evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

**Tento projekt je spolufinancován Evropským sociálním fondem a Státním rozpočtem ČR**
**InoBio – CZ.1.07/2.2.00/28.0018**

# Silviculture #1
# Introduction

**_Dr. Radek Pokorný_**

**_Laboratory of Ecological Physiology of Plants_**

evropský sociální fond v ČR
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# Who I am?

- Czech origin
- Graduated on Mendel University

  1995 Forest engineering (Ing.)

  2002 Applied and landscape ecology (Ph.D.)
- Assistant (1995-2002)
- Young scientist since 2003
- I have an open door policy- if I'm in, we can talk.
- Office address: Department of Silviculture, Mendel Univ., the 3rd floor or CzechGlobe, Poříčí 3b, Brno. Or, if you want to ensure that I will be available, contact me ahead of time (phone: 607 686 187, email: pokorny.r@czechglobe.cz or see me after class) to set up an appointment.

...

# Who are you?

One of the most important of the many disciplines in forestry is **silviculture**.

# Silviculture is based on knowledge of:

- Soil science
- Climatology
- Dendrology, botany
- Plant physiology
- Entomology, zoology
- Ecology
- Management
- Economy etc.

#These knowledge are not learned once for a lifetime. In a practice, continuing, informal kind of research in which understanding is sought, new ideas are applied, and old ideas are tested for validity.

# Puprose of the course

- Silviculture is the "**art and science**" of creating and maintaining communities of trees to meet specific objectives on a sustainable basis.
- The theory and practice of controlling the establishment, composition, and growth of stands of trees for any of the goods (including timber, pulp, energy, fruits, and fodder) and benefits (water, wildlife habitat, microclimate amelioration, and carbon sequestration) that they may be called upon to produce.
- In practicing silviculture, the forester draws upon knowledge of all natural factors that affect trees growing upon a particular site, and guides the development of the vegetation, which is either essentially natural or only slightly domesticated, to best meet the demands of society in general and ownership in particular. Based on the principles of forest ecology and ecosystem management, silviculture is more the imitation of natural processes of forest growth and development than a substitution for them.

# OBJECTIVES AND GOALS
## of the course

- This course will cover the principles for establishing, tending, and regenerating stands in the context of various ecological, economic, and social considerations. Students will develop a broad understanding of the silvicultural concepts and applications needed to manage forest stands for a variety of commodity and non-commodity values. Some of the values to be addressed in this course include timber production, wildlife habitat, water quality, recreation, forest health, and ecosystem restoration.

- Practical
  - Seminar paper

- Suggested Reading
  - Smith D. et al., 1997. The practice of silviculture: Applied forest ecology. By John Wiley & Sons, Inc.

I do not strictly "lecture", and I will seek your active engagement and contribution in discussing the reading material each day.

# Seminar paper content

- What is the history of silviculture in your country?
- What are the natural conditions for plant growth in your country?
- What are the dominant tree species in your forests and what are their ecological demands for optimal growth?
- What are the main principles of silvic in your forests?
- Choose one main problem in forestry of your country and present your opinion to solve it. /use literature/

# Evaluation and Performance Criteria

| Assignment | % of final grade |
|---|---|
| Seminar paper | 20 |
| Oral presentation | 10 |
| Articles | 5 |
| Test | 25 |
| Final exam | 40 |
| Σ | 100 |

| ***Letter Grade*** | ***Numeric Value [%]*** |
|---|---|
| A | 90-100 |
| $B^+$ | 87-89 |
| B | 80-86 |
| $C^+$ | 77-79 |
| C | 70-76 |
| D | 60-69 |
| E | <60 |

At the very minimum, the student is expected to attend class, complete all assignments on time, and be able to define the basic concepts and techniques of silviculture in seminar paper, exams, and other assignments.

After deadline late assignments will lose value at the rate of 10% per day.

In cases of extended illness or family emergencies, arrangements to make up missed exams or turn in late assignments must be communicate personally with me (phone, e-mail).

# The 1st definition

- Silviculture is the agriculture of trees- how to grow them, how to maximize growth and return, and how to manipulate tree species compositions to meet landowner objectives.

# The 2nd definition

- Silviculture is to forestry as agronomy is to agriculture. Like the rest of forestry itself, silviculture is an applied science that rests on the more fundamental natural and social sciences.

# The 3rd definition

- Silviculture is a kind of process engineering of forest architecture aimed at creating structures or developmental sequences that will serve the intended purpose, be in harmony with the environment, and withstand the loads imposed by environmental influences

# By other words..

- The art of producing and tending a forest
- The application of knowledge of silvics in the treatment of a forest
- The theory and practice of controlling forest establishment, composition, structure, and growth

## Silvics involves understending how tree grow, reproduce, and respond to environment changes

- The tiny embryo of the seed of the tree contains the potential to develop into the most majestic of plants. But if the environment is unfavorable, this potential will not be realized. Thus, responses of different species to environmental influences determine in part the success of silviculture. Silviculturists must know how the environment will affect the growth and development of trees they wish to manage.

*Silviculture is the ecology of the forest*

# The Purpose of Silviculture

- The dominant objective – timber production
- Benefits – water, wildlife, grazing, recreation, aesthetics...

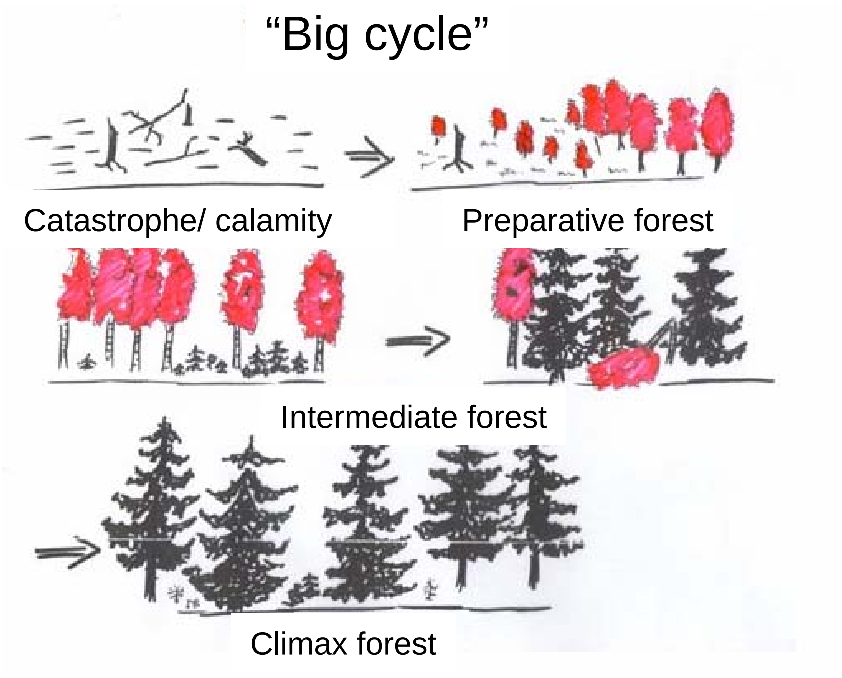
# Improving Nature Through Silviculture

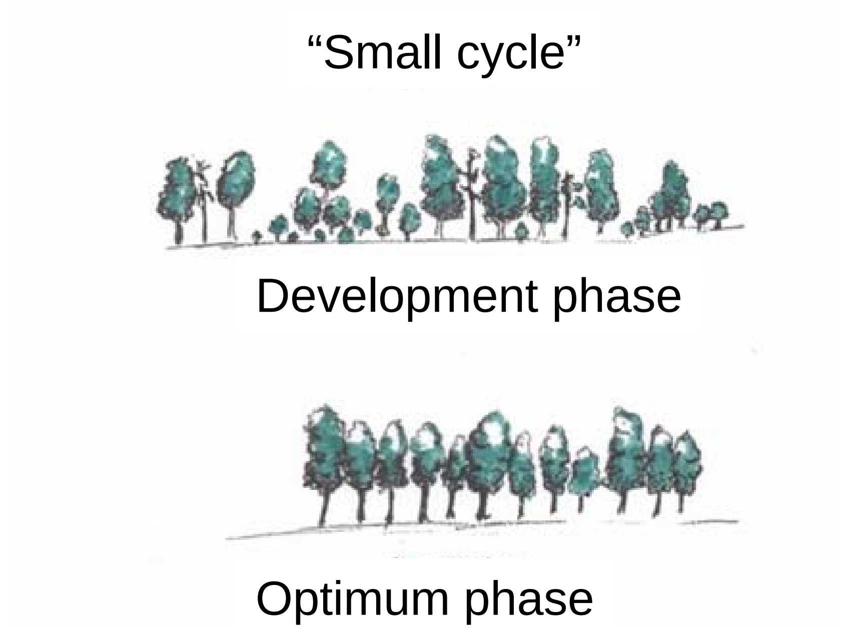
Human purpose is introduced by preference for certain tree species, stand structures, or processes of stand development that have desirable characteristics. Where fine forest have developed in nature, they are usually found to have the result of fortuitous dis-turbances followed by long periods of growth. In sillviculture, natural processes are deliberately guided to produce forests that are more useful than those of nature, and to do so in less time.

# Forest structure

- Species composition structure
- Age structure
- Spatial structure
- Functional structure

# Forest development cycle



# Forest form: highwood forest

- **Vysokokmenný les** (synonymum: Les vysoký) je na rozdíl od výmladkového lesa složen převážně ze dřevin obnovených generativní cestou (tj. semeny nebo **sazenicemi**). Tento lesnický termín se používá téměř výlučně pro vymezení lesů, které nejsou výmladkovými lesy nebo lesy sdruženými. Generativně obnovené stromy rostou z počátku pomaleji než výmladky, ale mají mnohem kvalitnější (rovné) kmeny. Vysokokmenný les tak díky kvalitnějšímu a silnějšímu dříví poskytuje vyšší finanční výnos než les výmladkový. Nevýhodou vysokokmenného lesa je mnohem delší obmýtí (oddálení finančních výnosů). Jde tedy o jeden ze tří tvarů lesa lišících se způsobem svého vzniku.

# Forest form: coppice forest; low forest; farm woodland

**Výmladkový les** (synonyma: **nízký les**, **pařezina**) je tvar lesa, který vzniká z **pařezových** a kořenových **výmladků**. Není tedy na rozdíl od **lesa vysokokmenného** ani uměle vysazen či vyset, ani nevzniká přirozenou obnovou (náletem). Využívá se schopností některých dřevin tvořit pařezové kořenové výmladky. Kmenové (přové) výmladky neboli vlky byly využívány k oklestnému hospodaření (například známé „hlavaté“ vrby). Způsob hospodaření spočívá v tom, že se dobře zmlazující listnaté porosty, vetšinou nízko u země, naholo pokácí a s vyrostlými výmladky se dále hospodaří (prořezávají se a periodicky kácejí). Nejčastějšími dřevinami ve výmladkovém lese bývaly buky, duby, habry, vždy s příměsí mnoha dalších dřevin. Na zamokřených půdách kralovala ve výmladkových lesích olše.

Výmladky pařezové i kořenové vyráží **olše šedá**, jilmy, javor babyka, **třešeň**, slivoně, **akát**, topoly, mnoho druhů vrb, rakytník řešetlákový a většina keřů. Téměř výlučně pařezovou výmladnost mají: buk lesní, habr, duby, jírovec maďal, jasan, javory, břízy, olše lepkavá, lípy, hrušně a jabloně, jeřáb břek, jeřáb ptačí, jeřáb muk.[1] Pro tvorbu výmladků je důležitá výška pařezů, poloha kořenů a jejich hloubka pod povrchem atp.

# Forest form: coppice-with-standard

•**Sdružený les** (Les střední) - je kombinací obou předchozích tvarů. Charakteristická je existence dvou nebo více pater. Horní patra jsou tvořena generativně obnovenými dřevinami (zpravidla v násobcích **obmýtí** pařeziny) a nejnižší etáž tvoří vegetativně obnovené výmladky.

**Intermediate stand treatments are forest management activities that take place in young, middle-aged, and mature woodlands, and often incorporate the** selective cutting or removal of trees, shrubs, brush, and woody vines in order to enhance current stand conditions and future desired outcomes. Intermediate treatments are commonly prescribed by professional foresters to improve species composition and wildlife habitat; regulate stand density; increase mast production; enhance timber quality and forest health; and promote and establish desirable advance regeneration. While designing your intermediate management treatments, remember to consider wildlife foot plots, brush piles, water sources, escape cover, and cavity and den trees. As a reminder, please protect your woodland from livestock grazing, wildfire, and invasive/exotic species.

# The Silvicultural System

| Component | Treatments |
|---|---|
| Regeneration | Natural<br>Artificial (seeding or planting) |
| Tending | Release cuttings<br>Pruning<br>Thinning<br>Intermediate cuts |
| Harvest<br>(regeneration method) | Clearcutting<br>Shelterwood<br>Seed tree<br>Selection system |

What could be under control?

# Control of Stand Structure Process

- The shape and sizes of stand

  Altered by many purposes- expediting silviculture treatments and harvesting, creating attractive scenery, governing animal or pest populations, trapping snow, and reducing wind damage. The shapes of stand should fitted to the immutable patterns dictated by soils and terrain.

- The internal structure of stand

  Determined by consideration such as variation in species and age classes (or lack of it), the arrangement of different layers or stories of vegetation, and the distribution of diameter classes.

- Controlling Establishment

  We can influence the time and place when regeneration occurs. Regeneration can take place naturally or, as is more common in the southeast, artificially by seeding or planting.

# Control of composition

Forest composition can be controlled by restricting species to ones biologically and or economically suited to the site. This can be done by:

- regulating intensity of cutting
- influencing the character of the seedbed
- scheduling the time and placement of cuttings
- seeding or planting

During subsequent tending, we can restrict forest composition to the most valuable trees by keeping:

- the best-formed trees
- fastest growing trees
- most valuable species

# Control of composition

- One objective of silviculture is to restrict the composition of stands to that most suited to the location from economic and biological standpoints.(i.e. total number of species in a managed forest is less than that of the natural forest).
- Species composition is controlled basically through regulating the kind and degree of disturbance during periods when new stands are being established. In this way environmental conditions can be adjusted to exclude undesirable species.
- Cutting, poisoning, controlled burning, or regulated feeding may be used to restrict the competition and regeneration of undesirable vegetation.
- Desirable species and genotypes can be favored in a more positive fashion by planting or artificial seeding. /nature improvement by introduction of species which are adaptable

# Control of stand density

We can control growth by regulating stand density (or number of trees per unit area). There are two ways this can be done.

- **Seek optimum stocking**: to achieve complete site utilization and capture mortality before it occurs.
- **Channel growth to selected trees**: concentrate growth onto selected species and individual trees, and channel the full productive capacity of the site onto fewer trees per acre.

# Control of stand density

- Inadequately managed forests are often too densely or too sparsely stocked with trees. If stand density is too low, the trees may be too branchy or otherwise malformed, and the unoccupied spaces are likely to be filled with unwanted vegetation.
- High stand density causes the production to be distributed over so many individual trees that none can grow at an optimum rate and too many may decline in vigor.
- Fires, destructive logging, grazing, agricultural clearances, and other kinds of forest devastation have already created many large, open areas that can be reforested only by planting.
- In unmanaged stands, severe losses are commonly caused by damaging agencies such as insects, fungi, fire, and wind, as well as by the loss of merchantable trees through competition. Proper control of damaging agencies can result in further increases in production. Adequate protection should be extended to all forests.

# Control of rotation length

- I most situations, there is an optimum size or age to which trees should be grown. The period of years required to grow stand to this specified condition of either economic or natural maturity is known as the rotation.
- Controlled reductions of stand density or such measures as fertilization and drainage can shorten rotations by making the final-harvest trees grow to the desired sizes at earlier ages.
- Premature cutting is a common type of mismanagement.
- Reservation of overmature trees or even of dead trees may be necessary for some wildlife species or simply for scenery.

# Conservation of site productivity

- The main objective of forestry is maintenance of the productivity!
- The site is the total combination of the factors, living and inanimate, of a place that determine this productivity!
- The basic supply of solar energy, the most vital site factor, is beyond silvicultural control! /manipulation of the microclimate
- Silviculture is concerned with the building and control of forest ecosystems. The continuity of life and the health of ecosytems ultimately depend on completion of ecological cycles of vital materials.
- Silviculture is usually far more the imitation of the natural processes of forest growth and development than substitution for them.
- The decisions made in silvicultural practice are based fully much on economic constraints and social objectives as on the natural factors that govern the forest. Recognition of objectives and limitations set by society in any given case reduces the silvicultural alternatives that need be considered. /forest management- forest planning, economic analysis, harvest scheduling etc.

# *The Silvicultural System*

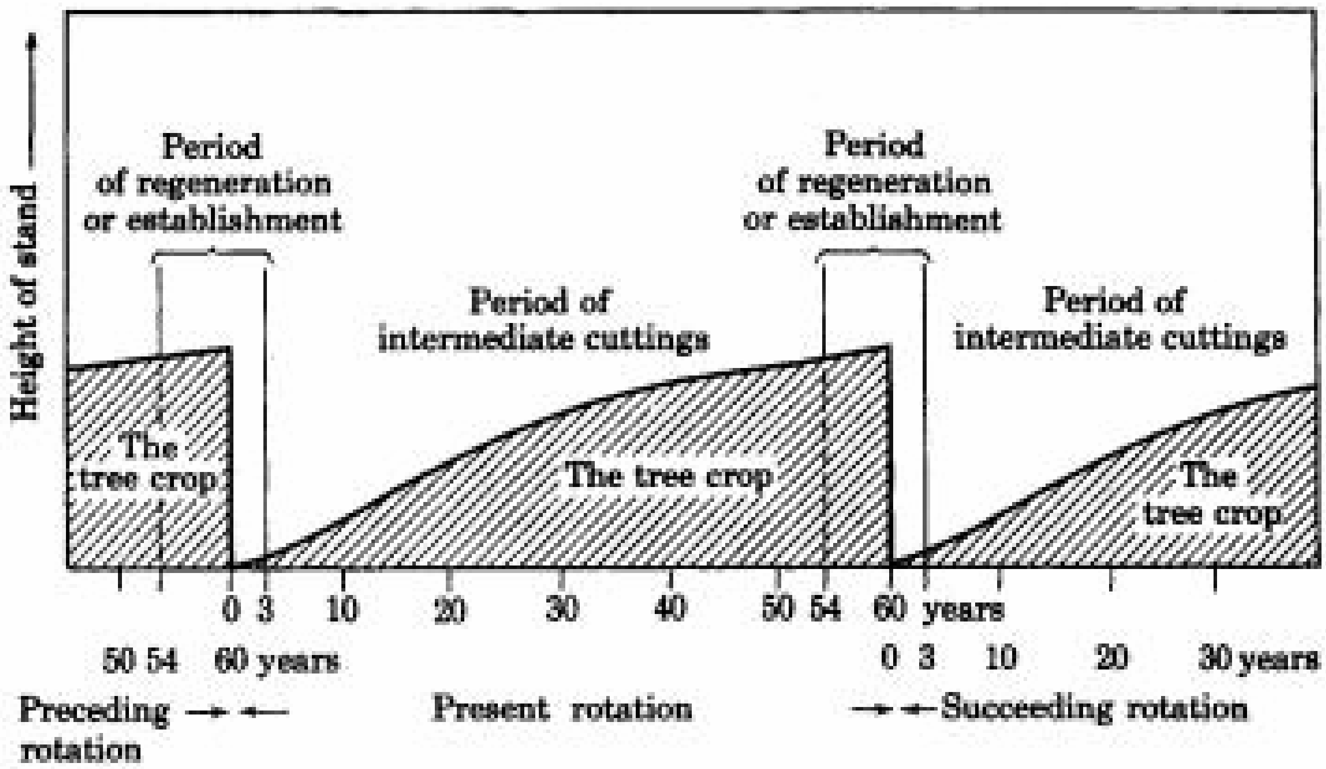
In forestry, we think of forests at two distinct levels:
the **stand level** and the **forest level**.

- A **tree** is a woody plant with distinguishable stem and crown in a habit.
- A **stand** is a contiguous group of trees sufficiently uniform in specie composition, arrangement of age classes, site quality, and condition to be a distinguishable unit.
- The term **forest** has a special meaning and denotes a collection of stands administrated as an integrated unit, usually under one ownership.

Stand Management

- In stand management we are working with a community of trees that are sufficiently uniform in composition, age, spatial arrangement, or other condition to distinguish it from adjacent communities.
- The production of benefits by forest stand is controlled by the developmental processes of those stands whether these benefits be wood, wildlife, water, forage, or scenery. The processes all of those that start with the birth of the stands, continue with competition between trees, and end with the death of old trees and their replacement.
  - Pure even-aged stand: a group of trees having no or a small difference in ages; by convention, with a spread of ages not exceeding 20% of the rotation* length.
  - Uneven-aged stands: a group of trees that differ significantly in ages; by convention, with a spread of ages exceeding 25% of the planned life span for an age class.
  - Mixed stands

# Rotation: the planned number of years between stand formation and cutting.




The relationship between the period of regeneration and the period of intermediate cuttings is shown for a sequence of even-aged stands managed on a 60–year rotation according to the shelterwood system. In this system the new stand is started before the older one is completely removed.

**Note**: Even-aged stands *never* have regeneration, tending, and harvest occurring simultaneously. Uneven-aged stands *always* do.

# Kinds of silvicultural treatmements

- Methods of reproduction
  - Include regeneration and establishment periods
- Tending or intermediate cutting

- Reproduction or regeneration cuttings- removing the old trees and creating environments favorable for establishment of regeneration.
- The regeneration period begins when preparatory measures start, and it ends when young trees, free to grow, are dependably established in acceptable numbers. /may extend from several years to decades
- The rotation is the period during which a single crop or generation is allowed to grow. The act of replacing old trees, either naturally or artificially, is called regeneration or reproduction.

# Methods of reproduction

- **High-forest methods – production stands originating mainly from seed**
  - **Clearcutting method –** removal of the entire stand in one cutting with reproduction obtained artificially or from seeds germinating after clearing operation.
  - **Seed-tree method** – removal of the old stand in one cutting, except for a small number of seed trees left singly or in small groups to provide for the establishment of advance regeneration.
  - **Shelterwood method** – removal of the old stand in a series of cuttings, which extend over a relatively short portion of the rotation, by means of which the establishment of one cohort of advance regeneration under the partial shelter of seed trees is encouraged.
  - **Selection method** – continual creation or maintenance of uneven-aged or multi-cohort stands by means of occasional replacement of single trees or small groups of trees with regeneration from any source

- **Coppice-forest methods – production of stands originating primarily from vegetative regeneration**
  - **Coppice method –** any type of cutting in which dependence is placed mainly on vegetative reproduction
  - **Coppice-with-standards method** – the combination, on the same area, of cohort-rotation coppice growth with scattered trees, which are grown on longer rotations and may be of seedling origin.

# Kinds of basic silvicultural impacts

Stand improvement operations or timber stand improvement

- Release operations
  - Treatments conducted to regulate species composition and improve very young stands
- Pruning
  - Those that involve only the branches are pruning.
- Thinning
  - Intermediate cuttings that are aimed primarily at controlling the growth of stands by adjusting stand density or species composition

Silvicultural system

Depends on stand stage, methods (type) of regeneration - impacts, intensity (the frequency and severity of cuttings during the rotation)

Harvesting, regenerating and tending of forests, designed to reduce injury (insects attack, pathogens, fire, wind..)

# Role of cuttings

- The techniques of silviculture proceed on the basic assumption that the vegetation on any site tends to extend itself aggressively to occupy the available growing space.
- The limit of growing space is usually set by the availability of light, water, inorganic nutrients, or carbon dioxide.
- Only way that forest can be altered or controlled is by killing trees and other plants. /one of the characteristics of life is death; if there were no death, there would be no space for new life./
- What is left or what replaces what is harvested is more important silviculturally than what is cut.
- The trees that must be reserved somewhere in the forest to continue production are the growing stock or forest capital.
- Cuttings regulate the amount of this growing stock and its distribution within individual stands or among the various stands that comprise the forest.

- Note for hunters: The animals ultimately depend on the vegetation for food and thus do not compete directly for the growing space.

# Practice

- The decision to practice forestry is usually a matter of ethics, politics, and social concern for posterity but not basically one of conventional economics.
- The removal cannot exceed the productive capacity of the forest.
- Intensity of silviculture varies widely, depending chiefly on economic circumstances.
  - Extensive - in remote areas, on poor sites, or where are not willing or able to make more than minimum investments. Is often plays a role where timber production is secondary to other purposes of forest management. However, the poorest and most ill-treated stands are often found on the best sites and most conveniently located stands, as they have been exploited first, most heavily, and most frequently. Inversely, the best forest are now often found on remote areas.
  - Intensive

In localities where it is customary to secure regeneration by planting, the forester may regard methods of natural regeneration only as matters of intellectual exercise. Conversely, where planted stands are an anathema or owners are not ready to invest in them, only natural regeneration may seem important.

# Harvesting Methods

***Clearcutting***

Clearcutting reproduces a new even-aged stand by completely removing the mature stand.Clearcutting as a silvicultural treatment has several characteristics:

- it causes a sudden environmental change
- it removes the seed source from the regeneration area
- the configuration of the clearcut may affect seed dispersal
- it begins a new rotation
- it will eliminate some pests that require forest cover
- overall, it temporarily removes the forest cover, transforming the forest community and environment.

Clearcutting followed by artificial (seeded or planted) regeneration has several advantages:

- we can avoid delay in restocking the site
- we can introduce a selected species, seed source, and genotype
- we can control arrangement and spacing
- we can achieve uniformity in the new stand
- we can overcome the problems associated with securing sufficient natural regeneration.

# Harvesting Methods

***Shelterwood Method***

The shelterwood method involves the removal of most of the mature stand at the end of the rotation, but a portion of the mature stand is left standing. The shelterwood method serves three basic purposes:

- To *prepare* the stand for production of abundant seed
- To *modify* the environment in a way that promotes germination and survival of the selected species
- To *build* up the amount and size of advance regeneration to ensure the prompt restocking of the new stand following overstory removal.

The shelterwood method involves a sequence of 3 cuttings:

1. **Preparatory Cuttings:** make the seed trees more vigorous and set the stage for regeneration.
2. **Establishment / Seed Cuttings:** open up enough vacant growing space to allow establishment of the new regeneration.
3. **Removal Cuttings:** uncover the new crop to allow it to fill the growing space.

# Harvesting Methods

The residual trees in the shelterwood must:

- be sturdy and windfirm
- be able to survive exposure
- flower and reproduce seed
- be the ***best*** trees of the mature stand

Keep in mind that the shelter trees must not occupy the entire site. A void must be created in order to make room for the new regeneration. The amount of shelter to leave will depend on the following factors:

- species characteristics (seeding and shelter requirements)
- the number of cuttings in the cutting sequence (1, 2, or 3)
- landowner objectives
- the size of the area to be regenerated
- the final removal harvest level required to be profitable

The shelter must be removed before it impedes the growth of the new stand or threatens its survival.

# Harvesting Methods

***Seed Tree Method***

The seed tree method is similar to the **shelterwood method** in that we are removing most of the mature overstory and leaving a portion standing. However, the **seed tree method** leaves only a few residuals as a seed source only. The residuals from this cut are too few and scattered to provide shelter.

A seed tree cut will introduce environmental changes similar to those of **clearcutting**. This type of cut will provide some opportunity to influence seed source through the selection of the seed trees.

The residual trees of a seed tree cut must:

- be genetically superior trees of the selected species
- be sturdy and windfirm
- be able to survive exposure
- flower and produce abundant seed
- be the **VERY BEST** trees of the mature stand - these will be your only hope for the future.

The number of seed trees to leave will depend on the following factors:

- the amount of seed each tree provides
- the expected survival of germinated seed
- the size of the area to be regenerated

# Harvesting Methods

***Selection method***

- removal of mature timber, usually the oldest or largest trees, either as single scattered individuals or in small groups at relatively short intervals, so that an uneven-aged stand is maintained.

# *Environmental Considerations*

- You may harvest a part of or all of your forest land only once or twice in your lifetime, but the visual disturbance caused by harvesting may make some people uncomfortable. Some may believe that a disturbance of this magnitude (i.e., a clearcut) may lead to environmental degradation. Often, this belief is more a perception of sight and emotions rather than true environmental degradation.
- Forest landowners have the opportunity to reduce the visual disruption caused by forest harvesting and to maintain the environmental integrity and aesthetic appeal of their lands

# World forests - Africa

**FIGURE 1** Subregional breakdown used in this report

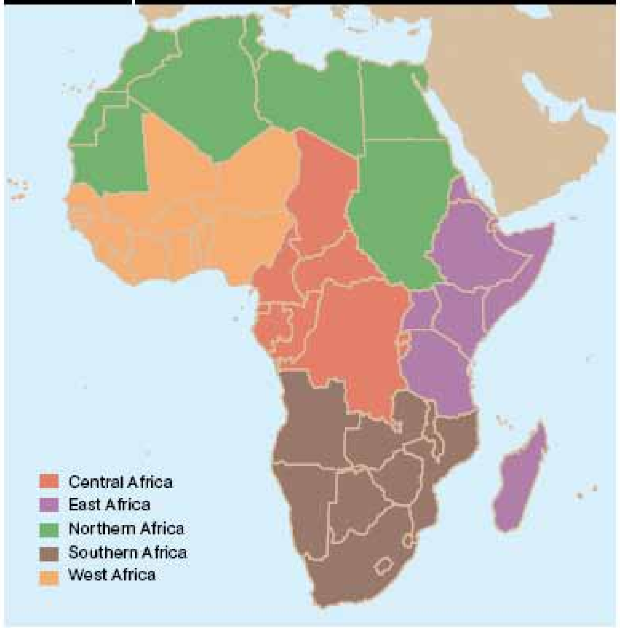
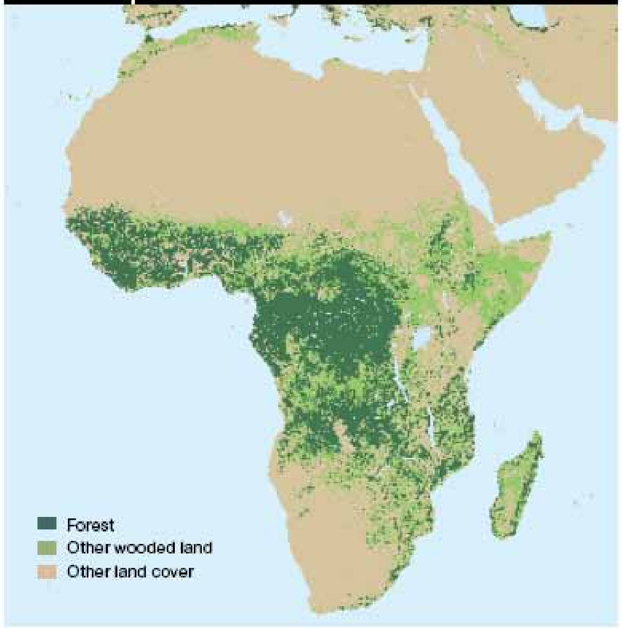


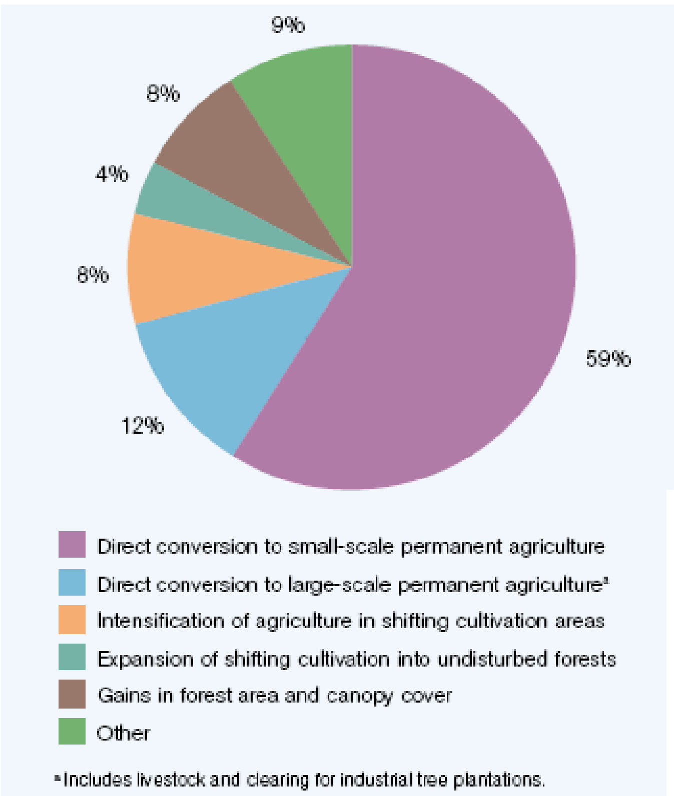

**FIGURE 2** Extent of forest resources




**Forest area: extent and change**

| Subregion | Area (1 000 ha) | | | Annual change (1 000 ha) | | Annual change rate (%) | |
|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 2005 | 1990–2000 | 2000–2005 | 1990–2000 | 2000–2005 |
| Central Africa | 248 538 | 239 433 | 236 070 | –910 | –673 | –0.37 | –0.28 |
| East Africa | 88 974 | 80 965 | 77 109 | –801 | –771 | –0.94 | –0.97 |
| Northern Africa | 84 790 | 79 526 | 76 805 | –526 | –544 | –0.64 | –0.69 |
| Southern Africa | 188 402 | 176 884 | 171 116 | –1 152 | –1 154 | –0.63 | –0.66 |
| West Africa | 88 656 | 78 805 | 74 312 | –985 | –899 | –1.17 | –1.17 |
| **Total Africa** | **699 361** | **655 613** | **635 412** | **–4 375** | **–4 040** | **–0.64** | **–0.62** |
| **World** | **4 077 291** | **3 988 610** | **3 952 025** | **–8 868** | **–7 317** | **–0.22** | **–0.18** |

# World forests - Africa




**Wood product output, 2006**

| Product | Global | Africa | Share (%) |
|---|---|---|---|
| Industrial roundwood *(million m³)* | 1 635 | 69.0 | 4 |
| Sawnwood *(million m³)* | 424 | 8.3 | 2 |
| Wood-based panels *(million m³)* | 262 | 2.5 | 1 |
| Pulp for paper *(million tonnes)* | 195 | 3.9 | 2 |
| Paper and paperboard *(million tonnes)* | 364 | 2.9 | 1 |
| Woodfuel *(million m³)* | 1 871 | 589.0 | 46 |

**SOURCE:** FAO, 2008a.


## SUMMARY

The forest situation in Africa presents enormous challenges, reflecting the larger constraints of low income, weak policies and inadequately developed institutions. Success stories exist but remain isolated because of fundamental economic and institutional weaknesses. Obstacles include:

- high dependence on land and natural resources and scant investment in development of human resources, skills and infrastructure;
- the low level of value addition in the economy, including the forest sector;
- the vastness of the informal sector, stemming from the weaknesses in the public sector and market mechanisms.

Focusing on the unique products and services required locally and globally and strengthening local institutions can be important ways of addressing forest resource depletion. Such efforts should build on successful experience with locally based sustainable resource management integrating agriculture, animal husbandry and forestry, and take advantage of local knowledge. The growing demand for environmental services – especially biodiversity and carbon sequestration – provides a particular opportunity for Africa.

# World forests – Asia and the Pacific

**FIGURE 8** Subregional breakdown used in this report

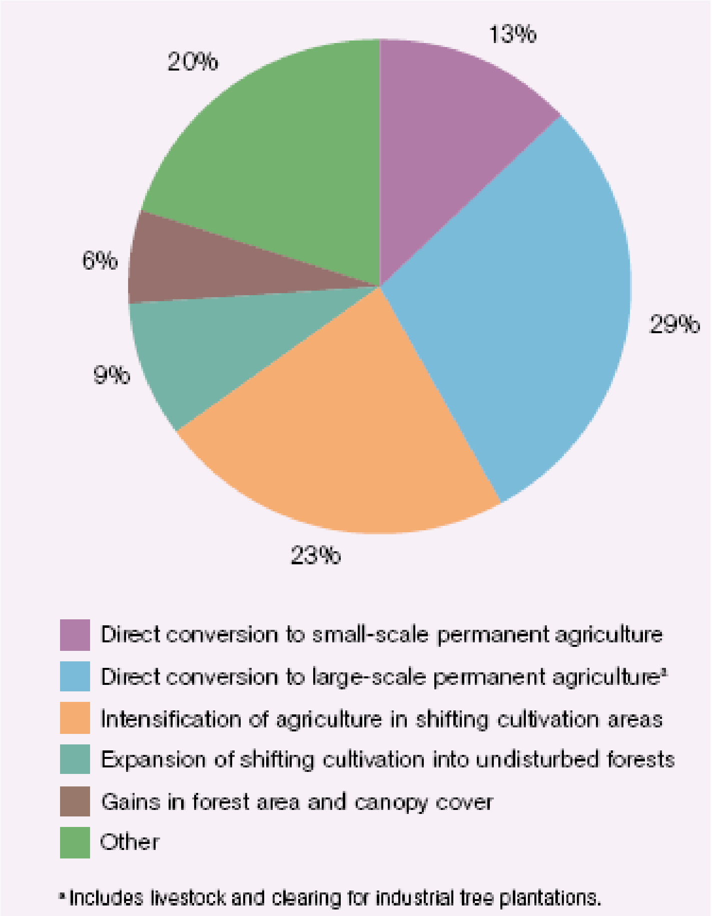

**FIGURE 9** Extent of forest resources


**Planted forest area change**

| Year | Extent of planted forests | | | Global total | Annual change in Asia and the Pacific |
|---|---|---|---|---|---|
| | Productive | Protective | Total | | |
| | *(million ha)* | | | | |
| 1990 | 67 | 36 | 103 | 209 | – |
| 2000 | 78 | 41 | 119 | 247 | 1.4 |
| 2005 | 90 | 46 | 136 | 271 | 2.8 |

**SOURCE:** FAO, 2006b.

# World forests – Asia and the Pacific





**SUMMARY**

Considering the great diversity of the region, a varied scenario is expected to unfold. While forest area will stabilize and increase in most of the developed countries and some of the emerging economies, most of the low- and middle-income forest-rich countries will witness continuing decline owing to expansion of agriculture (including the production of biofuel feedstock). Both traditional woodfuel and emerging bioenergy options will pose enormous land-use challenges. The rapid industrialization of the emerging economies will create great demand for primary commodities, which is likely to result in forest conversion in the remaining countries.

Demand for wood products will continue to rise in line with the growth in population and income. While the region is at the forefront of plantation forestry, its dependence on wood from other regions will continue in the foreseeable future. Overall, the region – especially some of the most populous countries – faces severe land and water constraints that may limit the scope for self-sufficiency in wood products.

The demand for forest environmental services will increase as incomes rise. Conservation involving local communities will receive greater emphasis. It remains to be seen how the post-2012 climate change arrangements evolve and whether initiatives such as REDD will actually provide sufficient incentives to refrain from forest clearance and other unsustainable uses.

# World forests – Europe

**FIGURE 18** Subregional breakdown used in this report


**FIGURE 19** Extent of forest resources

# World forests – Europe

**Forest area: extent and change**

| Subregion | Area (1 000 ha) | | | Annual change (1 000 ha) | | Annual change rate (%) | |
|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 2005 | 1990–2000 | 2000–2005 | 1990–2000 | 2000–2005 |
| CIS countries | 825 919 | 826 953 | 826 588 | 103 | −73 | 0.01 | −0.01 |
| Eastern Europe | 41 583 | 42 290 | 43 042 | 71 | 150 | 0.17 | 0.35 |
| Western Europe | 121 818 | 128 848 | 131 763 | 703 | 583 | 0.56 | 0.45 |
| **Total Europe** | **989 320** | **998 091** | **1 001 394** | **877** | **661** | **0.09** | **0.07** |
| **World** | **4 077 291** | **3 988 610** | **3 952 025** | **−8 870** | **−7 320** | **−0.22** | **−0.18** |

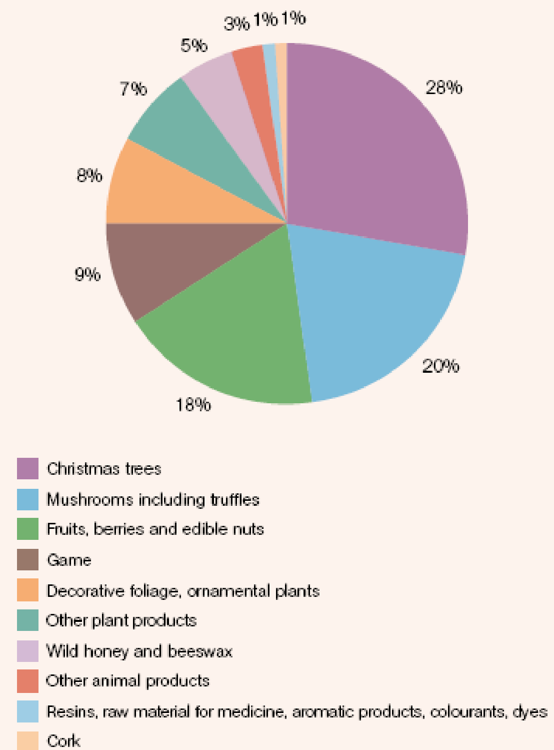
**Production and consumption of wood products**

| Year | Industrial roundwood (million m³) | | Sawnwood (million m³) | | Wood-based panels (million m³) | | Paper and paperboard (million tonnes) | |
|---|---|---|---|---|---|---|---|---|
| | Production | Consumption | Production | Consumption | Production | Consumption | Production | Consumption |
| 2000 | 483 | 473 | 130 | 121 | 61 | 59 | 100 | 90 |
| 2005 | 513 | 494 | 136 | 121 | 73 | 70 | 111 | 101 |
| 2010 | 578 | 543 | 147 | 131 | 82 | 79 | 128 | 115 |
| 2020 | 707 | 647 | 175 | 151 | 104 | 99 | 164 | 147 |

**Exports as percentage of production and imports as percentage of consumption, 2006**

| Subregion | Industrial roundwood | | Sawnwood | | Wood-based panels | | Paper and paperboard | |
|---|---|---|---|---|---|---|---|---|
| | Exports | Imports | Exports | Imports | Exports | Imports | Exports | Imports |
| | (%) | | | | | | | |
| CIS countries | 34 | 1 | 68 | 3 | 27 | 22 | 35 | 28 |
| Eastern Europe | 14 | 8 | 49 | 27 | 45 | 44 | 59 | 67 |
| Western Europe | 9 | 19 | 46 | 46 | 51 | 48 | 67 | 61 |
| **Total Europe** | **18** | **13** | **51** | **40** | **46** | **43** | **64** | **59** |
| **World** | **8** | **8** | **32** | **32** | **32** | **32** | **32** | **32** |

**FIGURE 23** Marketed non-wood forest products in Europe, percentage of total value



# World forests – Europe


## SUMMARY

Forest resources in Europe are likely to continue expanding. Fellings will probably remain below increment, and the provision of environmental services will continue as a primary concern, especially in Western Europe. Rules and regulations in this regard will make wood production less competitive in comparison with other regions.

Forest management will continue to serve a wide variety of demands. Economic viability is likely to remain a challenge, especially for small-scale forest owners, but the increased demand for woodfuel could change this.

While the forest industry, especially in Western Europe, may continue to lose competitiveness against other regions in labour-intensive segments, it is likely to retain leadership in the production of technologically advanced products, with much of the forest industry shifting to the production of "green" products.

Within the region, the differences in forestry between Eastern and Western Europe are likely to diminish as Eastern Europe catches up. The impacts of recent developments in the Russian Federation and in promoting wood energy are difficult to predict, and at present are mainly addressed for the short term.

# World forests – Latin America and the Caribbean

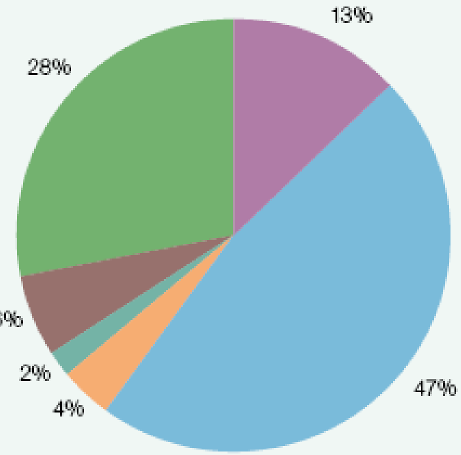


**Forest area: extent and change**

| Subregion | Area (1 000 ha) | | | Annual change (1 000 ha) | | Annual change rate (%) | |
|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 2005 | 1990–2000 | 2000–2005 | 1990–2000 | 2000–2005 |
| Caribbean | 5 350 | 5 706 | 5 974 | 36 | 54 | 0.65 | 0.92 |
| Central America | 27 639 | 23 837 | 22 411 | −380 | −285 | −1.47 | −1.23 |
| South America | 890 818 | 852 796 | 831 540 | −3 802 | −4 251 | −0.44 | −0.50 |
| **Total Latin America and the Caribbean** | **923 807** | **882 339** | **859 925** | **−4 147** | **−4 483** | **−0.46** | **−0.51** |
| **World** | **4 077 291** | **3 988 610** | **3 952 025** | **−8 868** | **−7 317** | **−0.22** | **−0.18** |

# World forests – Latin America and the Caribbean

**FIGURE 30** Direct causes of forest area changes in tropical Latin American countries, 1990–2000




[a] Includes livestock and clearing for industrial tree plantations.

## SUMMARY

The outlook for forests and forestry in Latin America and the Caribbean will be influenced by the pace of diversification of the economies and changes in land dependence (FAO, 2006c).

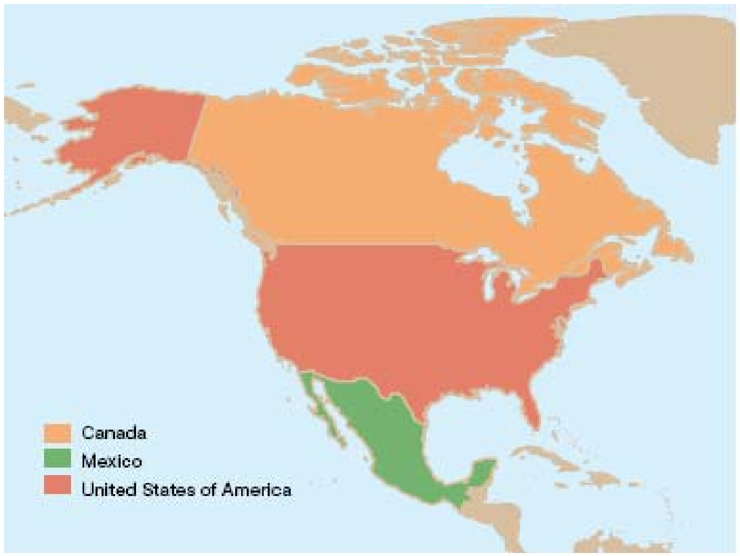
In most Central American and Caribbean countries, population densities are high; as urbanization increases, there is a significant shift away from agriculture and related activities, especially as smallholder agriculture becomes less remunerative. Tourism and remittances from migrant workers are becoming important sources of income. Agriculture-related forest clearance is declining and some cleared areas will revert to forest, as is already evident.

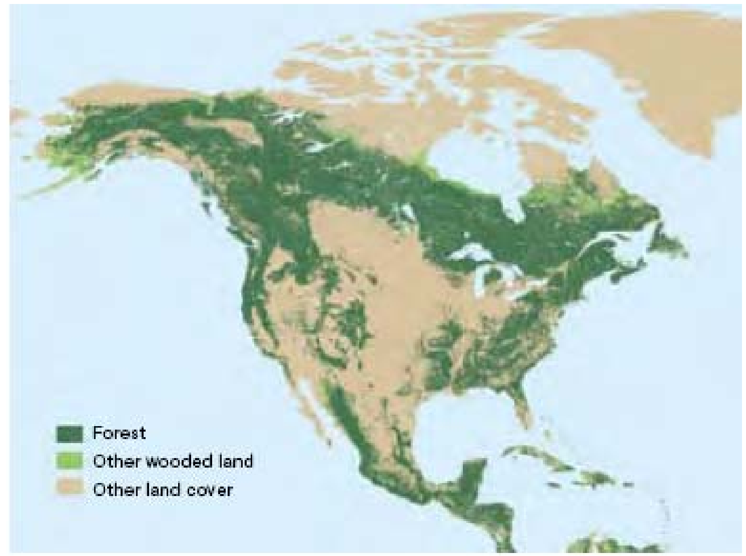
Although population density is low in South America, high food and fuel prices will favour continued forest clearance for increased production of livestock and agricultural crops for food, feed and biofuel to meet global demand – especially as South American economies increase linkages with emerging Asian economies.

Planted forests will spread, promoted by private investments and continuing global demand for wood products, especially from the emerging Asian economies. However, the accelerated plantation rate will not offset continuing deforestation.

In short, the pace of deforestation in South America is unlikely to decline in the near future. Heavily forested countries that are taking advantage of the expanding global demand for primary products and are pursuing a path of rapid economic development will find it extremely difficult to slow the rate of forest conversion. Provision of global public goods – for example carbon credits – may help to some extent. However, an effective mechanism for providing adequate incentives to refrain from forest clearance has yet to be developed.

# World forests –North America




**Forest area: extent and change**

| Country/region | Area (1 000 ha) | | | Annual change (1 000 ha) | | Annual change rate (%) | |
|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 2005 | 1990–2000 | 2000–2005 | 1990–2000 | 2000–2005 |
| Canada[a] | 310 134 | 310 134 | 310 134 | 0 | 0 | 0 | 0 |
| Mexico | 69 016 | 65 540 | 64 238 | –348 | –260 | –0.52 | –0.40 |
| United States of America | 298 648 | 302 294 | 303 089 | 365 | 159 | 0.12 | 0.05 |
| **Total North America[b]** | **677 801** | **677 971** | **677 464** | **17** | **–101** | **0** | **–0.01** |
| **World** | **4 077 291** | **3 988 610** | **3 952 025** | **–8 868** | **–7 317** | **–0.22** | **–0.18** |

# World forests –North America


**SUMMARY**

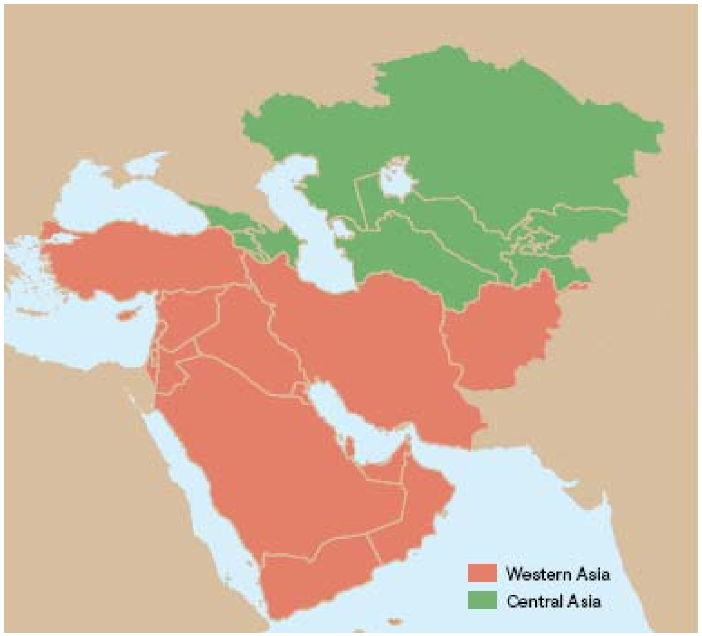
Uncertainty in North American forestry is a consequence of the current economic downturn in the United States and, in particular, the consequent declining construction sector demand. If this is part of a cycle leading to eventual recovery, there should be few major surprises in the next 10–15 years. However, the sector will need to address several challenges:

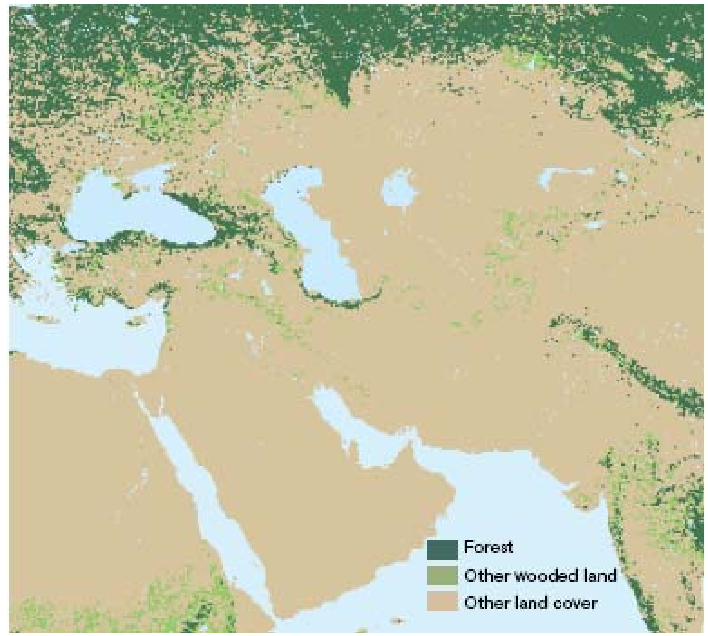
- climate change, the increasing frequency and severity of forest fires and damage by invasive pest species;
- challenges to sustainable forestry posed by the combination of increased global demand for food and biofuels and declining profitability of traditional wood industries;
- loss of competitiveness to emerging producers of wood products, especially Brazil, Chile and China, requiring continued innovation in order to expand exports and capture growing markets in Asia.

In Mexico, the rate of deforestation will continue to decline as urbanization continues and as increasing investments in reforestation and improved management practices result in more sustainable forest management.

While the economic viability of the forest industry may fluctuate and even decline, the provision of environmental services in North America will continue to gain in importance, driven by public interest. Many conservation initiatives will be spearheaded by civil-society organizations, which are able to mobilize substantial public support. Wood will be increasingly demanded as a source of energy, especially if cellulosic biofuel production becomes commercially viable.

# Western and Central Asia




**Forest area: extent and change**

| Subregion | Area (1 000 ha) | | | Annual change (1 000 ha) | | Annual change rate (%) | |
|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 2005 | 1990–2000 | 2000–2005 | 1990–2000 | 2000–2005 |
| Central Asia | 15 880 | 15 973 | 16 017 | 9 | 9 | 0.06 | 0.06 |
| Western Asia | 27 296 | 27 546 | 27 570 | 25 | 5 | 0.09 | 0.02 |
| **Total Western and Central Asia** | **43 176** | **43 519** | **43 588** | **34** | **14** | **0.08** | **0.03** |
| **World** | **4 077 291** | **3 988 610** | **3 952 025** | **−8 868** | **−7 317** | **−0.22** | **−0.18** |

**NOTE:** Data presented are subject to rounding.
**SOURCE:** FAO, 2006a.

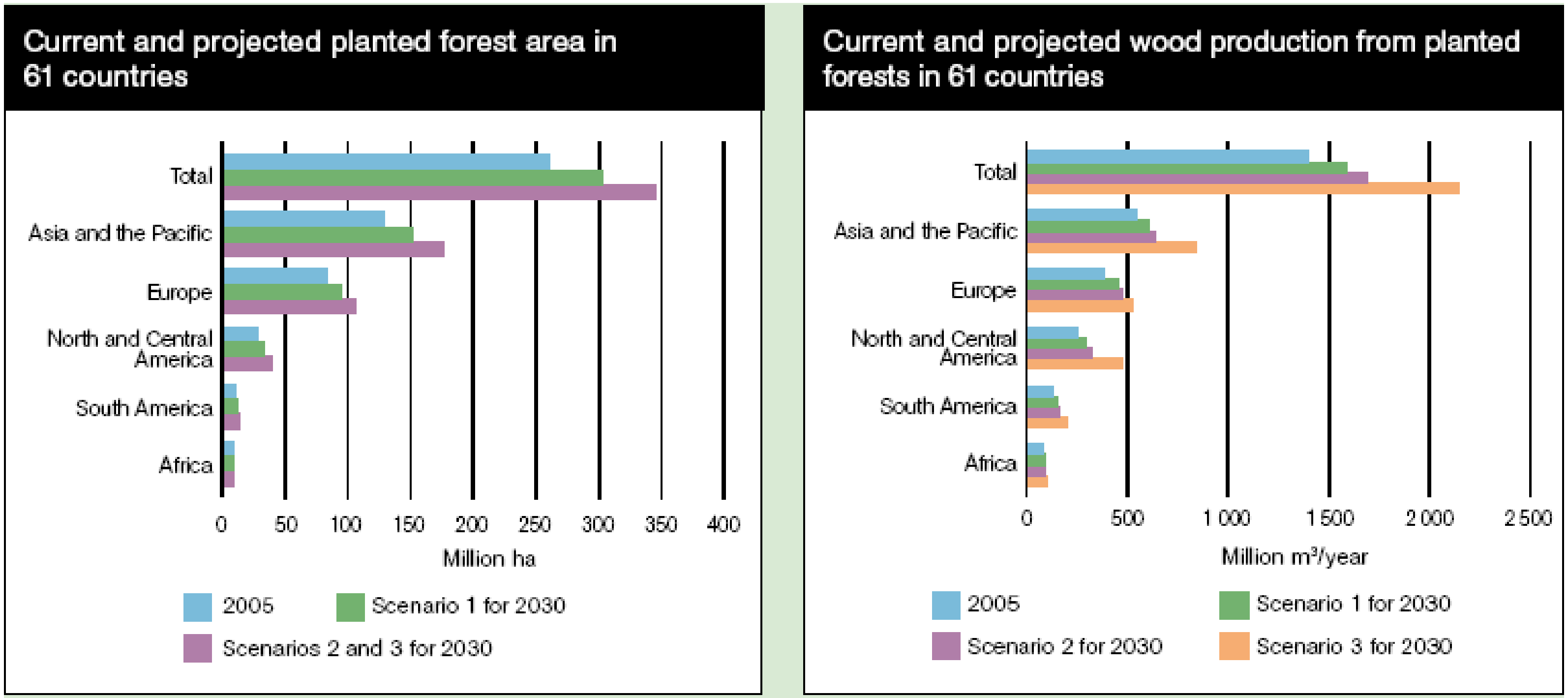
# Western and Central Asia

**SUMMARY**

The outlook for forests and forestry in Western and Central Asia is mixed. Income growth and urbanization suggest a stable or improving forest situation in some countries, but this will elude a number of low-income agriculture-dependent countries. Forest degradation may also persist in some countries that are relatively well off but have weak institutions.

Adverse growing conditions in most of the region's countries limit the prospects for commercial wood production. Rapidly increasing income and high population growth rates suggest that the region will continue to depend on imports to meet the demand for most wood products. Provision of environmental services will remain the main justification for forestry, especially arresting land degradation and desertification, protecting watersheds and improving the urban environment. Institution building, particularly at the local level, is needed to facilitate an integrated approach to resource management.

# Adapting for the future




**SOURCE:** Carle and Holmgren, 2008.

# Global demand for wood products

**Production and consumption of sawnwood**

| Region | Amount (million m³) | | | | | Average annual change (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Actual | | | Projected | | Actual | | Projected | |
| | 1965 | 1990 | 2005 | 2020 | 2030 | 1965–1990 | 1990–2005 | 2005–2020 | 2020–2030 |
| **Production** | | | | | | | | | |
| Africa | 3 | 8 | 9 | 11 | 14 | 3.7 | 0.5 | 1.6 | 1.9 |
| Asia and the Pacific | 64 | 105 | 71 | 83 | 97 | 2.0 | −2.6 | 1.1 | 1.6 |
| Europe | 189 | 192 | 136 | 175 | 201 | 0.1 | −2.2 | 1.7 | 1.4 |
| Latin America and the Caribbean | 12 | 27 | 39 | 50 | 60 | 3.3 | 2.5 | 1.7 | 2.0 |
| North America | 88 | 128 | 156 | 191 | 219 | 1.5 | 1.3 | 1.4 | 1.4 |
| Western and Central Asia | 2 | 6 | 7 | 10 | 13 | 4.6 | 1.5 | 2.6 | 2.2 |
| **World** | **358** | **465** | **417** | **520** | **603** | **1.1** | **−0.7** | **1.5** | **1.5** |
| **Consumption** | | | | | | | | | |
| Africa | 4 | 10 | 12 | 19 | 26 | 3.6 | 1.2 | 2.8 | 3.5 |
| Asia and the Pacific | 64 | 112 | 84 | 97 | 113 | 2.3 | −1.9 | 1.0 | 1.6 |
| Europe | 191 | 199 | 121 | 151 | 171 | 0.2 | −3.3 | 1.5 | 1.2 |
| Latin America and the Caribbean | 11 | 26 | 32 | 42 | 50 | 3.3 | 1.5 | 1.7 | 1.8 |
| North America | 84 | 117 | 158 | 188 | 211 | 1.3 | 2.0 | 1.2 | 1.2 |
| Western and Central Asia | 3 | 7 | 13 | 18 | 23 | 4.0 | 3.7 | 2.5 | 2.2 |
| **World** | **358** | **471** | **421** | **515** | **594** | **1.1** | **−0.8** | **1.4** | **1.4** |

**NOTE:** Data presented are subject to rounding.
**SOURCES:** FAO, 2008a, 2008c.

# Global demand for wood products

**Production and consumption of wood-based panels**

| Region | Amount (million m³) | | | | | Average annual change (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Actual | | | Projected | | Actual | | Projected | |
| | 1965 | 1990 | 2005 | 2020 | 2030 | 1965–1990 | 1990–2005 | 2005–2020 | 2020–2030 |
| **Production** | | | | | | | | | |
| Africa | 1 | 2 | 3 | 4 | 5 | 4.6 | 3.8 | 2.1 | 2.4 |
| Asia and the Pacific | 5 | 27 | 81 | 160 | 231 | 6.9 | 7.5 | 4.6 | 3.7 |
| Europe | 16 | 48 | 73 | 104 | 129 | 4.5 | 2.8 | 2.4 | 2.2 |
| Latin America and the Caribbean | 1 | 4 | 13 | 21 | 29 | 7.4 | 7.6 | 3.3 | 3.2 |
| North America | 19 | 44 | 59 | 88 | 110 | 3.4 | 2.0 | 2.7 | 2.2 |
| Western and Central Asia | 0 | 1 | 5 | 11 | 17 | 6.8 | 8.9 | 5.4 | 4.7 |
| **World** | **41** | **127** | **234** | **388** | **521** | **4.6** | **4.2** | **3.4** | **3.0** |
| **Consumption** | | | | | | | | | |
| Africa | 0 | 1 | 3 | 4 | 5 | 4.8 | 5.3 | 1.9 | 2.4 |
| Asia and the Pacific | 4 | 24 | 79 | 161 | 236 | 7.4 | 8.2 | 4.8 | 3.9 |
| Europe | 16 | 53 | 70 | 99 | 122 | 4.9 | 1.9 | 2.4 | 2.1 |
| Latin America and the Caribbean | 1 | 4 | 9 | 12 | 15 | 7.0 | 5.7 | 2.2 | 2.3 |
| North America | 20 | 43 | 70 | 96 | 115 | 3.1 | 3.3 | 2.1 | 1.8 |
| Western and Central Asia | 0 | 2 | 9 | 18 | 28 | 8.1 | 10.6 | 4.5 | 4.5 |
| **World** | **42** | **128** | **241** | **391** | **521** | **4.6** | **4.3** | **3.3** | **2.9** |

**NOTE:** Data presented are subject to rounding.
**SOURCES:** FAO, 2008a; FAO, 2008c.

# Global demand for wood products

**Production and consumption of paper and paperboard**

| Region | Amount (million tonnes) | | | | | Average annual change (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Actual | | | Projected | | Actual | | Projected | |
| | 1965 | 1990 | 2005 | 2020 | 2030 | 1965–1990 | 1990–2005 | 2005–2020 | 2020–2030 |
| **Production** | | | | | | | | | |
| Africa | 1 | 3 | 5 | 9 | 13 | 6.4 | 4.3 | 3.9 | 3.7 |
| Asia and the Pacific | 13 | 58 | 121 | 227 | 324 | 6.3 | 5.0 | 4.3 | 3.6 |
| Europe | 33 | 76 | 111 | 164 | 201 | 3.4 | 2.6 | 2.6 | 2.1 |
| Latin America and the Caribbean | 2 | 8 | 14 | 21 | 27 | 5.7 | 3.6 | 2.9 | 2.7 |
| North America | 48 | 91 | 109 | 141 | 169 | 2.6 | 1.2 | 1.8 | 1.8 |
| Western and Central Asia | 0 | 1 | 3 | 6 | 9 | 9.2 | 5.9 | 4.2 | 3.5 |
| **World** | **96** | **238** | **363** | **568** | **743** | **3.7** | **2.8** | **3.0** | **2.7** |
| **Consumption** | | | | | | | | | |
| Africa | 1 | 4 | 7 | 14 | 21 | 5.1 | 4.2 | 4.6 | 4.4 |
| Asia and the Pacific | 13 | 63 | 128 | 234 | 329 | 6.3 | 4.9 | 4.1 | 3.5 |
| Europe | 32 | 73 | 101 | 147 | 180 | 3.3 | 2.2 | 2.6 | 2.0 |
| Latin America and the Caribbean | 3 | 9 | 16 | 24 | 31 | 4.7 | 3.9 | 2.9 | 2.6 |
| North America | 46 | 87 | 106 | 138 | 165 | 2.6 | 1.3 | 1.8 | 1.8 |
| Western and Central Asia | 0 | 3 | 8 | 14 | 20 | 7.5 | 7.5 | 4.0 | 3.4 |
| **World** | **96** | **237** | **365** | **571** | **747** | **3.7** | **2.9** | **3.0** | **2.7** |

NOTE: Data presented are subject to rounding.
SOURCES: FAO, 2008a, 2008c.

# Global demand for wood products

**Production and consumption of industrial roundwood**

| Region | Amount (million m³) | | | | | Average annual change (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Actual | | | Projected | | Actual | | Projected | |
| | 1965 | 1990 | 2005 | 2020 | 2030 | 1965–1990 | 1990–2005 | 2005–2020 | 2020–2030 |
| **Production** | | | | | | | | | |
| Africa | 31 | 55 | 72 | 93 | 114 | 2.4 | 1.8 | 1.8 | 2.0 |
| Asia and the Pacific | 155 | 282 | 273 | 439 | 500 | 2.4 | −0.2 | 3.2 | 1.3 |
| Europe | 505 | 640 | 513 | 707 | 834 | 0.9 | −1.5 | 2.2 | 1.7 |
| Latin America and the Caribbean | 34 | 114 | 168 | 184 | 192 | 5.0 | 2.6 | 0.6 | 0.4 |
| North America | 394 | 591 | 625 | 728 | 806 | 1.6 | 0.4 | 1.0 | 1.0 |
| Western and Central Asia | 10 | 9 | 17 | 15 | 11 | −0.6 | 4.5 | −0.8 | −3.0 |
| **World** | **1 128** | **1 690** | **1 668** | **2 166** | **2 457** | **1.6** | **−0.1** | **1.8** | **1.3** |
| **Consumption** | | | | | | | | | |
| Africa | 25 | 51 | 68 | 88 | 109 | 2.9 | 1.9 | 1.8 | 2.1 |
| Asia and the Pacific | 162 | 315 | 316 | 498 | 563 | 2.7 | 0.0 | 3.1 | 1.2 |
| Europe | 519 | 650 | 494 | 647 | 749 | 0.9 | −1.8 | 1.8 | 1.5 |
| Latin America and the Caribbean | 33 | 111 | 166 | 181 | 189 | 4.9 | 2.7 | 0.6 | 0.4 |
| North America | 389 | 570 | 620 | 728 | 808 | 1.5 | 0.6 | 1.1 | 1.0 |
| Western and Central Asia | 10 | 10 | 19 | 22 | 19 | −0.2 | 4.4 | 1.1 | −1.3 |
| **World** | **1 138** | **1 707** | **1 682** | **2 165** | **2 436** | **1.6** | **−0.1** | **1.7** | **1.2** |

**NOTE:** Data presented are subject to rounding.
**SOURCES:** FAO, 2008a; 2008c.

# Global demand for wood products

**Production of bioenergy**

| Region | Amount (MTOE)[1] | | | | | Average annual change (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Actual | | | Projected | | Actual | | Projected | |
| | 1970 | 1990 | 2005 | 2020 | 2030 | 1970–1990 | 1990–2005 | 2005–2020 | 2020–2030 |
| Africa | 87 | 131 | 177 | 219 | 240 | 2.1 | 2.0 | 1.4 | 0.9 |
| Asia and the Pacific | 259 | 279 | 278 | 302 | 300 | 0.4 | 0.0 | 0.6 | −0.1 |
| Europe | 60 | 70 | 89 | 272 | 291 | 0.7 | 1.6 | 7.7 | 0.7 |
| Latin America and the Caribbean | 70 | 88 | 105 | 123 | 133 | 1.1 | 1.2 | 1.1 | 0.8 |
| North America | 45 | 64 | 65 | 86 | 101 | 1.8 | 0.1 | 2.0 | 1.6 |
| Western and Central Asia | 11 | 7 | 6 | 8 | 10 | −2.7 | −1.0 | 2.4 | 1.9 |
| **World** | **532** | **638** | **719** | **1 010** | **1 075** | **0.9** | **0.8** | **2.3** | **0.6** |

[1] MTOE = million tonnes oil equivalent.
NOTE: Data presented are subject to rounding.
SOURCES: FAO, 2008a, 2008c.

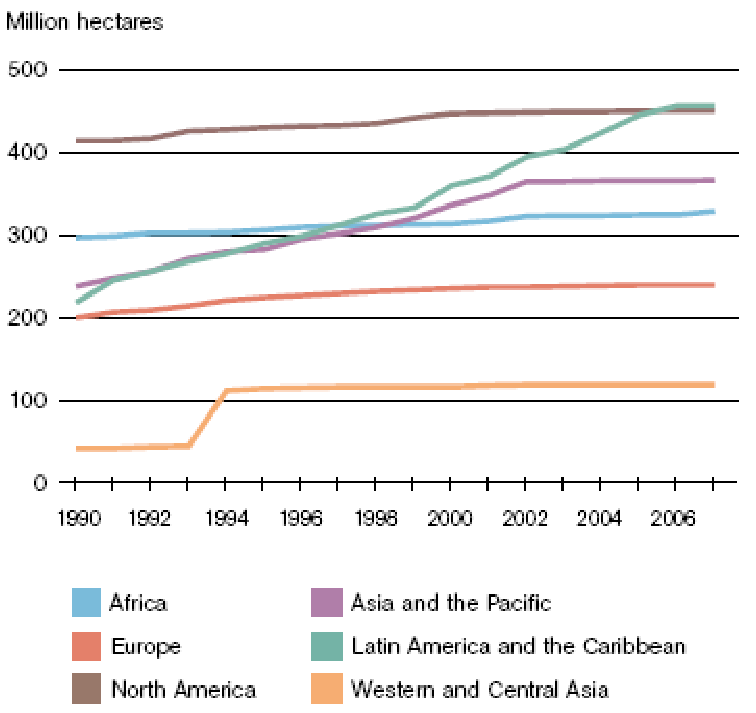
# Global demand for wood products

Gross value added

| Region | Roundwood production (US$ billion) | | Wood processing (US$ billion) | | Pulp and paper (US$ billion) | | Total (US$ billion) | | Contribution to GDP (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 2006 | 1990 | 2006 | 1990 | 2006 | 1990 | 2006 | 1990 | 2006 |
| Africa | 6 | 9 | 2 | 2 | 3 | 3 | 11 | 14 | 1.7 | 1.3 |
| Asia and the Pacific | 29 | 33 | 21 | 30 | 40 | 56 | 90 | 119 | 1.4 | 1.0 |
| Europe | 27 | 25 | 57 | 57 | 74 | 60 | 159 | 142 | 1.4 | 1.0 |
| Latin America and the Caribbean | 13 | 21 | 6 | 7 | 11 | 12 | 30 | 40 | 2.0 | 1.9 |
| North America | 21 | 27 | 35 | 53 | 73 | 67 | 129 | 147 | 1.4 | 1.0 |
| Western and Central Asia | 2 | 2 | 1 | 1 | 2 | 2 | 5 | 5 | 0.5 | 0.3 |
| **World** | **98** | **118** | **123** | **150** | **202** | **201** | **424** | **468** | **1.4** | **1.0** |

NOTE: Data presented are subject to rounding.

# Growth in terrestrial protected areas



# Type of institutions dealing with forest issues

**Public forestry agencies and enterprises**

- National policy formulation, legislation and planning, including national forest programmes
- Management of forests and forest industries and all related activities, including trade in forest products
- Regulatory and enforcement functions – providing a level playing field to other institutions involved in forest and tree resources management

**Private sector**

- Management of forests and other resources, including planted forests
- Production and processing of, and trade in, wood and non-wood products

**Civil-society organizations**

- Environmental and social advocacy in policy and market development and awareness generation

**Informal sector**

- Production and processing of, and trade in, wood and non-wood products

**International and regional organizations and initiatives**

- Intergovernmental forest policy, environment- and trade-related processes and conventions
- Financing, development and technical assistance, including technology transfer
- Regional collaboration arrangements
- Science and technology development and networking

# Science and technology in selected areas

- For most of the twentieth century, natural forests were the main source of wood and other products, and forest research focused on managing them sustainably. Various silvicultural systems were developed (e.g. selection and shelterwood systems), taking into account the density of important species, their growth rates, light and moisture requirements, their ability to regenerate naturally and competition between marketable and non-marketable species. Low-intensity harvesting was adopted to avoid undermining forest environmental services. Vulnerable areas were excluded from logging.

# Science and technology in selected areas

**Key players in forest science and technology**

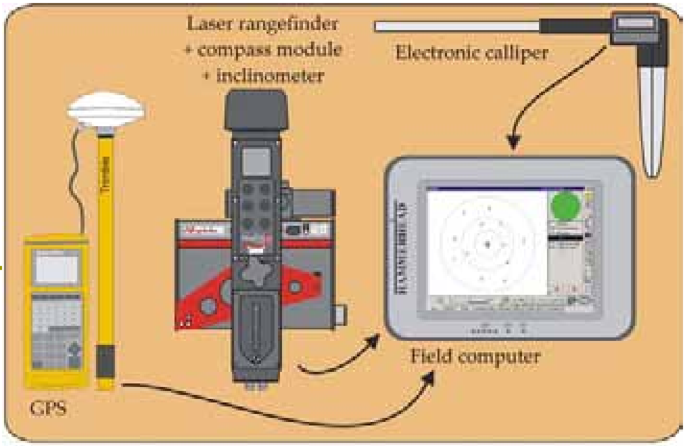
| Key players | Research focus | General trends |
|---|---|---|
| Public-sector forest research institutions | Basic and applied research in all aspects of forests and forestry<br>A significant share of research is not demand-driven, but provides the foundation for downstream applied and adaptive research | With few exceptions, declining because of reduced funding and concomitant reduction in human resources<br>Fragmentation of research agenda and weak linkages between research areas |
| Universities | Mostly focused on the science of forestry and to a limited extent on applied research leading to technology development | Declining public-sector funding compelling shifts in favour of more applied and adaptive research in collaboration with industry |
| Industry | Demand-driven research primarily undertaken by large enterprises<br>Focused on applied and adaptive research leading to the development of new processes and products that can be patented | Increased investments to raise competitiveness<br>Collaborative arrangements with public institutions and universities, largely to benefit from capacity in basic research |
| International public-sector research institutions and networks | Global and regional issues and research networking (but very few in number) | Shift in focus from technical aspects of forestry to policy issues, with increasing emphasis on social and environmental dimensions |
| Independent think tanks and civil-society research institutions | Mostly policy issues, with particular emphasis on environmental and social issues<br>Focused on supporting advocacy initiatives | Expanding influence, especially in policy processes at national and international levels |
| Manufacturers of equipment and machinery | Production of machinery and equipment that draws on many technologies for specific tasks | Intense competition and the constant need to upgrade machinery and add new features |

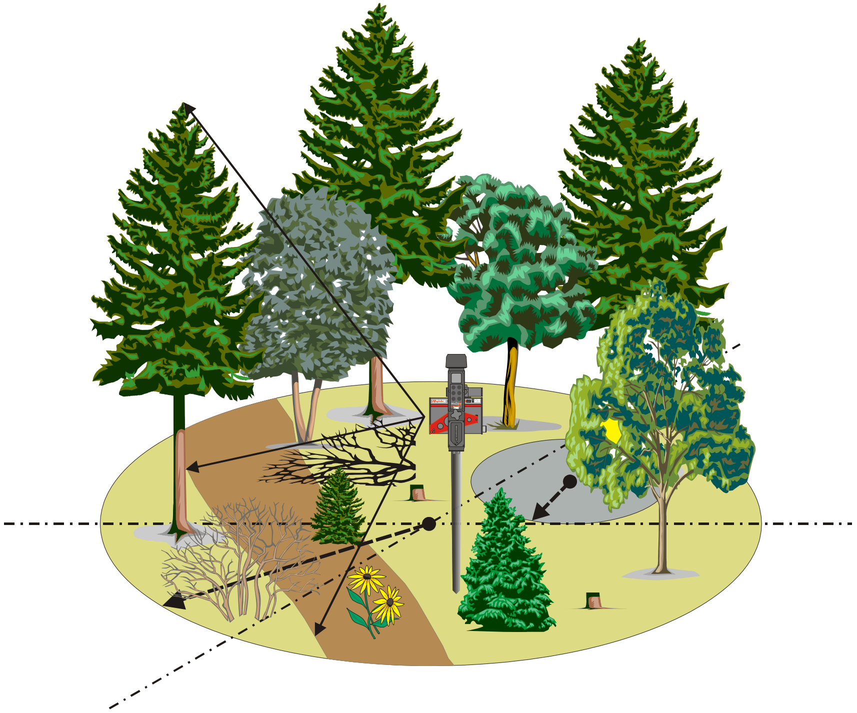
# Remote-sensing application in forestry

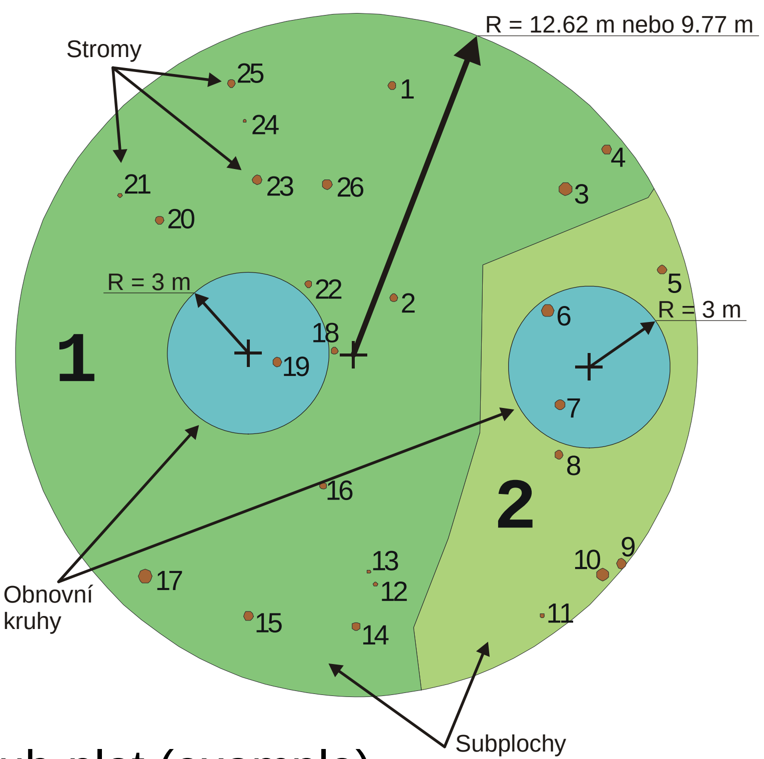
Remote-sensing techniques (including aerial photography and satellite imagery) have been used successfully for forest mapping and monitoring and make it possible to cover large areas consistently and cost-effectively. New technologies address technical challenges such as the variable height, structure, density and composition of forests. Airborne light detection and ranging using lasers can provide highly accurate estimates of tree cover and height; it can even assess the shape of individual trees. Space-borne radar (radio detection and ranging) is a promising new way to obtain estimates of stand volume and biomass and can penetrate clouds, overcoming some of the limitations of optical satellite sensors. New spectral sensing systems can measure a wide array of land and vegetation characteristics, making it possible to assess a range of forest attributes – helping to improve mapping of forest pests and diseases, for example.

# Field-Map

GPS unit
Laser scanner
Electronic compass
PC
Electronic caliper
Supporting accesories

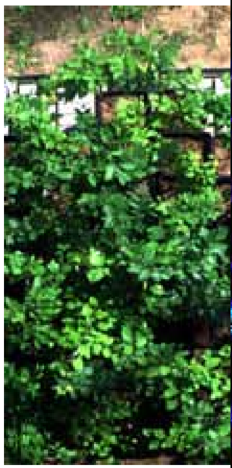


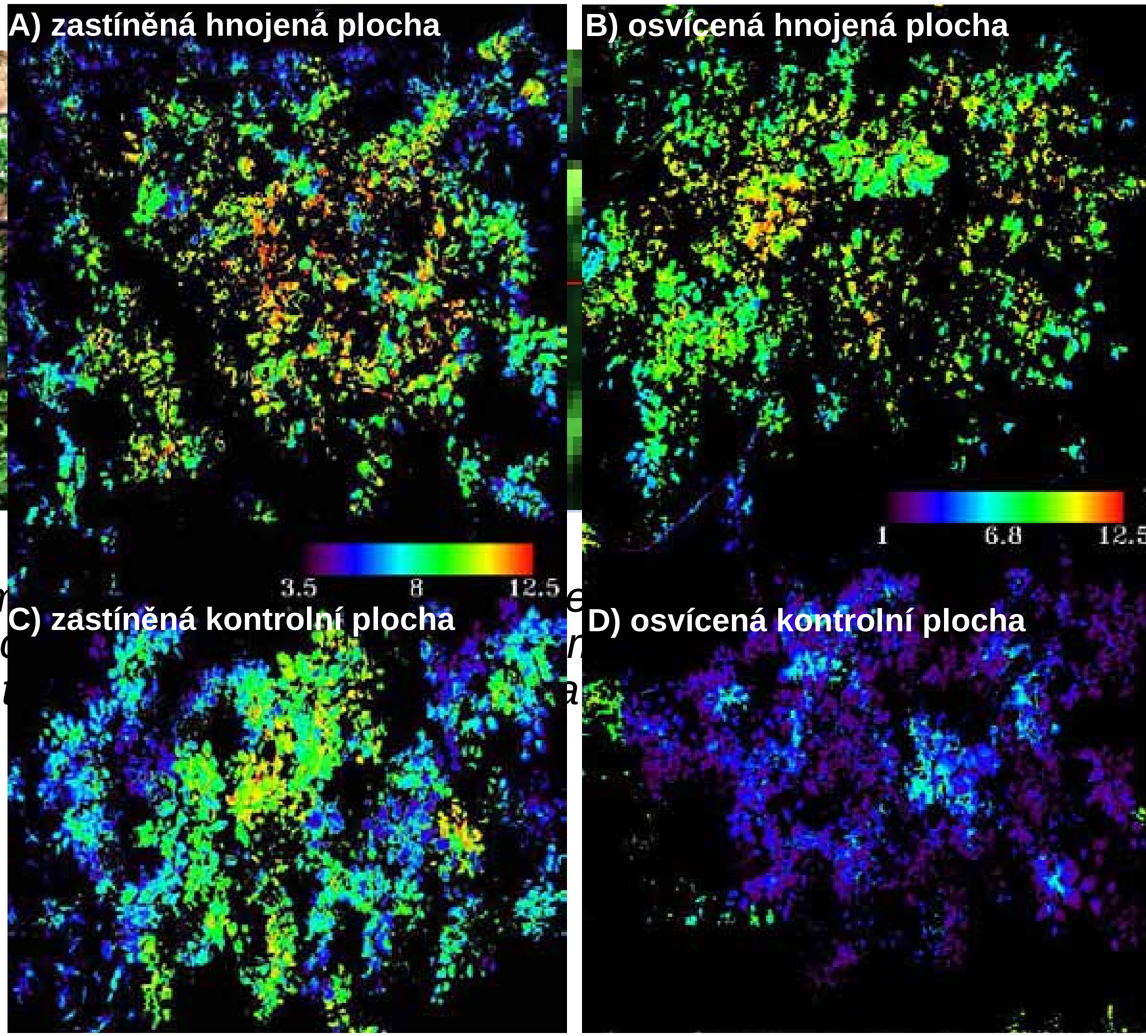



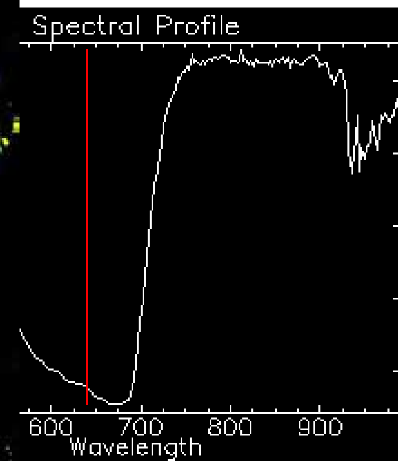



Inventoried plot with circle regeneration sub-plot (example).

# Hyperspectral sensor



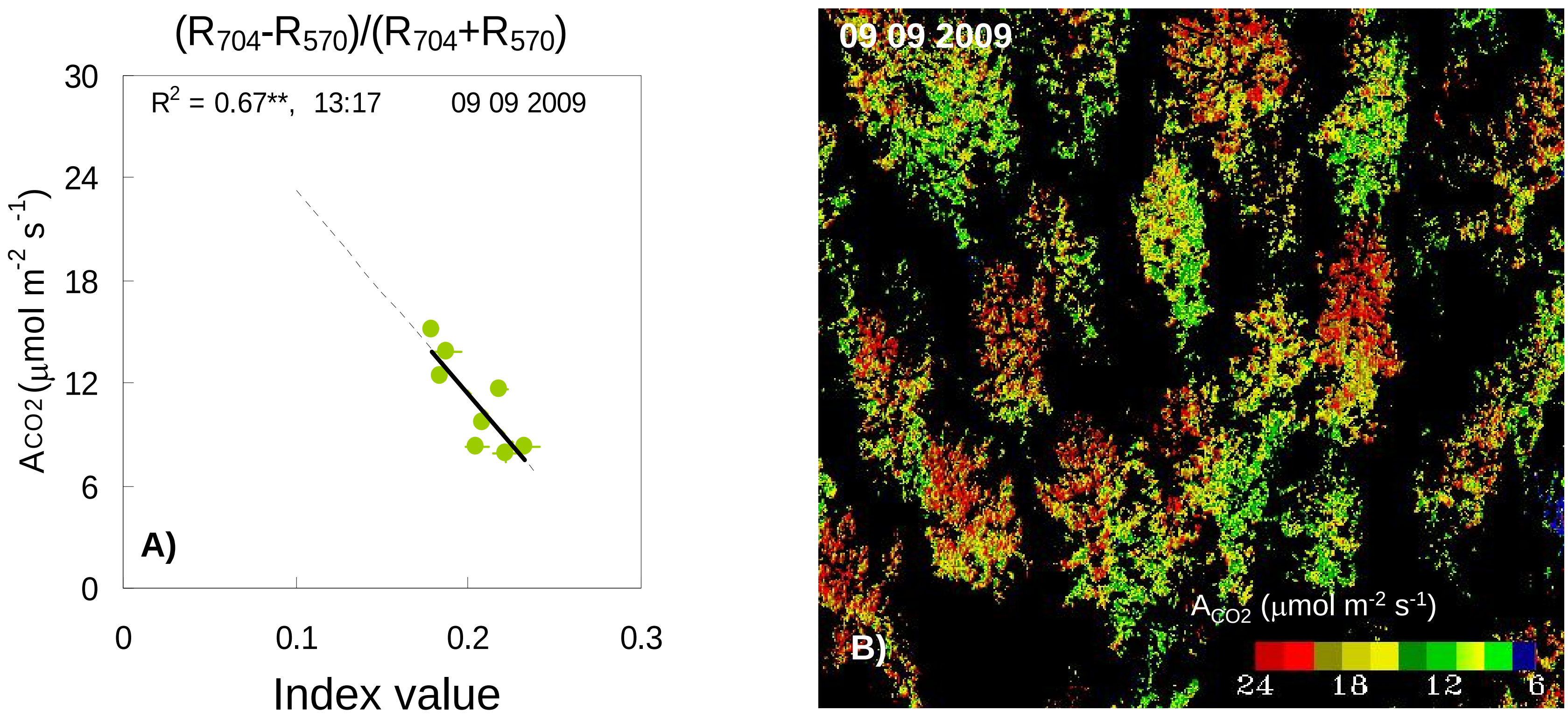



C

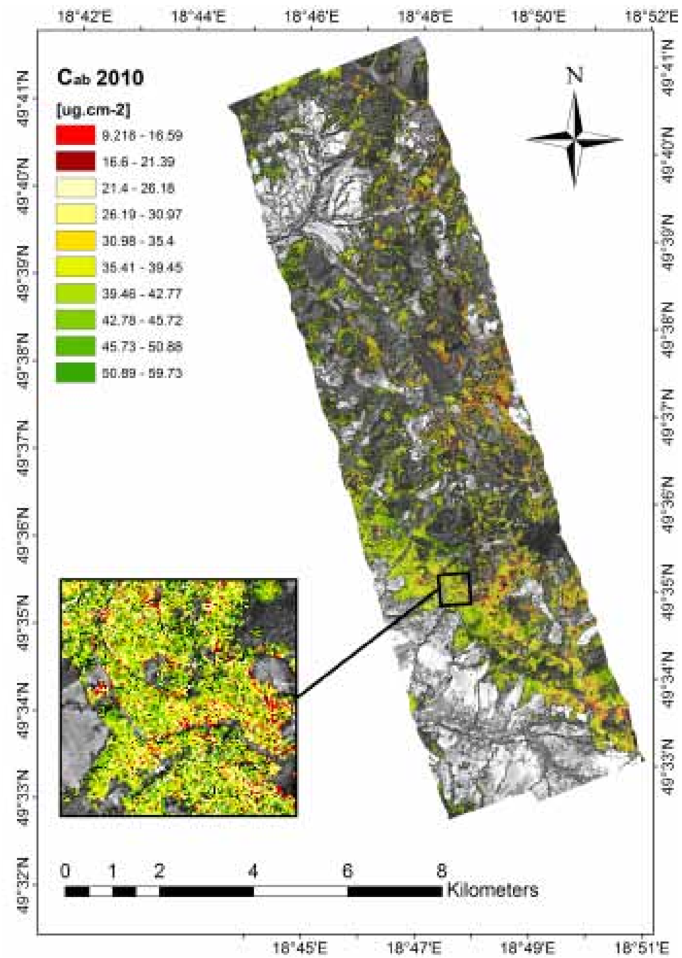
- *Exam… e … gust 2010) in real c… n… f (**B**) and spect… a… g pixel (**C**)*

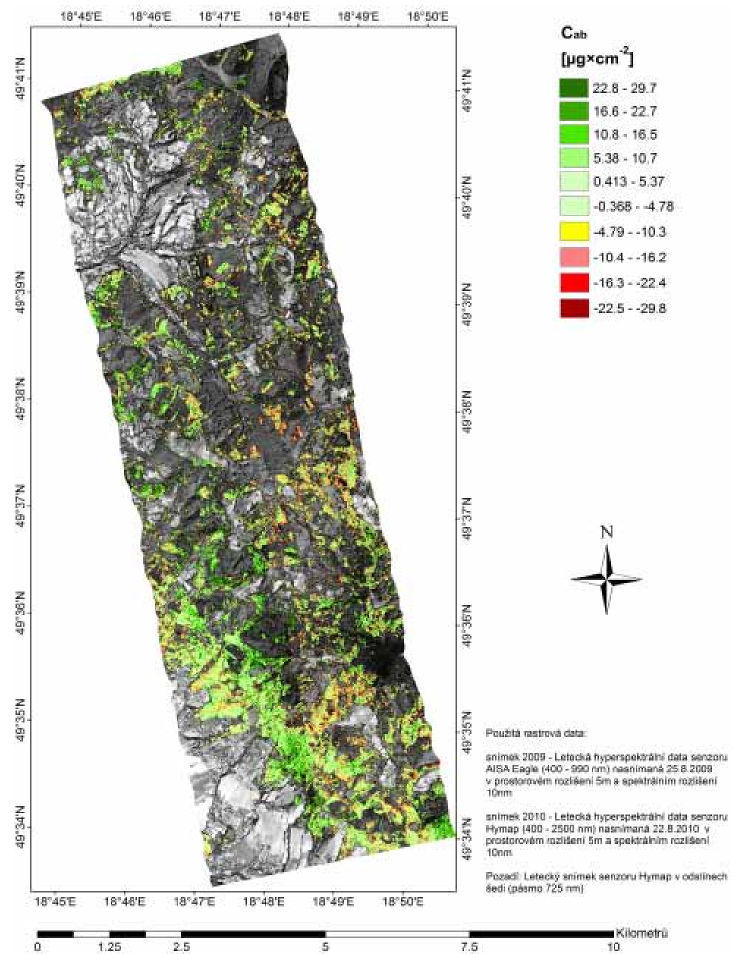
# Hyperspectral sensor




*Relationship between vegetation index (R704-R570/R704+R570)(**A**) and assimilation activity (ACO2, mmol m-2 s-1) (**B**). Figure (**B**) shows per pixels the green part of vegetation irradiated by photosyntheticaly active radiation (n> 200 000).*

# Example- Map of chlorophyll (a+b) content in Norway spruce forests /Beskydy Mts./

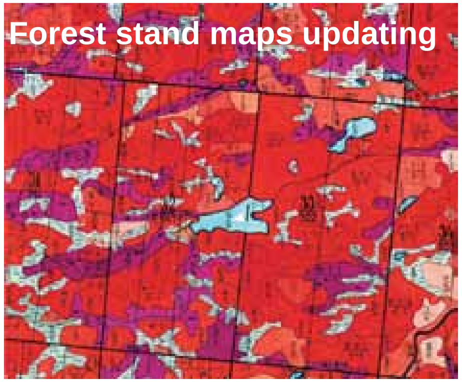


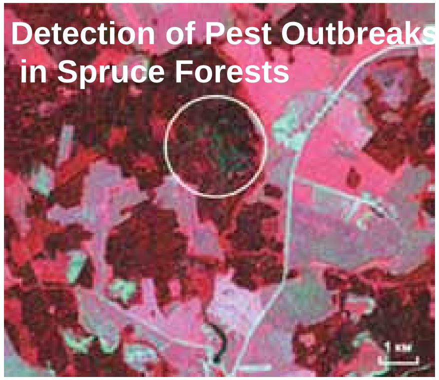



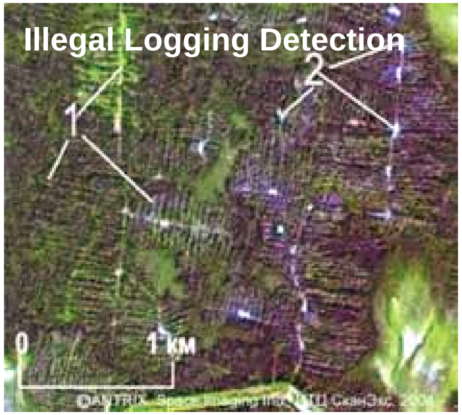

Difference map

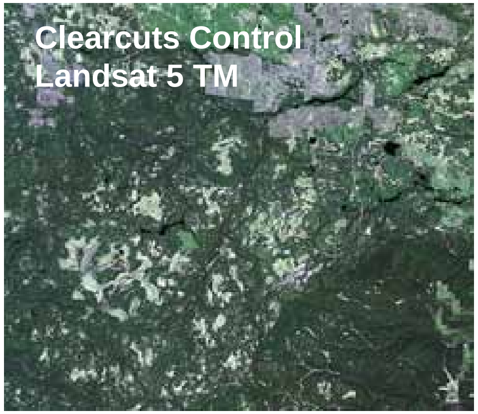
# Satellite images in forestry

- **The best effect of the space imagery is produced while solving the following problems:**
  - Forest acreage determination and spatial distribution of forests;
  - Tree species composition;
  - Mature and overmature forest discrimination;
  - Forest regeneration control of felled, burnt and windthrow areas;
  - Forest field shelter belts control in southern regions;
  - Monitoring of died-back areas during pests control.





http://www.scanex.ru/en/monitoring/default.asp?submenu=forestry&id=actualization

# Agrofoerestry

- Research on agroforestry, which comprises varied practices integrating crops, livestock and trees, aims to optimize these components in order to meet the economic, social, cultural and environmental needs of communities and households, while taking advantage of site-level variation in soils, topography and light and moisture availability. Agroforestry technologies are generally ecologically and culturally site-specific. They have traditionally been developed through “hands-on” experience and transmitted through the generations. Successful agroforestry systems and practices include alley cropping, silvipasture, windbreaks, hedgerow intercropping, parklands, home gardens and relay cropping. Some have been in existence for centuries, evolving in response to needs and constraints both on and off the farm. Formal agroforestry research applies the tools and techniques of modern science to help improve the traditional practices and enable their wider application. It generally takes a holistic perspective in that economic and other benefits are assessed with consideration given to the links among the different components. Agroforestry is currently responding to new market opportunities. Planting of trees on farms to supply wood to forest industries has increased significantly in many countries. Accordingly, new research issues have emerged, including for example interactions between tree crops and food crops and long-term sustainability of production with a focus on maintaining and improving productivity of land.

# Harvesting and processing of wood products

- Improving economic efficiency and minimizing environmental damage have been the primary objectives of harvesting innovations.

- New techniques have been developed to identify the source of logs using tags, paints and chemical compounds that can be read by detection devices. New-generation radio-frequency identification tags and bar codes can easily track the movement of logs from forests to markets, helping to distinguish legally from illegally sourced wood.

# Harvesting and processing of wood products

- Technological developments in wood processing largely focus on:
  - economic competitiveness, with an emphasis on reducing costs, improving quality and developing new products;
  - energy efficiency and production of energy during wood processing;
  - compliance with environmental standards, for example by reducing effluents and reusing water through “closed-loop processing” in the pulp and paper industry (Natural Resources Canada, 2008b).

- Many technological developments in wood processing have been consumer driven, as processing is near the end of the forest products value chain, close to consumers and, thus, compelled to respond to changing demands. Intense competition has also encouraged innovation. Traditional wood use was largely based on physical properties, especially strength, durability, working quality and appearance. Wood-processing technologies have improved mechanical and chemical properties, expanding uses and making it possible to employ species that were once considered less useful – for example, to use rubberwood (*Hevea brasiliensis*) for furniture and mediumdensity fibreboard. Biotechnology in the wood products sector has the potential to improve wood preservation properties.

# Harvesting and processing of wood products

- New sawmilling technologies include laser and X-ray scanners combined with high-power computing, which make it possible to scan and store information on log diameter, length and shape and to produce optimal sawing patterns for each log to maximize sawnwood recovery (Bowe *et al.,* 2002). Picture analysis to determine surface properties (e.g. knots and colour) has improved the sorting and grading of sawnwood. New methods have been introduced to control the drying process and to measure physical strength, revealing possible defects (Baudin *et al*., 2005). Other technological developments in wood processing include:
  - improved rate of recovery and the use of smalldimension timber, largely through improvements in sawmilling technologies and production of sliced veneer and reconstituted panels;
  - recycling, for example use of recovered paper;
  - the use of micro-organisms to bleach pulp and treat effluents in the paper industry, reducing costs and environmental impacts;
  - total use of wood through biorefineries producing a range of biomaterials and energy

# Genetically modified trees: blessing or curse?

- Advances in gene transfer technologies and tree genomics are providing new avenues for genetic modification of trees. Traits considered for genetic modification include herbicide tolerance, reduced flowering or sterility, insect resistance, wood chemistry (especially lower lignin content) and fibre quality, which could all boost economic potential. Increasing interest in cellulosic biofuels is focusing greater attention on genetic modification, in particular on reducing the lignin content in wood. However, research and deployment, including field trials of genetically modified trees, remain a contentious issue. Concerns have been raised about impacts on ecosystems, especially potential invasiveness, impacts on biodiversity and the transfer of genes to other organisms.

(Source: Evans and Turnbull, 2004)

# Biorefineries and production of new-generation biomaterials

- Initiatives in Europe and North America are transforming pulp and paper units into biorefineries – integrated industries that produce ethanol, starch, organic acids, polymers, oleochemicals, bioplastics and several food and feed ingredients from wood-processing residues. The biomass components are converted using a combination of technologies including novel enzymes, biocatalysts and micro-organisms. Biorefineries could become a cornerstone of a “green economy”, sharply reducing dependence on fossil fuels. Some products, such as bioplastics and thermoset resins, would be easily recycled and degraded at the end of the product life.

**sources:** US DoE, 2006; van Ree and Annevelink, 2007.

# Nanotechnology

- Nanotechnology, defined as the manipulation of materials measuring less than 100 nanometres (with 1 nanometre equalling one-billionth of a metre), is expected to revolutionize all aspects of production and processing, from production of raw materials to composite and paper products, permitting major advances in energy and material efficiency (Roughley, 2005; Reitzer, 2007). Most leading wood-product-producing countries are working on nanotechnology applications. Potential uses (Beecher, 2007) include:
  - lighter-weight stronger products developed from nanofibres;
  - coatings to improve surface qualities;
  - production that uses less material and less energy;
  - “intelligent” products with nanosensors for measuring forces, loads, moisture levels, temperatures, etc.

# Non-wood forest products

- Scientific research has focused on:
  - understanding the composition, properties and potential uses of different products;
  - low-cost technologies for the extraction and isolation of marketable components and for the addition of desirable characteristics, e.g. to facilitate storage and transportation;
  - improving processing technologies and developing new products, e.g. new plant-based pharmaceuticals and health and beauty products (the areas where most technological advances are taking place).

- Natural-resource degradation coupled with increasing demand has been the main driver of organized cultivation of yielding species.
- ..natural rubber, rattan, bamboo and some medicinal and aromatic plants, organized production and chemical substitution of natural components

# Challenges…

- We have still limited information on the economic consequences of changes in ecosystem services; the lack of quantitative models linking ecosystem change to environmental services; and the poor understanding of ecosystem structure and dynamics that determine thresholds and irreversible changes.
- Natural and planted forests offer significant greenhouse gas mitigation potential. However, there are large gaps in knowledge of the role of trees and forest ecosystems in climate change processes and the effect of changes in forest cover on forest carbon stocks and greenhouse gas emissions.
- Research on the protective role of coastal forests has intensified. Some researchers found that coastal forests reduce tsunami adverse impacts significantly, while others discovered that forests can also be a liability by adding to the debris that can damage human settlements.
- Forest hydrology research addresses areas such as the relationship between land use and water yield, an area where myths and misconceptions often dominate decisionmaking.