifolia
Ficus stolonifera
Ficus stricta
Ficus stupenda
Ficus subcordata
Ficus subgelderi
Ficus subtecta
Ficus subtrinervia

Ficus subulata
Ficus sundaica
Ficus superba
Ficus tarrenifolia
Ficus tinctoria
Ficus trichocarpa
Ficus tristanifolia
Ficus uncinata
Ficus urnigera
Ficus variegata
Ficus villosa
Ficus virens
Ficus xylophylla
Fissistigma fulgens
Flacourtia rukam
Flacourtiaceae
Fordia splendidissima
Fraxinus griffithii
Friesodielsia glauca
Galearia fulva
Ganophyllum falcatum
Ganua motleyana
Garcinia atroviridis
Garcinia bancana
Garcinia celebica
Garcinia cowa
Garcinia daedalanthera
Garcinia dulcis
Garcinia gaudichaudii
Garcinia mangostana
Garcinia nervosa
Garcinia parvifolia
Garcinia rheedei
Garcinia tetrandra
Gardeniopsis longifolia
Garuga floribunda
Gastonia papuana
Geunsia petandra
Gigantochloa levis
Gigantochloa ligulata
Gironniera hirta
Gironniera nervosa
Gironniera subaequalis
Glochidion philippicum
Glochidion superbum
Gluta macrocarpa
Gluta renghas
Gluta speciosa
Gluta wallichii
Gnetum gnemenoides

Gnetum gnemon
Gnetum latifolium
Gomphia serrata
Goniothalamus velutinus
Gonystylus confusus
Gonystylus hankenbergii
Gonystylus macrophyllus
Gordonia borneensis
Gossampinus malabarica
Grewia blattaefolia
Grewia cinnamomifolia
Grewia koordersiana
Guatteria odorata
Guioa bankensis
Guioa diplopetala
Gymnacranthera farquhariana
Gymnacranthera forbesii
Gymnacranthera paniculata
Harpullia arborea
Harpullia cupaniodes
Helicia excelsa
Helicia petiolaris
Heliciopsis lanceolata
Heliciopsis velutina
Heritiera arafensis
Heritiera littoralis
Heritiera simplicofolia
Heritiera sylvatica
Hibiscus tiliaceus
Homalium celebicum
Homalium foetidum
Homalium tomentosum
Hopea dasyrrhachis
Hopea dryobalanoides
Hopea dyeri
Hopea ferruginea
Hopea mengarawan
Hopea nervosa
Hopea sangal
Hopea sericea
Horsfieldia brachiata
Horsfieldia crassifolia
Horsfieldia grandis
Horsfieldia penangiana
Horsfieldia polyspherula
Horsfieldia sylvestris
Hugonia costata
Hydnocarpus sumatrana
Ilex beccariana
Ilex pleiobrachiata

Indorouchera griffithiana
Intsia bijuga
Intsia palembanica
Irvingin malayana
Jackia ornata
Kalappia celebica
Kandelia candel
Kayea navezii
Kibatalia maingayi
Kjellbergiodendron celebicum
Kleinhovia hospita
Knema hookeriana
Knema kunstleri
Knema latericia
Knema percoriacea
Kokoona reflexa
Koompassia excelsa
Koompassia malaccensis
Koordersiodendron pinnatum
Kunstleria ridleyi
Labisia pumila
Lagerstroemia ovalifolia
Leea aculeata
Leea indica
Leea rubra
Lepisanthes divaricata
Licania splendens
Linostoma pauciflorum
Lithocarpus bullatus
Lithocarpus cantleyanus
Lithocarpus caudatifolius
Lithocarpus celebicus
Lithocarpus confertus
Lithocarpus conocarpus
Lithocarpus cyclophorus
Lithocarpus elegans
Lithocarpus ewyckii
Lithocarpus hallieri
Lithocarpus hatusimae
Lithocarpus havilandii
Lithocarpus lampadarius
Lithocarpus leptogyne
Lithocarpus lucidus
Lithocarpus nieuwenhuisii
Lithocarpus pusillus
Lithocarpus sundaicus
Lithocarpus urceolaris
Litsea angulata
Litsea forma
Litsea oppositifolia

Livistona rotundifolia
Lophopetalum beccarianum
Lophopetalum javanicum
Lophopetalum pachypyllum
Lophopetalum pallidum
Lumnitzera littorea
Luvunga borneensis
Luvunga crassifolia
Macaranga indistincta
Macaranga maingayi
Macaranga mappa
Macaranga pruinosa
Macaranga tanarius
Macaranga trilobata
Madhuca crassipes
Madhuca glaberrima
Madhuca malacensis
Madhuca philippinensis
Maesa perlaurius
Maesa ramentacea
Maesopsis eminii
Magnolia candollii
Mallotus columnaris
Mallotus griffithianus
Mallotus laevigatus
Mallotus penangensis
Mallotus philippensis
Mallotus ricinoides
Mallotus stipularis
Mallotus tiliifolius
Mammea acuminata
Mangifera caesia
Mangifera foetida
Mangifera indica
Mangifera lagenifera
Mangifera macrocarpa
Mangifera similis
Manglietia glauca
Manilkara celebica
Manilkara fasciculata
Manilkara kauki
Maranthes corymbosa
Mastixia rostrata
Melaleuca leucadendron
Melanochyla elmeri
Melanochyla fulvinervis
Melanolepis multiglandulosa
Melanorrhoea wallichii
Melastoma malabathricum
Melia azedarach

Melia excelsa
Melochia umbellata
Memecylon acuminatissimum
Memecylon amplexicaule
Memecylon campanulatum
Memecylon costatum
Memecylon excelsum
Memecylon garcinioides
Memecylon oleifolium
Memecylon oligoneurum
Memecylon paniculatum
Mesua calophylloides
Mesua ferrea
Mezzettia leptopoda
Mezzettia parviflora
Mezzettia umbellata
Michelia velutina
Microcos hirsuita
Mimusops elengi
Mitrangyna speciosa
Mitrephora polyprena
Monocarpia marginalis
Morinda bracteata
Morinda citrifolia
Morus macroura
Moultonianthus leembruggianus
Musaendopsis beccariana
Myristica fatua
Myristica iners
Myristica maxima
Myristica villosa
Nauclea orientalis
Neonauclea calycina
Neonauclea lanceolata
Neonauclea moluccana
Neonauclea orientalis
Neonauclea subdita
Neoscortechinia kingii
Nephelium laurinum
Nephelium maingayi
Nephelium rapaseum
Nothaphoebe reticulata
Nyssa javanica
Ochanostachys amentacea
Octomeles sumatrana
Ormosia bancana
Ormosia sumatrana
Palaquium amboinense
Palaquium beccarianum
Palaquium calophyllum

Palaquium gutta
Palaquium leiocarpum
Palaquium obovatum
Palaquium obtusifolium
Palaquium ridleyi
Palaquium stellatum
Paninari glaberrima
Paramignya scandens
Parartocarpus venenosus
Parashorea aptera
Parashorea lucida
Parashorea malaanonan
Parashorea tomentella
Parasianthes falcataria
Parasianthes lebbeck
Parasianthes minahasae
Parasianthes procera
Parastemon urophyllum
Paratocarpus triandus
Parinari corymbosa
Parinari costata
Parishia insignis
Parishia maingayi
Parkia roxbarghii
Parkia singularis
Parkia speciosa
Payena leerii
Payena obscura
Pelthoporum pterocarpa
Pentace triptera
Pentaspadon motleyi
Peronema cancescens
Persea rimosa
Phaeanthus crassipetalus
Phaleria capitata
Phoebe elliptica
Phrynium basiflorum
Phrynium capitatum
Pimeleodendron amboinicum
Pimelodendron griffithianum
Pinus merkusii
Piper aduncum
Pipturus argentus
Pisonia umbellifera
Pithecellobium bubalinum
Pithecellobium ellipticum
Planchonella nitida
Planchonia grandis
Planchonia papuana
Planchonia valida

Platea latifolia
Podocarpus blumei
Podocarpus imbricatus
Podocarpus motleyi
Podocarpus neriifolius
Podocarpus wallichianus
Poikilospermum suaveolens
Polyalthia elliptica
Polyalthia glauca
Polyalthia grandiflora
Polyalthia hypoleuca
Polyalthia lateriflora
Polyalthia motleyana
Polyalthia rumphii
Polyalthia sumatrana
Polyosma kingiana
Polythia glauca
Pometia pinnata
Pometia tomentosa
Pongamia pinnata
Popowia pisocarpa
Pouteria firma
Pouteria malaccensis
Pouteria oxyedra
Prainea frutescens
Prainea limpato
Prunus arborea
Prunus beccarii
Pteleocarpus lompongus
Pternandra azurea
Pternandra coerulescens
Pternandra gibbosa
Pterocarpus indicus
Pterocymbium javanicum
Pterospermum diversifolium
Pterospermum javanicum
Pterygota forbesii
Quercus elmeri
Quercus gemelliflora
Quercus lineata
Quercus oidocarpa
Quercus spicata
Quercus subsericea
Quercus sumatrana
Quercus sundaica
Radermachera gigantea
Randia oppositifolia
Reinwardtiodendron humile
Rhodamnia cinerea
Rourea mimosoides

Ryparosa baccaurioides
Ryparosa javanica
Ryparosa kostermansii
Saccopetalum horsfieldii
Sageraea lanceolata
Salacia lanceolata
Salacia macrophylla
Samanea saman
Sandoricum koetjape
Santalum album
Santiria apiculata
Santiria conferta
Santiria griffithii
Santiria laevigata
Santiria rubingifolia
Santiria tomentosa
Sapium baccatum
Saurauia lepidocalyse
Saurauia leprosa
Saurauia tristyla
Scaphium macropodum
Schima walachii
Schizomeria serrata
Schleichera aleosa
Schoutenia ovata
Scleropyrum wallichianum
Scorodocarpus borneensis
Scutinanthe brunnea
Seaphium macropodum
Serianthes minahasae
Shorea acuminatissima
Shorea argentifolia
Shorea balangeran
Shorea bracteolata
Shorea coriacea
Shorea crassa
Shorea dealbata
Shorea faguetiana
Shorea gibbosa
Shorea gratissima
Shorea guiso
Shorea hopeifolia
Shorea johorensis
Shorea konsleyana
Shorea koordesii
Shorea kunstleri
Shorea laevifolia
Shorea laevis
Shorea lamellata
Shorea leprosula

Shorea leptocladus
Shorea macrantha
Shorea macrophylla
Shorea multiflora
Shorea ovalis
Shorea pachyphylla
Shorea palembanica
Shorea parvifolia
Shorea parvistipulata
Shorea pauciflora
Shorea pinanga
Shorea platyclados
Shorea quadrinervis
Shorea retinodes
Shorea retusa
Shorea robusta
Shorea rugosa
Shorea scabrida
Shorea seminis
Shorea sororia
Shorea sumatrana
Shorea teysmanniana
Shorea virescens
Sindora galedupa
Sindora leiocarpa
Sindora velutina
Sindora wallichii
Sloanea sigun
Sloetia elongata
Sonneratia alba
Spathodea campanulata
Spondias dulcis
Spondias pinnata
Sterculia comosa
Sterculia insularis
Sterculia macrophylla
Sterculia rynchophylla
Strombosia ceylanica
Strombosia javanica
Strychnos ignatii
Strychnos lucida
Styrax benzoin
Symplocos crassipes
Symplocos fasciculata
Symplocos henschelii
Syzygium alcine
Syzygium aphanomyrtoides
Syzygium beccarii
Syzygium borneense
Syzygium cerasiformis

Syzygium chrysanthemum
Syzygium clavatum
Syzygium confertum
Syzygium dyeriana
Syzygium garcinifolium
Syzygium gracile
Syzygium palembanica
Syzygium perpuncticulatum
Syzygium pseudosubtilis
Syzygium valdevenosum
Talauma candolii
Tarrietia javanica
Tarrietia symplicifolia
Taxus sumatrana
Tectona grandis
Teijsmanniodendron coriaceum
Terminalia bellirica
Terminalia cattapa
Terminalia celebica
Terminalia edulis
Ternstroemia magnifica
Tetractomia tetrandrum
Tetrameles nudiflora
Tetramerista glabra
Thottea penitilobata
Timonius borneensis
Timonius timon
Timonius villamilii
Toona sureni
Trema angustifolia
Trema orientalis
Trichadenia philippinensis
Trigoniastrum hypoleucum
Trigonopleura malayana
Triimma malaccensis
Triplochiton scleroxylon
Tristania whiteana
Turpinia sphaerocarpa
Ulmus lancifolia
Upunan borneensis
Urceola maingayi
Uvaria cauliflora
Vatica flavovirens
Vatica micrantha
Vatica oblongifolia
Ventilago borneensis
Vernonia arborea
Villebrunea rubescens
Vitex cofassus
Vitex gamosepala

Vitex quinata
Walsura pinnata
Weinmannia blumei
Willughbeia angustifolia
Willughbeia coriacea
Willughbeia macropoda
Xanthophyllum amoenum
Xanthophyllum griffithi
Xanthophyllum obscurum
Xanthophyllum scotichini
Xanthophyllum stipitatum
Xylopia elliptica
Xylopia ferruginea
Xylopia malayana
Zanthoxylum rhesta
Ziziphus angustifolia

5.2.2 - Tropical Mangroves

The mangrove forests of the Ganges Delta and western New Guinea are the most extensive in the world. The Asian mangroves, most widely distributed in the Indonesian archipelago and the Sundarbans of Bangladesh, are richer in species than comparable formations elsewhere. Mangrove forests can reach heights of 30 to 40 m and are best developed in sheltered bays or in extensive estuaries.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Avicennia alba
Avicennia officinalis
Avicennia marina
Bruguiera conjugata
Bruguiera cylindrica
Bruguiera gymnorrhiza
Carallia brachiata
Ceriops decandra
Ceriops tagal
Excoecaria agallocha
Rhizophora apiculata
Rhizophora mucronata
Sonneratia acida
Sonneratia alba
Sonneratia caseolaris
Nipa fruticans
Xylocarpus granatum

5.2.3 - Tropical Moist Deciduous Forest

This zone includes the lowlands of Sri Lanka; much of peninsular India; the hilly basin forming most of the country of Myanmar; the Red River valley and the lower foothills of the surrounding mountains in northern Viet Nam; the low plateaus on the western side of the Annamitic Range in southern Viet Nam, the Lao People's Democratic Republic and Cambodia; the plains and western foothills of the mountains in the Philippines; the low, flat, often swampy plains of the southern part of New Guinea and parts of Hainan Island and the Lezhou Peninsula in China.

Where the influence of the southwest monsoon is less, rainfall is generally between 1,000 and 2,000 mm with a dry season of three to six months. Temperatures are always high, with a mean temperature of the coldest month generally above 20°C but sometimes slightly lower, as in northern India, Myanmar or the Indochinese peninsula. In China, the southern parts of Lezhou and Hainan Island have a similar climate.

The natural vegetation is mostly deciduous or semi-deciduous forest, commonly known as monsoon forest. Many dominant trees belong to the Leguminosae, Combretaceae, Meliaceae or Verbenaceae. Dipterocarpaceae are also present, but less conspicuous than in the rain forest. Extensive deciduous forests remain on hilly parts of Myanmar and some patches in northern Viet Nam on the Red River plain. In the remaining part of Indochina the zone is widely covered with deciduous dipterocarp and teak forest. In Papua New Guinea there is a different type of dry evergreen or semi-evergreen deciduous forest.

In China, tropical moist deciduous forest is found below 700 m in basins and river valleys of the southern mountains on Hainan Island. In the central part of the island, coniferous forests grow on low mountains and hills at altitudes below 800 m.

In Asia, this ecologic zone covers an area equal to 141 million hectares, from which 51 million are forested (36%).

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia catechu
Acacia lebbeck
Acacia nilotica
Adina cordifolia
Afzelia xylocarpa
Aglaonema clarkei
Albizia procera
Aldrovanda vesiculosa
Alstonia scholaris
Altingia obovata
Amesiodendron chinense
Anisoptera scaphula
Anogeissus acuminata
Anthocephalus chinensis
Aphanamixis polystachya
Aquilaria agallocha
Artocarpus chama
Artocarpus chaplasha
Artocarpus heterophyllus
Azadirachta indica
Bassia latifolia
Bauhinia malabarica
Bombax ceiba
Calophyllum polyanthum
Castanopsis tribuloides
Chhota arusa
Chukrasia tabularis

Cirrhopetalum roxburghii
Crataeva magna
Cymbopogon osmastoni
Dalbergia sissoo
Debregeasia dentata
Dendrocalamus strictus
Derris robusta
Dillenia turbinata
Diospyros cordifolia
Diospyros hainanensis
Dipterocarpus alatus
Dipterocarpus turbinatus
Dysoxylum binectariferum
Engelhardtia roxburghiana
Ficus benjamina
Ficus racemosa
Ficus religiosa
Garuga floribunda
Garuga pinnata
Gironniera subaequalis
Gmelina arborea
Heritiera fomes
Heritiera parvifolia
Hippocratea marcantha
Homalium hainanensis
Homalium schlichtii
Hopea hainanensis
Hopea odorata
Hydnocarpus hainanense
Hydnocarpus kurzii
Intsia bijuga
Justica oreophylla
Knema bengalensis
Lagerstroemia parviflora
Lagerstroemia speciosa
Limnophila cana
Liquidambar formosana
Litchi chinensis
Lithocarpus fenzelianus
Litsaea polyantha
Lophopetalum fimbriatum
Madhuca hainanensis
Mangifera indica
Manglietia hainanensis
Mantisia spathulata
Marsdenia thyrsiflora
Melia azedarach
Mesua ferrea
Michelia balansae
Michelia champaca

Mitragyne parvifolia
Ophiorrhiza villosa
Ormosia balansae
Palaquium polyanthum
Palaya lata
Phrynium imbricum
Pinus latteri
Pinus merkusii
Podocarpus imbricata
Podocarpus nerifolia
Protium macgregorii
Pterospermum acerifolium
Pterospermum heterophyllum
Pterygota alata
Quercus acuminata
Quercus spicata
Rotala simpliciuscula
Samanea saman
Schefflera octophylla
Schleichera oleosa
Semecarpus subpanduriformis
Shorea robusta
Sindora cochinchinensis
Sindora glabra
Sonneratia griffithii
Spatholobus listeri
Sterculia foetida
Sterculia villosa
Sterospermum personatum
Swintonia floribunda
Syzygium cumini
Syzygium grande
Tamarindus indica
Taxus wallichiana
Tectona grandis
Terminalia catappa
Tetrameles nudiflora
Toona ciliata
Tournefortia roxburghii
Trewia nudiflora
Typhonium listeri
Vatica hainanensis
Vatica scaphula
Vernonia thomsoni
Vitex peduncularis
Vitex pinnata
Xylia kerrii
Xylocarpus mekongensis

5.2.4 - Tropical Dry Forest, Tropical Shrubland and Tropical Desert

The tropical dry forest ecologic zone of Asia comprises the coastal plains along the Gulf of Bengal and the northeastern part of the Deccan Plateau in India and Sri Lanka. In Myanmar, it includes the basin around Mandalay. The zone occupies the wide, flat alluvial basin of the Chao Phraya River in Thailand as well as the Korat Plateau and the Mekong River valley. In Cambodia, the area is the whole low central plain built by the lower Mekong River and the Tonle Sap. The Mekong delta in Viet Nam is part of this zone. Narrow coastal stretches also occur in southern Papua New Guinea. These areas are sheltered from the humid winds blowing from the oceans and only partially receive, in summer, the southwest monsoon. In winter they are influenced by the dry winds of the northeast monsoon. Rainfall ranges between 1,000 and 1,500 mm, with a dry season of five to eight months. Mean temperature of the coldest month is always above 15°C, often 20°C. Dry evergreen forest occurs on the dry eastern Coromandel Coast of India and in northern Sri Lanka. Dry deciduous dipterocarp forests and woodlands are more common throughout Viet Nam, the Lao People's Democratic Republic, Cambodia and Thailand. In mixed deciduous woodlands, teak and pine occur with dipterocarps or Leguminoseae. They are found in Thailand, Myanmar, the Lao People's Democratic Republic and Viet Nam. In India, woodlands are also common. In southern Papua New Guinea there are some dry deciduous forests with Myrtaceae and Eucalyptus woodland. This ecologic zone covers 146 million hectares in Asia, from which 95 million represent forest formations (65%).

The tropical shrubland zone of Asia occurs in an area equivalent to 121 million hectares, where only 10% represent forests (12 million hectares). Asian tropical deserts are found in 280 million hectares, from which none are forested.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Acacia arabica
Acacia asak
Acacia edgeworthii
Acacia ehrenbergiana
Acacia etbaica
Acacia farnesiana
Acacia hamulosa
Acacia jaquemontii
Acacia leucophloea
Acacia nilotica
Acacia oerfota
Acacia senegal
Acacia tortilis
Adenanthera pavonia
Aegle marmelos
Aegle marmelos
Ailanthus excelsa
Albizia amara
Albizia lebbek
Anogeissus latifolia
Azadirachta indica
Broussonetia papyrifera
Cadaba rotundifolia
Calligonum polygonoides
Capparis decidua

Capparis zeylanica
Cassia auriculata
Cassia fistula
Cassia javanica
Cassia siamea
Ceiba pentandra
Chloroxylon swietenia
Crotalaria burhia
Dalbergia latifolia
Dalbergia sissoo
Delonix elata
Delonix regia
Dipterocarpus intricatus
Dipterocarpus obtusifolius
Dipterocarpus tuberculatus
Erythrina indica
Grevillea robusta
Grewia tiliifolia
Hardwickia binata
Holoptelia integrifolia
Hyphaene thebaica
Leptadenia pyrotechnica
Leucaena leucocephala
Limonia acidissima
Maerua crassifolia
Manilkara hexandra
Maytenus emarginata
Parkia biglandulosa
Parkia biglandulosa
Peltophorum pterocarpum
Pentacme siamensis
Pinus merkusii
Pittosporum tetraspermum
Poinciana regia
Polyalthia longifolia
Pongamia pinnata
Prosopis cineraria
Prosopis juliflora
Salvadora oleoides
Salvadora persica
Samanea saman
Sericostoma pauciflorum
Shorea obtusa
Shorea talura
Tamarindus indica
Tamarix aphylla
Tamarix articulate
Tectona grandis
Terminalia arjuna
Terminalia bellirica

Terminalia paniculata
Wrightia tinctoria
Ziziphus nummularia
Ziziphus spina-christi
Ziziphus jujuba

5.2.5 - Tropical Mountain Systems

Asian tropical mountain systems include the eastern Himalayas; mountains stretching from Tibet to northern Indochina, the Malaysian Peninsula and the Annamitic Range; the central mountain ranges of the islands of Indonesia and the Philippines; relatively high peaks (over 2,000 m) in India and Sri Lanka; and mountains in the southwestern Arabian Peninsula.

Most tropical mountains of Asia, i.e. those reaching at least 1,500 to 2,000 m, have a wet climate. The Himalayas have a subtropical northwestern part and a tropical wet southeastern part. Nepal is a transitional region between these two areas. In all tropical mountains, between 1,000 to 1,500 m and 4,000 m, annual precipitation is more than 1,000 mm, sometimes more than 2,000 mm. There is a pronounced dry season of three to five months in the submontane zone of the eastern Himalayas, with the mean temperature of the coldest month above 15°C. Everywhere else, the dry season, if it occurs, is very short. The mean temperature of the coldest month rapidly decreases with increasing elevation. Above 4,500 to 5,000 m there is permanent snow.

The mountains in the southwestern Arabian Peninsula have a drier climate. Annual rainfall ranges from 400 mm in the lower foothills to 800 mm on the higher escarpments. There are two rainy seasons, March to April and July to September.

Forests generally cover the Himalayan slopes up to 4,000 m. Beginning around 1,000 m, tropical lowland forest is replaced by an evergreen forest.

In Myanmar and Thailand, evergreen oak forests are found above 1,500 m with pine forest. An evergreen forest with Lauraceae and Fagaceae grows from 1,500 to 2,000 m in the Lao People's Democratic Republic and Viet Nam while a mixed broad-leaved/coniferous forest takes over above this elevation. Woodlands with oaks and pines also occur at high altitude. In Thailand, northern Lao People's Democratic Republic and Viet Nam, these forests have been affected by shifting cultivation and mosaics of forests and thickets predominate at lower elevations.

In Malaysia, as well as in Indonesia and the Philippines, the montane (evergreen) rain forest still covers relatively large areas. This forest is best developed between 1,400 and 2,400 m altitude and is characterized by Fagaceae, Lauraceae, Juglandaceae, Magnoliaceae, conifers and others. In the subalpine zone, between 2,400 and 4,000 m, dense or discontinuous montane thickets are found. Coniferous forest often occurs in this belt. The alpine zone extends above 4,000 m.

Mountains are the only locations on the Arabian Peninsula where forests grow. From around 1,000 to 1,500 - 1,800 m is deciduous scrub or savannah. From 1,500 - 1,800 to 2,000 m is evergreen woodland or forest; from 2,000 to 3,000 m is coniferous forest.

In Asia, this ecologic zone encompasses 88 million hectares, from which 46% are forest (40 million hectares).

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abarema clypearia
Acacia confusa
Acacia delavayi
Acacia megaladena

Acacia pruinescens
Albizia bracteata
Albizia chinensis
Albizia henryi
Albizia kalkora
Albizia lebbek
Albizia mollis
Albizia odoratissima
Albizia sherrifii
Amphicarpaea bracteata
Amphicarpaea edgeworthii
Apios carnea
Apios delavayi
Araucaria cunninghamii
Araucaria hunsteinii
Araucaria montana
Astragalus balfourianus
Astragalus chiukiangensis
Astragalus dulongensis
Astragalus englerianus
Astragalus enneaphyllus
Atylosia mollis
Bauhinia bohniana
Bauhinia brachycarpa
Bauhinia delavayi
Bauhinia glauca
Bauhinia touranensis
Bauhinia yunnanensis
Caesalpinia crista
Caesalpinia curcullata
Caesalpinia sepiaria
Campylotropis capillipes
Campylotropis henryi
Campylotropis hirtella
Campylotropis howellii
Campylotropis macrocarpa
Campylotropis polyantha
Campylotropis prainii
Campylotropis trigonoclada
Campylotropis yunnanensis
Caragana franchetiana
Cassia leschenaultiana
Cassia siamea
Cassia sophora
Cassia tora
Casuarina junghuhniana
Catenaria caudata
Cladrastis sinensis
Clitoria mariana
Cochlianthus gracilis

Codariocalyx gyroides
Codariocalyx motorius
Codariocalyx polyantha
Crotalaria alata
Crotalaria assamica
Crotalaria ferruginea
Crotalaria sessiliflora
Dalbergia assamica
Dalbergia mimosoides
Dalbergia pinnata
Dalbergia stipulacea
Dalbergia szemaoensis
Dendrolobium triangulare
Derris marginata
Derris scabricaulis
Desmodium caudatum
Desmodium duclouxii
Desmodium elegans
Desmodium fallax
Desmodium gangeticum
Desmodium griffithianum
Desmodium heterocarpon
Desmodium laxiflorum
Desmodium megaphyllum
Desmodium microphyllum
Desmodium multiflorum
Desmodium oblatum
Desmodium oxyphyllum
Desmodium podocarpum
Desmodium racemosum
Desmodium reticulatum
Desmodium reticulatum
Desmodium rockii
Desmodium sequax
Desmodium triangulare
Desmodium williamsii
Desmodium yunnanense
Dumasia cordifolia
Dumasia forrestii
Dumasia hirsuta
Dumasia villosa
Dunbaria fusca
Dunbaria villosa
Entada phaseoloides
Entada pursaetha
Eriosema himalaicum
Erythrina arborescens
Flemingia ferruginea
Flemingia macrophylla
Flemingia philippinensis

Flemingia strobilifera
Gleditsia japonica
Glycine max
Hedysarum fistulosum
Hedysarum limitaneus
Indigofera amblyantha
Indigofera aralensis
Indigofera argutidens
Indigofera atropurpurea
Indigofera balfouriana
Indigofera hancookii
Indigofera howellii
Indigofera nigrescens
Indigofera pendula
Indigofera silvestrii
Indigofera spicata
Indigofera stachyodes
Indigofera subverticilata
Indigofera tengyuehensis
Juniperus procera
Kummerowia striata
Lens culinaris
Lespedeza cuneata
Lespedeza daurica
Lespedeza forrestii
Lespedeza juncea
Lespedeza tomentosa
Leucaena leucocephala
Lotus corniculatus
Millettia cinerea
Millettia dielsiana
Millettia dorwardii
Millettia pachycarpa
Millettia pulchra
Millettia sericosema
Mucuna birdwoodiana
Mucuna deeringiana
Mucuna macrocarpa
Mucuna sempervirens
Olea africana
Olea chrysophylla
Parochetus communis
Phaseolus minimus
Pinus roxburghii
Piptanthus leiocarpus
Piptanthus nepalensis
Pisum sativum
Pithecellobium clypearia
Podocarpium duclouxii
Podocarpium podocarpum

Podocarpium williamsii
Priotropis cytisoides
Psoralea corylifolia
Pterolobium punctatum
Pueraria edulis
Pueraria lobata
Pueraria peduncularis
Pueraria thomsonii
Pueraria wallichii
Rhynchosia rufescens
Shuteria involucrata
Shuteria vestita
Smithia ciliata
Smithia sensitiva
Spatholobus pulcher
Spatholobus suberactus
Stizolobium deeringianum
Trochonanhus comphoratus
Uraria clarkei
Vicia angustifolia
Vicia bungei
Vicia faba
Vicia sativa
Vicia tibetica
Vigna minima
Vigna vexillata

5.2.6 - Subtropical Humid Forest

In Asia, this ecological zone has its main distribution in southeastern China south of the Yangtze River, the southern tip of the Republic of Korea and the southern half of Japan. There are two distinct small geographic units in the Near East, humid forests at the foot of the Caucasus Mountains extending westward along the Black Sea and in the foothills of the Talysh Mountains at the Caspian Sea.

Winters are mild to warm and summers are hot and wet. Northerly cold fronts from Siberia heavily influence winter temperatures while in summer the Pacific monsoon brings large amounts of precipitation to the region.

Annual mean temperatures in China and the Korean Peninsula range from 15° to 17°C in the northern part of the zone to around 21°C in the south and southeast. Annual precipitation varies between 800 and 1,300 mm throughout the northern region, but further south it becomes wetter, up to 1,800 mm and sometimes 2,500 mm in low mountains. Annual rainfall diminishes towards the west, away from the coast. In the northern and central parts of the zone rainfall is evenly distributed throughout the year. In the south, most of the rain falls between May and October. A dry season from November to April is distinctive. The island of Taiwan Province of China is under the strong influence of the maritime monsoon climate, with higher average temperatures and greater rainfall.

The climate in Japan is greatly influenced by the monsoon. Generally speaking, the summers are very hot and the winters rather cold with snow and frosts. Mean annual temperature is around 14° to 17°C. The yearly precipitation over most of Japan is much greater than over the continent.

Mean annual precipitation ranges from around 1,200 mm to more than 2,500 mm locally with two peak rainy seasons, "Baiu" (June to July) and "Shurin" (autumn rain).

The climate of the coastal plains and lowlands south of the Black Sea and the Caspian Sea is warm-temperate with an annual average temperature around 14° to 15°C. Large amounts of precipitation fall throughout the year (1,500 to 2,000 mm, locally up to 4,000 mm). In the Colchis area the climate is mild owing to the influence of the Black Sea (yearly amplitude of the monthly average temperatures 15° to 19°C), with mild winters (average temperature of the coldest month 5° to 6°C).

Two types of woody vegetation prevail south of the Yangtze River in eastern China, pine forest and deciduous forest mixed with evergreen species. The mixed deciduous evergreen forests are a unique subtropical vegetation type. Bamboo stands are common in the region, with more than 20 species of *Phyllostachys*.

The western mid-latitude mountains feature conifer forests. Deciduous broad-leaved forests contain more than 300 woody species.

In the southeastern low mountain and hill region as well as the Sichuan Basin the representative vegetation is typically evergreen broad-leaved forests as well as coniferous forests. Distributed across the entire region is an evergreen broad-leaved laurel forest, as well as conifer forests. The region is one of the most important bamboo regions in China. There are two million hectares of *Phyllostachys edulis* in the area. Several other species from the same genus also occupy a broad range.

On the Yungui Plateau in southern and southwestern China, regional evergreen broad-leaved laurel forests are similar to those of eastern areas, consisting the same genera, Castanopsis, Lithocarpus, Cyclobalanopsis, Cinnamomum and Phoebe, but often with different species. The conifer forest here is dominated by conifers, which grows widely from 1,000 to 3,100 m, with pure stands usually from 1,600 to 2,800 m.

The forests of Taiwan Province of China are distributed along a distinct gradient from the coastal region to the high mountains. Southern subtropical rain forest covers low hills (below 500 m) in northern Taiwan. Evergreen broad-leaved forests extend to 500 to 1,800 m slopes.

The predominant natural vegetation in Japan is evergreen broad-leaved forest of several types. Conifers also occur in these forests. At higher elevations, conifers species grow in mixture with the broad-leaved evergreen species. The medium to lower strata contain small trees and shrubs of broad-leaved evergreen species. Secondary forests now cover large areas.

The two forests in the Near East, although of relatively small extent, are the most diverse and productive in the region. Both forests are dense broad-leaved summer-green types. Small areas of swamp and fen forests occur along riverbanks and estuaries. In Asia, this ecologic zones extents 208 million hectares. From that, 75 million are forested (36%).

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies chensiensis
Abies ernestii
Abies fargesii
Abies firma
Acer oblongum
Acer palmatum
Albizia macrophylla
Alnus barbata
Alnus subcordata

Aucuba japonica
Betula albo-sinensis
Carpinus betulus
Carpinus orientalis
Castanea sativa
Castanopsis carlesii
Castanopsis cuspidata
Castanopsis eyrei
Castanopsis fargesii
Castanopsis fargesii
Castanopsis hystrix
Castanopsis kawakamii
Castanopsis kusanoi
Castanopsis lamontii
Castanopsis sclerophylla
Castanopsis uraiana
Celtis sinensis
Chamaecypris obtusa
Cinnamomum camphora
Cinnamomum chekiangense
Cryptocarya chinensis
Cryptomeria japonica
Cunninghamia lanceolata
Cyclobalanopsis acuta
Cyclobalanopsis gilva
Cyclobalanopsis glauca
Cyclobalanopsis myrsinaefolia
Cyclobalanopsis salicina
Dalbergia hupeana
Damnacanthus indicus
Diospyros lotus
Elaeocarpus japonica
Engelhardtia roxburghiana
Fagus sylvatica orientalis
Ficus microcarpa
Hovenia dulcis
Ilex purpurea
Ilex rotunda
Ligustrum lucidum
Liquidambar formosana
Lithocarpus amygdalifolius
Lithocarpus brevicaudatus
Lithocarpus glabra
Lithocarpus ternaticupula
Machilus thunbergii
Neolitsea sericea
Phoebe sheareri
Phyllostachys bambusoides
Phyllostachys edulis
Phyllostachys heteroclada

Phyllostachys mannii
Phyllostachys nidularis
Phyllostachys nigra henonis
Picea complanata
Picea neoveitchii
Pinus armandii
Pinus bungeana
Pinus densiflora
Pinus henryi
Pinus massoniana
Pinus tabulaeformis
Pinus taiwanensis
Pinus yunnanensis
Pistacia chinensis
Platycladus orientalis
Podocarpus macrophyllus
Podocarpus nagi
Pterocarya pterocarpa
Quercus acutissima
Quercus acutissima
Quercus aliena acuteserrata
Quercus castaneifolia
Quercus dentata
Quercus fabrei
Quercus glandulifera
Quercus hartwissiana
Quercus iberica
Quercus imeretina
Quercus liaotungensis
Quercus serrata
Quercus variabilis
Taiwania cryptomerioides
Tilia miqueliana
Torreya nucifera
Toxicodendron vernicifluum
Tsuga sieboldii
Ulmus parvifolia
Zelkova carpinifolia
Zelkova schneideriana

5.2.7 - Subtropical Dry Forest, Subtropical Steppe and Subtropical Desert

The subtropical dry forest zone of Asia is confined to the Near East and occupies a relatively narrow belt along the Mediterranean Sea and the low hills running parallel to the coast. The northern part of the Jordan-Arava Rift Valley is also included. The zone has a typical Mediterranean climate with mild, humid winters and dry, moderately hot summers. Annual rainfall ranges from around 400 to 800 mm, decreasing from north to south. Various types of pine forest occur. Otherwise, the typical Mediterranean woody maquis vegetation dominates this zone. This zone covers an area of 13 million hectares, from which 4 million are forest (34%).

The Asian subtropical steppe zone is confined to western Asia, mainly the Near East but also in Afghanistan and Pakistan. The climate is semi-arid. Annual rainfall ranges from about 200 to 500 mm and falls during winter in the Near East. Eastern Afghanistan and Pakistan receive most of their rainfall from June to September. Although differences in temperature between seasons are relatively high, winters are not severe. The vegetation consists of low shrubs and grasses interspersed with sparse trees, particularly at wetter locations. At higher, more humid locations in the Near East a forest-steppe can be found. Owing to prolonged human activity the original vegetation has been considerably altered. Today this ecologic zone covers an are of 116 million hectares, from which only 2 million are covered with forest (2%).

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Acacia modesta
Acacia nilotica
Acacia senegal
Acacia seyal
Acacia tortilis
Acer hyrcanum
Acer monspessulanum
Amygdalus arabica
Amygdalus communis
Amygdalus korshinskyi
Amygdalus orientalis
Arbutus andrachne
Arbutus unedo
Arceuthos drupacea
Calicotome villosa
Carpinus orientalis
Castanea sativa
Celtis australis
Ceratonia siliqua
Cercis siliquastrum
Cinnamomum aromaticum
Cinnamomum zeylandica
Crataegus aronia
Daphne gnidioides
Dodonea viscosa
Ficus sycomorus
Fontanesia phillyreoides
Juglans regia
Juniperus phoenicia
Laurus nobilis
Liquidambar orientalis
Lonicera nummulariifolia
Melia azedarach
Myrtus communis
Nerium oleander
Olea cuspidata
Olea europaea
Ostrya carpinifolia
Phillyrea latifolia

Phoenis dactylifera
Phoenix theophrasti
Pinus brutia
Pinus halepensis
Pinus maritima
Pinus nigra
Pinus pinea
Pistacia atlantica
Pistacia lentiscus
Pistacia palaestina
Pistacia terebinthus
Pistacia verica
Populus alba
Populus euphratica
Prosopis cineraria
Prosopis farcta
Prosopis koelziana
Punica granatum
Pyrus bovei
Pyrus malus
Quercus aegilops
Quercus brantii
Quercus brutia
Quercus calliprinos
Quercus cerris
Quercus coccifera
Quercus ilex
Quercus infectoria
Quercus ithaburensis
Quercus libanis
Quercus robur
Quercus petrae
Quercus trojana
Quercus vulcanica
Rhamnus palaestina
Salix alba
Salix pendula
Santalum alba
Sorbus torminalis
Sorbus umbellata
Tamarix aphylla
Taxus baccata
Tetraclinis articulata
Ziziphus jujuba

5.2.8 - Subtropical Mountain Systems

Subtropical mountain systems cover extensive areas in Asia in a nearly continuous west-east belt from the mountains and highlands of Turkey to the eastern reaches of the Himalayas in southern China.

The climate of the Near Eastern mountain systems is extremely diverse, both in temperature and rainfall. Winter precipitation is predominant, ranging from 500 to 1,400 mm. The rainy season is from around September to May or June, while the rest of the summer is dry and hot.

All along the Himalayan ranges the rainfall increases from west to east and the climatic regime changes gradually from Mediterranean to typical monsoon types. The rain also decreases from the outer to the inner parts of the ranges. At the submontane and montane levels, rainfall ranges from less than 1,000 to 1,500 mm, with at least one or two dry months even up to seven or eight. The mean temperature of the coldest month varies from around 15°C in the submontane zone to less than 10°C above 2,000 m. Snow occurs above 3,000 m, with frequent winter frost. Precipitation is 500 to 1,000 mm.

China's subtropical mountains comprise the central interior highlands and southwestern high mountains. The region has a harsh climate at high elevations but warmer, moist conditions in the medium to low mountains. Annual mean temperature ranges from 8° to 18°C in eastern areas with the January mean above 0°C and the extreme low at -20°C. Annual rainfall is 800 to 1,200 mm, up to 3,000 mm locally. A dryer and colder climate prevails towards the western higher mountain areas. In southern Tibet, mean annual temperatures in the mountains are 6° to 8°C, average in winter is 2° to 4°C and in summer around 15°C. Annual precipitation ranges from 300 to 700 mm. River basins in the south at 500 m elevation are relatively warm and moist with annual rainfall more than 1,200 mm and a distinct dry-rainy seasonal change as a result of the impact from the Indian Ocean monsoon.

Mediterranean mountain vegetation is diverse and includes dense humid forests, shrubland, forest-steppe and treeless grass steppe. The forests can be either deciduous broad-leaved or coniferous. In Lebanon and the Syrian Arab Republic a summer-green oak forest is found between 1,000 and 1,600 m altitude. In western Turkey, black pine dominates this belt. From 1,500 to 2,000 - 2,200 m, there is a subalpine coniferous forest with cedar, fir and juniper. Juniper forest occupies the drier areas. Above 2,200 m, alpine dwarf shrubs and meadows occur.

Forest-steppe and steppe vegetation occupy major parts of the central highlands and plateaus of Turkey and Iran. At humid locations grows a deciduous oak forest, often in combination with juniper. Tree steppe with pistachio, almond and juniper occur at sub-dry locations.

Well-developed forest grows on the higher slopes of the mountains bordering the Black and Caspian Seas. At both locations we find summer-green dense forest between approximately 800 and 2,000 m. The Euxinian montane forest is composed of deciduous broad-leaved trees and conifers with species of oak, fir and pine.

Vegetation of the northwestern and western Himalayas is extremely diverse. In southern Afghanistan, open deciduous woodland is the dominant vegetation at medium high altitudes. Woodland 4 to 6 m high occurs from around 1,100 to 1,800-2,000 m. Between 2,000 and 2,800 m, communities of broad-leaved species of trees prevail.

In eastern Afghanistan and Pakistan, different types of west Himalayan evergreen sclerophyllous forests and woodlands occur. Woodland of oak is most extensive and occurs at an altitude of around 1,300 to 2,000 m. Depending on the water supply, they are either open woodlands with stunted trees 3 to 6 m high or true forests with trees 15 m or more in height. Oak communities are confined to the higher parts of wet mountains. The first dominates between 1,900 and 2,400 m, the latter from 2,400 to 2,900 m. Both species form rich, mesophylous forests 8 to 20 m in height.

Coniferous forests are the most extensive mountain forests. Chir pine forests dominate the lower mountain slopes from 900 m up to 1,700 to 2,000 m altitude, accompanied by some oaks and other broad-leaved species. West of the Indus, pine forest is found between 2,000 and 2,500 m. A dense forest of cedar is found between 2,500 and 3,100 m in areas with 450 to 650 mm annual rainfall. With decreasing rainfall, juniper gradually replaces the cedar. East of the Indus, increased precipitation favors blue pine. A dense, mixed forest dominated by conifers grows in high rainfall areas (greater than 800 mm per year) between 2,900 and 3,200 m. In areas with winter rains, juniper woodlands dominate at altitudes ranging from 1,500 to 3,000 m. Further eastward, under the monsoon-influenced climate, juniper woodland occurs above 3,000 m. Typical subalpine woody vegetation, ranging between 3,000 and 4,000 m altitude, is a mixture of conifers and broad-leaved low trees or shrubs.

In Azad Jammu and Kashmir, from 1,500 to 3,000 m, coniferous forests occur with pine and cedar, mixed with thickets and grasslands. Above 3,000 m they give way to mixed forests and woodlands. To the east, from Himachal Pradesh to central Nepal, the submontane level from 1,000 to 2,000 m is characterized by open woodlands with pine. Above 2,000 m, dense evergreen forests occur, with oaks or conifers, with mixed forests above 3,000 m.

The alpine conifer forests of China grow in pure stands on low and medium altitude mountains. Further west and at higher elevations are alpine conifer forests of highly cold-tolerant species dominated by conifers, which often form pure stands on north-facing slopes from 3,000 to 4,000 m. Conifer forests at medium elevations are dominated by pine. Southern subtropical monsoon rain forest occurs on valley lands under 500 m.

In central Taiwan Province of China, coniferous and broad-leaved mixed forests occupy mountain slopes from 1,800 m up to 3,000 m altitude. Alpine conifer forests occur in the Yushan and Bishan Mountains at elevations generally above 3,000 m.

This ecologic zone comprises 351 million hectares, from which 56 million hectares are now covered with forest (16%).

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies alba
Abies beshanzuensis
Abies chensiensis
Abies cilicica
Abies faberi
Abies firma
Abies georgei
Abies homolepis
Abies kawakamii
Abies recurvata
Abies spectabilis
Abies pindrow
Abies squamata
Abies webbiana
Abies ziyuanensis
Acer formosum
Acer insigne
Acer monspesullanum
Amygdalus communis
Amygdalus kuramica
Amygdalus orientalis
Betula albo-sinensis

Betula alnoides
Betula austrosinensis
Betula chinensis
Betula ermanii
Betula grossa
Betula jaquemontii
Betula utilis
Broussonetia papyrifera
Carpinus betulus
Cedrus brevifolia
Cedrus deodara
Cedrus libani
Celtis formosana
Chamaecyparis formosensis
Chamaecyparis obtusa
Cunninghamia lanceolata
Cupressus funebris
Cupressus sempervirens
Cyclobalanopsis stenophylloides
Dillenia pentagyna
Eurya acuminata
Eurya chinensis
Eurya emarginata
Eurya hayatai
Eurya japonica
Eurya loquaiana
Eurya nanjenshansis
Eurya taitungensis
Fagetea hyrcanica
Fagus orientalis
Ficus fistulosa
Fraxinus angustifolia
Fraxinus oxycarpa
Fraxinus ornus cilicica
Fraxinus xanthoxyloides
Gordonia axillaris
Hydrangea macrophylla
Hydrangea paniculata
Hydrangea petiolaris
Ilex cornuta
Ilex crenata
Ilex formosana
Ilex macrocarpa
Ilex serrata
Juniperus excelsa
Juniperus foetidissima
Juniperus oxycedrus
Juniperus seravschanica
Macaranga tanarius
Machilus japonica

Machilus zuihoensis
Mallotus paniculatus
Mallotus japonicus
Morus australis
Picea balfouriana
Picea complanata
Picea likiangensis
Picea linzhiensis
Picea morinda
Picea smithiana
Pinus roxburghii
Pinus excelsa
Pinus gerardiana
Pinus griffithii
Pinus massoniana
Pinus nigra
Pinus wallichiana
Pinus yunnanensis
Pistacia atlantica
Platanus orientalis
Populus tremula
Quercus baloot
Quercus boissieri
Quercus castaneifolia
Quercus cerris
Quercus dilatata
Quercus libani
Quercus persica
Quercus semecarpifolia
Rhododendron campanulatum
Salix babylonica
Salix cinerea
Salix matsudana
Sassafras randaiense
Schefflera octophylla
Shorea robusta
Strachirus himalaicus
Symplocos cochichinensis
Symplocos chinensis
Tamarix ramosissima
Tamarix chinensis
Tamarix hispida
Terminalia catappa
Tetrameles nudiflora
Tilia henryana
Tilia mongolica
Tilia pendula
Tilia petiolaris
Trema orientalis
Trochodendron aralioides

Tsuga chinensis
Turpinia formosana
Ulmus campestris
Ulmus glabra

5.2.9 – Temperate Continental Forest

This zone includes the temperate forests of China, the Korean Peninsula and Japan. In China, the annual mean temperature varies greatly, from 2°C in the north to 14°C in the south. Climate is distinctly seasonal; winter is relatively long (four to seven months) and spring short (one to three months). In the northern part, warm summers have monthly average temperatures above 20°C in the warmest month and a growing season lasting 100 to 150 days. Annual precipitation is between 400 and 800 mm for most of the area to 1,000 mm over the southeastern part of the zone. In the southern part, mean temperature in the coldest months still falls below 0°C. Warm summers bring the average temperature up to 24°C in the warmest month except in the mountains. The growing season lasts 200 days. Annual precipitation of 600 to 1,000 mm is unevenly distributed over the year. Coastal areas experience higher rainfall, 1,000 to 1,400 mm. Similar climatic conditions prevail on the Korean Peninsula and in northern Japan.

The northern part of the zone (in northeastern China) features well-stocked pine mixed forests on low mountains of 400 to 600 m. In contrast to the generally forested eastern part of northeastern China, the rest of the zone has little tree cover left. Pockets of natural second-growth forests exist, represented by pine and several deciduous oaks. The temperate forests of Japan are deciduous, summer-green, broad-leaved forests dominated by beech.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies holophylla
Abies nephrolepsis
Acer mono
Acer tegmentosum
Acer ukurunduense
Ailanthus altissima
Alnus japonica
Athyrium pycnocarpon
Betula costata
Betula davurica
Betula platyphylla
Betula mandschurica
Castanea mollissima
Catalpa bungei
Diospyros kaki
Dryopteris crassirhizoma
Fagus crenata
Fraxinus mandshurica
Fraxinus rynchophylla
Ginkgo biloba
Juglans mandshurica
Kalopanax septemlobus
Paulownia fortunei
Picea jezoensis
Picea koraiensis

Pinus densiflora
Pinus koraiensis
Pinus sylvestris
Pinus tabulaeformis
Platycladus orientalis
Populus davidiana
Pterocarya rhoifolia
Quercus acutissima
Quercus aliena
Quercus dentata
Quercus liaotungensis
Quercus mongolica
Quercus mongolica grosseserrata
Quercus serrata
Quercus variabilis
Robinia pseudoacacia
Sabina chinensis
Sophora japonica
Taxus cuspidata
Thuja koraiensis
Tilia amurensis
Tilia henryana
Tilia japonica
Tilia mongolica
Tilia pendula
Toona sinensis
Ulmus davidiana
Ulmus laciniata
Ziziphus jujuba

5.2.10 – Temperate Steppe and Temperate Desert

This ecological zone encompasses the vast steppes of Central Asia, occupying the eastern part of Inner Mongolia in China and central and eastern Mongolia.

The zone has a long, cold winter and a short, but warm, summer. Annual average temperatures vary between 2° and 10°C, with mean temperatures of the coldest month (January) ranging from -10° to -20°C. Mean temperature reaches 24°C in the warmest summer month. The growing season lasts 100 to 175 days. Annual rainfall ranges from 200 to 400 mm, locally up to 600 mm, and the maximum occurs during the second half of summer. Spring, as a rule, is dry. Natural vegetation is primarily grass and shrub steppe. In some areas, pockets of woodland can be found.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Ammodendron conollyi
Abies nephrolepis
Betula platyphylla
Haloxylon aphyllum
Haloxylon persicum
Larix principis-rupprechtii
Picea meyeri
Picea wilsonii

Pinus bungeana
Pinus sylvestris
Pinus tabulaeformis
Populus cathayana
Populus davidiana
Populus pseudosimonii
Populus simonii
Prosopis farcta

5.2.11 – Temperate Mountain Systems

The vast mountain systems of Central Asia, including the Tibetan Plateau in China and the Altai and Khangai mountain systems of Mongolia, comprise this ecological zone. The mountains of Japan also form part of the zone.

In the lower mountains of north-central China, mean annual temperature decreases from 14°C in the warmer eastern low hills to 8°C in the cooler western highlands. The difference in the July mean temperature is 20° versus 26°C between east and west, whereas January varies between 0° and -10°C. Similarly, mean annual precipitation typically averages 800 to 300 mm between east and west, most of which falls during summer. Nevertheless, this transitional region is seasonally moist enough to support monsoon vegetation.

On the Tibetan Plateau, temperature distribution generally follows elevation contour lines. Mean annual temperature goes from the 6° to 10°C range around 3,000 m, to 3° to 7°C above 4,000 m, to below -2°C above 5,000 m. Annual mean precipitation follows an east-west gradient from 800 mm on the eastern rim of the plateau to less than 50 mm in the west near the Pakistan-Afghanistan border.

The climate of the Mongolian mountain systems is characterized by widely ranging temperatures, both throughout the year and during the day. Annual precipitation ranges from approximately 200 to 600 mm, most of it falling during the second half of summer.

The transitional region of eastern China, including the Yellow Loess Plateau, has only limited natural forests, mostly in the high, inaccessible mountains. On the Yellow Loess Plateau and the surrounding areas, local residual woodlands are scattered with conifer and broadleaf species of trees.

Natural forests are better preserved in the western, higher mountains in the provinces of Gansu, Shanxi and Sichuan. Both conifer and broadleaf forests are present in these mountains. Spruce and fir dominate alpine conifer forests at 2,500 to 3,800 m. Conifer species that prefer a warmer environment, occupy lower elevations of 2,000 to 3,000 m or sometimes at 3,400 m, forming pure stands. Pine forests can extend up to 2,700 m. Deciduous broad-leaved forests are less prominent. Poplar and birch are the most common species on the 2,600 to 3,500 m slopes.

There is a great diversity of mountain vegetation in Mongolia. The forest belt mainly contains larch forests, sometimes mixed with Siberian cedar or stone pine and spruce or fir. On sandy sediments on the lower slopes pine stands dominate and, together with larch, form the forest-steppe belt. In Mongolian-Altai the forest belt is often absent. The forest belt of the Khangai Mountains is in the range of 1,800 to 2,300 m with larch stands. Thickets or birch with occasional larch cover the broad river valleys.

In Japan, the lower mountain zone is covered with deciduous beech forest dominated by beech and oak. The subalpine belt supports coniferous forests with fir. The altitudinal lower limit of the coniferous forests becomes gradually higher southwards, ranging from 700 m in northern Honshu to 1,500 m in central Honshu. Mixed forest ir present on ridges with shallow soils in the subalpine region of Honshu. Deciduous trees are found in the subalpine and alpine regions. Mixed or pure stands are developed on boulders and shallow soils along snow valleys and on subalpine volcanic habitats. Prevailing coniferous forests on Hokkaido are dominated by spruce and fir.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies chengii
Abies delavayi
Abies densa
Abies fabri
Abies fanjingshanensis
Abies fargesii
Abies faxoniana
Abies forrestii
Abies mariesii
Abies nephrolepis
Abies sachalinensis
Abies spectabilis
Abies squamata
Abies yuanbaoshanensis
Abies veitchii
Alnus maximowiczii
Betula albo-sinensis
Betula ermanii
Betula platyphylla
Betula utilis
Cupressus chengii
Dipteronia sinensis
Fagus crenata
Fraxinus chinensis
Larix principis-rupprechtii
Picea asperata
Picea brachytyla
Picea complanata
Picea glehnii
Picea jezoensis
Picea meyeri
Picea wilsonii
Pinus armandii
Pinus bungeana
Pinus sibirica
Pinus tabulaeformis
Platycladus orientalis
Populus cathayana
Populus davidiana
Populus purdomii
Potentilla fruticosa
Quercus baronii
Quercus crispula

Quercus liaotungensis
Sabina chinensis
Thuja standishii
Tilia chinensis
Toxicodendron vernicifluum
Tsuga chinensis
Tsuga diversifolia
Tsuga dumosa
Zelkova sinica

5.2.12 – Boreal Coniferous Forest

This zone is confined to the northern part of northeastern China. The zone is essentially Daxinganling (the Greater Xingan Range), a medium-altitude plateau. The zone has a rigorous climate with a long, cold winter. Mean annual temperature ranges between -1° and -6°C, the mean minimum of the coldest month is below -25°C and the extreme low is below -45°C. Soils are either permafrost or frozen for most of the year. Relatively warm summers bring a monthly mean temperature of 15°C in the warmest months with a growing season of about 90 days. Most of the annual mean precipitation of 500 mm falls during the summer season.

Forests in this zone are mostly simple, natural stands of three types. First, larch is widely spread on 300 to 1,100 m slopes. It forms large, pure stands as well as mixed stands with birch, poplar and oak.. Second, pine forests are mostly distributed in the north between 300 to 1,400 m. They mostly form small pure stands. In addition, pine forest is also found in the northwestern portion of the Daxinganling. Among deciduous broad-leaved forests, birch and poplar grow as natural second-growth forests following disturbance of larch, either in pure stands or in mixtures. Oak forests are found in the south on dry, south-facing slopes below 600 m. Deciduous broad-leaved mixed forests are scattered along the Heilongjiang River and its tributaries.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies balsamea
Abies fraseri
Abies koreana
Abies nephrolepis
Abies veitchii
Betula platyphylla
Betula szechuanica
Chosenia arbutifolia
Larix gmelinii
Pinus pumila
Pinus sibirica
Pinus sylvestris
Populus davidiana
Populus suaveolens
Quercus mongolica
Ulmus davidiana

5.3 – Europe (Incl. Russia)

Europe contains about 1 billion hectares of forests which corresponds to 27 percent of the world total. The Russian Federation alone accounts for 851 million hectares and Sweden and Finland for another 49 million hectares. The remaining 38 countries have together less than 15 percent of the forests in the region. Europe's forests amount to 1.4 ha per capita, which is considerably above the world average; however, the area per capita in Central and Southern Europe is much lower.

Table 5.03 - Forest Area per Ecologic Zone - Europe, incl. Russia (Million Hectares)

Ecologic Zone	*Total Area*	*Forest Cover*	*Forest Area*
Subtropical	**91**	**51%**	**46**
Dry	76	53%	40
Mountain	15	38%	6
Temperate	**719**	**32%**	**227**
Oceanic	130	22%	29
Continental	371	35%	130
Steppe	122	8%	10
Desert	9	0%	0
Mountain	87	67%	58
Boreal	**1,278**	**58%**	**742**
Coniferous	624	71%	443
Tundra	141	19%	27
Mountain	513	53%	272
Polar	**206**	**3%**	**6**
TOTAL	**2,294**	**44%**	**1,020**

Source: FAO, 2001

Almost all forests are located in the boreal ecological domain and Europe has almost 80 percent of all boreal coniferous forest. The net change of forest area is positive at 881,000 ha per year, corresponding to 1 percent annually. Figure 5.03 and 5.04 shows the European ecologic zones distribution.

Figure 5.03 – Western European Ecologic Zones

Source: FAO, 2001

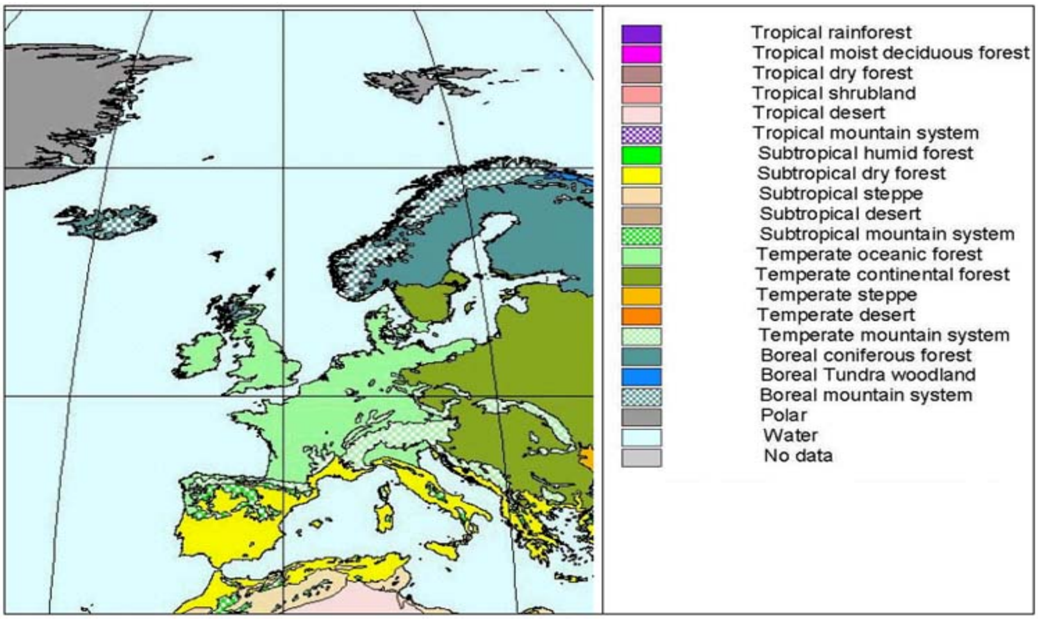
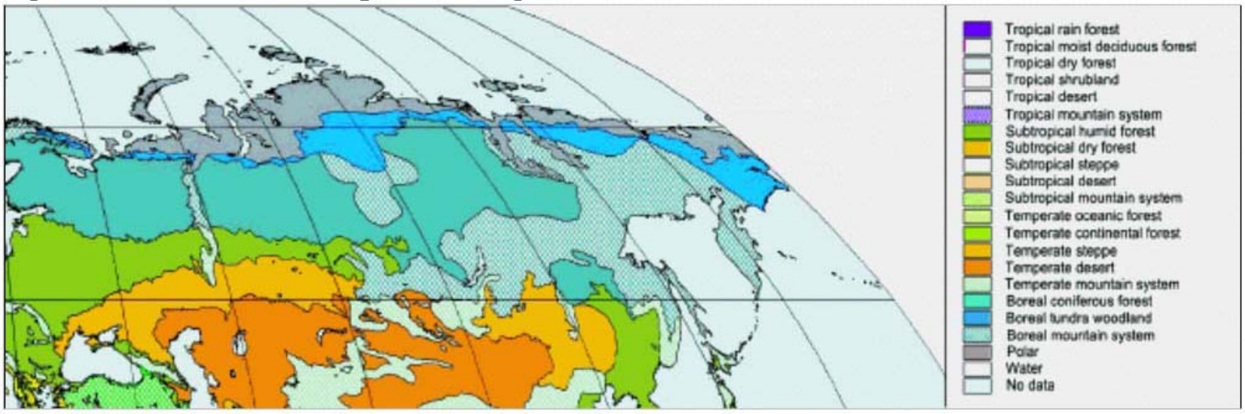


Figure 5.04 – Eastern European Ecologic Zones



Source: FAO, 2001

5.3.1 – Subtropical Dry Forest

In Europe, subtropical dry forests are found in the Mediterranean region below 800 m altitude, including the Iberian Peninsula (except the northern part), Rhone Basin, Apennines Peninsula, Dalmatia and Greece, as well as all the European islands of the Mediterranean Sea.

The Mediterranean climate provides dry, warm summers and cool, moist winters without severe frosts. Precipitation maxima are normally in November/December and February/March. Pronounced elevational relief produces substantial local differentiation. Average annual precipitation is between 400 and 900 mm, rarely above 1,200 mm (e.g. Kerkira) or below 400 mm (southeastern Spain, southeastern Crete). The amount of precipitation decreases slightly to the east. The average temperature of the warmest month is between 25° and 28°C, that of the coldest month between 6° and 13°C.

The original vegetation was evergreen sclerophyllous forest but much of it has long been impacted by anthropogenic influences. The tree species composition is usually rather monotonous. Only one species typically dominates the canopy, often one of the evergreen oak species. Oak compete most successfully on humid and subhumid sites. Under a 15 to 18 m tall tree layer with a closed canopy is usually a 3 to 5 m tall shrub layer.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies nebrodensis
Acer campestre
Acer monspessulanum
Acer obtusatum
Acer pseudoplatanus
Aeonium arboreum
Aesculus hippocastanum
Ailanthus altissima
Alnus glutinosa
Amelanchier ovalis
Andrache telephioides
Arbutus unedo
Atropa belladonna
Bellardia trixago
Betula aetnensis
Blechnum spicant
Botrychium lunaria
Broussonetia papyrifera
Bunias erucago
Calamagrostis arundinacea
Calamagrostis epigejos
Calicotome spinosa
Calicotome villosa
Carpinus orientalis
Carpobrotus acinaciformis
Carpobrotus edulis
Castanea sativa
Celtis aetnensis
Celtis australis
Ceratonia siliqua
Cercis siliquastrum
Cestrum parqui
Chamaerops humilis
Citrus aurantium
Citrus deliciosa
Citrus limon
Citrus medica
Cnidium silaifolium
Colutea arborescens
Cornus sanguinea
Corylus avellana
Crataegus azarolus
Crataegus laciniata
Crataegus monogyna
Cupressus sempervirens
Cynanchum acutum
Ephedra distachya
Ephedra fragilis
Ephedra major
Erianthus ravennae

Euonymys europaeus
Fagus sylvatica
Ferula communis
Ficus carica
Fontanesia phillyraeoides
Fortunella margarita
Fraxinus ornus
Fraxinus oxycarpa
Gleditsia triacanthos
Humulus lupulus
Ilex aquifolium
Ilex perado
Juglans regia
Juniperus communis
Juniperus hemisphaerica
Juniperus oxycedrus
Juniperus phoenicea
Justicia adathoda
Kochia saxicola
Laurus nobilis
Lithodora rosmarinifolia
Lonicera etrusca
Lonicera implexa
Lonicera xylosteum
Loranthus europaeus
Lycium europaeum
Lycium intricatum
Malus domestica
Malus sylvestris
Mespilus germanica
Morus alba
Morus nigra
Myrtus communis
Olea europaea
Osmunda regalis
Ostrya carpinifolia
Parkinsonia aculeata
Parthenocissus quinquefolia
Periploca laevigata
Phillyrea angustifolia
Phillyrea latifolia
Phytolacca dioica
Pinus halepensis
Pinus laricio
Pinus nigra
Pinus pinaster
Pinus pinea
Pirus amygdaliformis
Pirus communis
Pirus pyraster

Pistacia lentiscus
Pistacia terebinthus
Pistacia vera
Platanus orientalis
Polypodium australe
Polypodium interjectun
Polystichum aculeatum
Polystichum setiferum
Populus alba
Populus nigra
Prunus avium
Prunus cerasus
Prunus cocomilia
Prunus dulcis
Prunus mahaleb
Prunus spinosa
Prunus webbii
Pteridium aquilinum
Quercus amplifolia
Quercus calliprinos
Quercus cerris
Quercus congesta
Quercus dalechampii
Quercus fontanesii
Quercus gussonei
Quercus ilex
Quercus leptobalanos
Quercus petraea
Quercus pubescens
Quercus robur
Quercus suber
Quercus virgiliana
Retama raetam
Rhamnus alaternus
Rhamnus catharticus
Rhamnus lojaconi
Rhamnus oleoides
Rhamnus saxatilis
Rhus coriaria
Rhus pentaphylla
Rhus tripartita
Salix alba
Salix babylonica
Salix caprea
Salix cinerea
Salix fragilis
Salix gussonei
Salix pedicellata
Salix purpurea
Sarcopoterium spinosum

Solanum bonariense
Solanum dulcamara
Solanum elaeagnifolium
Solanum ferrugineum
Solanum luteum
Solanum melongena
Solanum nigrum
Solanum rostratum
Solanum sodomaeum
Solanum tuberosum
Sorbus aria
Sorbus aucuparia
Sorbus domestica
Sorbus graeca
Sorbus torminalis
Tamarix africana
Tamarix boveana
Tamarix canariensis
Tamarix dalmatica
Tamarix gallica
Tamarix parviflora
Taxus baccata
Tetraclinis articulata
Tilia platyphyllos
Ulmus canascens
Ulmus glabra
Ulmus minor
Viscum album
Vitex agnus-castus
Withania somnifera
Zelkova sicula
Ziziphus lotus

5.3.2 – Subtropical Mountain Forest

This zone includes the Iberian mountains (Cordillera Cantabrica, Sistema Central, Sistema Iberico, Penibética, Pyrenees), the Apennines, the Greek mountains (Pindus, Olympus, Peleponnesus, Crete), as well as the mountains of Corsica and Sardinia. The zone starts at about 600 to 800 m and extends up to 2,000 m, locally to 3,500 m.

The region is characterized by higher precipitation and a shorter summer drought period than the adjacent lowland region. Temperatures are lower with a greater frequency of frosts.

In contrast to the dry sclerophyllous forests, the vegetation of this zone is typically deciduous oak species. These forests are usually quite closed and shady. On the Iberian Peninsula, oak forests dominate on siliceous bedrock and base-rich sites. Closed and shady beech forests, partly with fir and spruce, locally with birch, replace the deciduous oak forests at higher elevations. At even higher altitudes the oak and beech forests are replaced by juniper and cypress woodland or by pine, as well as fir forests.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies alba
Abies borisii-regis
Abies cephalonica
Abies pinsapo
Abies nebrodensis
Aesculus hippocastanum
Betula pubescens
Cupressus sempervirens
Fagus sylvatica
Juniperus excelsa
Juniperus foetidissima
Juniperus polycarpos
Juniperus thurifera
Picea abies
Pinus nigra
Quercus faginea
Quercus pubescens
Quercus pyrenaica

5.3.3 – Temperate Oceanic Forest

The temperate oceanic forest zone combines spatially separated areas and comprises the Portugal-Spain coastline (Galicia, Asturia, Cantabrica, Euskal), the British Isles except for the Scottish Highlands and the mountainous regions, France apart from the southeastern mountainous and Mediterranean parts, Central Europe west of a rough line Danzig-Erfurt-Vienna and south of the Alps, including the Po plain. In Scandinavia, all of Denmark, southernmost Sweden and a narrow strip along the coast of Norway are included. Additionally, some climatically sheltered fjords up to 64°N belong to this zone.

The climate is influenced by the Gulf Stream and the proximity to the ocean. The influence decreases inland and is replaced in the Po plain by a different climatic parameter with similar effects. The average annual temperature ranges from 7° to 13°C and annual rainfall varies from 600 to 1,700 mm. While in coastal areas the temperature of the coldest month does not fall below 0°C, inland mean temperature is locally below 0°C.

Various types of beech forests and mixed beech forests are the dominant vegetation. These are most extensive in Germany and neighbouring countries. Pure beech forests are relatively dense. On nutrient-poor, acidic soils beech is partly mixed with oak in the canopy. These stands are poor in species. Today, natural beech forests have been extensively converted into farmland or have been transformed into mixed oak-hornbeam forests. Large areas have been reforested with spruce and Douglas fir.

Outside the distribution area of beech, oak-ash forests occupy base-rich, often calcareous soils. Oak-hornbeam forests dominate periodically moist soils. They often have a distinct vertical structure with a canopy and subcanopy. South of the Alps, oak and hornbeam occur together. In the southwest of the zone, oak forests occupy areas with a milder climate.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Carpinus betulus
Corylus avellana
Fagus sylvatica
Fraxinus excelsior

Ilex aquifolium
Quercus cerris
Quercus petraea
Quercus pubescens
Quercus robur
Salix cinerea
Taxus baccata
Tilia cordata
Tilia platyphyllos

5.3.4 – Temperate Continental Forest

This zone has a roughly triangular shape with the corners in Oslo, Sofia and Ufa. Southern Sweden, eastern Europe south of the line Helsinki-Novgorod-Perm and north of the line Bucharest-Charkov-Ufa are included. Additionally, most of the Balkan Peninsula and the foothills of the Crimean and Caucasus Mountains are part of the zone.

Owing to less influence of the Gulf Stream, annual rainfall gradually decreases from the west (about 700 mm) to the east (about 400 mm). Summers are warm and winters are cold in most of this region. Mean annual temperature is about 6° to 13°C in the west and decreases to 3° to 9°C in the east. The temperature of the coldest month ranges from below 0°C in Scandinavia and around 0°C in the Balkans to below -10°C in the Ural Mountains. In the northern parts of the zone, more than two months of the year have a mean temperature below 0°C. Additionally, precipitation diminishes from the northwest (greater than 700 mm) to the southeast (400 mm). Locally, in the foothills of the Caucasus, rainfall is very high.

The zone has various forest types, distributed along local and regional gradients of climate and nutrient availability. In the northern parts, mixed coniferous broad-leaved forests form a belt parallel to the circle of latitude. Spruce forests constitute most of the forest cover. On more acidic and drier soils pine forests replace spruce.

Further south, deciduous broad-leaved forests are represented by mixed oak-hornbeam and mixed lime-oak forests. Land clearing has massively decimated this type of forest.

Sessile oak, bitter oak and Balkan oak forests occur mainly in southeastern Europe and the Balkan countries. These species-rich, more open, mixed forests, dominated by oak occupy the central part of the Balkan Peninsula. Today, these formerly dense forests have been greatly reduced and isolated after long exploitation under the coppice with standard systems and for agricultural uses. Swamp and fen woods occur in small patches across the entire zone. Extensive areas of this vegetation still exist in the lowlands of Poland and Belarus.

Flood-plain vegetation is prominent along the middle sections and lower courses of the large rivers Rhine, Elbe, Oder, Vistula, Pripet, Desna, Volga, Save and Danube. Owing to long-term inundation, willow and poplar alluvial forests are rather poor in species. Hardwood flood-plain vegetation is highly varied in structure with oak, ash and elm. River regulation and embankment have resulted in a severe decline of near-natural habitat and nowadays only fragments of original flood-plain forests remain.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies borisiiregis
Acer campestre
Alnus glutinosa
Carpinus betulus

Fraxinus angustifolia
Fraxinus excelsior
Picea abis
Populus alba
Populus nigra
Quercus cerris
Quercus frainetto
Quercus petraea
Quercus robur
Salix alba
Salix fragilis
Tilia cordata
Tilia dasystyla
Tilia platyphyllos
Tilia petiolaris
Tilia tomentosa
Ulmus leavis
Ulmus minor

5.3.5 – Temperate Mountain Systems

This zone consists of the mountainous parts of the temperate domain, including the Cantabrican Mountains, Pyrenees, Massif Central, Jura, Alps, the highest sites of the British Isles mountains, the Central European uplands, Carpathians, Dinaric Alps, Balkan mountains, Rhodope Mountains, the High and Low Caucasus and the foothills of the Talysh Mountains as well as the southern Urals.

As the highest altitudinal belt of the temperate domain the mountain region is characterized by generally greater precipitation and lower temperature, the climate is extremely varied. Precipitation varies from less than 500 mm to more than 3,000 mm. The average annual temperature ranges from -4° to 8°C (locally 12°C) and the average January temperature at the highest altitudes fluctuates between -10° and -4°C.

Beech forests, particularly mixed beech forests comprise the vegetation of the lower belt in this region. As in the oceanic region, pure beech forests at higher altitudes are relatively dense. At higher altitudes, other tree species become more prominent.

At even higher altitudes, fir and spruce forests replace the beech forests. Around the timberline, pine scrub may occur. This scrub and krummholz grades at higher altitudes into alpine grasslands, various dwarf shrub vegetation and rock and scree vegetation of the alpine to nival belt.

In the Urals, the altitudinal zonation starts with lime-oak forests at the lowest level followed by herb-rich fir-spruce forests with broad-leaved trees such as elm and linden, as well as pine forests with larch.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies alba
Abies borisii-regis
Abies nordamanniana
Abies sibirica
Acer pseudoplatanus

Betula pendula
Betula medwediewii
Fagus sylvatica
Fraxinus excelsior
Larix sibirica
Picea abis
Picea obovata
Picea omorika
Picea orientalis
Pinus mugo
Pinus sylvestris
Populus tremula
Quercus robur
Sorbus aucuparia
Tilia cordata
Ulmus glabra

5.3.6 – Boreal Conifereous Forest

This zone occurs in some parts of Norway, most of Sweden, nearly all of Finland, northern Scotland and a wide belt in the western part of the Russian Federation south of the Arctic Circle as well as the southern part of Iceland. The zone also covers major areas in the eastern parts of the Russian Federation. A small island of lowland boreal forest is in the Russian Far East, north of the Amur River.

The western part of the zone has a cool-temperate, moist climate, varying from oceanic in the west to subcontinental in the interior and the east. Mean annual temperature is generally low and ranges from 8°C in Scotland to just above 1°C in the northern parts of the Russian Federation. Precipitation ranges from more than 900 mm in the west to 400 mm in the east, with extremes of 1,200 and 300 mm. A short growing period (less than 120 days) is characteristic. Evaporation is low and prolonged periods of drought are rare. Snow generally covers the ground for several months during the winter.

The climate of boreal western Siberia is influenced by the amount of solar energy, the Atlantic Ocean to the west and the powerful east Siberian winter anticyclone from the east. The climate of the northern part is under the influence of arctic atmospheric processes. To the south, the low winter temperature contrasts a relatively high summer temperature. The maximum precipitation (on average 500 mm) is in the center of the plain (about 60°N); to the north and south the amount of precipitation is lower. Throughout the zone, rainfall is concentrated during the growing period or warm season. Snow cover plays a significant role in western Siberia, defining the depth of frozen soils in winter and determining hydrology in summer.

In western Siberia, the average annual temperature is about -4°C (January, -22° to -24°C; July, 16° to 17°C), the growth period is about 85 days, the period with snow cover 190 to 200 days and annual precipitation 410 to 450 mm. To the south, the climate becomes significantly warmer. Between the Irtish and Yenisey Rivers, the average annual temperature increases to -0.4° to -1°C (January, -18° to -21°C; July, 16.5° to 18°C), the growth period to 100 to 115 days, snow cover 175 to 190 days and precipitation 410 to 550 mm.

In the sparse taiga of the eastern part of the middle Siberian Plateau the climate is continental, with little precipitation, dry springs and severe winters. The average annual temperature is -11° to -13°C (January, -38° to -43°C; July, 14° to 17°C), the growth period is 63 to 73 days, snow cover is 228 to 237 days and precipitation 200 to 290 mm. A major part of this area is covered by continuous permafrost, very deep (up to 600 m) and cold (-8° to -12°C) in the north, which crucially impacts the structure and functioning of forest ecosystems. The melting layer is from 0.2 to 0.5 m on wetlands and up to 0.5 to 0.8 m on drained sites.

The glaciers of northern Europe essentially wiped the land clean of most plant species. This great natural perturbation is still reflected in the species and vegetation diversity of the region. Most boreal forests are dominated by only a few conifer tree species, primarily spruce on moister ground and pine on drier ground. East of the White Sea, mainly closer to the Ural Mountains, Siberian conifer species such as pine, fir and larch may also occur. Deciduous species such as birch, aspen, alder and willow are characteristic of the early successional stages (especially birch and aspen) or may form smaller stands among the conifers. Stands of deciduous trees are mainly associated with special habitats, often disturbed by fire or floods, or occupy particular soils.

Mires form characteristic landscape elements in mosaics with various forest types. In parts of northern Finland, mires cover almost 50 percent of the land area. Raised bogs, with a central raised area of peat, are found in the southern part of the zone. The most common types of mire in the boreal region are fens on level or gently sloping ground, often mixed with smaller areas of open water, raised bogs, and drier, firm ground. Many of these areas, in Fennoscandia in particular, have been ditched and partly drained for agriculture or forestry. Modern technology has the potential to restructure and transform boreal forests and the landscape on a large scale.

In the eastern Russian Federation, the zonality and continentality of the climate define the distribution of vegetation. Higher humidity in the western part promotes dark coniferous forests (dominated by spruce and fir) while increasing dryness and continentality in the eastern part of the zone favours light coniferous forests (predominantly larch, but also pine to the south).

Swamps and marshland dominate the northern taiga of the western Siberian plain. Forests are confined to well-drained river valleys. They are dominated by Siberian cedar pine, with a mixture of Siberian spruce, birch and Siberian larch in the north and slow-growing fir in the south. Secondary birch forests are extensive.

Various raised and transitional bogs are prevalent in the middle taiga. Sparse cedar forests with birch usually grow in valleys. To the south, the amount of wetlands significantly decreases. Cedar-spruce and cedar-spruce-fir forests cover the uplands in the middle and southern taiga. Birch and aspen forests increase towards the south. Pine forests with lichens grow on drained sands.

To the east of the Yenisey River, dark coniferous taiga gives way to light coniferous larch and pine forests. In the northern part, in the basin of the Podkamennaja Tunguska River, larch-pine and pine forests with mosses predominate. Spruce and cedar forests with birch and aspen occur in river valleys. Hummocky peat covers significant areas. To the south, pine predominates. The most productive Asian pine forests grow in the basin of the Angara River where growing stock volume on the best sites can reach 500 to 600 m^3 per hectare.

To the east, in Central Yakutia, larch is the major dominant species. Other species, primarily pine and birch, occupy less than 10 percent of forested areas. To the north, in the northwestern part of Yakutia and partially in Evenkija and the Taimir national district, sparse northern taiga larch forests cover about 95 percent of the forested areas. Dwarf pine covers about 4 to 5 percent, while birch is very rare. Sparse larch forests are common in the south with a sparse low canopy layer of Siberian spruce.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies sibirica

Abies sachalinensis
Betula pendula
Larix sibirica
Picea abis
Picea obovata
Pinus pumila
Pinus sibirica
Pinus sylvestris
Populus tremula

5.3.7 – Boreal Tundra Woodland

In Europe, boreal tundra woodland forms a narrow belt on the Kola Peninsula and along the Arctic Circle to the Ural Mountains. Beyond the Urals, the zone is a rather wide belt stretching to the Pacific coast. Vast areas of tundra and bog vegetation alternate with sparse, low-productivity forests and shrubs. The northern part of the zone, 100 to 250-300 km wide, is a "human-induced treeless belt" where lack of forests is assumed to be a consequence of anthropogenic or natural disturbance, mostly wildfires.

The climate is cold but humid. In the European part, the average annual precipitation varies between 700 mm on the Kola Peninsula to 500 to 550 mm east of the Pechora River. The mean annual temperature on the Kola Peninsula is -1° to -2°C (average in January, -10° to -12°C; July, 9° to 12°C). Permafrost is discontinuous but widespread.

To the east, the climate is strongly impacted by continental, and partially maritime, arctic air masses, moderated only in the extreme east. The severity of winter increases from the coast inwards. All territories are under continuous deep and cold permafrost. The climate is most severe in central Siberia (between the Yenisey and Lena Rivers) where the average annual temperature decreases to -12° to -15°C (January, from -31° to -42°C; July, 11° to 14°C). The minimum temperature reaches -58° to -65°C. The growth period is very short, from 35 to 60 days. Annual precipitation amounts to 240 to 400 mm. Throughout the zone most of the precipitation falls during the warm period.

The vegetation of the European part of this zone comprises open woodlands of low-growing trees, mostly 4 to 6 m tall. The stands are predominantly composed of birch and spruce. While spruce dominates in the north of the Russian Plain and in the Urals, birch forms the woodland in the suboceanic areas of northeastern Europe. Further east, open woodlands of larch occur as small isolated stands on sandy soils. Mires often occupy wet depressions while the tundra woodland covers the slopes and other well-drained sites.

East of the Urals, open woodland is usually found in lower-lying and better-drained terrain along with tundra and mires. In the southern part of the zone, sparse coniferous forests follow the river valleys in narrow belts several kilometers wide. In most cases, trees are irregular in shape, with crooked boles, one-sided flag-like crowns, and sometimes a form resembling creeping arboreal plants. Soil cryogenic processes often cause the phenomenon of "tipsy forests". In western Siberia, the predominant species in the typically sparse forests is Siberian larch with an admixture of Siberian spruce. In central Siberia, larch is dominant and spruce forms the second canopy layer. To the east, in the basins of the Indigirka and Kolyma Rivers, the principal species are larch. Dwarf pine and bushy willows are abundant and exceed in area the "high" forests. Mongolian poplar and Korean willow grow in river valleys. The northern tree line goes along the reaches of the Kolyma River to the north of 69°N and to about 65°N in Chukotka, characterized by poplar, Korean willow and bushy alder.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Betula pubescens
Chosenia arbutifolia
Larix cajanderi
Larix gmelinii
Larix sibirica
Picea obovata
Pinus pumila
Populus suaveolens
Salix schwerin
Salix udensis

5.3.8 – Boreal Mountain Systems

The boreal mountain zone consists of six isolated mountainous regions - the uplands of Iceland, the Scottish Highlands, the Scandinavian mountains, the Urals, the higher northern part of the Central Siberian uplands and the vast mountain territories that occupy the south of Siberia and cover the major part of Yakutia and the Russian Far East.

In the mountains of northern Europe, the average annual temperature is nearly everywhere below 4°C. Only in coastal areas of southern Norway does the temperature reach 7°C. Annual precipitation is about 400 mm in the east and increases westwards, although orographic precipitation can locally be much higher. In the eastern Russian Federation, the climate of this zone is extremely diverse but generally severe. Snow cover is usually abundant and perseveres for a considerable time. Continuous, deep permafrost predominates. The harshest climate is found in the middle Siberian uplands and the mountains of northeastern Russian Federation. Here, mean annual temperatures range from -11° to -14°C, with January temperatures as low as -35° to -43°C, and minimum temperatures of -50° to -60°C. July temperatures are 13° to 16°C but the length of the growing period in these regions is only 60 to 80 days. Annual rainfall amounts to 200 to 300 mm, predominantly as snow. Conditions are less severe in other mountain areas, particularly those with higher minimum (January) temperatures. There is high variation in the amount of precipitation; for instance the high West Altai receives up to 2,000 mm of precipitation, which, together with rather warm conditions, favors growth of dark coniferous forest vegetation. In lower East Altai precipitation is much less, which favors development of larch forests.

Birch woodlands are widely distributed in the European part of the zone. They are composed of more or less open birch forests, partly with pine in the eastern parts. Above the timberline the forest vegetation is replaced by boreal alpine as well as subnival and nival vegetation. In Iceland, sparse mountain pioneer vegetation occupies the highest altitudes while in the Scottish Highlands blanket bogs, heaths and dwarf shrub vegetation cover the rounded hills. In the Ural Mountains, coniferous forests of pine, spruce and fir are common.

In the eastern Russian Federation, the distribution of forest vegetation, species composition and the productivity of forests vary widely over the vast mountain territories. Altitudinal ranges of vegetation belts and forests, in particular, depend on such factors as geographical location, climate, height of the mountain system, slope orientation, etc. While temperature is a major limiting factor in the north, the amount of precipitation and air humidity determines the distribution of forest altitudinal belts in the south.

In the middle Siberian Plateau, larch forests grow up to 750 to 850 m in the southern part and up to 450 to 600 m on south-facing slopes in the north. In the central and eastern parts of the plateau, forests cover only small areas at the mouths of some rivers. Dark coniferous taiga dominates in West Altai, the Salair Range, Kusnetsky Ala-Tau and the northern part of West Sajan. Above the foothill belt of aspen forests with fir lies a belt of fir taiga ("chernevaja") from 400-600 to 800-900 m, with aspen in lower parts and Siberian cedar pine in upper ones. Above that (up to 1,400 to 1,500 m) are typical dark coniferous forests dominated by cedar and fir, with a very modest admixture of spruce. Cedar forests occupy a subalpine belt from 1,500 to 1,800 m. The uppermost forest belt (1,800 to 2,400 m) is usually formed of cedar-larch forests. Eastern Altai has a well-developed belt of larch forests. Forests of the Tuva region are mostly represented by larch, which covers foothills and middle elevation mountains (up to 1,400 m). Cedar forms a narrow belt above the larch forests, usually in the eastern part of Tuva (up to 1,700 to 1,900 m).

An absolute dominance of larch is typical of the mountain country around Lake Baikal, usually in association with cedar and spruce with dwarf pine in the understorey. Dwarf pine and alder form a subalpine belt. Pine forests grow in river valleys. Towards the east, dark coniferous species do not play a significant role, but pine and birch are common. Rather productive larch and pine forests are found in the east, particularly in the mountain ranges nearer the Pacific coast.

In the mountains of southwestern Russian Asia, forest vegetation is expressed in the northern part by larch forests on cold soils and spruce forests on warmer soils, with an admixture of fir, birch and pine. Poplar, bird-cherry trees and others are common in the lower belt. Dwarf pine is widely distributed in high mountain areas. To the southeast, spruce and fir, with some admixture of Korean cedar pine and some broad-leaved species, constitute the zonal forest vegetation. Korean cedar pine, together with spruce, fir and broad-leaved species, including linden and different maples constitute a common forest type. There is a significant admixture of ash, elm and walnut, forming a belt of mixed coniferous broad-leaved forests, mostly in river valleys and lower parts of the mountains. Pine forests have decreased considerably during the past decades owing to insufficient management. Lowlands in the lower reaches of the Amur River are covered with spruce and fir forests, as is a major part of the forest belt in northern and middle Sikhote-Alin.

In the northeastern Russian Federation (the Yukagir Upland), sparse larch forests, either single-species or in association with birch, cover extensive areas. Korean willow and poplar grow in river valleys. Dwarf pine covers only a small area owing to the severity of the climate. In the central part, dominated by the mountain systems of the Vekhojansky and Chersky Ranges, a subalpine belt with dwarf pine is present at 1,400 to 1,800 m. Sparse larch forests form a belt between approximately 500 and 1,400 m on southern slopes. Relatively well-stocked larch forests cover the lower altitudinal belts and river valleys. Wildfires often decrease the productivity of larch forests. Four major altitudinal belts are observed to the east, in the coastal zone of the Okhotsk Sea. From low to high altitude they consist of a belt of stocked larch forests, on average up to 400 to 500 m; sparse larch forests with dwarf pine from about 400-500 to 700-1,200 m; a subalpine belt dominated by dwarf pine, usually above 700-1000 m to 900-1,400 m, and covering more than 50 percent of the area; and mountain tundra. To the west, on the Oimjakon Upland, continentality of climate increases significantly. Dwarf pine plays a significant role in the subalpine belt where precipitation is higher. Larch is a major forest-forming species, sometimes with an admixture of birch and poplar.

Forests in the mild, cool and very humid climate of the coastal part of Kamchatka are mostly dominated by stone birch, which forms specific open park-like forests. Dwarf pine, bushy alder and grassy-Sphagnum bogs can be found at the east coast, and raised bogs on the west coast. In mountain depressions along the Kamchatka River, bottoms and foothills of the depression are covered by larch and, in small areas, spruce forests. Further uphill is a belt of park-like birch forests. Peaks are covered by mountain tundra. Larch forests dominate the northern part of

Sakhalin Island while dwarf pine and sparse forests of birch occur along the coast and at the tree line. Rather productive spruce and fir forests grow on the middle part of the island. Elements of nemoral flora are found in forests of the southern part with oak, walnut and others. Bamboo brakes cover significant areas, in particular in the southern part of the island, as a result of intensive human-caused forest fires.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies nephrolepis
Abies sachalinensis
Abies sibirica
Betula cajanderi
Betula ermanii
Betula pubescens
Duschekia kamtschatica
Fraxinus mandshurica
Juglans mandshurica
Larix cajanderi
Larix gmelinii
Larix kurilensis
Myrica tomentosa
Picea ajanensis
Picea obovata
Pinus koraiensis
Pinus pumila
Pinus sibirica
Pinus sylvestris
Quercus mongolica
Tilia amurensis
Ulmus laciniata

5.4 – North And Central America

North America, Central America and the Caribbean together contain about 549 million hectares of forests, corresponding to 14 percent of the world total. The forests of North America, Central America and the Caribbean amount to 1.1 ha per capita, which is above the world average. The forest areas of Central America and the Caribbean are located mainly in the subtropical ecological domain. Forest cover in North America is distributed between the temperate and boreal ecological zones. Some 86 percent of the region's forests is in two large countries - Canada and the United States. The forests in the region do not constitute a major proportion of any ecological zone; however, this is the most diversified region with all but two ecological zones represented.

Table 5.04 - Forest Area per Ecologic Zone - North and Central America (Million Hectares)

Ecologic Zone	*Total Area*	*Forest Cover*	*Forest Area*
Tropical	**160**	**57%**	**91**
Rain forest	43	64%	28

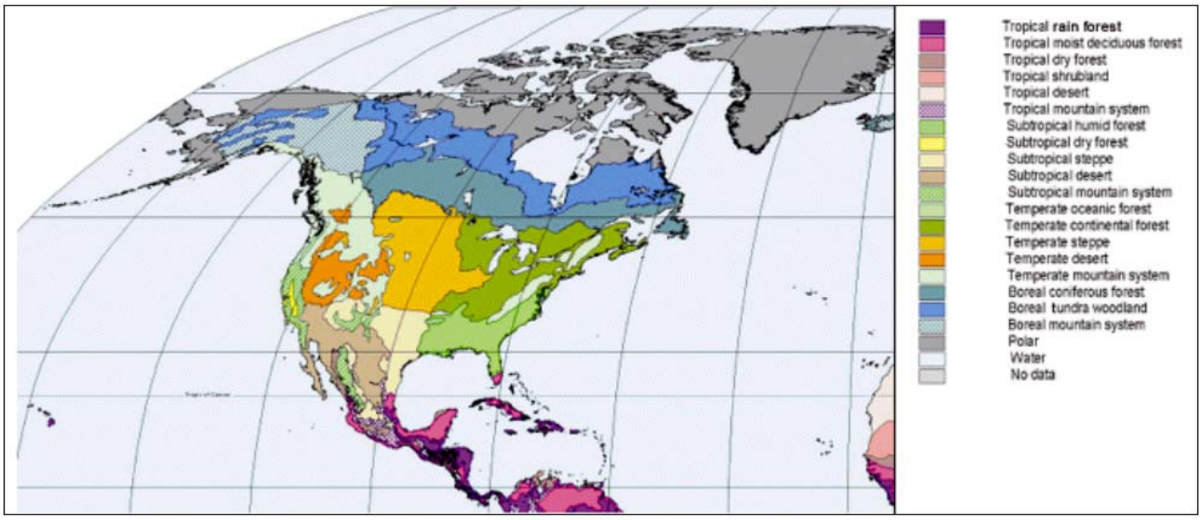
Ecologic Zone	*Total Area*	*Forest Cover*	*Forest Area*
Moist	68	53%	36
Dry	23	44%	10
Mountain	26	65%	17
Subtropical	**398**	**26%**	**102**
Humid	106	46%	49
Dry	9	23%	2
Steppe	116	8%	9
Desert	108	5%	5
Mountain	59	61%	36
Temperate	**712**	**25%**	**181**
Oceanic	4	39%	2
Continental	225	34%	77
Steppe	211	2%	4
Desert	75	8%	6
Mountain	197	47%	93
Boreal	**609**	**40%**	**242**
Coniferous	225	52%	117
Tundra	266	31%	82
Mountain	118	36%	42
Polar	**358**	**2%**	**7**
Total	**2,237**	**28%**	**622**

Source: FAO, 2001

The net change of forest area is -570,000 ha per year, which represents the sum of a high net loss in Central America and a considerable increase in the United States. Figure 5.05 shows the North and Central American ecologic zones distribution.

Figure 5.05 – North and Central American Ecologic Zones

Source: FAO, 2001



5.4.1 – Boreal Tundra Woodland

The Hudson Plain occupies a major area of this zone, while the western portion consists of subdued broad lowlands and plateaus incised by major rivers. The climate, influenced by cold arctic air, is characterized by short, cool summers and long, cold winters. Mean annual temperature ranges from -10° to 0°C, with mean temperature in summer from 6° to 14°C and in winter from -26° to -16°C. Snow and ice persist for six to eight months of the year. The mean annual precipitation is low in the west, ranging from 200 to 500 mm, but reaches 500 to 800 mm in the east, with portions of Labrador reaching 1,000 mm.

Vegetation associations of the Hudson Bay lowlands consist of arctic tundra and some boreal forest transition types. The better-drained sites support open woodlands of black spruce, tamarack and some white spruce. Balsam poplar, white spruce and white or paper birch are common along rivers.

East of these lowlands are large open stands of black spruce woodland as well as stunted black spruce and tamarack on the windswept plateaus. White spruce is also present. Alder thickets are common along riverbanks and other drainage areas. Other species include quaking aspen and balsam fir. Limited tree vegetation occurs along the exposed headlands of the Atlantic Coast and within the interiormost windswept barrens.

West of Hudson Bay, open stands of black and white spruce and tamarack dominate. Sometimes these open forests include jack pine as well. The western limits of the zone are characterized by open, generally slow-growing black spruce. Upland and foothill areas and southerly locales tend to be better drained and are somewhat warmer. Here, mixed-wood forests of white and black spruce, lodgepole pine, tamarack, white birch, trembling aspen and balsam poplar are common. Along nutrient-rich alluvial flats, white spruce and balsam poplar grow to sizes comparable to the largest in the boreal forest to the south.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies balsamea
Alnus incana
Betula papyrifera
Larix laricina
Picea glauca
Picea mariana
Pinus banksiana
Pinus contorta

Populus balsamifera
Populus tremuloides

5.4.2 – Boreal Coniferous Forest

A broadly rolling mosaic of uplands and associated wetlands dominates this zone. The climate is generally continental with long, cold winters and short, warm summers, modified in the east by the Atlantic Ocean. The mean annual temperature ranges from -4°C in central Canada to 5.5°C in the boreal regions of Newfoundland. Mean summer temperature varies between 11° and 15°C, with mean winter temperature from -20.5° C in the west to -1°C in the east. Mean annual precipitation varies between 100 and 625 mm with the exception of boreal Newfoundland, where average precipitation is higher, from 900 to 1,600 mm.

Much of the zone is distinguished by closed stands of conifers, largely white spruce, black spruce, balsam fir and tamarack. Common deciduous species include white birch, trembling aspen and balsam poplar. In the south, conifers such as eastern white pine, red pine and jack pine are evident. At the transition with forests to the south, species such as sugar maple, black ash and eastern white cedar are found.

Towards the western boundary of the zone the vegetation is medium to tall closed stands of trembling aspen, balsam poplar and jack pine with white and black spruce occurring in late successional stages. Lodgepole pine may dominate in some of the upland areas along with white spruce and balsam fir. Black spruce tends to be concentrated in the poorly drained valleys. Trembling aspen and balsam poplar characterize the transition to the south. White spruce and balsam fir are the climax species but are not widespread because of the frequent occurrence of fire.

Both open and closed black spruce and balsam fir forests are characteristic in the east. White birch and trembling aspen are typical of disturbed sites. White spruce is generally more tolerant of ocean spray and is more prevalent near the ocean. Wetlands are extensive, with a cover of stunted black spruce, tamarack and shrubs.

The northern part of the zone is transitional to the boreal tundra. Pure stands of jack pine or mixed stands of jack pine, white birch and trembling aspen are typical of the drier sites, while black spruce and balsam fir dominate wet sites.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies balsamea
Abies bifolia
Abies lasiocarpa
Acer saccharum
Betula papyrifera
Fraxinus nigra
Larix laricina
Picea glauca
Picea mariana
Pinus banksiana
Pinus contorta
Pinus resinosa
Pinus strobus
Populus balsamifera
Populus tremuloides

Thuja occidentalis

5.4.3 – Boreal Mountain Systems

Mountain ranges with numerous high peaks and extensive plateaus separated by wide valleys and lowlands characterize this zone. The climate ranges from cold, subhumid to semi-arid with long, cold winters and short, warm summers. Mean annual temperatures range from -10°C in the north to 5°C in the south. Mean summer ranges are 6.5° to 11.5°C and mean winter temperatures range between -13° and -25°C. Annual precipitation is lowest in valleys in the rain shadow of the Coast Range (less than 300 mm) and increases up to 1,500 mm at higher elevations of the interior mountains.

Vegetation at higher elevations ranges from arctic to alpine tundra. At lower elevations in the north, open woodlands of white spruce and white birch are mixed with dwarf birches and willows. The unglaciated Old Crow Basin has stunted stands of black spruce and tamarack with some white spruce. To the south, vegetative cover ranges from closed to open forest of white and black spruce, subalpine fir, lodgepole pine, trembling aspen, balsam poplar and white birch. Lodgepole pine and subalpine fir tend to disappear rapidly towards the north.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies lasiocarpa
Betula papyrifera
Picea glauca
Pinus contorta
Populus balsamifera
Populus tremuloides

5.4.4 – Temperate Oceanic Forest

This relatively small ecological zone occupies a north-south depression between the Pacific Coast Range and the Cascade Mountains. The nearness of the ocean profoundly moderates the climate, and annual temperatures average 9° to 13°C. Average rainfall ranges from around 400 to 1,500 mm, but more typically is from 750 to 1,150 mm. Fog partially compensates for the summer drought.

These forests are composed of mixtures of western red cedar, western hemlock and Douglas fir In the interior valleys, the forest is less dense than along the coast and often contains such deciduous trees as big-leaf maple, black cottonwood and, to the south, Oregon ash. There are woodlands that support open stands of oaks or are broken by groves of Douglas fir and other trees such as Oregon white oak and Pacific madrone. Clearing for cultivation has greatly reduced the area of these forests.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies mariesii
Abies procera
Acer circinatum
Acer glabrum
Acer macrophyllum
Alnus oregana
Alnus rubra
Alnus viridis

Arbutus menziesii
Cercocarpus montanus
Cornus sericea
Cornus unalaschkensis
Fraxinus latifolia
Juniperus communis
Picea sitchensis
Pinus attenuata
Pinus contorta
Pinus lambertiana
Populus balsamifera
Populus trichocarpa
Prunus virginiana
Pseudotsuga menziesii
Quercus garryana
Salix hookeriana
Salix lucida
Salix scouleriana
Salix sitchensis
Sorbus sitchensis
Symphoricarpos albus
Symphoricarpos mollis
Taxus brevifolia
Thuja plicata
Tsuga heterophylla

5.4.5 – Temperate Continental Forest

Warm summers and cool winters are typical of this zone. The weather is highly changeable. Mean annual temperatures range from 2° to 10°C. The mean summer temperature ranges from 16° to 18°C, with the winter mean ranging from -2.5° to -7°C. Annual precipitation over much of the zone ranges from 720 to 1,000 mm, reaching 1,500 mm near the Atlantic Coast. The proximity of the Atlantic Ocean moderates the climate of the eastern portion of the zone.

At one time the entire zone was heavily forested, but most of the forests around the Great Lakes and in the northeastern United States have succumbed to urbanization and conversion to agriculture. Forest cover varies from mixed coniferous/deciduous stands of white and red pine, eastern hemlock, red oak, sugar maple and white birch in the northern portions to the rich diversity of the deciduous Carolinian forest in the southwest.

The mixed mesophytic association, the deciduous forest with the greatest diversity, occupies well-drained sites. Widespread dominants include sugar maple, American beech, white elm, basswood, red and white oak, walnut, hickory, buckeye and eastern hemlock in addition to 20 to 25 other species. An oak association, with white oak and northern red oak as dominant species, occurs east of the Appalachian Mountains.

Further inland, where precipitation is lower, the drought-resistant oak-hickory association is dominant, with white oak, red oak, black oak, bitternut hickory and shagbark hickory. Wetter sites typically feature American or white elm, tulip-tree and sweetgum. Northern reaches of this association contain maple, beech and basswood.

Forests in the northeastern portion of the zone are generally mixed stands of conifers and deciduous species characterized by red spruce, balsam fir, yellow birch and sugar maple. Red and white pine and eastern hemlock occur to a lesser but significant degree. Some boreal species are present, including black spruce, white spruce, balsam poplar and white birch. Jack pine is prominent on sandy soils. Pine-oak forest occupies dry sandy soils along the northern coastal plain of the United States and is frequently exposed to naturally occurring fires. Eastern white cedaroccurs on mesic sites.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies balsamea
Acer negundo
Acer rubrum
Acer saccharinum
Acer saccharum
Amelanchier canadensis
Betula alleghaniensis
Betula lutea
Betula nigra
Betula papyrifera
Carpinus caroliniana
Carya cordiformis
Carya ovata
Celtis occidentalis
Fagus grandifolia
Fraxinus americana
Fraxinus nigra
Fraxinus pennsylvanica
Fraxinus quadrangulata
Gleditsia triancanthos
Gymnocladus dioica
Juglans cinerea
Juglans nigra
Juniperus virginiana
Larix laricina
Liquidambar styraciflua
Liriodendron tulipifera
Morus rubra
Ostrya virginiana
Picea glauca
Picea mariana
Picea rubens
Pinus banksiana
Pinus resinosa
Pinus strobus
Populus balsamifera
Populus deltoides
Populus grandidentata
Populus tremuloides
Prunus americana
Prunus pennsylvanica
Prunus serotina

Prunus virginiana
Quercus alba
Quercus bicolor
Quercus ellipsoidalis
Quercus macrocarpa
Quercus muehlenbergii
Quercus rubra
Quercus velutina
Robinia pseudoacacia
Sorbus americana
Thuja occidentalis
Tilia americana
Toxicodendron vernix
Tsuga canadensis
Ulmus americana
Ulmus rubra
Ulmus thomasii

5.4.6 – Temperate Steppe and Temperate Desert

The Temperate Steppe climate is greatly influenced by its location in the heart of the continent. The zone has a continental climate that is subhumid to semi-arid with short, hot summers and long, cold winters. Generally, precipitation is low and evaporation is high. Mean annual temperature ranges from 1.5° to 3.5°C. Mean winter temperature ranges from -12.5° to -8° C, with summer means from 14° to 16°C. Annual precipitation is variable, from 250 mm in the arid grasslands to near 700 mm in the higher-elevation wooded portions. Park-like stands of trembling aspen and balsam poplar lie at the northern edge of this zone, a transition to the boreal forest to the north. The aspen parkland has expanded considerably southwards since prairie fires were effectively eliminated. Patches of scrubby aspen and cottonwood, willow and box-elder occur on shaded slopes of valleys and river terraces. To the east, the zone consists of a mosaic of trembling aspen, bur oak and grasslands. Further south, oak and hickory become the dominant tree species in the transition zone with the eastern broadleaf forests.

The Temperate Desert zone covers the Great Basin, the northern Colorado Plateau in Utah and the plains and tablelands of the Columbia-Snake River Plateaus and the Wyoming Basin. The aridity of this zone is the result of the rain shadow of the Sierra Nevada and Cascade Mountains. Summers are hot and winters are cold, with stronger seasonal temperature extremes on the higher plateaus. The average annual temperature ranges from 4° to 13°C. Annual precipitation averages about 130 to 400 mm. Almost no rain falls during the summer months. Part of the winter precipitation falls as snow. The main vegetation, sometimes called sagebrush steppe, is made up of sagebrush and other shrub species mixed with short grasses. Above the sagebrush belt lies a woodland zone dominated by pinyon pine and juniper.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Acer negundo
Juniperus osteosperma
Juniperus scopulorum
Pinus edulis
Pinus monophylla
Populus balsamifera
Populus tremuloides

Prosopis reptans
Quercus macrocarpa

5.4.7 – Temperate Mountain Systems

This zone includes the Coast Range, the Rocky Mountains and the Appalachian Mountains. The climate is extremely varied, from a relatively humid maritime climate at low elevations along the Pacific Coast to cold, arctic conditions above the tree line in the Rocky Mountains. Along the coast the mean annual temperature ranges from 4.5°C in the north to 9°C in the south. Average annual precipitation is extremely variable, from 600 mm in the Gulf Islands to 4,000 mm to the north. The interior portion of the zone is similarly variable. The climate of the Appalachian Highlands is more temperate, with a distinct summer and winter. Average annual temperatures range from below 10°C in the north to about 18°C at the southern end. Average annual precipitation varies from 900 mm in the valleys to 2,000 mm on the highest peaks.

The temperate rain forests of the Pacific Coast Mountains are among the most productive in North America and contain some of the world's largest and longest-lived trees. This vegetation association is dominated by western hemlock or Pacific silver fir as climax species, although several other species are common. Big-leaf maple reaches its northern extension in the southern portion of this zone. It is generally found along creek beds and in other alluvial areas along with red alder and black cottonwood. At high elevations, up to 2,000 m, mountain hemlock, subalpine fir and amabilis fir assume prominence along with yellow or Pacific cedar, becoming open and stunted at higher elevations.

Amabilis fir, lodgepole pine and Sitka spruce are common in the north. At lower elevations in the north, western hemlock and western red cedar dominate with red alder pioneering on disturbed sites. The coastal Douglas fir association is found in the lee of the coastal mountains. Douglas fir dominates. Western red cedar is typical on wetter sites, and Garry oak and arbutus are abundant on drier sites.

Interior Douglas fir associations dominate in the rain shadow of the Coast Range and other mountain ranges. Fires have resulted in even-aged lodgepole pine stands at higher elevations, while ponderosa pine is the common seral tree at the warmer and drier lower elevations.

At mid elevations of the interior plateau regions, closed stands of Englemann spruce and subalpine fir are common. Lodgepole pine, western white pine, Douglas fir and trembling aspen reflect past fire history. At higher elevations the Englemann spruce-subalpine fir association begins to dominate. The forest often has an open parkland appearance. Under drier conditions, extensive stands of lodgepole pine and whitebark pine are common. Wetter areas may be dominated by mountain hemlock.

A western red cedar-western hemlock forest with a wide variety of conifer trees is characteristic of the interior wet belt of this zone. In addition to the two dominant species, other common trees include white spruce, Englemann spruce and subalpine fir. Douglas fir and lodgepole pine occur in drier areas. Englemann spruce, white spruce and subalpine fir are the dominant trees in subboreal plateau areas. Even-aged lodgepole pine and trembling aspen cover extensive areas of previously burned sites.

In the Appalachian Highlands, a vertical zonation prevails, with the lower limits of each forest belt rising towards the south. The valleys of the southern parts support a mixed oak-pine forest. Above this zone lies the Appalachian oak forest, dominated by a dozen species of white and black oaks. At higher elevations is hardwood forest composed of birch, American beech, maple, elm, red oak and basswood, with an admixture of eastern hemlock and white pine. Spruce-fir forest and meadows are found on the highest peaks. Mixed mesophytic forest extends into narrow valleys of the southern Appalachians, where oak vegetation predominates. The northern reaches are located in the transition zone between the boreal spruce-fir forest to the north and the deciduous forest to the south. Growth form and species are very similar to those found to the north, but red spruce tends to replace white spruce. Here the valleys contain a hardwood forest dominated by sugar maple, yellow birch and beech. Low mountain slopes are covered with a mixed forest of spruce, fir, maple, beech and birch. Above the mixed-forest zone lie pure stands of balsam fir and red spruce.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies amabilis
Abies balsamea
Abies lasiocarpa
Acer macrophyllum
Abies procera
Abies magnifica
Alnus rubra
Arbutus menziesii
Betula alleghaniensis
Chamaecyparis nootkatensis
Fagus americana
Picea engelmannii
Picea glauca
Picea rubens
Picea sitchensis
Pinus albicaulis
Pinus contorta
Pinus monticola
Pinus ponderosa
Populus tremuloides
Populus trichocarpa
Pseudotsuga menziesii
Quercus garryana
Quercus rubra
Thuja plicata
Tilia americana
Tsuga canadensis
Tsuga heterophylla
Tsuga mertensiana

5.4.8 – Subtropical Humid Forest

This zone comprises the Atlantic and Gulf coastal plains and piedmont. Winters are mild and summers hot and humid. Average annual temperature is 15° to 21°C. Annual precipitation ranges from around 1,000 to 1,500 mm, relatively evenly distributed throughout the year.

On the coastal plains temperate evergreen rain forest is the dominant natural vegetation. Subtropical rain forest has fewer tree species than its tropical counterpart; trees are not as tall, leaves are usually smaller and more leathery and the leaf canopy is less dense. Common species include evergreen oaks and species of laurel and magnolia. Further inland, the climax vegetation is medium-tall to tall forests of broadleaf deciduous and needleleaf evergreen trees. Loblolly pine, Pinus echinata and other southern yellow pine species dominate the stands, singly or in combination. Common associates include oak, hickory, sweetgum, blackgum, red maple and winged elm. Gum and cypress dominate the extensive coastal marshes and interior swamps along the Atlantic and Gulf Coasts.

Along the Mississippi River, small patches of riverine deciduous forests still occur, with an abundance of green ash, Carolina poplar, elm, cottonwood, sugarberry, sweetgum and water tupelo, as well as oak and baldcypress. Pecan is also present, associated with American sycamore, American elm and roughleaf dogwood.

Today, extensive forests of loblolly and slash pine are widespread in this zone, predominantly as plantations or second-growth forest following fire.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies fraseri
Acer negundo
Acer pensylvanicum
Acer rubrum
Acer saccharinum
Acer saccharum
Acer spicatum
Aesculus flava
Aesculus glabra
Aesculus octandra
Aesculus pavia
Ailanthus altissima
Albizia julibrissin
Amelanchier arborea
Aralia spinosa
Aristolochia macrophylla
Aristolochia tomentosa
Arundinaria gigantea
Asimina triloba
Betula alleghaniensis
Betula lenta
Betula nigra
Bignonia capreolata
Bumelia lycioides
Calycanthus floridus
Campsis radicans
Carpinus caroliniana
Carya carolinae-septentrionalis
Carya cordiformis
Carya glabra
Carya illinioiensis
Carya laciniosa
Carya ovalis
Carya ovata
Carya tomentosa
Castanea dentata
Catalpa speciosa

Celtis laevigata
Celtis occidentalis
Cephalanthus occidentalis
Cercis canadensis
Chionanthus virginicus
Cladrastis lutea
Clematis virginiana
Cocculus carolinus
Cordia alliodora
Cordia bicolor
Cornus alternifolia
Cornus controversa
Cornus drummondii
Cornus florida
Cornus foemina
Corylus americana
Cotinus obovatus
Crataegus marshalii
Crataegus mollis
Crataegus phaenopyrum
Diospyros virginiana
Elaeagnus umbellata
Eunymous atropurpureus
Euonymus alatus
Euonymus americana
Euonymus atropurpurea
Euonymus fortunei
Fagus grandifolia
Ficus aurea
Forestiera ligustrina
Fothergilla major
Frangula caroliniana
Fraxinus americana
Fraxinus pennsylvanica
Fraxinus quadrangulata
Gleditsia triacanthos
Gymnocladus dioicus
Halesia carolina
Halesia tetraptera
Hamamelis virginiana
Hedera helix
Hibiscus syriacus
Hydrangea arborescens
Hypericum frondosum
Ilex decidua
Ilex opaca
Ilex verticillata
Ilex vomitoria
Juglans cinerea
Juglans nigra

Juniperus communis
Juniperus virginiana
Kalmia latifolia
Leucothoe fontanesiana
Ligustrum vulgare
Lindera benzoin
Liquidambar styraciflua
Liriodendron tulipifera
Lithocarpus densiflorus
Lonicera fragrantissima
Lonicera maackii
Maclura pomifera
Magnolia acuminata
Magnolia fraseri
Magnolia grandiflora
Magnolia macrophylla
Magnolia tripetala
Magnolia virginiana
Malus sylvestris
Menispermum canadense
Morus rubra
Nyssa aquatica
Nyssa biflora
Nyssa sylvatica
Opuntia humifusa
Ostrya virginiana
Oxydendrum arboreum
Parthenocissus quinquefolia
Paulownia tomentosa
Philadelphus inodorus
Phoradendron flavescens
Phoradendron leucarpum
Picea rubens
Pinus echinata
Pinus elliottii
Pinus palustris
Pinus strobus
Pinus taeda
Pinus virginiana
Platanus occidentalis
Populus deltoides
Populus grandidentata
Prunus americana
Prunus angustifolia
Prunus hortulana
Prunus mexicana
Prunus munsoniana
Prunus pensylvanica
Prunus persica
Prunus serotina

Ptelea trifoliata
Pyrus communis
Quercus alba
Quercus bicolor
Quercus coccinea
Quercus falcata
Quercus imbricaria
Quercus laurifolia
Quercus lyrata
Quercus macrocarpa
Quercus marilandica
Quercus michauxii
Quercus muehlenbergii
Quercus myrtifolia
Quercus nigra
Quercus pagoda
Quercus palustris
Quercus phellos
Quercus prinus
Quercus rubra
Quercus shumardii
Quercus stellata
Quercus velutina
Quercus virginiana
Rhamnus caroliniana
Rhododendron alabamense
Rhododendron calendulaceu
Rhododendron catawbiense
Rhododendron maximum
Rhododendron prinophyllum
Rhododendron roseum
Rhus aromatica
Rhus copallinum
Rhus glabra
Rhus hirta
Rhus radicans
Rhus typhina
Robinia pseudoacacia
Rosa carolina
Rosa multiflora
Rosa setigera
Rubus allegheniensis
Rubus argutus
Rubus flagellaris
Rubus occidentalis
Rubus odoratus
Salix caroliniana
Salix nigra
Sambucus canadensis
Sambucus nigra

Sambucus racemosa
Sassafras albidum
Sideroxylon lycioides
Smilax bon-nox
Smilax glauca
Smilax rotundifolia
Sorbus americana
Staphylea trifolia
Symphoricarpos orbiculatus
Taxodium distichum
Taxus floridana
Thuja occidentalis
Tilia americana
Torreya taxifolia
Toxicodendron radicans
Tsuga canadensis
Ulmus alata
Ulmus americana
Ulmus rubra
Ulmus serotina
Vaccinium arboreum
Vaccinium pallidum
Vaccinium stamineum
Viburnum lantanoides
Viburnum prunifolium
Viburnum rufidulum
Vitis vulpina
Wisteria frutescens
Yucca filamentosa

5.4.9 – Subtropical Dry Forest, Subtropical Steppe and Subtropical Desert

The Subrtopical Dry Forest zone is situated on the Pacific Coast between approximately 30° and 45°N latitude. The climate is typically Mediterranean, characterized by hot, dry summers and mild winters, with precipitation associated with winter storms. Annual temperatures average about 10° to 18°C, with average summer temperature above 18°C and average winter temperatures above 0°C. Annual rainfall ranges from 200 to 1,000 mm depending on latitude and altitude, always with a pronounced summer drought. Extreme droughts are not uncommon. Coastal fog is typical, particularly from May through July.

Redwood is characteristic of the fog belt on seaward slopes in coastal northern California. Associated with it are Douglas fir and other conifers such as western hemlock and western red cedar. Along the coast in a narrow, patchy belt lies pine-cypress forest. Inland, the south-facing mountain slopes are covered by mixed forest, including tanoak, live oak, madrone and Douglas fir. The central and southern coastal areas are covered by chaparral, a mostly evergreen shrub vegetation. Several tree species are endemic to this region, including Monterey cypress, Torrey pine, Monterey pine and Bishop pine. Patches of live oak or valley oak woodland are found on the hills and lower mountains. A blue oak-foothill pine woodland community forms a ring around the Central Valley of California. Most of the coastal plains and interior valleys have been converted to urban use or irrigated agriculture.

The Subtropical Steppe zone is dominated by flat to rolling plains and plateaus. The climate is semi-arid subtropical. Summers are long and hot and winters are generally short and mild. Annual temperatures average 14° to 21°C. Annual precipitation varies considerably, from about 250 mm in the drier (mostly western) regions, to about 1,000 mm in the northeastern Prairie Parkland region. The zone is also subject to periodic intense droughts and frosts. A variety of natural vegetation is found in this zone. Grasslands in which shrubs and trees grow singly or in bunches are predominant. Locally, oak and juniper are mixed with grasses and mesquite. Because of the low rainfall they rarely grow higher than 5 to 7 m. The most characteristic tree is Ashe juniper. Live oak forest is found along the Gulf Coast. In the northeastern part of the zone, oak savannah, dominated by post oak and blackjack oak, forms a transition with the more humid subtropical forest zone. The generally higher Colorado Plateau has distinct vegetation. Woodland is the most extensive vegetation type, dominated by open stands of pinyon pine and several species of juniper. Cottonwoods and other trees grow along some of the permanent streams.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Acacia berlandieri
Acacia farnesiana
Acacia greggii
Acacia occidentalis
Acacia roemeriana
Acacia schaffneri
Acacia smallii
Acacia tortuosa
Acacia willardiana
Acacia wrightii
Acer barbatum
Acer grandidentatum
Acer leucoderme
Acer negundo
Acer rubrum
Aesculus glabra
Aesculus pavia
Alnus serrulata
Amelanchier utahensis
Aralia spinosa
Arbutus menziesii
Arbutus xalapensis
Asimina triloba
Betula nigra
Bumelia celastrina
Bumelia lanuginosa
Bumelia lycioides
Bursera fagaroides
Bursera microphylla
Caesalpinia cacalaco
Caesalpinia mexicana
Carpinus caroliniana
Carya aquatica
Carya cordiformis
Carya glabra glabra

Carya illinoinensis
Carya myristiciformis
Carya ovata
Carya texana
Carya tomentosa
Castanea pumila
Celtis laevigata
Celtis lindheimeri
Celtis occidentalis
Celtis reticulata
Celtis tenuifolia
Cercidium praecox
Cercidium texanum
Cercis canadensis
Cercis mexicana
Cercis occidentalis
Cercocarpus breviflorus
Cercocarpus montanus
Chilopsis linearis
Chionanthus virginicus
Condalia hookeri
Cordia boissieri
Cornus florida
Cotinus obovatus
Crataegus berberifolia
Crataegus brachyacantha
Crataegus calpodendron
Crataegus crus-galli
Crataegus greggiana
Crataegus marshallii
Crataegus mollis
Crataegus opaca
Crataegus reverchonii
Crataegus spathulata
Crataegus texana
Crataegus tracyi
Crataegus viridis
Cupressus arizonica
Cupressus macrocarpa
Cyrilla racemiflora
Diospyros texana
Diospyros virginiana
Ehretia anacua
Esenbeckia berlandieri
Fagus grandifolia
Ficus palmeri
Ficus petiolaris
Forestiera acuminata
Forestiera neomexicana
Fraxinus americana

Fraxinus berlandieriana
Fraxinus caroliniana
Fraxinus cuspidata
Fraxinus greggii
Fraxinus papillosa
Fraxinus pennsylvanica
Fraxinus texensis
Fraxinus velutina
Gleditsia aquatica
Gleditsia triacanthos
Halesia diptera
Helietta parvifolia
Ilex ambigua
Ilex coriacea
Ilex decidua
Ilex longipes
Ilex opaca
Ilex verticillata
Ilex vomitoria
Juglans major
Juglans microcarpa
Juglans nigra
Juniperus ashei
Juniperus depeeana
Juniperus erythrocarpa
Juniperus flaccida
Juniperus monosperma
Juniperus pinchotii
Juniperus scopulorum
Juniperus silicicola
Juniperus virginiana
Leucaena pulverulenta
Leucaena retusa
Liquidambar styraciflua
Lithocarpus densiflorus
Maclura pomifera
Magnolia grandiflora
Magnolia pyramidata
Magnolia virginiana
Malus angustifolia
Malus ioensis
Morus microphylla
Morus rubra
Myrica cerifera
Nyssa aquatica
Nyssa sylvatica
Ostrya chisosensis
Ostrya knowltonii
Ostrya virginiana
Parkinsonia aculeata

Persea borbonia
Pinus cembroides
Pinus concolor
Pinus echinata
Pinus edulis
Pinus muricata
Pinus palustris
Pinus ponderosa
Pinus radiata
Pinus remota
Pinus sabiniana
Pinus strobiformis
Pinus taeda
Pinus torreyana
Pistacia texana
Pithecellobium flexicaule
Pithecellobium mexicanum
Pithecellobium pallens
Planera aquatica
Platanus occidentalis
Populus deltoides
Populus fremontii
Populus tremuloides
Prosopis alba
Prosopis articulata
Prosopis glandulosa
Prosopis laevigata
Prosopis pubescens
Prosopis reptans
Prosopis spicigera
Prosopis strombulifera
Prosopis velutina
Prunus caroliniana
Prunus mexicana
Prunus munsoniana
Prunus murrayana
Prunus serotina
Prunus umbellata
Pseudotsuga menziesii
Quercus agrifolia
Quercus alba
Quercus arizonica
Quercus buckleyi
Quercus douglasii
Quercus drummondii
Quercus dumosa
Quercus emoryi
Quercus falcata
Quercus fusiformis
Quercus gambellii

Quercus glaucoides
Quercus gravesii
Quercus grisea
Quercus hemisphaerica
Quercus hypoleucoides
Quercus incana
Quercus laceyi
Quercus laurifolia
Quercus lobata
Quercus lyrata
Quercus macrocarpa
Quercus margaretta
Quercus marilandica
Quercus michauxii
Quercus mohriana
Quercus muehlenbergii
Quercus nigra
Quercus nuttallii
Quercus oblongifolia
Quercus phellos
Quercus pungens
Quercus rugosa
Quercus shumardii
Quercus similis
Quercus sinuata
Quercus stellata
Quercus texana
Quercus turbinella
Quercus velutina
Quercus virginiana
Rhamnus caroliniana
Rhus copallina
Rhus lanceolata
Robinia neomexicana
Robinia pseudoacacia
Sabal mexicana
Salix amygdaloides
Salix nigra
Salix taxifolia
Sambucus caerulea
Sambucus glauca
Sapindus drummondii
Sassafras albidum
Sequoia sempervirens
Sophora affinis
Sophora secundiflora
Styrax grandifolius
Symplocos tinctoria
Taxodium distichum
Taxodium mucronatum

Thuja plicata
Tilia caroliniana
Tsuga heterophylla
Ulmus alata
Ulmus americana
Ulmus crassifolia
Ulmus rubra
Vaccinium arboreum
Vauquelinia angustifolia
Viburnum rufidulum
Yucca carnerosana
Yucca elata
Yucca faxoniana
Yucca rostrata
Yucca torreyi
Yucca treculeana
Zanthoxylum clava-herculis

5.4.10 – Subtropical Mountain Systems

This zone comprises the southernmost portion of the Cascade Mountains and the Rocky Mountains, the Sierra Nevada, the Coast Range and the Western Sierra Madre. The climate is extremely diverse, with variation related to latitude, altitude and exposure. The prevailing west winds influence climatic conditions; the eastern slopes are much drier than the western slopes. Winter and annual precipitation increases with elevation; at high altitude precipitation is mostly snow.

Vegetation zones are well differentiated, generally in altitudinal belts. In the Sierra Nevada, southern Cascades and northern Coast Range, the slopes, from about 500 to 1,200 m, are covered by coniferous and shrub associations. On higher slopes, foothill pine and blue oak dominate, forming typical open or woodland stands. Above this belt, between 600 and 1,800 m in the Cascades and between 1,500 and 2,400 m or higher in the south, the most important trees are ponderosa pine, Jeffrey pine, Douglas fir, sugar pine, white fir, California red fir and incense cedar, but several other conifers are also present. The spectacular giant sequoia grows in a few groves on the western slopes. On the dry eastern slopes, Jeffrey pine replaces ponderosa pine. The subalpine zone begins at 1,800 to 2,500 m and extends upslope for about 300 m. Mountain hemlock, California red fir, lodgepole pine, western white pine and whitebark pine are important. The timberline ranges from about 2,100 m in the north to 3000 m in the south.

Further south in the drier California Coastal Range, the vegetation consists of sclerophyll forest and chaparral. Chaparral is found on south-facing slopes and drier sites, while forest appears on northfacing slopes and wetter sites. The most important evergreen trees are California live oak, canyon live oak, interior live oak, tanoak, California laurel, Pacific madrone, golden chinkapin and Pacific bayberry. At higher elevations and near the ocean, chaparral is often interspersed with coniferous forest.

Vegetation zones in the southern Rocky Mountains resemble those further north but occur at higher elevations. The foothill zone, reaching as high as 2,000 m, is characterized by mixed grasses, chaparral brush, oak-juniper woodland and pinyon-juniper woodland. At about 2,000 m, open forests of ponderosa pine are found, although pinyon and juniper occupy south-facing slopes. In Arizona, the pine forests are strongly infused with Chihuahuan pine and Apache pine. Pine forest is replaced at about 2,400 m by Douglas fir. Aspen is common in this zone and limber pine grows in places that are rockier and drier. At about 2,700 m the Douglas fir zone merges into a belt of Englemann spruce and corkbark fir. Limber pine and bristlecone pine grow in the rockier places. The alpine zone starts around 3,400 m.

The vegetation of the western Sierra Madre in Mexico includes both evergreen and deciduous forest, primarily composed of conifers and oaks. These grow usually from 10 to 30 m, sometimes reaching 50 m. Mountain cloud forest also occurs. Mexico has about 40 species of pine and more than 150 species of oak.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abies amabilis
Abies bracteata
Abies concolor
Abies durangensis
Abies flinckii
Abies grandis
Abies guatemalensis
Abies hickelii
Abies lasiocarpa
Abies lowiana
Abies magnifica
Abies mexicana
Abies religiosa
Abies vejarii
Arbutus menziesii
Calocedrus decurrens
Castanopsis chrysophylla
Lithocarpus densiflorus
Myrica californica
Picea engelmannii
Pinus albicaulis
Pinus contorta
Pinus engelmannii
Pinus flexilis
Pinus jeffreyi
Pinus lambertiana
Pinus leiophylla
Pinus longaeva
Pinus monticola
Pinus ponderosa
Pinus sabiniana
Populus tremuloides
Pseudotsuga menziesii
Quercus agrifolia
Quercus chrysolepis
Quercus douglasii
Quercus wislizeni
Sequoiadendron giganteum
Symplocos citrae
Tsuga mertensiana
Umbellularia californica

5.4.11 – Tropical Rain Forest

This zone encompasses parts of the Gulf coastal plain and the lowlands of the Chiapas Sierra Madre in Mexico as well as lowlands along the Caribbean Coast and small areas along the Pacific Coast in Central America. Parts of the Caribbean islands are also included. Year-round temperatures average between 20° and 26°C with little seasonal variation. The average annual precipitation range is 1,500 to 3,000 mm and in some areas may total more than 4,000 mm. The dry season lasts less than three months, occurring in winter. North of about 12°S latitude, hurricanes (tropical cyclones) bring very heavy regional rains from August to October.

The evergreen to semi-evergreen forest along the Atlantic Coast is tall and dense. The forest has a complex and diverse flora with approximately 5,000 vascular plant species. Canopy trees reach 30 to 40 m high, with emergent trees up to 50 m. The subcanopy layer is dense, with trees from 5 to 25 m tall. The understorey layers present a great variety of palms and tree ferns. Common tree species include paque or paleto, allspice tree, breadnut, manteco, masica, masaquilla, laurel, maria, hule, cuajada, caobina, seliyon, sangre de pozo, varillo, caoba, cumbillo or sombrerete, sangre real and San Juan or copai-yé wood. There are also well-developed rain forests in specific places on the Pacific side of Central America. Pine grows in infertile locations, alone or in association with oak.

An evergreen forest, intermediate in height, with two or three strata, grows between 400 and 1 300 m altitude on the wetter (Atlantic) side of the Central American ranges. Canopy trees are mostly 30 to 40 m tall. The subcanopy is very dense with trees 15 to 25 m tall.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abarema barbouriana
Abarema idiopoda
Abarema macradenia
Acosmiun panamense
Aiouea costaricensis
Albizia niopoides
Alfaroa costaricensis
Alfaroa guanacastensis
Alnus acuminata
Amanoa guianensis
Ampelocera hottlei
Anacardiun excelsum
Andira inermis
Aniba venezuelana
Anthodiscus chocoensis
Aspidosperma megalocarpon
Aspidosperma myristicifolium
Aspidosperma spruceanum
Astronium graveolens
Balizia elegans
Batocarpus costaricensis
Beilschmiedia anay
Beilschmiedia ovalis
Beilschmiedia pendula
Beilschmiedia sulcata
Billia columbiana
Billia hippocastanun

Bombacopsis quinata
Brosimum alicastrum
Brosimum costaricanun
Brosimum lactescens
Brosimum utile
Brunellia costaricensis
Buchenavia costaricensis
Bursera simarouba
Cabralea canjerana
Caesalpinia eriostachys
Calatola costaricensis
Calophyllum brasiliense
Calycophyllum candidissimum
Campnosperma panamensis
Carapa guianensis
Cariniana pyriformis
Caryocar costaricense
Caryodaphnopsis burgeri
Castilla elastica
Castilla tunu
Cedrela fissilis
Cedrela odorata
Cedrela salvadorensis
Cedrela tonduzii
Ceiba pentandra
Cespedesia macrophylla
Chimarrhis latifolia
Chimarrhis parviflora
Chloroleucon eurycyclum
Cinchona pubescens
Cinnamomum cinnamomifolium
Clethra mexicana
Coccoloba tuerckheimii
Cojoba arborea
Conceveiba pleiostemona
Copaifera aromatica
Copaifera camibar
Cordia alliodora
Cordia bicolor
Cordia gerascanthus
Cordia megalantha
Cornus disciflora
Couma macrocarpa
Couratari guianensis
Couratari scottmori
Croton smithianus
Cynometra hemitomophylla
Dalbergia congestiflora
Dalbergia glomerata
Dalbergia melanocardium

Dalbergia retusa
Dendropanax arboreus
Dialium guianense
Dilodendron costaricense
Diphysa americana
Dipteryx panamensis
Dussia macroprophyllata
Elaeoluma glabrescens
Enterolobium cyclocarpum
Enterolobium schomburgkii
Ficus insipida
Ficus yoponensis
Genipa americana
Gliricidia sepium
Goethalsia meiantha
Gordonia brandegei
Gordonia fruticosa
Grias cauliflora
Guaiacum sanctum
Guarea grandifolia
Guarea rhopalocarpa
Guettarda turrialbana
Haematoxylun brasiletto
Heliocarpus appendiculatus
Hernadia stenura
Hernandia didymantha
Hieronyma alchorneoides
Hieronyma oblonga
Humiriastrum diguense
Hura crepitans
Hymenaea courbaril
Hymenolobium mesoamericanum
Ilex skutchii
Inga alba
Inga coruscans
Jacaranda copaia
Lacunaria panamensis
Laetia procera
Lafoensia punicifolia
Laguncularia racemosa
Lecointea amazonica
Lecythis ampla
Lennea viridiflora
Licania affinis
Licania arborea
Licania operculipetala
Licania platypus
Licaria cufodontisii
Licaria excelsa
Licaria multinervis

Lippia myriocephala
Lippia torresii
Lonchocarpus costaricensis
Lonchocarpus ferrugineus
Lonchocarpus minimiflorus
Luehea seemannii
Lysiloma divaricatum
Maclura tinctoria
Macrohasseltia macroterantha
Magnolia poasana
Magnolia sororum
Manilkara chicle
Manilkara zapota
Maranthes panamensis
Mauria sessiliflora
Micropholis crotonoides
Minquartia guianensis
Mora oleifera
Mortoniodendron anisophyllum
Myrcianthes fragrans
Myrospermum frutescens
Myroxylon balsamum
Naucleopsis naga
Nectandra cissiflora
Nectandra cufodontisii
Nectandra kunthiana
Nectandra nitida
Nectandra ramonensis
Nectandra reticulata
Nectandra sinuata
Nectandra turbacensis
Newtonia suaveolens
Ochroma pyramidale
Ocotea austinii
Ocotea babosa
Ocotea brenesii
Ocotea dentata
Ocotea endresiana
Ocotea glaucosericea
Ocotea hartshorniana
Ocotea insularis
Ocotea mollifolia
Ocotea monteverdensis
Ocotea oblonga
Ocotea pseudopalmana
Ocotea puberula
Ocotea skutchii
Ocotea stenoneura
Ocotea valeriana
Ocotea veraguensis

Ocotea whitei
Oreomunnea pterocarpa
Ormosia velutina
Otoba novogranatensis
Panopsis suaveolens
Paramachaerium gruberi
Parinari excelsa
Parkia pendula
Pelliciera rizophorae
Peltogyne purpurea
Pentaclethra macroloba
Persea americana
Persea caerulea
Persea rigens
Persea schiedeana
Phyllocarpus septentrionalis
Pimenta dioica
Pinus caribaea
Piscidia carthagenensis
Platymiscium parviflorum
Platymiscium pinnatum
Pleurothyrium palmanum
Podocarpus costaricensis
Podocarpus guatemalensis
Podocarpus macrostachyus
Poulsenia armata
Pourouma bicolor
Pouteria congestifolia
Pouteria izabelensis
Pouteria viridis
Povedadaphne quadriporata
Prioria copaifera
Protium costaricense
Protium glabrum
Protium panamense
Protium pittieri
Prumnopitys standleyi
Prunus annularis
Prunus cornifolia
Pseudobombax septenatum
Pseudolmedia spurea
Pseudosamanea guachapele
Psidium sartorianum
Pterocarpus hayesii
Pterocarpus officinalis
Qualea paraensis
Quararibea asterolepis
Quercus brenesii
Quercus copeyensis
Quercus costaricensis

Quercus oocarpa
Quercus rapurahuensis
Rhizophora racemosa
Richeria dressleri
Rollinia microsepala
Roupala glaberrima
Roupala montana
Ruptiliocarpon caracolito
Sacoglottis trychogyma
Samane saman
Schefflera morototoni
Schizolobium parahyba
Sclerolobium costaricense
Sideroxylon capiri
Simarouba amara
Simarouba glauca
Simira maxoni
Sloanea faginea
Sloanea latifolia
Spondias mombin
Sterculia apetala
Stryphnodendron microstachyum
Swietenia humilis
Swietenia macrophylla
Symphonia globulifera
Tabebuia chrysantha
Tabebuia guayacan
Tabebuia impetiginosa
Tabebuia ochracea
Tabebuia rosea
Tachigali versicolor
Talauma gloriensis
Tapirira mexicana
Tapirira myriantha
Terminalia amazonia
Terminalia bucidioides
Terminalia oblonga
Tetragastris panamensis
Ticodendron incognitum
Trattinickia aspera
Trema integerrima
Trichilia adolfi
Ulmus mexicana
Vantanea barbourii
Vatairea lundelli
Virola guatemalensis
Virola koschnyi
Virola sebifera
Virola surinamensis
Vitex cooperii

Vochysia allenii
Vochysia ferruginea
Vochysia guatemalensis
Vochysia hondurensis
Vochysia megalophylla
Weinmannia pinnata
Weinmannia wercklei
Willianodendron glaucophyllum
Wimmeria sternii
Xylopia sericophylla
Zanthoxylon ekmanii
Zanthoxylon kellermanii
Zinowiewia costaricensis

5.4.12 – Tropical Moist Deciduous Forest

This zone consists of the lower Pacific part of the central mountain ranges in Central America, the plains and hills of the Yucatan Peninsula, humid parts of the Gulf of Mexico plains and the Everglades in the United States. The climate is drier than in the rain forest zone and the dry season is more pronounced (three to five months). Average annual precipitation is around 1,300 mm in El Salvador. It falls to less than 1,000 mm in Honduras and increases again from Nicaragua to Costa Rica. Most of the Yucatan Peninsula in Mexico receives 1,000 to 1,500 mm.

The predominant vegetation is deciduous high forest with three or four storeys and approximately 100 tree species in association on fertile soils. From Nicaragua southwards the associations are enriched by many South American. Certain distinct associations include pure stands of cativo on riparian flood lands, palm swamps and mangrove swamps on tidal estuaries.

A two-layer semideciduous, seasonal forest of medium height grows in the drier parts of the zone, from 600 to about 1,600 m. The canopy is are mostly dry-season deciduous trees about 25 m tall. Understorey trees are 10 to 20 m tall.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abrus precatorius
Acacia pennatula
Acrocomia spinosa
Agave sobolifera
Alchornea latifolia
Anacardium excelsum
Anacardium occidentale
Andira inermis
Annona glabra
Annona muricata
Annona reticulata
Annona squamosa
Ardisia spicigera
Aristolochia trilobata
Aspidosperma megalocarpon
Aspidosperma cruentum
Astronium graveolens
Ateleia pterocarpa

Bactris balanoidea
Balizia leococalyx
Bambusa longifolia
Bernoullia flammea
Bixa orellana
Blepharidium mexicanum
Bletia purpurea
Bomarea edulis
Bontia daphnoides
Bravaisia integerrima
Brosimum alicastrum
Brya ebenus
Buchenavia capitata
Bucida buceras
Bursera simarouba
Bursera simarouba
Bursera simaruba
Byrsonima coriacea
Byrsonima crassifolia
Cabomba palaeformis
Caesalpinia bonduc
Caesalpinia violacea
Calathea allouia
Calophyllum antillanum
Calophyllum brasiliense
Calophyllum calaba
Calycogonium squamulosum
Calycophyllum candidissimum
Canella winterana
Capraria biflora
Carapa guianensis
Carica papaya
Carludovica palmata
Cassia alata
Castilla elastica
Catalpa longissima
Cecropia obtusifolia
Cecropia peltata
Cecropia schreberiana
Cedrela odorata
Ceiba pentandra
Celtis laevigata
Chaetoptelea jamaicense
Chaetoptelea mexicana
Chimarrhis cymosa
Chione venosa
Chrysophyllum cainito
Chrysophyllum oliviforme
Citharexylum fruticosum
Cladium mariscus

Clethra occidentalis
Clusia flava
Coccoloba uvifera
Coccothrinax jamaicensis
Cochlospermum vitifolium
Cojoba arborea
Colubrina arborescens
Colubrina elliptica
Copaifera officinalis
Corchorus hirtus
Corchorus siliquosus
Cordia alliodora
Cordia curassavica
Cordia gerascanthus
Coussapoa oligocephala
Crescentia cujete
Crossopetalum rhacoma
Cucumis anguria
Curatella americana
Cymbopetalum penduliflorum
Dacryodes excelsa
Dialium guianense
Didymopanax morototoni
Dipteryx panamensis
Dussia martinicensis
Eleocharis interstincta
Entada gigas
Eryngium foetidum
Eschweilera calyculata
Eschweilera subglandulosa
Eugenia ligustrina
Eugenia stahlii
Eupatorium odoratum
Eupatorium triplinerve
Fevillea cordifolia
Ficus cookii
Ficus glabrata
Garcinia humilis
Genipa americana
Ginoria nudiflora
Gliricidia sepium
Gossypium barbadense
Gouania lupulina
Guada spinosa
Guaiacum officinale
Guaiacum sanctum
Guarea glabra
Guarea grandifolia
Guarea guidonia
Guatteria anomala

Guatteria caribaea
Guazuma ulmifolia
Guettarda valenzuelana
Gynerium sagittatum
Haenianthus salicifolius
Heliconia latispatha
Hernandia sonora
Hibiscus elatus
Homalium racemosum
Hura crepitans
Hyeronima clusioides
Hymenaea courbaril
Hymenocallis littoralis
Ilex cassine
Ilex krugiana
Ilex guianensis
Ilex panamensis
Inga laurina
Inga sapindoides
Inga vera
Ischnosiphon arouma
Jatropha curcas
Juglans insularis
Juglans jamaicensis
Justicia angusta
Justicia pectoralis
Justicia secunda
Justicia breviflora
Justicia caudata
Justicia chiapensis
Justicia chlorostachya
Justicia comata
Justicia inequalis
Justicia lindeniana
Justicia pectoralis
Justicia tuerckheimiana
Lecythis ollaria
Lecythis pisonis
Lecythis usitata
Lemna minuta
Licania platypus
Lindenia rivalis
Lonchocarpus guatemalensis
Lonchocarpus luteomaculatus
Lonchocarpus pentaphyllus
Lonchocarpus sericeus
Lucuma salicifolia
Ludwigia octovalvis
Luehea speciosa
Lysiloma acapulcense

Lysiloma bahamensis
Lysiloma latisiliqua
Machaerium marginatum
Maclura tinctoria
Magnolia cubensis
Magnolia schideana
Malpighia emarginata
Mammea americana
Manicaria plukenetii
Manilkara bidentata
Manilkara jaimiqui
Manilkara zapota
Matayba apetala
Melicoccus bijugatus
Meliosma herbertii
Micropholis guyanensis
Micropholis rugosa
Microtea debilis
Mimosa pigra
Mimosa pudica
Mirandaceltis monoica
Muntingia calabura
Myrciaria floribunda
Myrica cerifera
Myrica mexicana
Najas wrightiana
Nectandra antillana
Nectandra coriacea
Neurolaena lobata
Ochroma lagopus
Ochroma pyramidale
Ocotea martinicensis
Ormosia jamaicensis
Oxandra laurifolia
Pachira aquatica
Pancratium littorale
Parthenium hysterophorus
Pereskia aculeata
Petitia domingensis
Petiveria alliacea
Phoebe montana
Phragmites australis
Phyla stoechadifolia
Phyllanthus amarus
Picrasma excelsa
Pilocarpus racemosus
Pilosocereus royeni
Pimenta dioica
Pimenta racemosa
Pinus oocarpa

Pinus pseudostrobus
Pinus tenuifolia
Piriqueta cistoides
Piscidia carthagenensis
Piscidia piscipula
Pithecellobium arboreum
Platymiscium dimorphandrum
Platymiscium yucatanum
Pluchea carolinensis
Polygonum acuminatum
Pontederia sagittata
Porophyllum ruderale
Pouteria multiflora
Prioria copaifera
Prunus occidentalis
Pseudobombax ellipticum
Pseudolmedia oxyphyllaria
Psidium guajava
Pterocarpus rohrii
Quararibea funebris
Quassia amara
Quercus anglobonduensis
Quercus corrugata
Quercus crassifolia
Quercus oocarpa
Quercus peduncularis
Quercus skinneri
Rollinia mucosa
Roupala montana
Ruellia tuberosa
Ryania speciosa
Salix humboldtiana
Sapindus saponaria
Scheelea liebmannii
Schizolobium parahybum
Sebastiana longicuspis
Sideroxylon celastrinum
Sideroxylon foetidissimum
Sideroxylon reclinatum
Sideroxylon salicifolium
Simarouba amara
Solanum americanum
Spirodela polyrrhiza
Spondias mombin
Spondias purpurea
Stachytarpheta jamaicensis
Stahlia monosperma
Sterculia apetala
Strychnos panamensis
Swietenia macrophylla

Swietenia mahagoni
Tabebuia heterophylla
Tabebuia pentaphylla
Talauma dodecapetala
Talauma mexicana
Talauma mexicana
Taxodium distichum
Tecoma stans
Terminalia amazonia
Terminalia chiriquensis
Terminalia latifolia
Tetragastris balsamifera
Thespesia grandiflora
Thespesia populnea
Trema lamarckianum
Trema micranthum
Trichilia moschata
Triumfetta semitriloba
Turnera ulmifolia
Typha domingensis
Utricularia gibba
Vatairea lundellii
Virola guatemalensis
Vitex divaricata
Vitex gaumeri
Vitex kuylenii
Vitex trifolia
Vochysia guatemalensis
Wolffia brasiliensis
Ximenia americana
Xylopia muricata
Ziziphus rignonii

5.4.13 – Tropical Dry Forest

This zone comprises flat narrow lowlands or low hilly areas up to 1,000 m altitude, located mainly along the Pacific Coast but also including interior depressions of the Sierra Madre and the northwestern plain of the Yucatan Peninsula in Mexico. The tropical climate of the zone is characterized by short intense episodes of rainfall, especially during the summer. Overall, average annual precipitation is between 600 and 1,600 mm. The dry season varies from five to eight months.

The dominant vegetation formation is dry deciduous forest. A diverse flora is present and low deciduous and semideciduous forests predominate. The forests are from 4 to 15 m tall and have three distinct strata. Southern floristic elements are prominent along with numerous endemic genera on the Pacific side. Legumes dominate the tree flora. Since these species are extremely fire resistant, they are often found on soils seriously degraded by excessive cropping and burning. In northwestern Costa Rica, in the Guanacaste region, a similar association occurs on pumice soils. This association differs in that oak accompanies the other species.

The two vegetation associations covering the major part of the zone on the Pacific Coast differ little in tree species but are quite distinct in terms of dominant species. In Mexico, the low deciduous forests contain about 6,000 vascular plant species, of which 40 percent are endemic. Where the water table is high in fertile soils, as on river flats, a taller and more luxuriant forest occurs.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia farnesiana
Acacia goldmanii
Acacia greggii
Acacia mcmurphyi
Acacia peninsularis
Achras zapota
Agave angustifolia
Alnus arguta
Anacardium excelsum
Andira inermis
Arbutus xalapensis
Astragalus fastidius
Astragalus insularis
Astragalus magdalenae
Astragalus nuttallianus
Astragalus prorifer
Astronium graveolens
Bombacopsis quinata
Brosimum alicastrum
Byrsonima crassifolia
Calliandra californica
Cedrela mexicana
Celtis iguanaea
Celtis pallida
Cercidium microphyllum
Cercidium praecox
Chlorophora tinctoria
Cordia globosa
Crataeva tapia
Crotalaria micans
Curatella americana
Cybistax donnell-smithii
Dalbergia glabra
Dalea bicolor
Dalea cliffortiana
Dalea megalostachya
Dalea mollis
Desmanthus fruticosus
Enterolobium cyclocarpum
Errazurizia benthamii
Errazurizia megacarpa
Erythroxylum mexicanum
Ficus goldmanii
Ficus palmeri

Ficus petiolaris
Forestiera phillyreoides
Fraxinus uhdei
Galactia striata
Heliotropium curassavicum
Hoffmanseggia intricata
Hymenaea courbaril
Leucaena leucocephala
Lysiloma candida
Mimosa spirocarpa
Olneya tesota
Pachycereus pecten-aboriginum
Pachycormus discolor
Parkinsonia aculeata
Petalostemon evanescens
Phaseolus acutifolius
Phaseolus filiformis
Phaseolus lunatus
Pithecellobium confine
Pithecellobium dulce
Pithecellobium saman
Platymiscium lasiocarpum
Platymiscium yucatanum
Plumeria rubra
Prosopis articulata
Prosopis glandulosa
Prosopis juliflora
Prosopis laevigata
Prosopis palmeri
Prosopis pubescens
Prosopis reptans
Prosopis spicigera
Prosopis tamaulipana
Prosopis velutina
Prunus fremontii
Prunus ilicifolia
Prunus lyonii
Psorothamnus emoryi
Quercus oblongifolia
Quercus oleoides
Rhamnus crocea
Rhus integrifolia
Rhus kearneyi
Rhus lentii
Rhus microphylla
Rhynchosia minima
Schinus molle
Schoepfia californica
Schrankia diffusa
Senna confinis

Senna covesii
Senna purpusii
Stenocereus standleyi
Sweetia panamensis
Swietenia humilis
Tabebuia chrysantha
Tephrosia palmeri
Tephrosia vicioides
Tilia mexicana
Vauquelinia californica
Zizyphus obtusifolia
Zizyphus parryi

5.4.14 – Tropical Mountain Systems

The climate in the mountain areas varies enormously. Wind-exposed areas are normally wet, while interior valleys are usually moist or dry. Monthly mean temperature shows little seasonal variation but ranges from 12°C at about 1,500 m to less than 6°C at 3,800 m on mountain summits.

Broadleaf forests prevail in highland areas of Mexico, Guatemala, Honduras and Nicaragua, but pine forests are also very common. In the mountain areas of Guatemala where annual rainfall is less than 1,000 mm, the most notable trees are pine and several species of oak. Other genera from the temperate zone such as willow and maple are also represented. On sites where annual precipitation exceeds 1,000 mm, the climax forest consists of mixed broadleaf forest, including members of the Lauraceae and Ericaceae families. The forest here is tall and very dense, with canopy trees generally reaching 30 m in height, and it has a dense shrub layer.

The high area of Costa Rica and Panama includes several altitudinal belts. The so-called coffee belt, between 600 and 1,600 m, is an important zone in Central America since most of the population lives there. This belt is part of the previously described tropical lowland zone. From 1,600 m to approximately 2,800 m, the vegetation can is either very tall oak forest or mixed Lauraceae-rich forest. The tall oak forest is a high, comparatively open stand, characterized by emergent, large-crowned oaks reaching up to 50 m, and a lower stratum of relatively small to medium-sized trees. The Lauraceae-rich forest is not as tall as the oak forest but still reaches 30 m in height. The forest is very dense, with multiple strata. Genera represented from the Lauraceae family include Ocotea, Phoebe, Nectandra and Persea. From 2 800 to 3,500 m there are many shrubs and a bamboo species. In the primary forest, evergreen oaks dominate the tree canopy, which reaches a height of some 25 to 30 m.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Pinus pseudostrobus
Quercus copeyensis
Quercus costaricensis
Quercus seemanni

5.5 – Oceania

Oceania as a whole contains less than 200 million hectares of forests corresponding to 5 percent of the world total. Oceania's forests amount to 6.6 ha per capita, which is the highest at world level. Almost all forests are located in the tropical ecological domain. The dry forest types in

Australia dominate the region's forest area.

Table 5.05 - Forest Area per Ecologic Zone - Oceania (Million Hectares)

Ecologic Zone	*Total Area*	*Forest Cover*	*Forest Area*
Tropical	**210**	**40%**	**84**
Rain forest	46	78%	36
Moist	3	56%	2
Dry	47	51%	24
Shrub	107	17%	18
Mountain	7	55%	4
Subtropical	**603**	**9%**	**55**
Humid	28	40%	11
Dry	12	63%	8
Steppe	147	22%	32
Desert	416	1%	4
Temperate	**42**	**36%**	**15**
Oceanic	22	36%	8
Mountain	20	36%	7
Total	**855**	**18%**	**154**

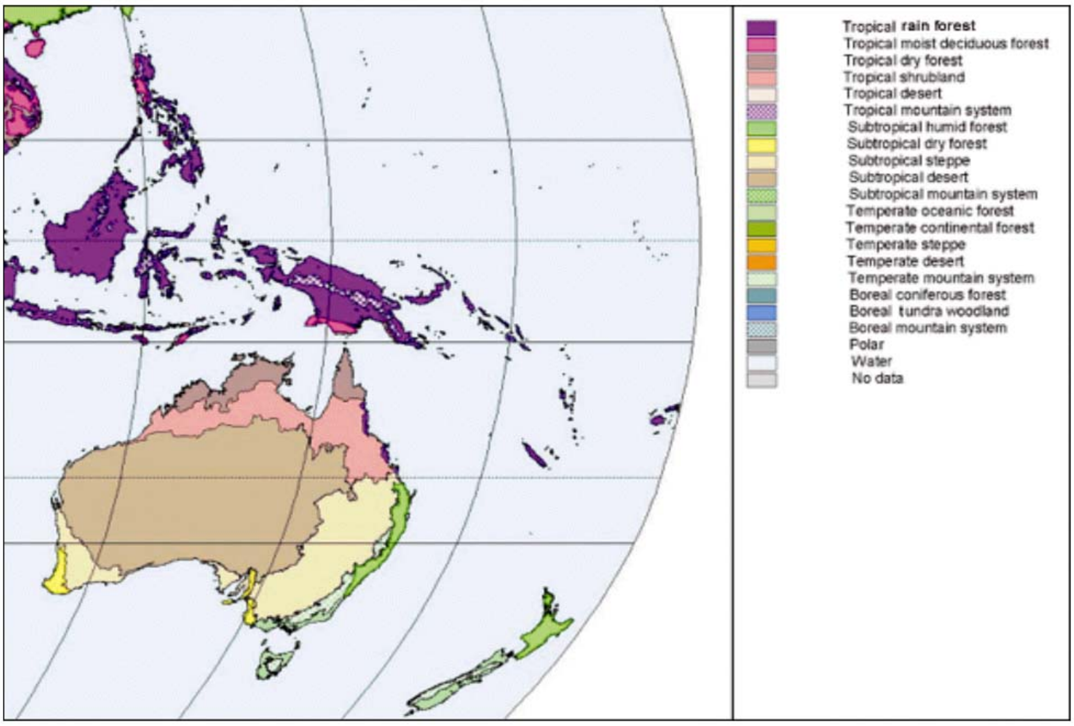
Source: FAO, 2001

Forest plantation areas are located mainly in Australia and New Zealand and represent 1.4 percent of the total forest area. The annual net loss, based on country reports, is estimated at 365,000 ha, corresponding to 0.2 percent annually.

Oceania comprises of Australia, New Zealand, Papua New Guinea and the Pacific Islands (Micronesian, Melanesian and Polynesian archipelagos). The descriptions of the ecological zones of Papua New Guinea are dealt with under Asia. This country forms an ecological entity with the western half of the island of New Guinea, Irian Jaya, a province of Indonesia. Figure 5.06 shows the Oceanian ecologic zones distribution.

Figure 5.06 – Oceanian Ecologic Zones

Source: FAO, 2001



5.5.1 – Tropical Rain Forest

Oceania, the Pacific Islands and small patches in northeastern Australia (Queensland) constitute this zone, in addition to a large portion of Papua New Guinea.

The climate of the Pacific Islands is dominated by the trade winds and most of islands have ample precipitation. The average annual precipitation generally varies between 1,500 and 4,000 mm and the dry season is seldom severe. Locally, rainfall depends on the relief and the leeward side may be fairly dry. Mean temperature at sea level is about 23°C near the Tropics and 27°C at the equator, with little difference between the hottest and coolest months. Cyclonic disturbances mainly affect the western Pacific archipelagos (Melanesia and western Micronesia).

The coastal area of northeastern Australia has a tropical wet climate and receives the highest annual rainfall in Australia. It has a mean annual precipitation of 1,500 to 2,500 mm with some areas exceeding 4,500 mm. There is a marked summer maximum (January to March). The mean annual temperature is around 23°C.

The rain forests of the tropical Pacific Islands are generally evergreen. Their structure is comparable to that of the Indo-Malayan forests but the flora of the dominant strata is often relatively poor. The tallest hardwood forests, with heights ranging from 30 to 45 m, are found on deep volcanic soils. About a dozen species are the main constituents of the canopy, overtopped occasionally by banyan figs. In Vanuatu, Fiji and Samoa this forest type is somewhat lower (about 30 m) and floristically slightly different. New Caledonian flora is totally different from that of the forests in other parts of Melanesia. Clusiaceae, Cunoniaceae, Myrtaceae, Myrtoideae, Proteaceae and Sapotaceae predominate in the upper stratum. A poorer forest grows on the limestone atolls. In certain special environments a single species dominates the upper stratum. Examples are the *Nothofagus* spp. forests in New Caledonia and the *Metrosideros collina* forest that is found throughout the tropical Pacific. Coniferous forests belonging to the Araucariaceae, Cupressaceae, Podocarpaceae and Taxaceae families have a limited distribution throughout the Pacific.

Tropical rain forests constitute around one million hectares of Australia's forests. The forest canopy ranges from around 30 to 40 m high with emergent trees up to 50 m. They resemble the rain forests of Indo-Malaya in floristic composition except for the complete absence of Dipterocarpaceae. The presence of several primitive and restricted angiosperm genera add a further distinctive character to the rain forests. In swamp forests, limited to the coastal zone, paperbark forest often constitutes the main canopy species along with numerous palms.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia aulacocarpa
Acacia mangium
Acacia melanoxylon
Acanthus ebracteatus
Acemna smithii
Aceratium concinnum
Aceratium doggrellii
Aceratium ferrugineum
Aceratium siriocolepsis
Acmena divaricata
Acmena resa
Acronychia acidula
Acronychia chooreechillum
Acronychia crassipetala
Acronychia parviflora
Acronychia pubescens
Acronychia vestita
Agathis atropupurca
Agathis lanceolata
Agathis macrophylla
Agathis ovata
Agathis robusta
Aglaia meridionalis
Alangium javanicum
Albizia salomomnensis
Alloxylon flammeum
Alphitonia petriei
Alphitonia whitei
Antiaris toxicaria
Araucaria bernieri
Araucaria bidwillii
Araucaria biramulata
Araucaria columnaris
Araucaria cunninghamii
Araucaria humboldtensis
Araucaria laubenfelsii
Araucaria luxurians
Araucaria montana
Araucaria muelleri
Araucaria nemorosa
Araucaria rulei
Araucaria schmidii
Araucaria scopulorum
Araucaria subulata

Archidendron oblongum
Archidendron vaillantii
Archirhodomyrtus beckleri
Areca catechu
Ascarina maheshewarii
Asplenium australia
Athropteris palisotii
Austrobaileya maculata
Austromyrtus acmenioides
Austromytus dallachinna
Backhousia angustifolia
Backhousia citriodora
Backhousia myrtifolia
Barringtonia asiatica
Barringtonia papeh
Barringtonia racemosa
Beilschmidia bancroftii
Beilschmiedia collina
Beilschmiedia oligandra
Beilschmiedia recurva
Belliolum haplopus
Bleasdalea bleasdalei
Blechnum castiliginium
Blepharocarya involucrigera
Bombax ceiba
Bowenia spectabillis
Brachychiton acerifolius
Breynia oblongifolia-stipitata
Bubbia queenslandiana
Bubbia semecarpoides
Bubbia whiteana
Buchanania arborescens
Buckinghamia celsissima
Buckinghamia ferruginiflora
Burckella obovata
Callicapra longifolia
Callicapra pedunculata
Callophyllum pseudovitiense
Calophyllum australianum
Calophyllum bicolor
Calophyllum costatum
Calophyllum inophyllum
Calophyllum kiong
Calophyllum lonchophyllum
Calophyllum montanum
Calophyllum neocaledonicum
Calophyllum peekalii
Calophyllum pseudovitiense
Calophyllum ramiflorum
Calophyllum sil

Calophyllum soulattrie
Calophyllum tomentosum
Calophyllum touriga
Calophyllum vexans
Calphyllum pseudovitiense
Campnosperma auriculatum
Campnosperma brevipetiolatum
Campnosperma coriaceum
Cananga odorata
Canarium baileyannum
Canarium muellerii
Cardwellia sublimis
Castanospermum australe
Castanospermum brevivexillum
Castanospora alpandii
Casuarina equisetifolia
Casuarina papuana
Ceratopetalum apetalum
Ceratopetalum arbutifolium
Ceratopetalum corymbosum
Ceratopetalum gummiferum
Ceratopetalum hylandii
Ceratopetalum iugumensis
Ceratopetalum macrophyllum
Ceratopetalum monopetalum
Ceratopetalum montanum
Ceratopetalum succirubrum
Ceratopetalum tetrapterum
Ceratopetalum virchowii
Cerbera manghas
Ceriops tagal
Chelonespermum banikiense
Chrysophyllum lanceolatum
Colona scabra
Commersonia bartramia
Corynocarpus cribbianus
Cryptocarya cinnamomifolia
Cryptocarya corrugata
Cryptocarya densiflora
Cryptocarya exfoliata
Cryptocarya hyspodia
Cryptocarya mackinnoniana
Cryptocarya oblata
Cryptocarya pleurosperma
Cryptocarya rigida
Cupaniospsis anacardioides
Cyathea brackenridgei
Cyathea cooperi
Dacrycarpus vieillardii
Dacrydium araucarioides

Daphnandra repandula
Darlingia darlingiana
Darlingia ferruginea
Darlingia spectatissima
Davellia Pixidata
Delarbrea michieana
Dendrocnide excelsa
Dendrocnide moroides
Dillenia alata
Dillenia andreana
Dillenia crenata
Dillenia grossulariifolia
Dillenia procumbens
Dillenia salomonensis
Dillenia terneriflora
Dillenia volubilis
Diospyros ferrea
Diploglottis bracteata
Diploglottis dyplyllostegin
Dolichandrono spathacea
Doryphora aromatica
Doryphora sassafras
Drypetes australasica
Drypetes lasiogyna
Dysoxylum klanderi
Dysoxylum oppositifolium
Dysoxylum rufum
Dysoxylum setosum
Elaeocarpus acuminatus
Elaeocarpus angustifolius
Elaeocarpus arnhemicus
Elaeocarpus baeuerlenii
Elaeocarpus bancroftii
Elaeocarpus carolinae
Elaeocarpus concinnus
Elaeocarpus coorangooloo
Elaeocarpus corymbifer
Elaeocarpus costatus
Elaeocarpus culminicola
Elaeocarpus cyaneus
Elaeocarpus deplanchei
Elaeocarpus donianus
Elaeocarpus drymophilus
Elaeocarpus elliffii
Elaeocarpus eucalyptifolius
Elaeocarpus eumundi
Elaeocarpus ferruginiflorus
Elaeocarpus foveolatus
Elaeocarpus grahamii
Elaeocarpus grandiflorus

Elaeocarpus grandis
Elaeocarpus holopetalus
Elaeocarpus johnsonii
Elaeocarpus kirtonii
Elaeocarpus largiflorens
Elaeocarpus linsmithii
Elaeocarpus longifolius
Elaeocarpus longipetiolatus
Elaeocarpus michaelii
Elaeocarpus obovatus
Elaeocarpus parviflorus
Elaeocarpus peduncularis
Elaeocarpus petiolosus
Elaeocarpus reticulatus
Elaeocarpus ruminatus
Elaeocarpus sericopetalus
Elaeocarpus sphaericus
Elaeocarpus stellaris
Elaeocarpus thelmae
Elaeocarpus williamsianus
Elattostachys microcarpa
Endiandra acuminata
Endiandra bessaphila
Endiandra cowleyana
Endiandra hypotephea
Endiandra insignis
Endiandra longipedicellata
Endiandra monotana
Endiandra monothyra
Endiandra palmerstonii
Endiandra sideroxylon
Endiandra tooram
Endospermum medullosum
Endospermum myrmecophilum
Epipremnum amplissimum
Erytera serrilata
Erythrina orientalis
Erythrina variegata
Eucalyptus camaldulensis
Eucalyptus citriodora
Eucalyptus exserta
Eucalyptus intermedia
Eucalyptus maculata
Eucalyptus pellita
Eucalyptus tereticornis
Eucalyptus tessellaris
Eucalyptus urophylla
Eugenia effusa
Eugenia tierneyana
Euodia bonwickii

Euodia elleryana
Euodia vitiflora
Eupomatia barbata
Eupomatia belgraveana
Eupomatia bennettii
Eupomatia laurina
Euroschinus falcata
Fagraea gracilipes
Fagraea racemosa
Falcatifolium taxoides
Ficus aculeata
Ficus adenosperma
Ficus albipila
Ficus aspera
Ficus atricha
Ficus australis
Ficus austrina
Ficus backhousei
Ficus baileyana
Ficus beckleri
Ficus bellingeri
Ficus benghalensis
Ficus benjamina
Ficus brachypoda
Ficus bubulia
Ficus cairnsii
Ficus carica
Ficus carinata
Ficus casearia
Ficus caulobotrya
Ficus cerasicarpa
Ficus colossea
Ficus columnaris
Ficus congesta
Ficus conjesta
Ficus cooperi
Ficus copiosa
Ficus coronata
Ficus coronulata
Ficus crassipes
Ficus cristobalensis
Ficus cunninghamii
Ficus cylindrica
Ficus depressa
Ficus destruens
Ficus dictyophleba
Ficus dielsii
Ficus drupacea
Ficus edelfeltii
Ficus ehretioides

Ficus esmeralda
Ficus eugenioides
Ficus fasciculata
Ficus fitzalanii
Ficus fraseri
Ficus frondosa
Ficus frutescens
Ficus glabella
Ficus glomerata
Ficus gracilipes
Ficus hederacea
Ficus henneana
Ficus hillii
Ficus hispida
Ficus hispidioides
Ficus hombroniana
Ficus huegelii
Ficus illiberalis
Ficus indecora
Ficus infectoria
Ficus lachnocaula
Ficus lacor
Ficus leichhardtii
Ficus leptoclada
Ficus leucotricha
Ficus macrophylla
Ficus magnifolia
Ficus matanoensis
Ficus melinocarpa
Ficus mesotes
Ficus micracantha
Ficus microcarpa
Ficus mollior
Ficus mourilyanensis
Ficus muelleri
Ficus muntia
Ficus nervosa
Ficus nesophila
Ficus nodosa
Ficus novae-georgiae
Ficus nugentii
Ficus obliqua
Ficus opposita
Ficus orbicularis
Ficus pachystemon
Ficus pantoniana
Ficus parkinsonii
Ficus philippinensis
Ficus pilosa
Ficus pinkiana

Ficus platypoda
Ficus pleurocarpa
Ficus podocarpifolia
Ficus polyantha
Ficus pritzelii
Ficus psychotriifolia
Ficus puberula
Ficus pubinervis
Ficus pumila
Ficus racemosa
Ficus religiosa
Ficus retusa
Ficus rigida
Ficus rigo
Ficus rubiginosa
Ficus salicina
Ficus saruensis
Ficus saxophila
Ficus scabra
Ficus scabrifolia
Ficus sclerosycia
Ficus scobina
Ficus semicostata
Ficus septica
Ficus serpyllifolia
Ficus setistyla
Ficus shirleyana
Ficus simmondsii
Ficus smithii
Ficus stenocarpa
Ficus stipulata
Ficus stipulosum
Ficus subcaudata
Ficus subgelderi
Ficus subglabra
Ficus subinflata
Ficus subpuberula
Ficus subtrinervia
Ficus subulata
Ficus superba
Ficus thynneana
Ficus tinctoria
Ficus trichostyla
Ficus triradiata
Ficus tryonii
Ficus validinervis
Ficus variegata
Ficus vesca
Ficus virens
Ficus virgata

Ficus virginea
Ficus vitellina
Ficus watkinsiana
Ficus xerophila
Ficus yarrabensis
Flindersia acuminata
Flindersia australis
Flindersia bennettiana
Flindersia bourotiana
Flindersia brassii
Flindersia brayleyana
Flindersia chatawaiana
Flindersia collina
Flindersia dissosperma
Flindersia gravesii
Flindersia ifflaiana
Flindersia laevicarpa
Flindersia leichardtii
Flindersia maculata
Flindersia maculosa
Flindersia mazlinii
Flindersia oppositifolia
Flindersia oxleyana
Flindersia pimenteliana
Flindersia pubescens
Flindersia schottiana
Flindersia strzeleckiana
Flindersia tysonii
Flindersia unifoliolata
Flindersia xanthoxyla
Galbulimima baccata
Galbulimima belgraveana
Garcinia sessilis
Gardenia merikin
Geissois biagiana
Gleichinia kajewskii
Glochidion ferdinandi
Glochidion harveyanum
Gmelina dalrympleana
Gmelina dalrympleana
Gmelina elliptica
Gmelina fasciculiflora
Gmelina leichhardtii
Gmelina macrophylla
Gmelina moluccana
Gmelina schlechteri
Goniothalamus australis
Grevillea baileyana
Grevillea hilliana
Guioa lasioneura

Guioa pteropoda
Gulubia hombronii
Gymnostoma australianum
Gynotroches axillaris
Halfordia kendack
Halfordia scleroxyla
Harpullia frutescens
Harpullia rhyticarpa
Heritiera littoralis
Hernandia cordigera
Heterospathe woodfordiana
Hibiscus tiliaceus
Hibiscus tiliaceus
Hollandaea sayeriana
Homalium circumpinnatum
Homallium tatambense
Horsfieldia spicata
Idiospermum australiense
Inocarpus fagiferus
Instia bijuga
Irvingbaileya australis
Jagera dasyantha
Jagera pseudorlus
Kleinhovia hospita
Leea indica
Lethedon setosa
Licuala lautherbachii
Lindera queenslandica
Litsea leefeana
Lumnitzera littorea
Macaranga tanarius
Mackinlaya macrosciadia
Mallotus discolor
Maranthes corymbosa
Melaleuca viridiflora
Melia azedarach
Melicope broadbentiana
Melicope elleryana
Melicope vitiflora
Metrosideros collina
Metroxylon salomonense
Mischocarpus anodontus
Mischocarpus pyriformis
Montrouziera cauliflora
Morinda citrifolia
Musgravea heterophylla
Musgravea stenostachya
Myrtus acmenioodes
Neogullauminia cleopatra
Neolitsea australieasis

Neoscortechinia forsbesii
Neostrearia fleckeri
Nothofagus pullei
Nothofagus grandis
Nothofagus starkenborghii
Nothofagus moorei
Nypa fruticans
Ochrosia eliptica
Omalanthus novo-guineensis
Opisthiolepis hetrophylla
Ostrearia australiana
Pandanus monticola
Parachidendron pruinosum
Parinari anamensis
Parinari corymbosa
Parinari costata
Parinari gigantea
Parinari griffithiana
Parinari laurina
Parinari nonda
Parinari salomonensis
Pemphis acidula
Pennantia cunninghamii
Phaleria cleodendron
Pimelodendron amboinicum
Pithecellobium pruinosum
Pittosporum ferrugineum
Pittosporum revolutum
Pittosporum rubiginosum
Placospermum coriaceum
Planchonella macrocarpa
Planchonella thyrsodiea
Pleiogynium timorense
Podocarpus elatus
Podocarpus pilgeri
Polyscias elegans
Polyscias murrayi
Pometia pinnata
Pouteria castanosperma
Pouteria pohlmaniana
Premna corymbosa
Prumnopitys amara
Pteris pacifica
Pteris umbrata
Pterocarpus idicus
Pterocarpus indicus
Pullea stutzeri
Quassia indica
Quintinia sieberi
Quintinia verdonii

Racembambos scandens
Randia angustifolia
Randia chartacea
Randia tuberculosa
Rehderophoenix subdisticha
Rhodamnia argentea
Rhodamnia costata
Rhodamnia rubescens
Rhodamnia sessiliflora
Rhodomyrtus macrocarpa
Rhodomyrtus pervagata
Rockinghamia angustifolia
Sampucas australasica
Sarcopteryx martyana
Sarcotechia lanceolata
Sarcotoechia serrata
Schistocarpaea johnsonii
Schizomeria carrii
Schizomeria clemensiae
Schizomeria floribunda
Schizomeria gorumensis
Schizomeria ilicina
Schizomeria novoguineensis
Schizomeria orthophlebia
Schizomeria ovata
Schizomeria serrata
Schizomeria versteeghii
Schizomeria whitei
Siphonodon membranaceus
Sloanea australis
Sloanea langii
Sloanea macbrydei
Solanum capsicoides
Solanum dallachii
Solanum viride
Solanum viridifolium
Sphenostemom papuantum
Stenocarpus reticulatus
Stenocarpus sinuatus
Streblus glaber
Strongylocarium latius
Synima cordierorum
Synoum muelleri
Syzygium bungadinnia
Syzygium canicortex
Syzygium cormiflorum
Syzygium endophloium
Syzygium fibrosum
Syzygium gustavioides
Syzygium johnsonii

Syzygium kuranda
Syzygium luehmanii
Syzygium papyraceum
Syzygium wesa
Syzygium wilsonii
Tasmannia isipida
Tasmannia membrabea
Terminalia arenicola
Terminalia arostrata
Terminalia bellerica
Terminalia biangulata
Terminalia brassii
Terminalia bursarina
Terminalia calamansanai
Terminalia canescens
Terminalia carpentariae
Terminalia catappa
Terminalia chillagoensis
Terminalia chlorocarpa
Terminalia circumalata
Terminalia complanata
Terminalia crassifolia
Terminalia cunninghamii
Terminalia discolor
Terminalia edulis
Terminalia erythrocarpa
Terminalia ferdinandiana
Terminalia fitzgeraldii
Terminalia grandiflora
Terminalia hadleyana
Terminalia insularis
Terminalia latipes
Terminalia melanocarpa
Terminalia microcarpa
Terminalia muelleri
Terminalia oblongata
Terminalia petiolaris
Terminalia platyphylla
Terminalia platyptera
Terminalia porphyrocarpa
Terminalia prostrata
Terminalia pterocarpa
Terminalia pterocarya
Terminalia rogersii
Terminalia sericocarpa
Terminalia subacroptera
Terminalia supranitifolia
Terminalia thozetii
Terminalia volucris
Tetrasynandra laxiflora

Tetrasynandra longipes
Toechima erythrocarpum
Toona ciliata
Triunia erythrocarpa
Triunia montana
Tysmanniodendron ahernianum
Vitex cofassus
Waterhousea unipunctata
Weinmannia biagiana
Wikstroemia indica
Xanthophyllum octandrum
Xylocarpus granatum

5.5.2 – Tropical Mangroves

Mangroves cover rather large areas in the Melanesian archipelagos and in the Caroline Islands. They can reach a height of 25 m and the main constituents are Rhizophoraceae. Along the northern Australian coasts, which have tides of up to 10 m, are mangrove forests.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Avicennia marina
Bruguiera gymnorhiza
Ceriops tagal
Rhizophora stylosa
Sonneratia caseolaris

5.5.3 – Tropical Dry Forest, Tropical Shrubland and Tropical Desert

The Tropical Dry Forest zone is confined to the northern parts of Australia. These northern tropics have a marked seasonal alternation in moisture conditions, with an intense drought lasting six to eight months throughout the winter, followed by monsoon rainfall. The zone receives an average annual precipitation of 1,000 to 1,400 mm with around 75 percent falling in the monsoon period. The mean annual temperature is around 27°C with a mean summer maximum of 33°C. Average minimum temperatures during the monsoon period are around 23°C. The main natural vegetation is eucalypt forest and woodland. Various types occur, characterized by different dominant Eucalyptus species.

Melaleuca forests occur throughout the zone on damp or wet sites. Often these forests are narrow strips of dense pure stands along streams and swamps. Small patches of so-called semi-evergreen vine forests or monsoon forests occur along watercourses, around lagoons and on patches of soil fed by springs or runoff water from the uplands. The dominants are chiefly deciduous.

The Tropical Shrubland zone is located in the northern part of Australia immediately inland of the more humid coastal zones. The semi-arid tropics of northern Australia have a marked seasonal variation in moisture conditions with a pronounced winter drought lasting six to eight months followed by substantial monsoonal rainfall. The zone receives an average annual precipitation of 700 mm, ranging from around 350 mm to 1,000 mm. Most of the precipitation occurs during December to March, with drought conditions for the remainder of the year. The mean annual temperature is around 26°C. The natural vegetation is largely Eucalyptus forests and woodlands. The vegetation of the center of the zone is mainly Eucalyptus woodlands and Acacia forests and woodlands. Lance wood is the most widespread specie in the central northern acacia woodlands. Another characteristic vegetation are the "boxes", medium-height Eucalyptus woodlands in drier areas. At the southern end of the zone, silverleaf ironbark becomes dominant as does brigalow, which has now largely been cleared.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Acacia abbreviata
Acacia abrupta
Acacia acradenia
Acacia adoxa
Acacia adsurgens
Acacia alleniana
Acacia amanda
Acacia amentifera
Acacia ammobia
Acacia ampliceps
Acacia ancistrocarpa
Acacia aneura
Acacia arafurica
Acacia argyraea
Acacia armitii
Acacia asperulacea
Acacia auricoma
Acacia auriculiformis
Acacia ayersiana
Acacia basedowii
Acacia bivenosa
Acacia brachystachya
Acacia brockii
Acacia calcicola
Acacia cambagei
Acacia cataractae
Acacia catenulata
Acacia chippendalei
Acacia chisholmii
Acacia citriodora
Acacia clelandii
Acacia colei
Acacia conjunctifolia
Acacia conspersa
Acacia convallium
Acacia coriacea
Acacia cowleana
Acacia cuthbertsonii
Acacia cyperophylla
Acacia delicatula
Acacia desmondii
Acacia dictyophleba
Acacia difficilis
Acacia dimidiata
Acacia ditricha
Acacia dolichophylla

Acacia douglasica
Acacia drepanocarpa
Acacia dunnii
Acacia echinuliflora
Acacia elachantha
Acacia estrophiolata
Acacia filipes
Acacia froggattii
Acacia galioides
Acacia georginae
Acacia gonocarpa
Acacia gonoclada
Acacia gracilenta
Acacia grasbyi
Acacia hammondii
Acacia harpophylla
Acacia helicophylla
Acacia helmsiana
Acacia hemignosta
Acacia hemsleyi
Acacia hilliana
Acacia holosericea
Acacia homalophylla
Acacia humifusa
Acacia hyaloneura
Acacia inaequilatera
Acacia jasperensis
Acacia jennerae
Acacia jensenii
Acacia kelleri
Acacia kempeana
Acacia laccata
Acacia lacertensis
Acacia lamprocarpa
Acacia latescens
Acacia latifolia
Acacia latzii
Acacia leptocarpa
Acacia leptophleba
Acacia ligulata
Acacia limbata
Acacia linarioides
Acacia longipedunculata
Acacia lycopodiifolia
Acacia lysiphloia
Acacia macdonnelliensis
Acacia maconochieana
Acacia maitlandii
Acacia malloclada
Acacia megalantha

Acacia melleodora
Acacia mimula
Acacia minutifolia
Acacia minyura
Acacia monticola
Acacia mountfordiae
Acacia multisiliqua
Acacia multistipulosa
Acacia murrayana
Acacia neurocarpa
Acacia nuperrima
Acacia nyssophylla
Acacia olgana
Acacia oligoneura
Acacia oncinocarpa
Acacia orthocarpa
Acacia orthotricha
Acacia oswaldii
Acacia pachyacra
Acacia pachycarpa
Acacia pachyphloia
Acacia pallidifolia
Acacia paraneura
Acacia pellita
Acacia perryi
Acacia peuce
Acacia phlebocarpa
Acacia pickardii
Acacia platycarpa
Acacia plectocarpa
Acacia praelongata
Acacia praetermissa
Acacia prainii
Acacia producta
Acacia proiantha
Acacia pruinocarpa
Acacia ptychophylla
Acacia ramulosa
Acacia repens
Acacia retivenea
Acacia rhodophloia
Acacia richardsii
Acacia rigescens
Acacia sabulosa
Acacia salicina
Acacia scopulorum
Acacia sericoflora
Acacia setulifera
Acacia shirleyi
Acacia simsii

Acacia spondylophylla
Acacia stellaticeps
Acacia stenophylla
Acacia stigmatophylla
Acacia stipuligera
Acacia stipulosa
Acacia stowardii
Acacia strongylophylla
Acacia suberosa
Acacia sublanata
Acacia subternata
Acacia sutherlandii
Acacia symonii
Acacia synchronicia
Acacia tenuissima
Acacia tephrina
Acacia tetragonophylla
Acacia thomsonii
Acacia tolmerensis
Acacia torulosa
Acacia translucens
Acacia tropica
Acacia tumida
Acacia umbellata
Acacia undoolyana
Acacia valida
Acacia validinervia
Acacia victoriae
Acacia wickhamii
Acacia wiseana
Acacia yirrkallensis
Atriplex canescens
Atriplex nummulria
Atriplex glauca
Atriplex halimus
Atriplex semibaccata
Atriplex vesicaria
Atriplex indica
Brachychiton populneum
Cassia sturtii
Callitris glauca
Callitris intratroopica
Callitris robusta
Eucalyptus brevifolia
Eucalyptus dichromophloia
Eucalyptus drepanophylla
Eucalyptus grandifolia
Eucalyptus leptophleba
Eucalyptus melanophloia
Eucalyptus miniata

Eucalyptus pruinosa
Eucalyptus setosa
Eucalyptus tectifica
Eucalyptus terminalis
Eucalyptus tetradonta
Melaleuca dealbata
Melaleuca leucadendra
Melaleuca minutifolia
Melaleuca viridiflora

5.5.4 – Subtropical Humid Forest

The subtropical humid forest zone comprises the east coast of Australia, roughly between 23° and 35°S, and the North Island of New Zealand. The coastal areas of southern Queensland and northern New South Wales have a subtropical humid climate with mild winters and hot summers. Mean annual precipitation across the region is 1,100 mm, with areas on the Queensland/New South Wales border receiving in excess of 2,200 mm and rain-shadow areas receiving as little as 700 mm annually. Precipitation is reasonably well distributed. The mean annual temperature of the region is around 18°C with the northern extent 3° hotter and the southern extent 2° colder. The climate of the North Island of New Zealand is strongly influenced by the ocean. Extremes of heat and cold are absent. The mean summer temperature is 16° to 18°C with mean winter temperature around 10°C. Rainfall is high, rather regular over the island and ranges from around 1,000 mm to more than 1,500 mm (on the central plateau), with the maximum during winter.

The dominant vegetation in Australia is open Eucalyptus forest that generally exceeds 30 m tall and can often reach 50 m, while in the moist valley bottoms, warm temperate rain forests are the dominant life form. The vegetation in the center of this region is extremely diverse. In the north the inland medium-open eucalypt forests are dominated by *Eucalyptus tereticornis* and *Corymbia maculata* while the coastal forests are dominated by bloodwoods. Further to the west numerous rain shadows occur that are dominated by dry ironbark forests and woodlands.

At the center of the region, on the Queensland/New South Wales border, warm temperate rain forest is the dominant forest type. Outside this area it mainly occurs as narrow strips in the valley bottoms of Eucalyptus forest. Coachwood characterizes the rain forests between latitudes 37° and 28°S. The forests have three tree layers and in this respect resemble the richest rain forests in the tropics. In areas with lower rainfall, a drier type of rain forest appears. To the south of the Queensland border, medium to tall open Eucalyptus forests dominate the landscape, with dozens of distinct floristic communities.

Conifer-broadleaf forest represents the subtropical or warm-temperate evergreen forests of the North Island of New Zealand. Conifers, where present, form the tallest storey, usually as well-spaced, large-crowned trees, but they can also form continuous canopies. Most of the tree species are podocarps, the tallest species reaching heights of over 40 m, exceptionally 60 m. There are also two species of Libocedrus and, north of 38°S, the massive kauri. Hardwoods and some of the less-tall podocarps form the next storey, which is usually the main canopy. A host of small trees form a subcanopy and fill gaps. Small patches of beech forest occur on poor soils and at higher altitudes.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia longifolia
Acacia mearnsii

Acmena smithii
Agathis australis
Araucaria cunninghamii
Araucaria columnaris
Araucaria bidwillii
Araucaria heterophylla
Argyrodendron actinophyllum
Argyrodendron trifoliolatum
Brachychiton discolor
Casuarina cunninghamiana
Ceratopetalum apetalum
Corymbia maculata
Doryphora sassafras
Drypetes australasica
Eucalyptus acmenioides
Eucalyptus crebra
Eucalyptus fibrosa
Eucalyptus grandis
Eucalyptus intermedia
Eucalyptus melanophloia
Eucalyptus microcorys
Eucalyptus pilularis
Eucalyptus saligna
Eucalyptus tereticornis
Eucalyptus tessellaris
Podocarpus totara
Schizomeria ovata
Tristania laurina

5.5.5 – Subtropical Dry Forest, Subtropical Steppe and Subtropical Desert

The Subtropical Dry Forest is a climatically very distinct zone found in two locations in southern Australia: the southwestern tip around Perth and the central east around Adelaide. The climate occurs in two slightly different Mediterranean forms and has a significant rainfall gradient that has a major impact on the type of vegetation. The area approximately 200 km south and east to 500 km north of Perth in Western Australia has hot, dry summers. Mean annual precipitation within is around 750 mm to 1,000 mm, mostly falling between May and August. The annual average temperature is around 16°C. The southern tip of Western Australia and areas to the south of Adelaide in South Australia have slightly cooler summers and are subject to a significant rainfall gradient. The region receives 400 to 800 mm of annual precipitation in Victoria and South Australia and between 1,000 mm and 1,300 mm on the southern coast of Western Australia, with approximately 60 percent falling between May and September. The annual average temperature is 15°C. The south coast of Western Australia is generally around two degrees warmer than the rest of the zone. The vegetation in the southwest is floristically distinct from the rest of Australia. On fertile soils derived from granite, two tall forests occur: karri, where rainfall exceeds 1,000 mm in the south, and red tingle. On laterite and lateritic strew, jarrah and marri are dominant and on the coastal limestones. Karri is one of the tallest Eucalyptus in Australia and can reach a height of about 85 m and a diameter of about 7 m.

Forests up to 40 m high, with an almost closed canopy, occur in the wetter areas while in drier areas the forests reach a height of 12 to 24 m and are more open. The original vegetation covering the Lofty Block and the Naracoorte Coastal Plain was significantly different from the agricultural lands and low open Eucalyptus woodlands that occur there today. The region was originally dominated by low to medium Eucalyptus woodlands in the lower rainfall areas with gum and peppermint species. Medium-open stringybark forests and shrubby understoreys dominated the higher rainfall areas. Vegetation of the Naracoorte Coastal Plain was similar in many areas to that of the Lofty Block, with the addition of heaths in the poorly drained lowlands and inter-dune swales and Eucalyptus-mallee formations.

The Subtropical Steppe zone is confined to Australia and separated into two distinct units, a northeastern part with typical subtropical characteristics and a southern part with "warm temperate" influences. The northeastern area has a significant climatic gradient that has a major impact on vegetation. Southwestern Queensland and northwestern New South Wales have a subtropical semi-arid climate with mild winters and hot summers. The mean annual precipitation of 350 mm is fairly evenly distributed throughout the year, with a slight increase from December to February. The mean annual temperature of the region is around 2°C. The region is commonly known as the Mulga Lands. Southern central Queensland and northern central New South Wales have a subtropical semi-arid climate with mild winters and hot summers. The mean annual precipitation is 560 mm, decreasing to 350 mm towards the interior and increasing to 700 mm on the western slopes of the Great Dividing Range.

Precipitation is evenly distributed throughout the year, with a slight increase from December to February. The mean annual temperature of the region is around 19°C. This zone covers regions commonly known as the Southern Brigalow Belt, the Darling Riverine Plain, the South Western Slopes of New South Wales and the Cobar Peneplain. The southern part has a semi-arid climate with a marked winter increase in precipitation. It has average annual precipitation of 375 mm with as little as 250 mm in inland areas and up to 600 mm at higher altitudes (300 m) towards the coast. Precipitation is markedly winter dominant, increasing from east to west. The mean annual temperature is around 17°C. Low Acacia aneura woodlands and shrublands commonly known as "mulga" dominate the Mulga Lands. This species occurs as small trees in the higher rainfall eastern margins and as low shrub towards the interior. Five primary vegetation types occur within the Southern Brigalow Belt. These are: ironbark woodlands on the eastern margins; ironbark and Callitris forests; brigalow forests and woodlands and poplar box woodlands in the central and interior regions. All also occur as mixed forest and mosaics of relatively pure stands.

River redgum and blackbox dominate the Darling Riverine Plain. The Cobar Peneplain is dominated by mulga shrublands. Other species include myall, nelia and gidgee. Box woodlands dominate the South Western Slopes. All the above vegetation communities have considerable economic importance. They all provide grazing for domestic stock and large tracts have been cleared for cultivation. Mallee is the dominant natural vegetation over large areas of the Murray-Darling, Riverina, Eyre and York Block and Mallee regions of Western Australia. The term "mallee", an aboriginal word, describes Eucalyptus with many stems arising at ground level from a large, bulbous woody structure called a lignotuber or "mallee" root. There are more than 100 mallee species and many species that occur as both mallee and tree forms. Common species include: white mallee, which dominates the wetter communities in South Australia; lerp mallee and narrow-leaved red mallee, occurring on deep sands; giant mallee, congoo mallee, yorell and redwood characterizing the main mallee alliance in the east; and tall sand mallee, confined to Western Australia found over a wide range of soil types. In more arid areas mallee is usually replaced by acacias and at the upper rainfall limit (circa 400 mm per year) by single-stemmed Eucalyptus, often of the same species. The Wheatbelt region of Western Australia has been highly modified for agriculture and today only remnants of the original vegetation exist. Medium-height Eucalyptus woodlands 10 to 30 m high with low understoreys were once dominant with jarrah forests in the higher rainfall areas to the west giving way wandoo and then salmon gum with decreased rainfall.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Acacia acanthoclada
Acacia acinacea
Acacia adsurgens
Acacia alcockii
Acacia ammobia
Acacia anceps
Acacia ancistrophylla
Acacia aneura
Acacia araneosa
Acacia argyrophylla
Acacia ayersiana
Acacia baileyana
Acacia barattensis
Acacia basedowii
Acacia beckleri
Acacia brachybotrya
Acacia burkittii
Acacia calamifolia
Acacia calcicola
Acacia cambagei
Acacia cambagei
Acacia carneorum
Acacia clelandii
Acacia colletioides
Acacia confluens
Acacia continua
Acacia coriacea
Acacia cretacea
Acacia cupularis
Acacia cyclops
Acacia cyperophylla
Acacia dealbata
Acacia dentifera
Acacia dictyophleba
Acacia dodonaeifolia
Acacia elachantha
Acacia enterocarpa
Acacia erinacea
Acacia estrophiolata
Acacia euthycarpa
Acacia farinosa
Acacia fernesiana
Acacia genistifolia
Acacia georginae
Acacia gilesiana
Acacia gillii
Acacia glandulicarpa

Acacia gracilifolia
Acacia grasbyi
Acacia grayana
Acacia gunnii
Acacia hakeoides
Acacia halliana
Acacia harpophylla
Acacia havilandiorum
Acacia helmsiana
Acacia hemiteles
Acacia hexaneura
Acacia imbricata
Acacia iteaphylla
Acacia jennerae
Acacia kempeana
Acacia lasiocarpa
Acacia latzii
Acacia leiophylla
Acacia ligulata
Acacia lineata
Acacia loderi
Acacia longifolia
Acacia maitlandii
Acacia mearnsii
Acacia melanoxylon
Acacia melleodora
Acacia menzelii
Acacia merrallii
Acacia microcarpa
Acacia minyura
Acacia mitchellii
Acacia montana
Acacia murrayana
Acacia mutabilis
Acacia myrtifolia
Acacia nematophylla
Acacia notabilis
Acacia nyssophylla
Acacia olgana
Acacia oswaldii
Acacia oxycedrus
Acacia pachyacra
Acacia papyrocarpa
Acacia paradoxa
Acacia paraneura
Acacia pendula
Acacia pickardii
Acacia pinguifolia
Acacia podalyriifolia
Acacia praemorsa

Acacia prainii
Acacia pravifolia
Acacia pruinocarpa
Acacia pulchella
Acacia pycnantha
Acacia quornensis
Acacia ramulosa
Acacia retinodes
Acacia rhetinocarpa
Acacia rhigiophylla
Acacia rhodophloia
Acacia rigens
Acacia rivalis
Acacia rostellifera
Acacia rupicola
Acacia salicina
Acacia saligna
Acacia sclerophylla
Acacia simmonsiana
Acacia spilleriana
Acacia spinescens
Acacia spooneri
Acacia stenophylla
Acacia stowardii
Acacia stricta
Acacia strongylophylla
Acacia suaveolens
Acacia symonii
Acacia tarculensis
Acacia tenuior
Acacia tenuissima
Acacia tetragonophylla
Acacia toondulya
Acacia trineura
Acacia triquetra
Acacia validinervia
Acacia verniciflua
Acacia victoriae
Acacia whibleyana
Acacia wilhelmiana
Actinostrobus pyramidalis
Adenanthos cygnorum
Agonis flexuosa
Agonis linearifolia
Allocasuarina fraseriana
Allocasuarina verticillata
Banksia attenuata
Banksia grandis
Banksia littoralis
Banksia marginata

Banksia menziesii
Banksia ornata
Brachychiton populneum
Callitris glauca
Callitris gracilis
Callitris preissii
Casuarina obesa
Casuarina cunninghamiana
Corymbia calophylla
Dryandra sessilis
Eucalyptus accedens
Eucalyptus alba
Eucalyptus albens
Eucalyptus baxteri
Eucalyptus blakelyi
Eucalyptus calophylla
Eucalyptus camaldulensis
Eucalyptus crebra
Eucalyptus decipiens
Eucalyptus diversicolor
Eucalyptus diversifolia
Eucalyptus dumosa
Eucalyptus eremophila
Eucalyptus fibrosa
Eucalyptus foecunda
Eucalyptus gomphocephala
Eucalyptus globulus
Eucalyptus gracilis
Eucalyptus incrassata
Eucalyptus jacksonii
Eucalyptus laeliae
Eucalyptus lanepoolei
Eucalyptus largiflorens
Eucalyptus leucoxylon
Eucalyptus marginata
Eucalyptus melliodora
Eucalyptus microcarpa
Eucalyptus obliqua
Eucalyptus odorata
Eucalyptus oleosa
Eucalyptus patens
Eucalyptus populnea
Eucalyptus rudis
Eucalyptus salmonophloia
Eucalyptus sideroxylon
Eucalyptus socialis
Eucalyptus todtiana
Eucalyptus viminalis
Eucalyptus wandoo
Hovea trisperma

Hypocalymma angustifolium
Hypocalymma robustum
Kingia australis
Leptospermum lanigerum
Malaleuca decussa
Malaleuca lanceolata
Melaleuca acerosa
Melaleuca cuticularis
Melaleuca huegelii
Melaleuca incana
Melaleuca lanceolata
Melaleuca preissiana
Melaleuca rhaphiophylla
Melaleuca teretifolia
Melaleuca viminea
Olearia axillaris
Santalum acuminatum
Spyridium globulosum
Typha domingensis
Xanthorrhoea preissii
Xylomelum occidentalis

5.5.6 – Temperate Oceanic Forest

This zone covers the southeastern coast of Australia, Tasmania and the lowlands of South Island, New Zealand. The southeastern coast of mainland Australia and Tasmania has a humid, mild winter climate. Annual precipitation varies from around 600 mm in the Gippsland region in Victoria to in excess of 2,000 mm in western Tasmania. Precipitation is distributed throughout the year with a slight winter dominance, more pronounced in western Tasmania. The annual average temperature varies from around 9°C in western Tasmania to 13°C in southern Victoria and eastern Tasmania.

The western, coastal part of South Island of New Zealand has a humid climate. Annual rainfall ranges from around 1,800 mm to locally more than 4,000 mm, rather evenly distributed throughout the year. To the east of the Southern Alps, the climate is distinctly drier, with annual rainfall from 400 to 800 mm, locally below 400 mm. Also, temperatures become more extreme here, as the region is sheltered from the moderating western ocean winds. The mean annual temperature ranges from 13°C in the north to 9° in the south.

Cool temperate rain forests are found in the wetter parts of western Tasmania. These forests are often dominated by myrtle with conifers such as huon pine, celery top pine and King Billy pine. In lowland areas, the rain forests are dominated by. In Victoria, cool temperate rain forests occur in restricted areas in the coastal ranges. Dominant canopy species include southern sassafras and mountain quandong. Dry ash, stringybark and peppermint forests dominate areas of moderate rainfall to the east of this zone on the mainland and Tasmania. Many of the wetter areas of this zone in Tasmania are dominated by tall messmate/stringybark forest.

Beech and conifer-beech-broadleaf forests dominate the western lowlands and lower hills of New Zealand's South Island. In these forests, conifers form a scattered overstorey. Beeches form the main canopy, with *Nothofagus fusca* predominating on the deeper, more freely drained sites. In the extremely humid fjord country in the southwest, where rainfall exceeds 6,000 mm, the Nothofagus forests are similar in nature to those of southern Chile.

The east of South Island has little forest vegetation owing to much lower rainfall. Patches of beech-conifer-broadleaf forest occur, adjoining a wide variety of mostly anthropogenic vegetation. There is evidence that, prior to human intervention, a zone of microphyllous woodland grew under moisture regimes intermediate between those supporting forest and semi-arid grasslands.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia melanoxylon
Anodopetalum biglandulosum
Atherosperma moschatum
Athrotaxis selaginoides
Coprosma virescens
Dacrydium cupressinum
Discaria toumatou
Elaeocarpus holopetalus
Eucalyptus botryoides
Eucalyptus cypellocarpa
Eucalyptus delegatensis
Eucalyptus dives
Eucalyptus fastigata
Eucalyptus gummifera
Eucalyptus nitens
Eucalyptus nitida
Eucalyptus obliqua
Eucalyptus radiata
Eucalyptus regnans
Eucalyptus sieberi
Eucalyptus viminalis
Lagorostrobus franklinii
Leptospermum ericoides
Nothofagus cunninghamii
Nothofagus fusca
Nothofagus menziesii
Nothofagus solandri
Nothofagus truncata
Olearia lineata
Phyllocladus aspleniifolius
Podocarpus ferruginea
Quintinia acutifolia
Sophora microphylla
Weinmannia racemosa

5.5.7 – Temperate Mountain Systems

In Australia, this zone consists of the Tasmanian Highlands, the Southeastern Highlands, the Australian Alps and the New England Tablelands. New Zealand's Southern Alps on South Island are also part of the zone.

The highlands and tablelands of southeastern Australia have a cool temperate climate with annual precipitation ranging from around 600 mm at lower elevations to 1,200 mm at higher elevations. Precipitation is evenly distributed throughout the year, with most months receiving 70 to 80 mm. The annual mean temperature is around 12°C with mainland areas around 2° hotter and Tasmania 4° cooler. The Alps region of southeastern Australia receives average annual precipitation of 1 300 mm, with higher elevation areas receiving in excess of 2,000 mm, much of it as snow. Precipitation is fairly evenly distributed throughout the year. The annual average temperature for the region is around 9°C.

The climate of the Southern Alps in New Zealand is cold temperate, characterized by high annual rainfall, particularly on the western slopes. Frost and snow are abundant in winter and to some extent at all seasons.

The lower-elevation rolling hills of the southeast highlands and the elevated plateaus and hills of the New England Tablelands were originally covered with Eucalyptus forests and woodlands of stringy bark/peppermint/box species. Today, these communities mainly occur as open woodlands used for grazing.

In sheltered areas receiving more than 1,000 mm annual rainfall, tall wet Eucalyptus forests dominate with species such as alpine ash, mountain white gum and manna gum forming open forests where the canopy exceeds 40 m. The outstanding example of these forests occurs in the southern ranges of southern Victoria and Tasmania where mountain ash trees commonly exceed 70 m in height and can reach over 90 m on the best sites. In Tasmania, cool temperate rain forests are dominated by myrtle, while blackwood often forms an understorey 10 to 30 m tall.

The lower- and medium-altitude zones of the mountains of South Island, New Zealand are mostly covered by beech forest. The timberline is at around 1,200 m in the north and decreases to around 850 m in the south. Locally, beech forest is absent and depauperate conifer-broadleaf forest extends into the subalpine belt.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia melanoxylon
Dracophyllum traversi
Eucalyptus albens
Eucalyptus blakelyi
Eucalyptus caliginosa
Eucalyptus dalrympleana
Eucalyptus delegatensis
Eucalyptus laevopinea
Eucalyptus melliodora
Eucalyptus nova-anglica
Eucalyptus regnans
Eucalyptus viminalis
Griselinia litoralis
Libocedrus bidwillii
Metrosideros umbellata
Nothofagus cunninghamii
Nothofagus menziesii
Nothofagus solandri
Olearia ilicifolia
Podocarpus halii
Weinmannia racemosa

5.6 – South America

South America contains about 885 million hectares of forests which corresponds to 23 percent of the world total. South American forests amount to 2.6 ha per capita, which is considerably above the world average. Almost all forests are located in the tropical ecological domain, and South America has about 54 percent of all tropical rain forests. The proportion of forest cover in the tropical rain forest zone is 82 percent.

Table 5.06 - Forest Area per Ecologic Zone - South America (Million Hectares)

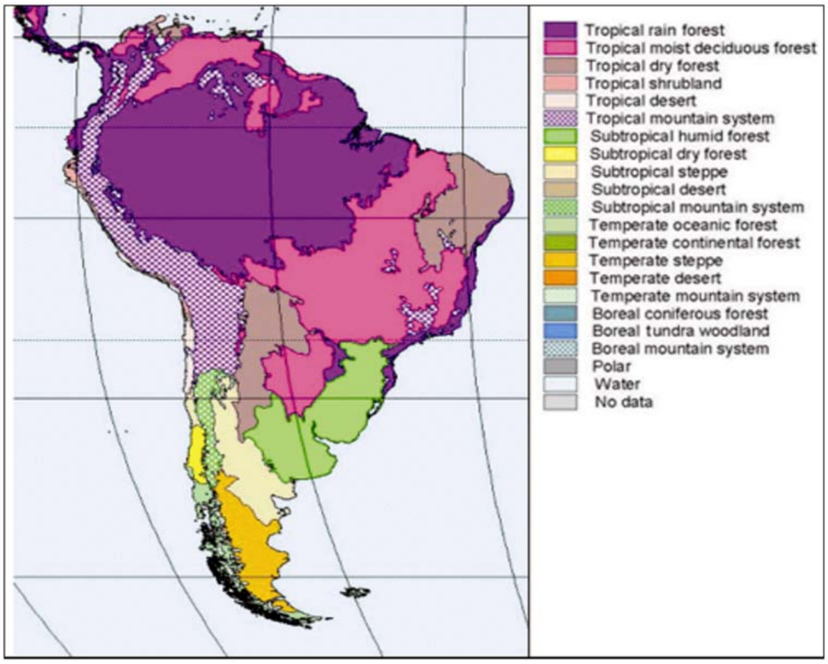
Ecologic Zone	*Total Area*	*Forest Cover*	*Forest Area*
Tropical	**1,484**	**58%**	**855**
Rain forest	668	82%	548
Moist	433	27%	117
Dry	169	86%	145
Shrub	10	13%	1
Desert	14	0%	0
Mountain	190	23%	44
Subtropical	**218**	**10%**	**21**
Humid	120	9%	11
Dry	10	89%	9
Steppe	64	1%	1
Mountain	24	4%	1
Temperate	**84**	**11%**	**10**
Oceanic	26	29%	8
Steppe	50	1%	1
Mountain	8	20%	2
Total	**1,786**	**50%**	**886**

Source: FAO, 2001

Forest plantations represent just 1 percent of the total forest cover. The annual net loss, based on country reports, is high at 3.7 million hectares annually, corresponding to 0.4 percent annually. Figure 5.07 shows the South American ecologic zones distribution.

Figure 5.07 – South American Ecologic Zones

Source: FAO, 2001



5.6.1 – Tropical Rain Forest

The tropical rain forests of South America extend over the whole Amazonian Basin, the Pacific coast of Colombia and Ecuador, the Atlantic coast of Brazil and the Parana River valley. Huge amounts of rain fall in the heart of the Amazon Basin and along the western coast (more than 3,000 mm, even up to 8,000 mm). Elsewhere, rainfall is between 1,000 and 3,000 mm, often with a short dry period in winter. Temperatures are high, especially in the Amazonian region, where the mean temperature of the coldest month is always above 20°C. On the Atlantic coast, mean temperatures decrease as latitude increases (15° to 20°C).

The Amazon Basin contains the world's largest area of tropical rain forest. In this vast extent at least 10 to 20 different vegetation types might be distinguished. The wettest type is found in the upper basin of the Amazon River, the State of Amapa in Brazil and the west coast of Colombia. The vegetation is luxuriant, multilayered evergreen forest, up to 50 m tall, with emergent trees. The most important tree families are Annonaceae, Bombacaceae, Burseraceae, Clusiaceae, Euphorbiaceae, Leguminosae, Moraceae and Sterculiaceae.

The most extensive rain forest is somewhat drier and occurs in the Amazon Basin and on the eastern foothills of the central Andes. It is a multilayered forest up to 40 m tall, with or without emergent trees, mainly evergreen but with marked leaf reduction during the short dry season. In Brazil, Leguminosae are particularly important. Evergreen swamp forest covers large areas in the Amazon region, particularly in the delta of the Amazon River.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abarema brachystachya
Abarema langsdorffii
Acacia polyphylla
Acnistus breviflorus
Aegiphila sellowiana
Aiouea saligna
Albizia edwallii
Albizia hasslerii
Alchornea glandulosa
Alchornea triplinervia

Alchorneopsis floribunda
Alchorneopsis trimera
Alexa grandiflora
Alibertia concolor
Allantoma lineata
Allophylus edulis
Allophylus petiolatus
Alseis floribunda
Alsophila setosa
Amaioua guianensis
Amaioua intermedia
Amanoa guianensis
Amburana acreana
Ampelocera edentula
Anacardium giganteum
Anacardium spruceanum
Anadenanthera colubrina
Anadenanthera peregrina
Andira anthelmia
Andira fraxinifolia
Andira inermis
Andira parviflora
Andira retusa
Aniba canelilla
Aniba firmula
Aniba parviflora
Aniba roseodora
Annona cacans
Annona glabra
Annona montana
Aparisthmium cordatum
Apeiba burchelli
Apeiba echinata
Apulea molaris
Apuleia leiocarpa
Apuleia molaris
Artocarpus integrifolia
Aspidosperma album
Aspidosperma carapanauba
Aspidosperma desmanthum
Aspidosperma ellipsocarpum
Aspidosperma oblongum
Aspidosperma olivaceum
Aspidosperma parvifolium
Aspidosperma pyricollum
Aspidosperma sandwithianum
Aspidosperma warmingii
Astrocaryum aculeatissimum
Astrocaryum aculeatum
Astronium gracile

Astronium lecointei
Astronium urundeuva
Ateleia glazioveana
Attalea dubia
Baccharis cassinifolia
Baccharis semiserrata
Bactris gasipaes
Bactris lindmaniana
Bactris setosa
Bagassa guianensis
Barnebya dispar
Batesia floribunda
Bathysa meridionalis
Bertholletia excelsa
Bixa arborea
Blepharocalyx salicifolius
Bombax aquaticum
Bombax globosum
Bombax longipedicellatum
Bombax munguba
Bombax paraensis
Bowdichia major
Bowdichia nitida
Bowdichia virgilioides
Brosimum acutifolium
Brosimum amplicoma
Brosimum glaucum
Brosimum glaziovii
Brosimum guianense
Brosimum lactescens
Brosimum parinarioides
Brosimum potabile
Brosimum rubescens
Buchenavia capitata
Buchenavia grandis
Buchenavia kleinii
Buchenavia parvifolia
Bunchosia fluminensis
Byrsonima aerugo
Byrsonima ligustrifolia
Byrsonima niedenzuiana
Cabralea canjerana
Caesalpina echinata
Calophyllum brasiliense
Calycophyllum spruceanum
Calycorectes australis
Calyptranthes eugeniopsoides
Calyptranthes grandifolia
Calyptranthes lanceolata
Calyptranthes lucida

Calyptranthes rubella
Calyptranthes strigipes
Campomanesia guaviroba
Campomanesia xanthocarpa
Campsiandra laurifolia
Capsicodendron dinisii
Capsicum lucidum
Caraipa grandifolia
Caraipa richardiana
Carapa guianensis
Cariniana estrellensis
Cariniana ianeirensis
Cariniana legalis
Cariniana micrantha
Caryocar glabrum
Caryocar microcarpum
Caryocar villosum
Casearia decandra
Casearia obliqua
Casearia sylvestris
Cassia scleroxylon
Castilla ulei
Cecropia glaziovii
Cecropia pachystachya
Cedrela fissilis
Cedrela odorata
Cedrelinga catenaeformis
Ceiba burchelli
Ceiba pentandra
Centrolobium paraense
Centrolobium robustum
Centrolobium tomentosum
Cephaelis hastisepala
Cestrum amictum
Chamaecrista adiantifolia
Chaunochiton kappleri
Chimarrhis turbinata
Chionanthus filiformis
Chinchona pubescens
Chinchona succirubra
Chlorophora tinctoria
Chorisia speciosa
Chrysophyllum flexuosum
Chrysophyllum inornatum
Chrysophyllum parananense
Chrysophyllum viride
Cinnamomum glaziovii
Citharexylum cinerium
Citharexylum myrianthum
Citronella megaphylla

Clarisia racemosa
Clethra scabra
Clethra uleana
Clinostemon mahuba
Clusia criuva
Clusia parviflora
Coccoloba alnifolia
Coccoloba crescentiaefolia
Coccoloba salicifolia
Conomorpha peruviana
Copaifera duckei
Copaifera langsdorffii
Copaifera reticulata
Copaifera trapezifolia
Cordia alliodora
Cordia bicolor
Cordia exaltata
Cordia goeldiana
Cordia magnoliifolia
Cordia scabrifolia
Cordia sellowiana
Cordia sylvestris
Cordia trichotoma
Couma guianensis
Couma macrocarpa
Couratari guianensis
Couratari multiflora
Couratari oblongifolia
Couratari stellata
Couroupita guianensis
Coussapoa microcarpa
Coussarea contracta
Croton celtidifolius
Croton floribundus
Crudia amazonica
Crudia bracteata
Crudia oblonga
Crudia pubescens
Cryptocarya aschersoniana
Cryptocarya micrantha
Cryptocarya moschata
Cryptocarya saligna
Crysophyllum anomalum
Cupania oblongifolia
Cupania vernalis
Cyathea atrovirens
Cyathea corcovadensis
Cyathea leucofolis
Cyathea phalerata
Cybistax antisyphilitica

Cynometra hostmaniana
Cynometra spruceana
Dahlstedtia pentaphylla
Dahlstedtia pinnata
Dalbergia brasiliensis
Dalbergia frutescens
Dalbergia nigra
Dalbergia spruceana
Daphnopsis racemosa
Dendrobangia boliviana
Dendropanax cuneatum
Dendropanax monogynum
Dialium guianensis
Dicksonia sellowiana
Dicorynia guianensis
Dicypellium caryophilatum
Didymopanax angustissimum
Didymopanax macrocarpum
Didymopanax morototoni
Dinizia excelsa
Diospyros brasiliensis
Diospyros praetermissa
Diploon cuspidatum
Diplotropis martiusii
Diplotropis purpurea
Dipteryx ferrea
Dipteryx magnifica
Dipteryx odorata
Dipteryx polyphylla
Drimys brasiliensis
Duguetia lanceolata
Ecclinusa ramiflora
Ecllinusa guianensis
Elisabetha paraensis
Endlicheria paniculata
Endopleura uchi
Enterolobium barnebianum
Enterolobium contortisiliquum
Enterolobium maximum
Enterolobium schombugkii
Eperua bijuga
Eperua falcata
Erisma calcaratum
Erisma lanceolatum
Erisma uncinatum
Erythrina dominguezzi
Erythrina glauca
Erythrina speciosa
Erythroxylon amplifolium
Erythroxylum frangulifolium

Eschweilera coriacea
Eschweilera grandiflora
Esenbeckia grandiflora
Eugenia bacopari
Eugenia beaurepaireana
Eugenia catharinae
Eugenia cerasiflora
Eugenia cuprea
Eugenia eurysepala
Eugenia excelsa
Eugenia florida
Eugenia glomerata
Eugenia involucrata
Eugenia moraviana
Eugenia mosenii
Eugenia multicostata
Eugenia neolanceolata
Eugenia neomyrtifolia
Eugenia oblongata
Eugenia pruinosa
Eugenia sclerocalyx
Eugenia stictosepala
Eugenia stigmatosa
Eugenia stipitata
Eugenia subavenia
Eugenia sulcata
Eugenia tinguyensis
Eugenia umbelliflora
Eupatorium itatiayense
Euplassa cantareirae
Euplassa legalis
Euplassa pinnata
Euterpe edulis
Euterpe oleracea
Euxylophora paraensis
Faramea marginata
Faramea montevidensis
Ficus enormis
Ficus glabra
Ficus gomelleira
Ficus guaranitica
Ficus insipida
Ficus maxima
Ficus organensis
Ficus pertusa
Ficus pulchella
Franchetella gongrijpii
Franchetella sagotiana
Gallesia integrifolia
Garcinia gardneriana

Geonoma elegans
Geonoma gamiova
Geonoma schottiana
Glycydendron amazonicum
Gochnatia polymorpha
Gomidesia affinis
Gomidesia anacardiaefolia
Gomidesia fenzliana
Gomidesia flagellaris
Gomidesia palustris
Gomidesia schaueriana
Gomidesia sellowiana
Gomidesia spectabilis
Gomidesia tijucensis
Gordonia fruticosa
Goupia glabra
Guapira asperula
Guapira opposita
Guarea guidonia
Guarea kunthiana
Guarea macrophylla
Guarea silvatica
Guarea trichilioides
Guatteria amazonica
Guatteria australis
Guatteria olivacea
Guatteria poeppigiana
Guatteria procera
Heisteria silviani
Hevea brasiliensis
Hevea guianensis
Hibiscus tiliaceus
Hieronyma alchorneoides
Hieronyma laxiflora
Hirtella hebeclada
Hirtella hebeclada
Humiria floribunda
Humiriastrum dentatum
Humiriastrum excelsum
Hura creptans
Hyeronima alchorneoides
Hymenaea courbaril
Hymenaea courbaril altissima
Hymenaea oblongfolia
Hymenaea palustris
Hymenaea parvifolia
Hymenolobium excelsum
Hymenolobium flavum
Hymenolobium heterocarpum
Hymenolobium janeirense

Hymenolobium modestum
Hymenolobium nitidum
Hymenolobium petraeum
Hymenolobium pulcherrimum
Hymenolobium sericeum
Ilex chamaedrifolia
Ilex dumosa
Ilex integerrima
Ilex inundata
Ilex microdonta
Ilex paraguariensis
Ilex pseudobuxus
Ilex taubertiana
Ilex theezans
Inga alba
Inga capitata
Inga edulis
Inga luschnathiana
Inga marginata
Inga nitida
Inga paraensis
Inga sessilis
Inga striata
Iryanthera grandis
Iryanthera sagotiana
Jacaranda copaia
Jacaranda micrantha
Jacaranda puberula
Jacaratia spinosa
Labatia macrocarpa
Laetia procera
Laguncularia racemosa
Lamanonia speciosa
Lecythis idatimon
Lecythis lurida
Lecythis pisonis
Lecythis zabucaja
Licania guianensis
Licania heteromorpha
Licania kunthiana
Licania licaniaeflora
Licania longistyla
Licania macrophylla
Licania micrantha
Licania octandra
Licaria aritu
Licaria cannella
Licaria rigida
Linociera mandioccana
Lonchocarpus cultratus

Luehea divaricata
Luehea speciosa
Lueheopsis duckeana
Machaerium acutifolium
Machaerium nictitans
Machaerium vellosianum
Maclura tinctoria
Macoubea guianensis
Macrolobium acaciaefolium
Malouetia arborea
Manicaria saccifera
Manilkara amazonica
Manilkara bidentata
Manilkara huberi
Manilkara inundata
Manilkara subsericea
Maprounea guianensis
Maquira coriacea
Margaritaria nobilis
Marlierea bipennis
Marlierea obscura
Marlierea reitzii
Marlierea silvatica
Marlierea suaveolens
Marlierea tomentosa
Martiodendron elatum
Matayba elaeagnoides
Matayba guianensis
Matayba juglandifolia
Mauritiella pacifica
Maytenus evonymoides
Maytenus glaucescens
Maytenus robusta
Maytenus schumanniana
Meliosma sellowii
Memora peregrina
Metrodorea flavida
Mezilaurus itauba
Mezilaurus lindaviana
Miconia brasiliensis
Miconia budlejoides
Miconia cabussu
Miconia cinerascens
Miconia cinnamomifolia
Miconia cubatanensis
Miconia dodecandra
Miconia hyemalis
Miconia latecrenata
Miconia rigidiuscula
Miconia saldanhaei

Miconia sellowiana
Miconia theizans
Miconia valtherii
Micrandra elata
Micropholis egensis
Micropholis guianensis
Micropholis melinoniana
Mimosa bimucronata
Minquartia guianensis
Mollinedia argyrogyna
Mollinedia schottiana
Mora paraensis
Moronobea coccinea
Mouriri chamissoana
Mouriri glazioviana
Myrceugenia campestris
Myrceugenia miersiana
Myrceugenia myrcioides
Myrceugenia seriatoramosa
Myrcia bicarinata
Myrcia cymoso-paniculata
Myrcia dichrophylla
Myrcia fallax
Myrcia formosiana
Myrcia glabra
Myrcia grandiflora
Myrcia hatschbachii
Myrcia heringii
Myrcia insularis
Myrcia multiflora
Myrcia obtecta
Myrcia oligantha
Myrcia pubipetala
Myrcia racemosa
Myrcia richardiana
Myrcia rostrata
Myrcia rufescens
Myrcianthes cionei
Myrciaria floribunda
Myrocarpus frondosus
Myroxylon balsamum
Myrsine coriacea
Myrsine umbellata
Nectandra cuspidata
Nectandra grandiflora
Nectandra lanceolata
Nectandra leucantha
Nectandra megapotamica
Nectandra membranacea
Nectandra oppositifolia

Nectandra pichurim
Nectandra psammophila
Nectandra puberula
Neea schwackeana
Neomitranthes glomerata
Neomitranthes obscura
Neoxythece elegans
Newtonia psilostachya
Newtonia suaveolens
Ochroma pyramidale
Ocotea aciphylla
Ocotea basicordatifolia
Ocotea baturitensis
Ocotea canaliculata
Ocotea catharinensis
Ocotea caudata
Ocotea corymbosa
Ocotea costulata
Ocotea cymbarum
Ocotea daphnifolia
Ocotea dispersa
Ocotea divaricata
Ocotea elegans
Ocotea glomerata
Ocotea guianensis
Ocotea indecora
Ocotea kuhlmannii
Ocotea laxa
Ocotea minarum
Ocotea odorifera
Ocotea pretiosa
Ocotea puberula
Ocotea pulchella
Ocotea rubra
Ocotea silvestris
Ocotea teleiandra
Oenacarpus distichus
Onychopetalum amazonicum
Oreopanax capitatum
Oreopanax fulvum
Ormosia arborea
Ormosia coutinhoi
Ormosia flava
Ormosia nobilis
Ormosia paraensis
Osteophloeum platyspermum
Ouratea multiflora
Ouratea parviflora
Ouratea vaccinioides
Panopsis sessilifolia

Parahancornia amapa
Parapiptadenia rigida
Parinari brasiliensis
Parinari excelsa
Parinari rodolphii
Parkia gigantocarpa
Parkia multijuga
Parkia pendula
Parkia velutinia
Pausandra morisiana
Peltogyne maranhensis
Peltogyne paniculata
Peltogyne paradoxa
Pera glabrata
Perebea guianensis
Persea major
Peschiera catharinensis
Picramnia camboita
Picrasma crenata
Pimenta pseudocaryophyllus
Piper aduncum
Piper arboreum
Piper gaudichaudianum
Piptadenia gonoacantha
Piptadenia paniculata
Piptocarpha angustifolia
Piptocarpha axillaris
Pithecellobium jupunba
Pithecellobium pedicellare
Pithecellobium racemosum
Pithecellobium saman
Platonia insignis
Platymiscium filipes
Platymiscium floribundum
Platymiscium trinitatis
Platymiscium ulei
Podocarpus sellowii
Posoqueria latifolia
Pourouma guianensis
Pouteria beaurepairei
Pouteria caimito
Pouteria guianensis
Pouteria hispida
Pouteria lasiocarpa
Pouteria macrocarpa
Pouteria macrophylla
Pouteria pachycarpa
Pouteria pariry
Pouteria psammophila xestophy
Pouteria torta

Pradosia lactescens
Prieurella prieurii
Protium heptaphyllum
Protium kleinii
Protium sagotianum
Protium spruceanum
Protium tenuifolium
Prunus brasiliensis
Prunus myrtifolia
Prunus sellowii
Pseudobombax grandiflorum
Pseudobombax munguba
Pseudocopaiva chodatiana
Pseudopiptadenia warmingii
Psidium cattleianum
Psidium guajava
Psychotria carthagenensis
Psychotria hastisepala
Psychotria leiocarpa
Psychotria mapourioides
Psychotria nemorosa
Psychotria nuda
Psychotria pubigera
Psychotria suterella
Pterocarpus rohrii
Pterodon pubescens
Qualea albiflora
Qualea coerulea
Qualea paraensis
Quiina glaziovii
Ragala sanguinolenta
Randia armata
Rapanea ferruginea
Rapanea hermogenii
Rapanea intermedia
Rapanea lancifolia
Rapanea parvifolia
Rapanea venosa
Raphia taedigera
Rauwolfia pentaphylla
Rhamnus sphaerosperma
Richardella macrocarpa
Richeria australis
Rollinia mucosa
Rollinia sericea
Roupala consimilis
Roupalla montana
Roupalla paulensis
Rudgea jasminioides
Rudgea jasminoides

Rudgea recurva
Rudgea viliiflora
Sacoglotis amazonica
Sacoglottis ceratocarpa
Sacoglottis guianensis
Samanea tubulosa
Sandwithiodoxa egregia
Sapium glandulatum
Sapium marmieri
Schefflera morototoni
Schefflera paraensis
Schinus terebinthifolius
Schizolobium amazonicum
Schizolobium parahybae
Schoepfia brasiliensis
Sclerolobium chrysophyllum
Sclerolobium denudatum
Sclerolobium goeldianum
Sclerolobium melanocarpum
Sclerolobium paraense
Scleronema micranthum
Scleronema praecox
Sedum praealtum
Seguieria glaziovii
Senna multijuga
Senna silvestris silvestris
Simarouba amara
Siphoneugenia guilfoyleiana
Siphoneugenia reitzii
Sloanea guianensis
Sloanea lasiocoma
Sloanea monosperma
Sloanea obtusifolia
Solanum cinnamomeum
Solanum erianthum
Solanum pseudoquina
Solanum sactaecatharinae
Solanum swartzianum
Sorocea bonplandii
Spirotheca rivieri
Spondias lutea
Spondias mombin
Sterculia chicha
Sterculia pilosa
Sterculia pruriens
Sterculia speciosa
Stryphnodendron paniculatum
Stylogine laevigata
Styrax acuminatus
Styrax glabratus

Styrax leprosus
Swartzia acutifolia
Swartzia corrugata
Swartzia glazioviana
Swartzia grandifolia
Swartzia racemosa
Swartzia simplex
Swietenia macrophylla
Syagrus romanzoffiana
Symaba subcymosa
Symphonia globulifera
Symplocos lanceolata
Symplocos laxiflora
Symplocos trachycarpos
Symplocos variabilis
Syzygiopsis oppositifolia
Syzygiopsis pachycarpa
Syzygyum jambos
Tabebuia alba
Tabebuia cassinoides
Tabebuia catarinensis
Tabebuia chrysantha
Tabebuia chrysotricha
Tabebuia impetiginosa
Tabebuia insignis
Tabebuia serratifolia
Tabebuia umbellata
Tabernaemontana hystrix
Tachigalia alba
Tachigalia myrmecophylla
Talauma ovata
Tapirira guianensis
Tapura singularis
Taralea oppositifolia
Terminalia amazonica
Terminalia dichotoma
Terminalia guianensis
Ternstroemia brasiliensis
Tetragastris altissima
Tetragastris panamensis
Tetrastylidium grandifolium
Tetrorchidium rubrivenium
Tibouchina pulchra
Tibouchina reitzii
Tibouchina sellowiana
Tibouchina trichopoda
Torresia acreana
Trattinickia burserifolia
Trattinickia rhoifolia
Trema micrantha

Trichilia casarettii
Trichilia elegans
Trichilia lepidota
Trichilia silvatica
Trichillia lecointei
Triplaris surinamensis
Urera baccifera
Vantanea parviflora
Vatairea guianensis
Vatairea paraensis
Vatairea sericea
Vataireopsis speciosa
Vernonia diffusa
Vernonia petiolaris
Vernonia quinqueflora
Virola bicuhyba
Virola cuspidata
Virola duckei
Virola gardneri
Virola michelii
Virola oleifera
Virola surinamensis
Vitex montevidensis
Vitex polygama
Vitex triflora
Vochysia bifalcata
Vochysia guianensis
Vochysia hankeana
Vochysia inundata
Vochysia maxima
Vochysia obscura
Vochysia vismiaefolia
Vouacapoua americana
Weinmannia discolor
Weinmannia humilis
Weinmannia paullinifolia
Xylopia brasiliensis
Xylopia langsdorffiana
Xylopia nitida
Xylosma glaberrima
Xylosma pseudosalzmannii
Zanthoxyllum rhoifolium
Zanthoxylum hyemale
Zanthoxylum rhoifolium
Zizyphus itacaiunensis
Zollernia ilicifolia
Zollernia paraensis

5.6.2 – Tropical Mangrove

Mangrove forests are well established in the larger estuaries along the Atlantic and, to a lesser extent, Pacific coasts. The largest mangroves are found in Brazil. From the sea inland there is first a lower belt, and, finally, on higher ground vegetation dominated higher vegetation is often edged on its landward side by a fringe of palms.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Ardisia granatensis
Avicennia germinans
Avicennia nitida
Avicennia schaueriana
Avicennia tomentosa
Canocarpus erectus
Conostegia polyandra
Laguncularia racemosa
Rhizophora brevistyla
Rhizophora mangle
Rustia occidentalis

5.6.3 – Tropical Moist Deciduous Forest

This zone roughly corresponds to the Brazilian and Guiana Shields. A wide area with rather high rainfall but a pronounced dry season that extends around the wet Amazonian Basin.

This large zone is mainly covered by cerrado in Brazil, a mosaic of grasslands, tree savannas and woodlands with patches of semi-deciduous forest. The flora is rich, with Leguminosae and Myrtaceae prevalent in the tree and shrub canopies. In some areas a real forest occurs, the cerradao - a short semi-deciduous forest, 10 to 15 m tall, of medium density. In northern Argentina, around Salta, a similar forest grows on the foothills of the Andes.

An evergreen seasonal or semi-deciduous forest grows on the edge of the Amazonian Basin and in the Andean foothills. In Argentina, Paraguay and Bolivia this fairly dense forest includes three tree canopies, the tallest reaching 30 m.

In Venezuela, the flora and physiognomy of the llanos have some similarity with the Brazilian cerrado. These are tall grasslands with evergreen broad-leaved trees. A deciduous thorn forest occurs in some places.

The zone also includes the grasslands of the Pantanal, the world largest wetlands, and also the junction of the Paraguay and Parana Rivers in Argentina and the residual forest on the low plain of the Cauca River in Columbia.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Abarema langsdorffii
Acacia caven
Acacia polyphylla
Acanthococos emensis
Achatocarpus praecox
Acnistus arborescens
Acosmium subelegans
Actinostemon concepcionis
Actinostemon concolor

Aegiphila mediterranea
Aegiphila paraguariensis
Aegiphila sellowiana
Albizia edwallii
Alchornea glandulosa
Alchornea triplinervia
Allophylus edulis
Allophylus guaraniticus
Alseis floribunda
Amaioua guianensis
Anadenanthera colubrina
Anadenanthera peregrina
Anemopaegma glaucum
Annona cacans
Annona crassiflora
Apuleia leiocarpa
Aspidosperma peroba
Aspidosperma polyneuron
Aspidosperma ramiflorum
Astronium fraxinifolium
Astronium graveolens
Astronium urundeuva
Ateleia guaraya
Austroplenckia populnea
Balfourodendron riedelianum
Banara parviflora
Banara tomentosa
Bastardiopsis densiflora
Bauhinia forficata
Bougainvillea glabra
Bougainvillea spectabilis
Brosimum glaucum
Bunchosia pallescens
Byrsonima coccolobifolia
Cabralea canjerana
Caesalpinia coriaria
Caesalpinia echinata
Calliandra foliolosa
Calliandra tweediei
Calycorectes psidiiflorus
Calyptranthes concinna
Calyptranthes grandifolia
Campomanesia eugenioides
Campomanesia guaviroba
Campomanesia guazumifolia
Campomanesia xanthocarpa
Capparis coccolobifolia
Caryocar brasiliense
Casearia decandra
Casearia gossypiosperma

Casearia obliqua
Casearia sylvestris
Cecropia glaziovii
Cecropia pachystachya
Cedrela fissilis
Celtis aculeata
Celtis spinosa
Centrolobium tomentosum
Cercidium praecox
Cestrum amictum
Cestrum calycinum
Cestrum intermedium
Chamaecrista polystachya
Chomelia obtusa
Chorisia speciosa
Chrysophyllum gonocarpum
Chrysophyllum marginatum
Cinnamomum sellowianum
Citronela paniculata
Citronella gongonha
Citronella megaphylla
Clethra scabra
Colubrina glandulosa
Combretum laxum
Copaifera langsdorffii
Cordia ecalyculata
Cordia rufescens
Cordia trichotoma
Cordyline dracaenoides
Coudenbergia warmingii
Couepia grandiflora
Coutarea hexandra
Croton floribundus
Croton urucurana
Cryptocarya aschersoniana
Cupania oblongifolia
Cupania vernalis
Curatella americana
Dalbergia frutescens
Dalbergia miscolobium
Dalbergia violacea
Dasyphyllum tomentosum
Dendropanax cuneatus
Diatenopteryx sorbifolia
Didymopanax calvum
Didymopanax vinosum
Diospyros hispida
Duguetia lanceolata
Endlicheria paniculata
Enterolobium contortisiliquum

Erythrina falcata
Erythroxylon deciduum
Erythroxylon suberosum
Esenbeckia febrifuga
Esenbeckia grandiflora
Eugenia blastantha
Eugenia convexinervia
Eugenia florida
Eugenia gardneriana
Eugenia hiemalis
Eugenia involucrata
Eugenia moraviana
Eugenia pyriformis
Eugenia ramboi
Eugenia sulcata
Eugenia uniflora
Eugenia verrucosa
Euterpe edulis
Ficus enormis
Ficus glabra
Ficus guaranitica
Ficus insipida
Ficus luschnatiana
Ficus monckii
Ficus obtusiuscula
Ficus organensis
Gallesia gorazema
Gallesia integrifolia
Gordonia fruticosa
Guapira opposita
Guarea guidonia
Guarea kunthiana
Guarea macrophylla
Guatteria australis
Guazuma ulmifolia
Helietta apiculata
Heliocarpus americanus
Hennecartia omphalandra
Hexachlamys itatiaiensis
Holocalyx balansae
Hura crepitans
Hybanthus biggibosus
Ilex theezans
Inga edulis
Inga marginata
Inga ruiziana
Inga sessilis
Inga striata
Inga uruguensis
Inga virescens

Jacaranda micrantha
Jacaranda puberula
Jacaratia spinosa
Justicia brasiliana
Kielmeyera coriacea
Lafoensia densiflora
Lafoensia pacari
Leandra lacunosa
Lippia urticoides
Lonchocarpus campestris
Lonchocarpus cultratus
Lonchocarpus leucanthus
Lonchocarpus muehlbergianus
Lonchocarpus subglaucescens
Luehea divaricata
Luehea uniflora
Machaerium acutifolium
Machaerium angustifolium
Machaerium brasiliense
Machaerium hatschbachii
Machaerium minutiflorum
Machaerium nyctitans
Machaerium paraguariense
Machaerium scleroxylon
Machaerium stipitatum
Machaerium vellosianum
Maclura tinctoria
Margaritaria nobilis
Matayba elaeagnoides
Matayba guianensis
Maytenus ilicifolia
Maytenus robusta
Melanoxylon brauna
Melanoxylon braunia
Metrodorea nigra
Miconia cinerascens
Miconia discolor
Miconia minutiflora
Miconia sellowiana
Miconia tristis
Mitranthes widgreniana
Mollinedia clavigera
Mollinedia ulleana
Myrceugenia miersiana
Myrcia arborescens
Myrcia bombicyna
Myrcia breviramis
Myrcia laruotteana
Myrcia multiflora
Myrcia obtecta

Myrcia rostrata
Myrcia venulosa
Myrciaria ciliolata
Myrciaria floribunda
Myrocarpus frondosus
Myroxylum peruiferum
Myrsine coriacea
Myrsine guianensis
Myrsine umbellata
Nectandra megapotamica
Nectandra oppositifolia
Nectandra puberula
Neomitranthes glomerata
Ocotea corymbosa
Ocotea diospyrifolia
Ocotea elegans
Ocotea indecora
Ocotea kuhlmannii
Ocotea porosa
Ocotea puberula
Ocotea pulchella
Ocotea silvestris
Ocoteca basicordatifolia
Ocoteca langsdorffii
Ouratea spectabilis
Pachystroma longifolium
Parapiptadenia rigida
Patagonula americana
Peltophorum dubium
Pera obovata
Persea alba
Persea venosa
Peschiera australis
Peschiera catharinensis
Phytolacca dioica
Picramnia parvifolia
Picramnia ramiflora
Picrasma crenata
Pilocarpus pennatifolius
Piper amalago
Piper arboreum
Piper crassinervium
Piper tuberculatum
Piptadenia flava
Piptadenia gonoacantha
Piptadenia inaequalis
Piptocarpha regnelii
Piptocarpha sellowii
Piptocarpha tomentosa
Pisonia ambigua

Plinia rivularis
Plinia trunciflora
Poecilanthe parviflora
Pouteria gardneriana
Prockia crucis
Prosopis alba
Prosopis nigra
Prunus brasiliensis
Prunus myrtifolia
Prunus sellowii
Pseudobombax grandiflorum
Pseudopiptadenia warmingii
Psidium guajava
Psychotria carthagenensis
Pterocarpus rohrii
Pterogyne nitens
Qualea cordata
Randia armata
Rapanea lancifolia
Rauwolfia sellowii
Rollinia emarginata
Rollinia exalbida
Rollinia rugulosa
Rollinia sericea
Rollinia sylvatica
Roupala montana
Rudgea jasminoides
Ruprechtia laxiflora
Sapium glandulatum
Schefflera morototoni
Schinopsis brasiliensis glabra
Schinus terebinthifolius
Sebastiania brasiliensis
Sebastiania commersoniana
Seguieria aculeata
Seguieria glaziovii
Seguieria guaranitica
Senna bicapsularis
Senna splendida
Simira corumbaensis
Sloanea monosperma
Solanum argenteum
Solanum caavurana
Solanum erianthum
Solanum sactaecatharinae
Sorocea bonplandii
Strychnos brasiliensis
Stryphnodendron adstringens
Styrax acuminatus
Styrax ferrugineus

Syagrus oleracea
Syagrus romanzoffiana
Symplocos lanceolata
Symplocos pubescens
Symplocos tenuifolia
Tabebuia chrysotricha
Tabebuia impetiginosa
Tabebuia ochracea
Tapirira guianensis
Terminalia reitzii
Ternstroemia brasiliensis
Tetrorchidium rubrivenium
Trema micrantha
Trichilia casarettii
Trichilia catigua
Trichilia claussenii
Trichilia elegans
Trichilia pallens
Trichilia pallida
Triplaris americana
Urera baccifera
Vitex montevidensis
Vochysia tucanorum
Xylosma pseudosalzmannii
Zanthoxylum chiloperone
Zanthoxylum hyemale
Zanthoxylum rhoifolium
Zanthoxylum riedelianum
Zanthoxylum stipitatum
Zeyheria tuberculosa
Zygia cauliflora

5.6.4 – Tropical Dry Forest, Tropical Shrubland and Tropical Desert

The South American tropical dry forest is found in areas sheltered from the humid trade winds, where the climate is drier. These regions may be close to the sea, as northeast Brazil and the Caribbean coast, or inland, such as the Argentine chaco. Rainfall varies between 500 and 1,000 mm or less with a dry season of five to eight months. Temperatures are always high near the Equator (mean temperature of the coldest month greater than 20°C) but lower in the chaco, which extends to 34°S. In Brazil, the typical vegetation is the caatinga, xerophytic vegetation types varying from dense to very open. The trees are more or less deciduous, thin-stemmed and with a low canopy (5 to 10 m). The flora is rich, with fairly numerous Leguminosae species, and often includes Cactaceae. The palms assume considerable importance in flood plains.

In Argentina, the chaco is a wooded region of relative ecological homogeneity between the tropical and subtropical zones. The prevailing vegetation is deciduous dry forest with many climatic and, above all, edaphic variations. All these types are characterized by quebracho. The most humid forests occur in the east, a drier forest in the west and xerophilous forest on the lower Andean foothills. In the coastal region of the Caribbean, deciduous forests and woodlands rich in Leguminosae once occupied a large part of the plain. Agriculture and thickets have largely replaced these forests. Similar woodlands with Cactaceae grow along the Gulf of Guayaquil in Peru and Ecuador.

The tropical shrubland zone extends along the Pacific coast of South America from south of the Gulf of Guayaquil to the Tropic of Capricorn, forming a narrow belt between the lower slopes of the Andes and the coastal desert. Rainfall is less than 500 mm, with a long dry season of eight to nine months and high temperatures (always more than 20°C). To the south, in Peru, rainfall is even less than 100 mm, but a light drizzle maintains high humidity and allows some plants to live. Xeromorphic woodlands are represented by algarrobo, found on the southern coast of the Gulf of Guayaquil. In western Venezuela, a deciduous thorn woodland grows under the same conditions. It is a multilayered woodland 8 to 15 m high.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Acacia bahiensis
Acacia farnesiana
Acacia piauhiensis
Acallypha multicaulis
Aeschynomene monteiroi
Agonandra brasiliensis
Allamanda blanchettii
Allophylus puberalus
Allophylus quercifolius
Alternanthera brasiliana
Amburana cearensis
Anacardium microcarpum
Anacardium occidentale
Anadenanthera colubrina
Anadenanthera macrocarpa
Aniseia pickelii
Annona coriacea
Arrabidea dispar
Aspidosperma cuspa
Aspidosperma multiflorum
Aspidosperma pirifolium
Aspidosperma pyricollum
Astronium fraxinifolium
Astronium urundeuva
Ateleia ovata
Auxemma glazioviana
Auxemma oncocalix
Balfourodendron riedelianum
Basiloxylon brasiliensis
Bauhinia acuarana
Bauhinia catingae
Bauhinia cheilanta
Bauhinia pentandra
Bocoa mollis
Bombax discolor
Brosimum gaudichaudii
Brosimum guianensis
Buchenavia capitata

Bulnesia arborea
Bursera graveolens
Byrsonima crassifolia
Byrsonima crispa
Byrsonima dispar
Byrsonima gardneriana
Byrsonima sericea
Byrsonima vaccinifolia
Byrsonima verbascifolia
Caesalpinia corymbosa
Caesalpinia echinata
Caesalpinia bracteosa
Caesalpinia ferrea
Caesalpinia leiostachya
Caesalpinia microphylla
Casalpinia pyramidalis
Callisthene fasciculata
Campomanesia dichotoma
Campomanesia viatoris
Capparis angulata
Capparis cynophalophora
Capparis flexuosa
Capparis hastata
Capparis jacobinae
Capparis angulata
Capsicum flexuosum
Caryocar coriaceum
Casearia sylvestris
Cassia apoucoita
Cassia flexuosa
Cavanillesia platanifolia
Cedrela odorata
Ceiba glaziovii
Ceiba trichistandra
Cenostigma macrophyllum
Centrolobium microchaete
Chamaecrista desvauxii
Chloroleucon foliolosum
Clorophora tinctoria
Clusia nemorosa
Cnidoscolus obtusifolius
Cnidoscolus quercifolius
Coccoloba alnifolia
Coccoloba brasiliensis
Coccoloba laevis
Cochlospemun regium
Cocos comosa
Combretum lanceolatum
Combretum leprosum
Combretum duarteanum

Commiphora leptophloes
Copaifera luetzelburgii
Copernicia cerifera
Cordia argirophylloides
Cordia globosa
Cordia insignis
Cordia latiloba
Cordia leucocephala
Cordia lutea
Cordia multispicata
Cordia piauhiensis
Cordia trichotoma
Coutarea hexandra
Cranocarpus gracilis
Croton adenocalix
Croton argyrophylloides
Croton micans
Croton sonderianus
Curatella americana
Cybistax antisyphilitica
Cyperus diffusus
Cyperus schomburgkianus
Dalbergia decipulares
Dalechampia pernambucensis
Derris araripensis
Didymopanax morototoni
Dimophandra gardneriana
Duguetia furfuraceae
Enterolobium contortisiliquum
Erythrina velutina
Erythroxylum citrifolium
Erythroxylum revolutum
Esenbeckia grandiflora
Eugenia copacabanense
Eugenia hirta
Eugenia nhanica
Eugenia ovalifolia
Eugenia speciosa
Eugenia uniflora
Ficus catappafolia
Ficus nymphaefolia
Fícus organensis
Ficus paraensis
Ficus pertusa
Geoffreya striata
Guapira laxa
Guapira opposita
Guatteria oligocarpa
Guazuma ulmifolia
Guettarda angelica

Hancornia speciosa
Helicteres baruensis
Helicteris hepitandra
Hexachlamys itatiaide
Himatanthus drasticus
Hirtella ciliata
Hybanthus ipecacuanha
Hymenaea courbaril
Hymenaea martiana
Hymenaea rubiflora
Hymenaea stigonocarpa
Hymenaea velutina
Hyptidendron amethystoides
Hyptis salzamani
Indigofera blachetiana
Inga bahiensis
Jacaranda jasminoides
Jaracatia spinosa
Jatropha mollissima
Jatropha mutabilis
Krameria tomentosa
Lantana camara
Licania parviflora
Lippia gracilis
Loxopterigium huasango
Luetzelburgia auriculata
Luhea ochrophylla
Machaerium angustifolium
Machaerium ovalifolium
Magonia glabrata
Manihot epruinosa
Manihot dichotoma
Manihot pseudoglaziovii
Manihot esculenta
Manilkara triflora
Maytenus impressa
Maytenus rigida
Melanoxylon brauma
Mimosa caesalpiniifolia
Mimosa tenuiflora
Mouriri cearensis
Myracroduon urundeuva
Myrcia bahiensis
Myrcia luniana
Myrcia multiflora
Myrcia rostrata
Myrcia silvatica
Myrciaria tenella
Myroxylon peruiferum
Nectandra mollis

Neomitranthes langsdorffii
Norantea guianensis
Ocotea duartei
Ocotea gardneri
Ocotea glomerata
Ocotea pallida
Oeceocladis maculata
Oncidium cebolleta
Ouratea cuspidata
Palicourea aenveofusca
Palicourea guianesis
Parapiptadenia zenhtneri
Parkia platycephala
Peltogyne confertiflora
Peltogyne pauciflora
Phoebe brasiliensis
Pilocarpus jaborandi
Piptadenia biuncifera
Piptadenia moniliformis
Piptadenia obliqua
Piptadenia stipulacea
Piptadenia viridiflora
Pithecellobium diversifolium
Pithecellobium multiflorum
Pithecellobium saman
Pithecellobium trapezifolium
Pithecellobium unguis-cati
Plathymenia foliolosa
Platypodium elegans
Podocarpus sellowii
Prockia crucis
Prosopis affinis
Prosopis alba
Prosopis chilensis
Prosopis elata
Prosopis ferox
Prosopis fiebrigii
Prosopis hassleri
Prosopis juliflora
Prosopis kuntzei
Prosopis laevigata
Prosopis nigra
Prosopis pallida
Prosopis pubescens
Prosopis reptans
Prosopis rojasiana
Prosopis rubrifolia
Prosopis ruscifolia
Prosopis strombilifera
Prosopis tamarugo

Prosopis vinalillo
Protium brasiliense
Protium heptaphyllum
Pseudobombax marginatum
Pseudobombax grandiflorum
Psidium myrsionioides
Psidium oligospermum
Psychotria colorata
Psychotria hoffmannseggianna
Pterocarpus violaceus
Ptilochaeta bahiensis
Qualea parviflora
Qualea parviflora
Rapanea umbellata
Rapanea guianensis
Rhamnidium molle
Roupala cearensis
Roupala montana
Ruellia asperula
Salvertia convallariaeodora
Sapium glandulatum
Schinopsis glabra
Schinus molle
Sebastiana brasiliensis
Senna spectabilis
Sigmatanthus trifoliatus
Simaba ferruginea
Simaba trichiloides
Simarouba amara
Simarouba versicolor
Spathicarpa hastfolia
Spondias mombim
Spondias tuberosa
Stryphnodendron coriaceum
Syagrus comosa
Tabebuia aurea
Tabebuia billbergii
Tabebuia caraiba
Tabebuia heptaphylla
Tabebuia impetiginosa
Tabebuia serratifolia
Tocoyena brasiliensis
Tocoyena formosa
Terminalia fagifolia
Thyrsodium schmburgkianum
Trema micrantha
Trichilia pseudostipulares
Triplaris gardneriana
Vanillosmopsis arborea
Vatairea macrocarpa

Vitex cymosa
Vitex gardneriana
Vitex polygama
Wulffia stenoglossa
Ximenia americana
Zanthoxylum rhoifolium
Zizyphus thyrsiflora
Zizyphus joazeiro
Zollernia ulei

5.6.5 – Tropical Mountain Systems

The tropical mountains are mainly the Andean Range, extending from northern Colombia and Venezuela to 28° to 29°S. However, some areas in Venezuela and Brazil have similar climatic conditions. The mountain regions experience lower temperatures, leading to specific vegetation types above 1,000 to 1,500 m. Precipitation varies greatly but the region is still tropical, with a low annual range of temperature. Ecofloristic zones can generally be differentiated by altitude.

In the northern Andes (Colombia and Venezuela), both the eastern and western faces of the mountains are well watered. Precipitation ranges from 1,500 to 5,000 mm. The mean temperature of the coldest month is often close to 15°C, but drops down to 10°C or lower with increasing elevation. There is generally no dry season, or a very short one. In some places there is heavy cloud cover and very frequent fog. Frost occurs above 2,000 m.

South of Ecuador there is a contrast between the very wet eastern side of the Andes and the drier Andean valleys and western side. On the eastern face, the climate is similar to that of the northern Andes. In the inter-Andean valleys, even in Colombia and Venezuela, precipitation is 1,000 to 1,500 mm (sometimes less) and the dry season is two to five months. On the western face, in Peru, precipitation is lower (less than 500 mm) and the climate is very dry or semi-arid. In Venezuela, the southern part of the Guiana Shield reaches 1,000 to 3,000 m with a fairly even annual precipitation distribution.

Between 1,000 and 1, 800 to 2,400 m in the northern Andes many of the lowland taxa still persist, but a number of distinctly highland elements also enter the lower montane forest. The montane or upper montane forest, starting at 1,800 to 2,400 m, may extend in places up to 3,400 m. An increasing number of typical montane species enter the flora. In the drier parts, montane forests are evergreen seasonal. Above this zone, subalpine forests may extend up to 3,800 m in some places. On the high ridges exposed to wet winds there is montane cloud forest with an "elfin woodland" of low gnarled trees with abundant mosses and lichens.

In Peru and Bolivia, the wet eastern face of the Andes bears submontane and montane forests similar to those of the northern Andes. In the drier inter-Andean valleys the forest often becomes deciduous, even xerophilous, but often very degraded and transformed into thicket or scrub. On the western slopes of the Andes, under a very dry climate, scrub woodland replaces forest.

In the non-Andean highlands, the submontane level is rather similar to the lowland forest but of lower stature and with a slightly different flora.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia macracantha
Alchornea bogotensis
Alchornea glandulosa
Alchornea sidifolia

Alchornea triplinervia
Alibertia concolor
Alnus acuminata
Aspidosperma olivaceum
Bathysa meridionalis
Bohemeria fallax
Brunellia comocladifolia
Brunellia occidentalis
Buddleya coriacea
Buddleya incana
Cabralea canjerana
Caesalpinia spinosa
Campomanesia guaviroba
Capsicodendron dinisii
Casearia decandra
Casearia sylvestris
Cecropia pachystachya
Cedrela fissilis
Cestrum peruvianum
Cestrum racemosum
Chrysophyllum viride
Cinchona cuatrecasasii
Citronela paniculata
Clethra scabra
Coccoloba salicifolia
Coccoloba warmingii
Copaifera trapezifolia
Croton celtidifolius
Cryptocarya aschersoniana
Cryptocarya moschata
Cupania oblongifolia
Cupania vernalis
Cytharexylon ilicifolium
Cytharexylon montanum
Daphnopsis beta
Dasyphyllum popayanense
Dicksonia sellowiana
Didymopanax angustissimum
Drimys brasiliensis
Drimys winteri
Eugenia hiemalis
Eugenia melanogyna
Euterpe edulis
Garcinia gardneriana
Gomidesia affinis
Gordonia fruticosa
Gynoxys sodiori
Hyeronima alchorneoides
Hypericum laricifolium
Ilex brevicuspis

Ilex dumosa
Ilex paraguariensis
Ilex taubertiana
Ilex theezans
Inga sessilis
Inga virescens
Iochroma macrocalyx
Jacaranda puberula
Lamanonia speciosa
Lupinos bicolor
Marlierea suaveolens
Marlierea tomentosa
Miconia rigidiuscula
Miconia rugulosa
Mimosa quitensis
Monnina salicifolia
Mouriri chamissoana
Myrceugenia myrcioides
Myrcia obtecta
Myrcia racemosa
Myrcia richardiana
Myrcianthus alaternifolia
Myrcianthus rhopaloides
Myrsine coriacea
Myrsine umbellata
Nectandra megapotamica
Nectandra oppositifolia
Ocotea architectorum
Ocotea catharinensis
Ocotea corymbosa
Ocotea diospyrifolia
Ocotea odorifera
Ocotea puberula
Ocotea pulchella
Ocotea teleiandra
Oreopanax mucronulatus
Oreopanax seemanianum
Ormosia arborea
Ouratea parviflora
Persea major
Phyllanthus salvifolius
Piper cordatum
Piper nodosum
Podocarpus oleifolius
Podocarpus sellowii
Polilepys weberbaueri
Polilepys incana
Posoqueria latifolia
Prunus brasiliensis
Prunus serotina

Psychotria longipes
Rollinia rugulosa
Roupala rhombifolia
Rudgea jasminoides
Sloanea guianensis
Sloanea lasiocoma
Solanum rufescens
Solanum sactaecatharinae
Sorocea bonplandii
Syagrus romanzoffiana
Symplocos lanceolata
Symplocos pichindensis
Tabebuia alba
Terminalia australis
Tibouchina sellowiana
Tournefortia scabrida
Vallea stipularis
Vaccinium floribundum
Vernonia discolor
Vernonia puberula
Vernonia quinqueflora
Vitex montevidensis
Weinmannia balbisiana
Weinmannia discolor
Weinmannia humilis
Weinmannia paullinifolia
Zanthoxylum rhoifolium

5.6.6 – Subtropical Humid Forest

This zone includes plateaus and lowlands on the Atlantic side of the continent in southern Brazil, Uruguay and Argentina. The two main climatic characteristics are lower temperatures in winter (mean temperature of the coldest month less than 15°C) and rainfall evenly distributed throughout the year. However, rainfall decreases from the north (1,000 to 2,500 mm) to the south (600 to 1,000 mm).

The natural vegetation of the wetter higher parts of the zone is the Araucaria forest. It is a mixed broad-leaved/coniferous forest some 50 m tall dominated by the *Araucaria angustifolia*. The forest is very dense, with multiple strata. Genera represented from the Lauraceae family include Ocotea, Phoebe, Nectandra and Persea. Today this forest type is very fragmented because of its unsustainable exploitation for timber, and land use conversion for agriculture or cattle raising.

Grasslands are the main vegetation in lower parts of this zone, called pampa, that encompasses the extreme south of Brazil, all Uruguay and eastern Argentina. Riparian forests fringe the main rivers.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Acacia polyphylla
Acacia recurva
Actinostemon concolor
Aegiphila mediterranea

Aegiphila sellowiana
Albizia niopoides
Albizia polycephala
Alchornea glandulosa
Alchornea sidifolia
Alchornea triplinervia
Alibertia concolor
Allophylus edulis
Allophylus guaraniticus
Allophylus membranifolius
Alseis floribunda
Alsophila setosa
Anadenanthera colubrina
Annona cacans
Apuleia leiocarpa
Araucaria angustifolia
Arecastrum romanzoffianum
Aspidosperma discolor
Aspidosperma parvifolium
Aspidosperma polyneuron
Aspidosperma olivaceum
Aspidosperma pyricollum
Aspidosperma subincanum
Astronium graveolens
Ateleia glazioveana
Baccharis dentata
Balfourodendron riedelianum
Banara parviflora
Banara tomentosa
Bastardiopsis densiflora
Bathysa meridionalis
Bauhinia affinis
Bauhinia forficata
Bauhinia geminata
Bauhinia longifolia
Blepharocalyx salicifolius
Bougainvillea spectabilis
Brosimum lactescens
Cabralea canjerana
Calliandra foliolosa
Calycorectes australis
Calycorectes duarteanus
Calycorectes psidiiflorus
Calypranthes gramica
Calyptranthes concinna
Calyptranthes eugeniopsoides
Calyptranthes grandifolia
Calyptranthes hatschbachii
Calyptranthes lucida
Campomanesia guaviroba

Campomanesia guazumifolia
Campomanesia xanthocarpa
Capsicodendron dinisii
Cariniana estrellensis
Casearia decandra
Casearia gossypiosperma
Casearia lasiophylla
Casearia obliqua
Casearia sylvestris
Cassia leptophylla
Cecropia pachystachya
Cedrela fissilis
Celtis tala
Celtis triflora
Centrolobium robustum
Cestrum amictum
Cestrum calycinum
Cestrum intermedium
Chomelia obtusa
Chorisia speciosa
Chrysophyllum gonocarpum
Chrysophyllum inornatum
Chrysophyllum marginatum
Chrysophyllum viride
Cinnamomum glaziovii
Cinnamomum riedelianum
Cinnamomum sellowianum
Cinnamomum vesiculosum
Citharexylum myrianthum
Citharexylum solanacium
Citronela paniculata
Citronella gongonha
Citronella megaphylla
Citronella mucronata
Clethra scabra
Clusia parviflora
Copaifera langsdorffii
Copaifera trapezifolia
Cordia ecalyculata
Cordia trichotoma
Cordyline australis
Cordyline dracaenoides
Coussarea contracta
Coutarea hexandra
Croton floribundus
Cryptocarya aschersoniana
Cryptocarya moschata
Cupania vernalis
Cyphomandra patrum
Dalbergia brasiliensis

Dalbergia frutescens
Daphnopsis fasciculata
Daphnopsis racemosa
Dasyphyllum spinescens
Dasyphyllum tomentosum
Diatenopteryx sorbifolia
Dicksonia sellowiana
Didymopanax angustissimum
Drimys brasiliensis
Duranta vestita
Endlicheria paniculata
Enterolobium contortisiliquum
Erythrina crista-galli
Erythrina falcata
Erythroxylon amplifolium
Erythroxylon argentinum
Erythroxylon deciduum
Esenbeckia grandiflora
Eugenia beaurepairiana
Eugenia blastantha
Eugenia burkartiana
Eugenia cerasiflora
Eugenia hiemalis
Eugenia involucrata
Eugenia moraviana
Eugenia myrtifolia
Eugenia pluriflora
Eugenia prismatica
Eugenia pyriformis
Eugenia ramboi
Eugenia riedeliana
Eugenia speciosa
Eugenia subavenia
Eugenia uniflora
Eugenia uruguayensis
Eugenia verrucosa
Euplassa cantareirae
Faramea porophylla
Ficus guaranitica
Ficus enormis
Ficus insipida
Ficus monckii
Gleditschia amorphoides
Gochnatia polymorpha
Gomidesia affinis
Gomidesia palustris
Gomidesia sellowiana
Gomidesia spectabilis
Gordonia fruticosa
Guapira opposita

Guarea kunthiana
Guarea macrophylla
Guatteria australis
Guetarda uruguensis
Heisteria silvianii
Heliocarpus americanus
Hexachlamys itatiaiensis
Hippocratea andina
Holocalyx balansae
Ilex brevicuspis
Ilex dumosa
Ilex integerrima
Ilex microdonta
Ilex paraguariensis
Ilex taubertiana
Ilex theezans
Inga heterophylla
Inga lentiscifolia
Inga sellowiana
Inga sessilis
Inga striata
Inga uruguensis
Inga virescens
Jacaranda micrantha
Jacaranda puberula
Jacaratia spinosa
Justicia brasiliana
Lafoensia pacari
Lamanonia speciosa
Lamanonia ternata
Leandra barbinervis
Lippia urticoides
Lithraea aroeirinha
Lithraea brasiliensis
Lonchocarpus campestris
Lonchocarpus cultratus
Lonchocarpus leucanthus
Lonchocarpus muehlbergianus
Lonchocarpus subglaucescens
Luehea divaricata
Machaerium hatschbachii
Machaerium minutiflorum
Machaerium nyctitans
Machaerium paraguariense
Machaerium stipitatum
Machaerium villosum
Maclura tinctoria
Manihot grahanii
Margaritaria nobilis
Marlierea reitzii

Matayba elaeagnoides
Matayba guianensis
Matayba juglandifolia
Maytenus evonymoides
Maytenus ilicifolia
Maytenus robusta
Metrodorea stipularis
Miconia rigidiuscula
Miconia sellowiana
Miconia tristis
Mimosa bimucronata
Mimosa scabrella
Mollinedia clavigera
Mollinedia elegans
Mollinedia schottiana
Mollinedia triflora
Myrceugenia euosma
Myrceugenia glaucescens
Myrceugenia grisea
Myrceugenia miersiana
Myrceugenia regnelliana
Myrcia arborescens
Myrcia breviramis
Myrcia cymoso-paniculata
Myrcia glabra
Myrcia hatschbachii
Myrcia laruotteana
Myrcia multiflora
Myrcia obtecta
Myrcia rostrata
Myrcia selloi
Myrcia sosias
Myrcia tenuivenosa
Myrcianthes pungens
Myrciaria ciliolata
Myrciaria cuspidata
Myrciaria floribunda
Myrciaria tenella
Myrciaria tenuiramis
Myrocarpus frondosus
Myrrhinium loranthoides
Myrsine coriacea
Myrsine umbellata
Nectandra grandiflora
Nectandra lanceolata
Nectandra megapotamica
Nectandra membranacea
Nectandra oppositifolia
Nectandra paranaensis
Ocotea aciphylla

Ocotea acutifolia
Ocotea bicolor
Ocotea catharinensis
Ocotea corymbosa
Ocotea diospyrifolia
Ocotea elegans
Ocotea glaziovii
Ocotea indecora
Ocotea nutans
Ocotea odorifera
Ocotea porosa
Ocotea pretiosa
Ocotea puberula
Ocotea pulchella
Ocotea silvestris
Ormosia arborea
Paramyrciaria delicatula
Parapiptadenia rigida
Patagonula americana
Peltophorum dubium
Persea cordata
Persea major
Persea venosa
Peschiera australis
Phoebe amoena
Phytolacca dioica
Picramnia excelsa
Picramnia parvifolia
Picramnia ramiflora
Picrasma crenata
Pilocarpus pennatifolius
Pimenta pseudocaryophyllus
Piper amalago
Piptadenia gonoacantha
Piptocarpha angustifolia
Piptocarpha axillaris
Piptocarpha sellowii
Piptocarpha tomentosa
Pisonia ambigua
Platymiscium floribundum
Plinia rivularis
Plinia trunciflora
Podocarpus lambertii
Podocarpus sellowii
Poecilanthe parviflora
Posoqueria latifolia
Pouteria torta
Prockia crucis
Protium kleinii
Prunus brasiliensis

Prunus myrtifolia
Prunus sellowii
Prunus subcoriacea
Pseudobombax grandiflorum
Psidium cattleianum
Psidium cinereum
Psidium longipetiolatum
Psychotria longipes
Psychotria sessilis
Psychotria suterella
Pterocarpus rohrii
Pterogyne nitens
Quillaja brasiliensis
Randia armata
Randia nitida
Rapanea intermedia
Rapanea lancifolia
Rapanea parvifolia
Raulinoreitzia leptophlebia
Rauwolfia sellowii
Rhamnus sphaerosperma
Rollinia emarginata
Rollinia exalbida
Rollinia rugulosa
Rollinia sylvatica
Roupala brasiliensis
Rudgea jasminoides
Ruprechtia laxiflora
Salix humboldtiana
Sapium glandulatum
Schefflera morototoni
Schinus molle
Schinus terebinthifolius
Scutia buxifolia
Sebastiania brasiliensis
Sebastiania commersoniana
Sebastiania membranifolia
Seguieria guaranitica
Seguieria langsdorffii
Sessea regnelii
Sickingia sampaioana
Sloanea garckeana
Sloanea guianensis
Sloanea lasiocoma
Sloanea monosperma
Solanum argenteum
Solanum erianthum
Solanum granuloso-leprosum
Solanum mauritianum
Solanum pseudoquina

Solanum sactaecatharinae
Solanum swartzianum
Sorocea bonplandii
Strychnos brasiliensis
Styrax acuminatus
Styrax leprosus
Styrax longiflorus
Syagrus romanzoffiana
Symplocos brasiliensis
Symplocos celastrinea
Symplocos glanduloso-marginata
Symplocos tenuifolia
Symplocos tetrandra
Symplocos uniflora
Tabebuia alba
Tabebuia cassinoides
Talauma ovata
Terminalia australis
Terminalia brasiliensis
Terminalia triflora
Ternstroemia brasiliensis
Tetrorchidium rubrivenium
Tibouchina pulchra
Tibouchina sellowiana
Trema micrantha
Trichilia casarettii
Trichilia catigua
Trichilia claussenii
Trichilia elegans
Trichilia pallens
Urera baccifera
Vernonia diffusa
Vernonia discolor
Vernonia petiolaris
Virola bicuhyba
Vitex megapotamica
Vitex montevidensis
Vochysia tucanorum
Weinmannia discolor
Xylosma ciliatifolia
Xylosma glaberrima
Xylosma prockia
Xylosma pseudosalzmannii
Zanthoxylum chiloperone
Zanthoxylum hyemale
Zanthoxylum kleinii
Zanthoxylum rhoifolium
Zanthoxylum riedelianum
Zanthoxylum rugosum

5.6.7 – Subtropical Dry Forest and Subtropical Steppe

The Subtropical Dry Forest is a zone of lowlands, less than 200 km wide, that lies between the Andes foothills and the Pacific Ocean. The rainfall regime is of the Mediterranean type, with summer drought (two to seven months) and winter rains. Annual precipitation varies from 500 mm in the northern coastal region to 2,000 mm on the Andean foothills. Winter temperatures are cool (10° to 15°C). The climax is sclerophyllous evergreen forest or woodland with xerophytic species. Palms grow in a narrow area northeast of Valparaiso. Much of the forest has been degraded and replaced by secondary thorny thicket or replaced by agriculture. Towards the south or in the Andean foothills, where precipitation is higher, the sclerophyllous forest gives way to open deciduous mesophytic forest.

Two regions belong to the Subtropical Steppe ecological zone. One is located to the west of the Andes, covering most of the Chilean Norte Chico and forming a transitional area between the previous zone and the Atacama Desert. The other is to the east of the Andes, an extensive region in central Argentina of transition between the tropical chaco, subtropical pampa and temperate steppes to the south. Rainfall ranges from 100 to 800 mm and the dry period is very long, up to nine months. The mean temperature of the coldest month may be less than 10°C. In Chile, rainfall is even lower, from less than 100 to 400 mm. Temperatures are warmer than in Argentina, with mean temperature of the coldest month between 13° and 15°C. In this zone the densest vegetation type is a deciduous thicket, turning into large areas of thorn woodland. In the drier inland plain is subdesert shrubland.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Acacia caven
Aextoxicon punctatum
Araucaria araucana
Austrocedrus chilensis
Drimys winteri
Jubaea chilensis
Laurelia serrata
Lithraea caustica
Nothofagus dombeyi
Nothofagus obliqua
Nothofagus procera
Peumus boldus
Prosopis abbreviata
Prosopis affinis
Prosopis alba
Prosopis alpataco
Prosopis argentina
Prosopis burkartii
Prosopis caldenia
Prosopis calingastana
Prosopis campestris
Prosopis castellanosii
Prosopis chilensis
Prosopis denudans
Prosopis elata
Prosopis ferox
Prosopis fiebrigii

Prosopis flexuosa
Prosopis hassleri
Prosopis humilis
Prosopis kuntzei
Prosopis laevigata
Prosopis nigra
Prosopis pugionata
Prosopis reptans
Prosopis ruizleali
Prosopis ruscifolia
Prosopis sericantha
Prosopis strombulifera
Prosopis tamarugo
Prosopis torquata
Prosopis vinalillo
Quillaja saponaria

5.6.8 – Subtropical Mountain Systems

The subtropical Andes lie roughly from 26° to 40°S. From 1,000 m to nearly 7,000 m altitude, the climate is cold everywhere. The area is bordered to the west by the highest peaks, forming a barrier against the winds blowing from the Pacific Ocean. As a result, precipitation is low, generally less than 300 mm. The dry season mainly occurs in spring and summer (October-December). Strong winds make the effects of aridity and cold more pronounced.

In the lower reaches of the Andes, between 1,000 m and 1,800 to 2,400 m, we find submontane beech forest on the wetter slopes. Drier slopes are covered with evergreen sclerophyllous shrubs or xerophytic deciduous woodland. Higher up, the vegetation changes gradually into a steppe.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Aetoxicon punctatum
Alnus acuminata
Araucaria araucana
Austrocedrus chilensis
Drimys winteri
Laurelia serrata
Nothofagus dombeyi
Nothofagus obliqua
Nothofagus procera
Persea lingue

5.6.9 – Temperate Oceanic Forest

South of 38°S the western side of the Andes is well watered owing to oceanic influences. The dryness decreases from north to south, together with decreasing temperatures. Rainfall ranges from 1,000 to 3,500 mm, evenly distributed throughout the year. The mean temperature of the coldest month is lower than 10°C in the north and decreases to about 0°C in the south. In eastern Patagonia, rainfall is less than 1,000 mm with mean monthly temperatures always lower than 10°C.

The northern part of the region harbours a broad-leaved, very dense evergreen forest up to 40 to

45 m tall, with equally dense undergrowth. Species of Nothofagus dominate the tree canopy. A slight lowering of temperature at higher altitude or latitude gives rise to a less species-rich, mixed broad-leaved/coniferous forest.

Among the species to be planted in this ecologic zone can be mentioned the ones that follow:

Aetoxicon punctatum
Drimys winteri
Eucryphia cordifolia
Fitzroya cupressoides
Nothofagus antarctica
Nothofagus dombeyi
Nothofagus nitida
Nothofagus obliqua
Nothofagus procera
Pilgerodendron uviferum
Podocarpus nubigena

5.6.10 – Temperate Mountain Systems and Temperate Steppe

The central part of the Patagonian Andes, up to 52°S, reaches 2,000 to 3,000 m elevation. The western upper slopes are wet, whereas the eastern side is drier. The most striking climatic features are cold, snow and winds.

Subalpine beech forest lies below the timberline on the wettest slopes. This elfin type has low multistemmed trees, greatly deformed by the weight of snow. These forests are transitional to scrub and grasslands at higher altitudes. On the drier slopes and towards the eastern drier zone a beech forest occurs. It is transitional between the purely evergreen lowland forests and the deciduous forests that lie below the timberline on the drier sites.

Among the species to be planted in these ecologic zones can be mentioned the ones that follow:

Adesmia campestris
Atriplex lampa
Austrocedrus chilensis
Berberis buxifolia
Bougainvillea spinosa
Fitzroya cupressoides
Cassia aphylla
Cercidium praecox
Chuquiraga avellanedae
Chuquiraga erinacea
Larrea cuneifolia
Larrea divaricata
Larrea nitida
Mulinum spinosum
Neosparton ephedroides
Nothofagus betuloides
Nothofagus pumilio
Pilgerodendron uviferum
Prosopis alpataco
Prosopis argentina
Prosopis calingastana

Prosopis castellanosii
Prosopis denudans
Prosopis ruizleali
Schinus poligamun

6 – AREAS TO BE FORESTED

As seen on item 4, there are several methods to forest a specific area. The most simple method is the natural regeneration, but that implies the existence of formed forests in the vicinity, and the isolation of the non forested areas from grazing. When there are no more forests in a certain area, that area must be reforested. The areas to be covered with forest can be divided into micro and macro regional terms.

6.1 – Micro-Regional Areas

6.1.1 - River and Creek Banks

A river is a large natural waterway. It is a specific term for large streams, stream being the umbrella term used for all flowing natural waterways. The term "stream" may be used to refer to smaller streams, as may creek, run, fork, etc. Passage via a river or stream is the usual way rainfall on land finds its way to the ocean or other large body of water such as a lake. A river consists of several basic parts, originating from headwaters or a spring at the source, that flow into the main stream. The riparian strips on watercourses should be covered with forest, as shown on table 6.01.

Table 6.01 – Areas to be Forested Alongside Rivers and Streams

River or Stream Width	*Forest Width*
Up to 10 meters	30 meters
11 - 50 meters	50 meters
51 – 200 meters	100 meters
201 – 600 meters	200 meters
More than 600 meters	500 meters

Riparian areas or zones are the areas of vegetation directly separating land from water and immediately adjacent land that is frequently inundated, or, in other words, the floodways of streams. Vegetation in riparian areas typically consists of plants that either are emergent aquatic plants, or herbs, trees and shrubs that thrive in close proximity to water. Experience world-wide has shown the need to preserve riparian strips on watercourses. Devoid of trees, many areas denuded in this fashion quickly deteriorate. Figure 6.01 shows a river with riparian vegetation.

Figure 6.01 – River with Riparian Vegetation

Source: USDA, 2004

6.1.2 – Headwaters, Lakes, Ponds and Coastal Lines

A lake is a large body of water, usually fresh water, surrounded by land. Large lakes are sometimes referred to as "inland seas" and small seas are sometimes referred to as lakes. The term lake is also used to describe a feature such as Lake Eyre, which is dry most of the time but become filled under seasonal conditions of heavy rainfall. Figure 6.02 shows a lake still without the protective riparian vegetation.

Figure 6.02 – A Lake Without Riparian Vegetation

Source: Borde Hill Garden, 2004

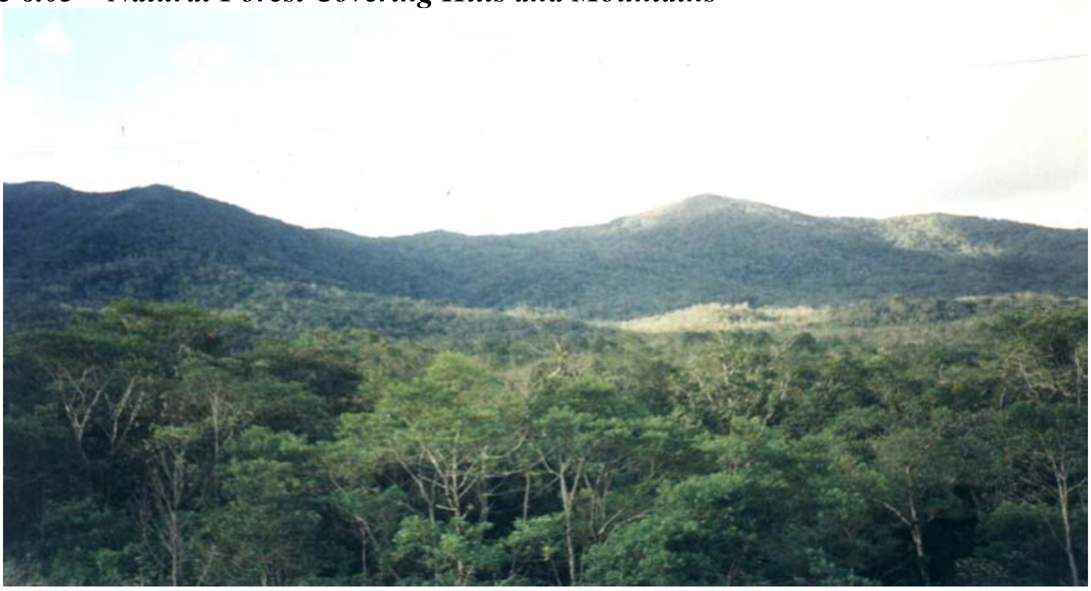
Similarly to the rivers and streams, the areas around headwaters, lakes, ponds and coastal lines should be forested. In this case, there should exist a forest cover in a radium of at least 50 meters from the edges of headwaters, lakes and ponds, and of at least 100 meters around the coastal lines.

6.1.3 – Mountains and Hills

A mountain is a landform that extends above the surrounding terrain in a limited area. A mountain is generally much higher and steeper than a hill, but there is considerable overlap, and usage often depends on local custom. The height of the feature makes it either a hill or, if higher and steeper, a mountain. The absolute heights of features termed mountains and hills vary greatly according to an area's topography.

Mountains are not generally favored for human habitation; the weather is harsher, less food is available, and there is little level ground suitable for farming. Therefore, in the areas with a declivity superior to 45 degrees, forest is the most suitable land use, providing all the services and goods seen on item 3. Figure 6.03 shows mountains and hills covered with natural forest.

Figure 6.03 – Natural Forest Covering Hills and Mountains



6.1.4 – Dunes and Bars

A dune is a hill of sand built by eolian (wind-related) processes. Bare dunes are subject to shifting location and size based on their interaction with the wind. The "valley" or trough between dunes is called a slack. Some coastal areas have one or more sets of dunes running parallel to the shoreline directly inland from the beach. In most such cases the dunes are important in protecting the land against potential ravages by storm waves from the sea. Although the most widely distributed dunes are those associated with coastal regions, the largest complexes of dunes are found inland in dry regions and associated with ancient lake or sea beds. Dunes also form under the action of water flow (alluvial processes), on sand or gravel beds of rivers, estuaries and the sea-bed. All these areas should be covered with forest.

A bar is a linear shoaling landform feature within a body of water. Bars tend to be long and narrow (linear) and develop where a current (or waves) promote deposition of particles, resulting in localized shallowing (shoaling) of the water. Bars can appear in the sea, in a lake, or in a river. They are typically composed of sand, although could be of any particulate matter that the moving water has access to and is capable of shifting around (for example, soil, silt, gravel, cobble, shingle, or even boulders). The size of the particles comprising a bar is related to the size of the waves or the strength of the currents moving the material, but the availability of material to be worked by waves and currents is also important. The term bar can apply to landform features over a considerable range in size, from just a few meters in a small stream to marine depositions stretching for hundreds of kilometres along a coastline, often called barrier islands. All these areas should be covered with forest.

Figure 6.04 – Dunes Without Forest Cover

Dunes are generally naturally fixate under natural succession or natural regeneration processes (see item 4.4). However, some areas may have had its natural vegetation extinct, as in the case of the Ameland Island, in The Netherlands. Besides that region is fairly moist, human interference eradicated most of the natural vegetation. Only a couple of species of grassland survived. But the remaining grass started to die because of acid rain, leaving the sand dunes of that island uncovered, what was threatening the local villages. The government first planted more resistant grass species to fixate the dunes and provide some organic matter to the soil. Later, pine trees started to be planted. After a couple of thinnings, the forest was enriched with shade tolerant species of trees.

6.2 – Macro-Regional Areas

Fragile ecosystems are important ecosystems, with unique features and resources. Fragile ecosystems include deserts, semi-arid lands, mountains, wetlands, small islands and certain coastal areas. Most of these ecosystems are regional in scope, as they transcend national boundaries. All these areas should be recovered through the methods shown on item 4. Here it is given special emphasis on the arid, semi-arid and mountain regions.

6.2.1 – Arid and Semi-Arid Regions

Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Desertification affects about one sixth of the world's population, 70 per cent of all drylands, amounting to 3.6 billion hectares, and one quarter of the total land area of the world. The most obvious impact of desertification, in addition to widespread poverty, is the degradation of 3.3 billion hectares of the total area of rangeland, constituting 73 per cent of the rangeland with a low potential for human and animal carrying capacity; decline in soil fertility and soil structure on about 47 per cent of the dryland areas constituting marginal rainfed cropland; and the degradation of irrigated cropland, amounting to 30 per cent of the dryland areas with a high population density and agricultural potential.

Figure 6.05 – The River Euphrates Banks

The priority in combating desertification should be the implementation of preventive measures for lands that are not yet degraded, or which are only slightly degraded. However, the severely degraded areas should not be neglected. In combating desertification and drought, the participation of local communities, rural organizations, national Governments, non-governmental organizations and international and regional organizations is essential (DESA, 1992).

- **Strengthening the Knowledge Base**

Strengthening the knowledge base and developing information and monitoring systems for regions prone to desertification and drought, including the economic and social aspects of these ecosystems is one of the key issues to revert the impacts human civilization has caused on fragile ecosystems.

– *Basis for Action*

The global assessments of the status and rate of desertification conducted by the United Nations

Environment Program (UNEP) in 1977, 1984 and 1991 have revealed insufficient basic knowledge of desertification processes. Adequate world-wide systematic observation systems are helpful for the development and implementation of effective anti-desertification programs. The capacity of existing international, regional and national institutions, particularly in developing countries, to generate and exchange relevant information is limited. An integrated and coordinated information and systematic observation system based on appropriate technology and embracing global, regional, national and local levels is essential for understanding the dynamics of desertification and drought processes. It is also important for developing adequate measures to deal with desertification and drought and improving socio-economic conditions.

− *Objectives*

One of the objectives is to promote the establishment and/or strengthening of national environmental information coordination centers that will act as focal points within Governments for sectorial ministries and provide the necessary standardization and back-up services; to ensure also that national environmental information systems on desertification and drought are linked together through a network at subregional, regional and interregional levels;

Another objective is to strengthen regional and global systematic observation networks linked to the development of national systems for the observation of land degradation and desertification caused both by climate fluctuations and by human impact, and to identify priority areas for action; also, to establish a permanent system at both national and international levels for monitoring desertification and land degradation with the aim of improving living conditions in the affected areas (DESA, 1992).

- **Forestation And Reforestation Activities**

Desertification affects about 3.6 billion hectares, which is about 70 per cent of the total area of the world's drylands or nearly one quarter of the global land area. In combating desertification on rangeland, rainfed cropland and irrigated land, preventative measures should be launched in areas which are not yet affected or are only slightly affected by desertification; corrective measures should be implemented to sustain the productivity of moderately desertified land; and rehabilitative measures should be taken to recover severely or very severely desertified drylands.

An increasing vegetation cover would promote and stabilize the hydrological balance in the dryland areas and maintain land quality and land productivity. Prevention of not yet degraded land and application of corrective measures and rehabilitation of moderate and severely degraded drylands, including areas affected by sand dune movements, through the introduction of environmentally sound, socially acceptable, fair and economically feasible land-use systems. This will enhance the land carrying capacity and maintenance of biotic resources in fragile ecosystems (DESA, 1992).

− *Objectives*

As regards areas not yet affected or only slightly affected by desertification, one of the objectives is to ensure appropriate management of existing natural formations (including forests) for the conservation of biodiversity, watershed protection, sustainability of their production and agricultural development, and other purposes, with the full participation of indigenous people. Another is to rehabilitate moderately to severely desertified drylands for productive utilization and sustain their productivity for agropastoral/agroforestry development through, soil and water conservation, among other. Also, to increase the vegetation cover and support management of biotic resources in regions affected or prone to desertification and drought, notably through such activities as forestation/reforestation, agroforestry, community forestry and vegetation retention schemes. Finally, to improve management of forest resources, including fuelwood, and to reduce fuelwood consumption through more efficient utilization, conservation and the enhancement, development and use of other sources of energy, including alternative sources of energy (DESA, 1992).

– *Activities*

Implement urgent direct preventive measures in drylands that are vulnerable but not yet affected, or only slightly desertified drylands, by introducing (i) improved land-use policies and practices for more sustainable land productivity; (ii) appropriate, environmentally sound and economically feasible agricultural and pastoral technologies; and (iii) improved management of soil and water resources.

Carry out accelerated forestation and reforestation programmes, using drought-resistant, fast-growing species, in particular native ones, combined with community-based agroforestry schemes. In this regard, creation of large-scale reforestation and forestation schemes, particularly through the establishment of green belts, should be considered, bearing in mind the multiple benefits of such measures.

Implement urgent direct corrective measures in moderately to severely desertified drylands, in addition to the measures listed above, with a view to restoring and sustaining their productivity.

Promote improved land/water/crop-management systems, making it possible to combat salinization in existing irrigated croplands; and to stabilize rainfed croplands and introduce improved soil/crop-management systems into land-use practice.

Promote participatory management of natural resources, including rangeland, to meet both the needs of rural populations and conservation purposes, based on innovative or adapted indigenous technologies.

Promote in situ protection and conservation of special ecological areas through legislation and other means for the purpose of combating desertification while ensuring the protection of biodiversity.

Promote and encourage investment in forestry development in drylands through various incentives, including legislative measures;

Promote the development and use of sources of energy which will lessen pressure on ligneous resources, including alternative sources of energy and improved stoves (DESA, 1992).

- **Eradication of Poverty**

In areas prone to desertification and drought, current livelihood and resource-use systems are not able to maintain living standards. In most of the arid and semi-arid areas, the traditional livelihood systems based on agropastoral systems are often inadequate and unsustainable, particularly in view of the effects of drought and increasing demographic pressure. Poverty is a major factor in accelerating the rate of degradation and desertification. Action is therefore needed to rehabilitate and improve the agropastoral systems for sustainable management of rangelands, as well as alternative livelihood systems (DESA, 1992).

– *Objectives*

Create the capacity of village communities and pastoral groups to take charge of their development and the management of their land resources on a socially equitable and ecologically sound basis.

Improve production systems in order to achieve greater productivity within approved programs for conservation of national resources and in the framework of an integrated approach to rural development.

Provide opportunities for alternative livelihoods as a basis for reducing pressure on land resources while at the same time providing additional sources of income, particularly for rural populations, thereby improving their standard of living (DESA, 1992).

– *Activities*

The management-related activities involve: (i) adopt policies at the national level regarding a decentralized approach to land-resource management, delegating responsibility to rural organizations; (ii) create or strengthen rural organizations in charge of village and pastoral land management; (iii) establish and develop local, national and intersectoral mechanisms to handle environmental and developmental consequences of land tenure expressed in terms of land use and land ownership. Particular attention should be given to protecting the property rights of women and pastoral and nomadic groups living in rural areas; (iv) create or strengthen village associations focused on economic activities of common pastoral interest (market gardening, transformation of agricultural products, livestock, herding, etc.); (v) promote rural credit and mobilization of rural savings through the establishment of rural banking systems; (vi) develop infrastructure, as well as local production and marketing capacity, by involving the local people to promote alternative livelihood systems and alleviate poverty; (vii) establish a revolving fund for credit to rural entrepreneurs and local groups to facilitate the establishment of cottage industries/business ventures and credit for input to agropastoral activities.

The data and information activities should: (i) conduct socio-economic baseline studies in order to have a good understanding of the situation in the program area regarding, particularly, resource and land tenure issues, traditional land-management practices and characteristics of production systems; (ii) conduct inventory of natural resources (soil, water and vegetation) and their state of degradation, based primarily on the knowledge of the local population (e.g., rapid rural appraisal); (iii) disseminate information on technical packages adapted to the social, economic and ecological conditions of each; (iv) promote exchange and sharing of information concerning the development of alternative livelihoods with other agro-ecological regions.

International and regional cooperation and coordination activities are: (i) promote cooperation and exchange of information among the arid and semi-arid land research institutions concerning techniques and technologies to improve land and labor productivity, as well as viable production systems; (ii) coordinate and harmonize the implementation of programs and projects funded by the international organization communities and non-governmental organizations that are directed towards the alleviation of poverty and promotion of an alternative livelihood system (DESA, 1992).

- **Anti-Desertification Programs**

In a number of developing countries affected by desertification, the natural resource base is the main resource upon which the development process must rely. The social systems interacting with land resources make the problem much more complex, requiring an integrated approach to the planning and management of land resources. Action plans to combat desertification and drought should include management aspects of the environment and development, thus conforming with the approach of integrating national development plans and national environmental action plans (DESA, 1992).

– *Objectives*

Strengthen national institutional capabilities to develop appropriate anti-desertification programs and to integrate them into national development planning.

Develop and integrate strategic planning frameworks for the development, protection and management of natural resources in dryland areas into national development plans, including national plans to combat desertification, and environmental action plans in countries most prone to desertification.

Initiate a long-term process for implementing and monitoring strategies related to natural resources management.

Strengthen regional and international cooperation for combating desertification through the adoption of legal and other instruments, among other (DESA, 1992).

– *Activities*

Management-related activities are: (i) establish or strengthen, national and local anti-desertification authorities within government and local executive bodies, as well as local committees/associations of land users, in all rural communities affected, with a view to organizing working cooperation between all actors concerned, from the grass-roots level (farmers and pastoralists) to the higher levels of government; (ii) develop national plans of action to combat desertification and as appropriate, make them integral parts of national development plans and national environmental action plans; (iii) implement policies directed towards improving land use, managing common lands appropriately, providing incentives to small farmers and pastoralists, involving women and encouraging private investment in the development of drylands; (iv) ensure coordination among ministries and institutions working on anti-desertification programmes at national and local levels.

- **Drought Preparedness**

Drought, in differing degrees of frequency and severity, is a recurring phenomenon throughout much of the developing world, especially Africa. Apart from the human toll - an estimated 3 million people died in the mid-1980s because of drought in sub-Saharan Africa - the economic costs of drought-related disasters are also high in terms of lost production, misused inputs and diversion of development resources.

Early-warning systems to forecast drought will make possible the implementation of drought-preparedness schemes. Integrated packages at the farm and watershed level, such as alternative cropping strategies, soil and water conservation and promotion of water harvesting techniques, could enhance the capacity of land to cope with drought and provide basic necessities, thereby minimizing the number of environmental refugees and the need for emergency drought relief. At the same time, contingency arrangements for relief are needed for periods of acute scarcity.

– *Objectives*

Develop national strategies for drought preparedness in both the short and long term, aimed at reducing the vulnerability of production systems to drought.

Strengthen the flow of early-warning information to decision makers and land users to enable nations to implement strategies for drought intervention.

Develop and integrate drought-relief schemes and means of coping with environmental refugees into national and regional development planning.

– *Activities*

Management-related activities include: (i) design strategies to deal with national food deficiencies in periods of production shortfall. These strategies should deal with issues of storage and stocks, imports, port facilities, food storage, transport and distribution; (ii) improve national and regional capacity for agrometeorology and contingency crop planning. Agrometeorology links the frequency, content and regional coverage of weather forecasts with the requirements of crop planning and agricultural extension; (iii) prepare rural projects for providing short-term rural employment to drought-affected households. The loss of income and entitlement to food is a common source of distress in times of drought. Rural works help to generate the income required to buy food for poor households; (iv) establish contingency arrangements, where necessary, for food and fodder distribution and water supply; (v) establish budgetary mechanisms for providing, at short notice, resources for drought relief; (vi) establish safety nets for the most vulnerable households.

- **Environmental Education**

The experience to date on the successes and failures of programs and projects points to the need for popular support to sustain activities related to desertification and drought control. But it is necessary to go beyond the theoretical ideal of popular participation and to focus on obtaining actual active popular involvement, rooted in the concept of partnership. This implies the sharing of responsibilities and the mutual involvement of all parties. In this context, this program area should be considered an essential supporting component of all desertification-control and drought-related activities.

– *Objectives*

Develop and increase public awareness and knowledge concerning desertification and drought, including the integration of environmental education in the curriculum of primary and secondary schools.

Establish and promote true partnership between government authorities, at both the national and local levels, other executing agencies, non-governmental organizations and land users stricken by drought and desertification, giving land users a responsible role in the planning and execution processes in order to benefit fully from development projects.

Ensure that the partners understand one another's needs, objectives and points of view by providing a variety of means such as training, public awareness and open dialogue.

Support local communities in their own efforts in combating desertification, and to draw on the knowledge and experience of the populations concerned, ensuring the full participation of women and indigenous populations.

– *Activities*

Management-related activities are: (i) adopt policies and establish administrative structures for more decentralized decision-making and implementation; (ii) establish and utilize mechanisms for the consultation and involvement of land users and for enhancing capability at the grass-roots level to identify and/or contribute to the identification and planning of action; (iii) define specific program/project objectives in cooperation with local communities; design local management plans to include such measures of progress, thereby providing a means of altering project design or changing management practices, as appropriate; (iv) introduce legislative, institutional/organizational and financial measures to secure user involvement and access to land resources; (v) establish and/or expand favorable conditions for the provision of services, such as credit facilities and marketing outlets for rural populations; (vi) develop training programs to increase the level of education and participation of people, particularly women and indigenous groups, through, literacy and the development of technical skills, among other; (vii) create rural banking systems to facilitate access to credit for rural populations, particularly women and indigenous groups, and to promote rural savings; (viii) adopt appropriate policies to stimulate private and public investment.

6.2.2 – Mountain Regions

Mountains are an important source of water, energy and biological diversity. Furthermore, they are a source of such key resources as minerals, forest products and agricultural products and of recreation. As a major ecosystem representing the complex and interrelated ecology of our planet, mountain environments are essential to the survival of the global ecosystem. Mountain ecosystems are, however, rapidly changing. They are susceptible to accelerated soil erosion, landslides and rapid loss of habitat and genetic diversity. On the human side, there is widespread poverty among mountain inhabitants and loss of indigenous knowledge. As a result, most global mountain areas are experiencing environmental degradation. Hence, the proper management of mountain resources and socio-economic development of the people deserves immediate action.

Figure 6.06 – Desertified Mountain Region

About 10 per cent of the world's population depends on mountain resources. A much larger percentage draws on other mountain resources, including and especially water. Mountains are a storehouse of biological diversity and endangered species.

- **Knowledge About Mountain Ecosystems**

Mountains are highly vulnerable to human and natural ecological imbalance. Mountains are the most sensitive areas to all climatic changes in the atmosphere. Specific information on ecology, natural resource potential and socio-economic activities is essential. Mountain and hillside areas hold a rich variety of ecological systems. Because of their vertical dimensions, mountains create gradients of temperature, precipitation and insolation. A given mountain slope may include several climatic systems - such as tropical, subtropical, temperate and alpine - each of which represents a microcosm of a larger habitat diversity. There is, however, a lack of knowledge of mountain ecosystems. The creation of a global mountain database is therefore vital for launching programs that contribute to the sustainable development of mountain ecosystems.

− *Objectives*

Undertake a survey of the different forms of soils, forest, water use, crop, plant and animal resources of mountain ecosystems, taking into account the work of existing international and regional organizations.

Maintain and generate database and information systems to facilitate the integrated management and environmental assessment of mountain ecosystems, taking into account the work of existing international and regional organizations.

Improve and build the existing land/water ecological knowledge base regarding technologies and agricultural and conservation practices in the mountain regions of the world, with the participation of local communities.

Create and strengthen the communications network and information clearing-house for existing organizations concerned with mountain issues.

Improve coordination of regional efforts to protect fragile mountain ecosystems through the consideration of appropriate mechanisms, including regional legal and other instruments.

Generate information to establish databases and information systems to facilitate an evaluation of environmental risks and natural disasters in mountain ecosystems.

– *Activities*

The management-related activities embrace: (i) strengthen existing institutions or establish new ones at local, national and regional levels to generate a multidisciplinary land/water ecological knowledge base on mountain ecosystems; (ii) promote national policies that would provide incentives to local people for the use and transfer of environment-friendly technologies and farming and conservation practices; (iii) build up the knowledge base and understanding by creating mechanisms for cooperation and information exchange among national and regional institutions working on fragile ecosystems; (iv) encourage policies that would provide incentives to farmers and local people to undertake conservation and regenerative measures; (v) diversify mountain economies, by creating and/or strengthening tourism, in accordance with integrated management of mountain areas, among other; (vi) integrate all forest, rangeland and wildlife activities in such a way that specific mountain ecosystems are maintained; (vi) establish appropriate natural reserves in representative species-rich sites and areas.

- **Protect Fragile Mountain Ecosystem**

Nearly half of the world's population is affected in various ways by mountain ecology and the degradation of watershed areas. About 10 per cent of the Earth's population lives in mountain areas with higher slopes, while about 40 per cent occupies the adjacent medium- and lower-watershed areas. There are serious problems of ecological deterioration in these watershed areas. For example, in the hillside areas of the Andean countries of South America a large portion of the farming population is now faced with a rapid deterioration of land resources. Similarly, the mountain and upland areas of the Himalayas, South-East Asia and East and Central Africa, which make vital contributions to agricultural production, are threatened by cultivation of marginal lands due to expanding population. In many areas this is accompanied by excessive livestock grazing, deforestation and loss of biomass cover.

Soil erosion can have a devastating impact on the vast numbers of rural people who depend on rainfed agriculture in the mountain and hillside areas. Poverty, unemployment, poor health and bad sanitation are widespread. Promoting integrated watershed development programs through effective participation of local people is a key to preventing further ecological imbalance. An integrated approach is needed for conserving, upgrading and using the natural resource base of land, water, plant, animal and human resources. In addition, promoting alternative livelihood opportunities, particularly through development of employment schemes that increase the productive base, will have a significant role in improving the standard of living among the large rural population living in mountain ecosystems.

– *Objectives*

Develop appropriate land-use planning and management for both arable and non-arable land in mountain-fed watershed areas to prevent soil erosion, increase biomass production and maintain the ecological balance.

Promote income-generating activities, such as sustainable tourism, fisheries and environmentally sound mining, and to improve infrastructure and social services, in particular to protect the livelihoods of local communities and indigenous people.

Develop technical and institutional arrangements for affected countries to mitigate the effects of natural disasters through hazard-prevention measures, risk zoning, early-warning systems, evacuation plans and emergency supplies.

– *Activities*

The management-related activities should: (i) undertake measures to prevent soil erosion and promote erosion-control activities in all sectors; (ii) establish task forces or watershed development committees, complementing existing institutions, to coordinate integrated services to support local initiatives in animal husbandry, forestry, horticulture and rural development at all administrative levels; (iii) enhance popular participation in the management of local resources through appropriate legislation; (iv) support non-governmental organizations and other private groups assisting local organizations and communities in the preparation of projects that would enhance participatory development of local people; (v) provide mechanisms to preserve threatened areas that could protect wildlife, conserve biological diversity or serve as national parks; (vi) develop national policies that would provide incentives to farmers and local people to undertake conservation measures and to use environment-friendly technologies; (vii) undertake income-generating activities in cottage and agro-processing industries, such as the cultivation and processing of medicinal and aromatic plants; (viii) undertake the above activities, taking into account the need for full participation of women, including indigenous people and local communities, in development.

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