Silvicultural system selection dictates harvesting systems and equipment (if any). Steep slopes in much of the northern coniferous forest also influence equipment selection. In general, cable systems are required on steeper ground while ground-based systems can be used if slopes do not exceed 30–50%. Soils of the northern coniferous forest are young and often thin, which influences equipment selection. The risk of soil degradation is generally greater with ground-based systems. Harvesting is highly mechanized on large-scale western North American operations whereas in Eastern and Central Europe, power saws and small tractors are used in small-scale forestry operations. In Asia, past forestry practices have significantly compromised the productivity of the northern coniferous forest due to flooding and erosion. Small-scale fuelwood collection and mechanized harvesting are both practiced in the Asian northern coniferous forest.

Significance

The northern coniferous forest provides a significant proportion of the world's industrial forest products as well as nontimber forest products and environmental services. It helps to maintain the social fabric of indigenous peoples and preserve aboriginal culture. The northern coniferous forest also provides services such as watershed integrity, habitat, and recreational and leisure opportunities. Compared to boreal and subalpine forest, the northern coniferous forest is diverse and productive. A challenge for northern coniferous forest managers, worldwide, is to maintain structural and species diversity without compromising the potential of the northern coniferous forest to provide its products and environmental services.

See also: **Operations**: Forest Operations Management. **Temperate and Mediterranean Forests**: Southern Coniferous Forests; Subalpine and Boreal Forests; Temperate Broadleaved Deciduous Forest. **Temperate Ecosystems**: Pines; Spruces, Firs and Larches

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Southern Coniferous Forests

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Introduction

When referring to coniferous forests, an image comes to mind of the great boreal forests of the northern hemisphere or carefully managed and regular pine plantations. The native conifer forests of the southern hemisphere rarely conform to this image. In fact, except in a few cases, the term 'coniferous forest' is a misnomer and most of the associations described in this section might more properly be called 'forests with a coniferous element.' Most of the southern hemisphere conifers are of exclusively southern hemisphere families or, in the case of those families which are represented in both hemispheres, are of genera which are represented only in the southern hemisphere. In a total of 67 conifer genera and 557 species worldwide, 31 genera and some 200 species are largely southern and 160 species are totally southern. Of those genera that are found in both hemispheres only one 'northern' genus is found in the southern hemisphere while 12 'southern' species extend into the northern hemisphere mainly into

closely adjacent areas such as Malesia, the Philippines and northern South America. The Pinaceae, which dominate northern forests, are not represented in the southern hemisphere except in extensive plantations or as naturalized exotics.

Conifer forests in the northern hemisphere tend to dominate in more extreme climates where the ability of conifers to compete with angiosperms is enhanced. Thus, they are most abundant at high altitude, high latitude, and in other cold, high rainfall areas. These areas are more extensive in the north, with the great high latitude land-dominated boreal region having no southern analog since the break-up of Gondwana.

The other factor that has a bearing on the differences between the northern and southern conifer forests is the relatively greater oceanic effects on the climate of the southern hemisphere. Annual seasonal effects are less extreme than in the large continental masses of the north, but conversely there are greater, and less regular, year to year climatic changes under the influence of such phenomena as the El Niño Southern Oscillation.

The southern conifers tend to occupy similar niches to their northern cousins, but the geographic extent of the niches is much smaller and as a result, many species of southern conifer have small geographical ranges. There is fossil evidence that southern conifer diversity was much higher at times in the past.

There are close analogs in both conifer genera and forest types across the southern lands as a result of their common Gondwanan heritage. Fossil records indicate that Antarctica once shared a similar coniferous flora. South Africa, which has only a limited conifer flora, is the exception to this and there are puzzling aspects to both its present-day and fossil coniferous flora.

Little study has been carried out on the ecological associates of the southern conifers, especially fungal associations. The Araucariaceae, Podocarpaceae and *Callitris* spp. (Cupressaceae) in Australia have vesicular–arbuscular mycorrhizae (VAM). *Wollemia nobilis* (Araucariaceae) also has ecto-endomycorrhiza. VAM mycorrhizae have been associated with Araucariaceae and Podocarpaceae since the Jurassic.

There is a range of particular insects associated with the Araucariaceae, including weevils, chrysomelid leaf beetles, and scolytid bark beetles. The first two araucarian beetle groups have been associated since the early Jurassic while the bark beetles colonized them at the end of the Cretaceous.

As with the northern conifers, many of the southern conifers are very desirable timber species and were heavily exploited (and overexploited) for timber. As will be discussed later, several species have been plantation grown and natural stands have been managed for silviculture. In addition *Araucaria araucana* and *A. angustifolia* in South America and *A. bidwillii* in Australia were valued for their edible nuts and played an important part in indigenous culture in two continents.

Coniferous Forest Types in the Southern Hemisphere

To cover the diversity of those forests containing southern conifers in a brief treatment such as this is best done using a simple classification drawing on the similarity between southern forests. The following classification is introduced:

1. Tropical and subtropical rainforests with coniferous elements, with or without coniferous emergents.
2. Warm temperate rainforest with coniferous emergents.
3. Temperate rainforests containing conifers.
4. Arid zone coniferous forests and woodlands.
5. Heathland and shrubland with coniferous emergents/components.
6. Alpine and subalpine shrubland and forest with conifers.

Some clarification is required for these terms. Tropical and subtropical rainforests are complex forests with multiple layers and characterized by large numbers of lianas and epiphytes. The complexity and leaf sizes generally reduce from tropics to subtropics and with increasing altitude and/or soil fertility. Warm temperate rainforests are found only in Australia and are much simpler rainforests (often dominated by older Gondwanan elements) on less fertile soils. The cool temperate rainforests are the classic fern/southern beech/conifer forests of southern Australia, Chile and Argentina, and New Zealand.

Often these forests can overlap. On the central coast of New South Wales the three types are found at the same latitude but separated by soil/moisture/altitude gradients.

In using such a classification, there is a range of species with specialist niches, which will be omitted, e.g., *Microstrobos fitzgeraldii* with a specialized niche in the spray zone of waterfalls in the Blue Mountains of New South Wales, Australia. There are also likely to be oversimplifications and omissions in dealing with such a complex subject in such a brief treatment. For instance the monkey-puzzle (*Araucaria araucana*) in Chile and Argentina exists in forest types (3), (4), (5), and (6) but is only dealt with below in (5). Further reading will be necessary to elaborate such a complex subject.

1. Tropical and Subtropical Rainforests with Coniferous Elements, with or without Coniferous Emergents

Forests of this type are represented in Australia, New Caledonia and other Pacific Islands, New Guinea, and South America. With *Agathis* spp. as an emergent they also extend into Malesia. It is important to note that while conifers are emergent they are not the only emergents as in many parts of the forest large angiosperms such as *Ficus* spp. are also important. While the lower forest layers are normally dominated by angiosperms, conifers especially Podocarpaceae and Cupressaceae can also form an important part of both the canopy and understory.

The most developed of these types of forest are found in New Caledonia, especially on the 'Grand Terre' or Main Island. New Caledonia has a total of 43 conifer species of which 26 are found in rainforest associations. The high diversity of conifers and the survival of many primitive angiosperms on New Caledonia is attributed to the dominance (but not exclusivity) of ultramafic soils on the island which acted as a barrier to many modern species. However, the ultramafics are an intrusion that postdates the Gondwanan geology of New Caledonia so the conifers have radiated since the ultramafics were put in place. The ultramafics may have been a barrier to the movement of some angiosperm groups on to these areas (e.g., Poaceae does not occur on New Caledonian ultramafics), so making radiation and survival more likely. Where this forest occurs there is often a gradient from a lowland rainforest to an evergreen cloud forest. Overall 14 species of Araucariaceae, 11 species of Podocarpeaceae, two Cupressaceae and a single species of Taxaceae occupy niches in these forests. The araucarians (*Araucaria* and *Agathis* species) plus *Retrophyllum comptonii* and *Dacrydium araucarioides* form both the canopy and emergent layers (however, these latter two form an emergent layer only on 'cuirasse' boulder fields that are largely unvegetated), and *Austrotaxus spicatus*, *Libocedrus austrocaledonica*, and the majority of the Podocarpaceae are found in the understory. Angiosperms such as *Metrosideros* (Myrtaceae) and *Quintinia* (Saxifragaceae), and primitive groups such as Winteraceae are also found in the understory and canopy. Most species have strong Gondwanan associations. In some areas unusual, almost pure tree layer stands occur, such as *Agathis montana* on several mountain tops and *Neocallitropsis* in some wetlands in the south of the main island, and *Araucaria columnaris* in a pure narrow band on calcareous rocks on the seashore on the main island, the Isle of Pines, and the Loyalty Islands.

Through the Pacific Islands between New Guinea and Fiji similar associations of conifers occur. These rainforests are often more complex and diverse than New Caledonia, but the number of conifer species is lower, with one coniferous emergent (*Agathis macrophylla*) and from one to seven species of podocarps. The isolated South Pacific island Norfolk Island has one emergent araucarian, Norfolk Island pine (*Araucaria heterophylla*) which now dominates foreshore ornamental plantings in warmer parts of the world.

New Guinea has variants of the same structure but once again with high diversity with four species of Araucariaceae, 29 species of Podocarpeaceae, and two Cupresseaceae. As with New Caledonia, the araucarians tend to be emergent with the other conifers mixed with angiosperms in the canopy and understory. The podocarps are rare at low altitude (mostly *Podocarpus*, some *Falcatifolium*, etc.) but increase with altitude and may dominate mid and upper altitude forests (mostly *Dacrycarpus* and *Dacrydium*). The Araucariaceae have a patchy distribution in the forests. There is little information on the ecology of *Agathis macrophylla* and the threatened *A. spathulata*, but more is known of the biology of hoop pine (*Araucaria cunninghamii* var. *papuana*) and klinki pine (*A. hunsteinii*). Both are mast seeders and occur in lower to mid montane forests with overlapping ranges. They can form mixed stands but normally either one or the other is found with klinki most common from 700 to 1000 m above sea level and hoop more common above 1000 m. In these forests the tall emergent *Araucaria* spp. appear to exhibit additive basal area, where the presence of emergents does not tend to subtract from the total basal area of the remainder of the stand. This phenomenon has also been reported from the temperate kauri forests of New Zealand.

In Australia, this type of forest extends from Cape York in Queensland to south of Sydney but only one podocarp species is present in the southern part of the range, south of Coffs Harbour. North of Coffs Harbour, on the New South Wales north coast, emergent Araucariaceae become a feature and other conifer species gradually increase. Overall there are five Araucariaceae, six Podocarpaceae, and one Cupresseaceae (*Callitris macleayana*) present in these forests. Araucarian emergents are most commonly found in drier types of rainforest or on poorer substrates. The most common is *Araucaria cunninghamii*, which has a discontinuous distribution from Dorrigo (near Coffs Harbour) to Cape York. *Araucaria bidwillii* has a restricted distribution (which appears to be an interglacial refugium) north

and west of Brisbane and in two relict areas north and south of Cairns. *Agathis robusta* is found in a small area in South Queensland and the wet tropics while *A. atropurpurea* and *A. microstachya* are confined to scattered areas of the wet tropics. The forests containing Araucariaceae are normally known as Araucarian vine forests (in several variants). Extensive plantations of *Araucaria cunninghamii* have been planted in Queensland as well as a small area of *A. bidwillii*.

In tropical and subtropical South America two Araucariaceae and up to seven podocarps occur in tropical montane forests. The podocarps follow a similar pattern to Australia as part of a generally angiosperm dominated forest, with seven species in Peru declining to one in northeast Argentina. In southeast Brazil and northeast Argentina they form part of the canopy under the emergent Parana pine (*Araucaria angustifolia*) in an association known as Araucarian moist forest, which in the past formed extensive stands. It is interesting to note the structural similarities of many of these forests in different continents (**Figures 1** and **2**). Extensive plantations of *A. angustifolia* have been established in Brazil, as well as *A. araucana* in Andes of Chile and Argentina, from wet forests including *Nothofagus* at high altitude, to dry open forests on the Argentinean side.

Figure 1 *Araucaria angustifolia* forest, Brazil. Courtesy of Rudi Seitz.

In South Africa, three of the four podocarp species may be considered to be part of a subtropical evergreen forest, although the forest is not strictly analogous to any of the other southern conifer forests in this group and has structural similarity to some of the simpler subtropical rainforest types of Australia.

Status In Australia and New Caledonia these forests, while heavily cleared and logged in the past, are generally well protected although some minor clearing on private land still occurs. In South America and New Guinea clearing for agriculture and illegal or poorly controlled logging remains a continuing threat.

2. Warm Temperate Rainforest with Coniferous Emergents

This is one of the most restricted types and is found only in Australia from Victoria to the Queensland on poorer soils derived from rhyolite, trachyte, and metasediments in the northern part and on the more fertile eutrophic rocks in southern cooler regions. It requires rainfall over 1300 mm per year. It is characterized by a two-strata layer with a more limited range of species than the above type, with stranglers, palms, woody vines, and buttressing rare or absent. The tree trunks tend to be slender and uniform in appearance. Tree and ground ferns are frequent, and epiphytes can be common but are not generally abundant in the numbers or species present. Angiosperms are such species as coachwood (*Ceratopetalum apetalum*), sassafras (*Doryphora sassafras*), and scentless rosewood (*Synoum glandulosum*). Hoop pine (*Araucaria cunninghamii*) is found in some patches north of Dorrigo, but its main claim to fame is that it is in this association that Wollemi pine (*Wollemia nobilis*), representing a third araucarian genus (previously only known from fossils) was found in 1994, with a tiny distribution in two stands in deep sandstone gorges just north of Sydney.

Status Most of this type is found in protected areas, but smaller patches embedded in sclerophyll forest may be vulnerable to wildfire. *Wollemia nobilis* has adapted to wildfire by strong coppicing mechanisms. The main threat to *W. nobilis* is considered to be introduction of pathogens by illegal visitors to the site.

3. Temperate Rainforests Containing Conifers

These forests are the dominant vegetation of the wetter coastal and montane areas of Chile and Argentina, New Zealand, and Tasmania. In only a

Figure 2 *Araucaria bidwillii* forest, Bunya Mountains, Queensland, Australia.

few parts of this forest type are conifers as dominant as they are in the equivalent forest types of the North American Pacific coast, but there are also few areas where conifers are not part of this forest.

The conifer families present are Araucariaceae, Cupressaceae, Podocarpaceae, and, in Tasmania only, Taxodiaceae (although Taxodiaceae is now generally included in the Cupressaceae). The most common angiosperms associated with such species are old Gondwanan families such as the family Winteraceae and species of *Nothofagus*, *Metrosideros*, *Quintinia*, *Weinmannia*, etc.

Conifer dominated forests of alerce (*Fitzroya cupressoides*) and *Pilgerodendron uviferum* once dominated the wet soils of the valley between the Chilean coastal ranges and the Andes but were cleared by early Spanish settlers restricting this forest type to less conifer dominated montane forests, although *P. uviferum* is still present in large stands in the Chiloe archipelago.

Conifer dominated forests are also present on the west coast of New Zealand's South Island, on wet river terraces. These forests are dominated by the podocarps *Dacrydium cupressinum*, *Prumnopitys ferruginea*, *P. taxifolia*, *Dacrycarpus dacryioides*, and *Manoao colensoi*. These forests are associated with the angiosperms *Metrosideros*, *Knightia*, *Quintinia*, and *Weinmannia*. There is a great variation in the dominance of conifers in other areas of New Zealand. *Nothofagus* species tend to dominate the forests closer to the treeline but *Libocedrus* is a major component sometimes dominating stands. Other conifers also occur in these beech forests. There appears to be a long-term dynamic interaction between *Nothofagus* and conifers depending on large- and small-scale disturbance. Indeed disturbance is a major factor in most forests with a high conifer component. In Westland, the river terrace forest probably results from periodic flooding, while in the central North Island the large podocarp stands appear to have been associated with the enormous Taupo eruption that occurred about 1800 years ago. There is evidence that over time the podocarps decline until angiosperms dominate the canopy, but podocarps remain as emergents and enough survive to maintain a population until the next catastrophic disturbance.

In New Zealand's northland, the kauri (*Agathis australis*) is added to the forest mix to form some of New Zealand's most famous forests with some existing kauris up to 50 m tall and up to 4.5 m in diameter. While not tall by world standards, this tree has little taper until the crown so the kauri appears as a solid block of timber. There is evidence that the kauri as a component of mixed angiosperm coniferous forests has expanded and retreated with long-term climatic variation.

In Tasmania, conifers are a less dominant feature of the forests but podocarps such as celery top pine (*Phyllocladus aspeniifolius*) and King Billy pine

(*Athrotaxis selaginoides*) occur in rainforests dominated by *Nothofagus* and sassafras (*Atherosperma moschatum*). Probably one of the main reasons for the nondominance of conifers is the dynamic, fire-mediated relationship between rainforest and wet tall eucalypt forest. The other important rainforest species, a podocarp, Huon pine (*Lagarstrobos franklinii*), is virtually confined to riparian forests of the south and southwest with the exception of a few stands away from the river systems.

Status In Chile, this forest is not secure particularly in the northern part of the forested region. Although a reasonable percentage is in protected areas, not all forest types are represented. Much clearing occurred during early European settlement especially in the valley between the coastal range and the Andes. A variety of pressures still exists including clearing, selective legal and illegal logging affecting forest structure and replacement by exotic plantations. In New Zealand much of the original forest was cleared for agriculture, grazing, and exotic plantation. Much remains in mountainous areas and in the Westland area of the South Island. Remnant areas in the North Island are now generally secure. In Tasmania, large areas are preserved in the World Heritage area, but in large areas where eucalypt is logged the cyclical progression to rainforest has been halted by silviculture practice.

4. Arid Zone Coniferous Forests and Woodlands

The *Callitris* forests and woodlands of Australia, and the drier forests of cipré (*Austrocedrus chilensis*) in Chile and Argentina form an unusual and distinctive coniferous forest type and one where the forest ecology is most sensitive to human interference. The almost extinct drier mountain forests of Clanwilliam cedar (*Widdringtonia cedarbergensis*) and *W. schwartzii* with an asteraceous understory of the South African Cape region also fit into this group. In dense stands of these species, fire has an extreme behavior with high rate of spread, crown fire, and spotting. Even in more open woodland with these species, fire can be intense due to dry grass and shrub understory. The Pilliga Scrub in New South Wales, one of the largest cypress forests, has been referred to as 'big fire country' with up to 100 000 ha of a total of 500 000 ha being burnt in one fire.

The forests have contrasting post-European fire histories. The cipré forests originally covered a vast area of the drier foothills and lower slope area of the Andes in Chile and Argentina. It is a long-lived species which existed in an environment of infrequent catastrophic disturbance (e.g., volcanic activity) and requires a time period of over a 100 years to regenerate. With more frequent fires since European settlement a large area of its former range has been converted to shrubland. Fire and overexploitation have also reduced the South African cedar forests (*Juniperus* extends in to southern hemisphere in Africa, but is northern in relationship) to small remnants, although there is now a strong conservation push to preserve and extend these.

The *Callitris* forests have had a more complex history. The most common forest consists of *Callitris glaucophylla* as a codominant with a number of *Eucalyptus*, *Angophora* and *Casuarina* species. This forest type extends from southern Queensland into northern Victoria. Other species such as *Callitris priessii* and *C. endlicheri* also form similar, but more geographically restricted forests. *Callitris intratropica* forms small stands in savanna vegetation in northern Australia and several species also form similar associations in sandy soils of some coastal areas. Early records and analysis of stumps indicates that under Aboriginal land management practices the *C. glaucophylla* forest was more an open woodland with a grassy understory (**Figure 3**).

Cessation of Aboriginal burning following European settlement combined with a series of good seasons resulted in a dense but fire-prone forest dominated by cypress. This forest has since been modified and diminished by a variety of factors.

Most important has been clearing for grazing and agriculture, with large areas cleared particularly since 1945. Grazing by rabbits and severe drought has also impacted on populations with some populations not recovering from extreme droughts. Although wildfire often stimulates 'wheatfield' regeneration, overfrequent fire can cause loss of this ecosystem. A large number of forests can no longer be considered natural (however that may be defined in this complex system), as they are silviculturally manipulated production forests.

Status The Australian *Callitris* forests, although under pressure, can be regarded as secure due to their large area and management as a timber resource.

The cedar forests of South Africa and the cipré forests of South America are threatened. The following are listed by the IUCN (World Conservation Union) as threats to the cipré forests. They could be repeated almost exactly for *Widdringtonia* in southern Africa:

- Habitat loss/degradation – agriculture – livestock (ongoing);
- Habitat loss/degradation – land management of non-agricultural areas (ongoing);
- Habitat loss/degradation – extraction – wood – clear-cutting (ongoing);

Figure 3 *Callitris glaucophylla* woodland in New South Wales, circa 1910. Reproduced with permission from Baker RT and Smith HG (1910) *A Research on the Pines of Australia*, Technical Education Series no. 16. Sydney, Australia: New South Wales Department of Education, Technical Education Branch, Government Printer.

- Habitat loss/degradation – infrastructure development – human settlement (ongoing);
- Habitat loss/degradation – fires (ongoing);
- Invasive alien species (directly affecting the species) – pathogens/parasites (ongoing)
- Changes in native species dynamics – predators.

5. Heathland and Shrubland with Coniferous Emergents/Components

These are interesting associations and are found in four widely dispersed forms: *Araucaria araucana* in southern South America, *Widdringtonia* in 'fynbos' heathland in South Africa, 'maquis' with araucarian emergents in New Caledonia, and 'kwongan' (heathlands) with *Actinostrobus* species in southwest Australia.

As previously discussed the *Araucaria araucana* forests in drier high altitude sites could be regarded as part of a number of associations, but it has been included here as fire interactions form a common component of these associations. *Araucaria araucana* has a range of fire adaptations including basal epicormic buds, protected terminal buds and thick bark. The trees grow over a shrub canopy made up primarily of *Nothofagus* species (the structure differs at lower altitudes and higher moisture areas and can vary in height). Some of these higher altitude stands of *A. araucana* in many ways appear to provide a structural analog to high-latitude southern hemisphere Cretaceous forests.

In New Caledonia, araucarians exist in most forest types, but the most interesting are emergent araucarians of a number of species up to 7–8 m high overtopping a shrub layer to 2.5 m on ultrabasic substrates. Other conifers may also occur in the shrub to small tree layer (*Dacrydium*, *Podocarpus*, *Neocallitropsis*).

In the Cape Province of South Africa *Widdringtonia* spp. are small tree emergents above a heath layer of Proteaceae, Restionaceae, and ericoid shrubs. All species are to some degree fire dependent, seeding after fire from retained cones. *Widdringtonia whytei* has fire resistant bark, and *W. cupressoides* resprouts after fire from underground tubers, an unusual habit in conifers. All species have suffered badly under a regime of overfrequent fires.

Interestingly, a similar habit is found in southwest Western Australia in kwongan where one of the two *Actinostrobus* species is also a resprouter. In nearby tall eucalypt forests (and extending on to adjacent

heaths) is the only fire-adapted podocarp, *Podocarpus drouynianus*, which resprouts after fire.

Status The *A. araucana* forests are protected but still vulnerable to the wide range of human impacts including illegal logging. In New Caledonia, the maquis areas are not suitable for agriculture, but are subject to human-induced wildfires. In South Africa the communities containing *Widdringtonia* are badly affected by wildfire, alien species invasion, and overexploitation of *Widdringtonia* for timber. However, active conservation activities are targeting preservation of all the species but particularly *W. cedarbergensis*. In Western Australia the kwongan has been affected by overclearing, overfrequent fire, and infection by the exotic root fungus *Phytophthora cinnamomi*.

6. Alpine and Subalpine Shrubland and Forest with Conifers

In South America, South Africa, New Guinea, and New Zealand there is a range of montane and subalpine forest types that are typical of these areas. Generally these tend to be part of an altitudinal gradation, e.g., afromontane forest contains *Widdringtonia* species that are also common at lower altitudes and *Librocedrus* in New Zealand also forms a distinctive subalpine forest type.

Only in Australia has a distinctive alpine conifer flora developed (or persisted). Two Tasmanian podocarps, *Microcachrys tetragona* and *Microstrobos niphophilus*, occur as shrubs above the eucalypt treeline. A Tasmanian Cupresseaceae, *Diselma archeri*, although most common as a shrub in the alpine and subalpine zone, also extends below the treeline. *Podocarpus lawrencei* occurs as a pioneer shrub on alpine scree slopes in Tasmania, New South Wales, and Victoria but is also found as a small tree below the treeline. In Tasmania, King Billy pine (*Athrotaxis selaginoides*) can exist as a low twisted 'krummholz' tree in subalpine shrubland. The second true species, *A. cupressoides* (pencil pine) occurs at higher altitudes than *A. selaginoides*, although there is overlap between the two. It has more compact foliage and does not grow to such a large tree.

Status The Australian alpine zone is very small and fragile by world standards and is vulnerable to climate change. Warmer temperatures could effectively eliminate Australian alpine areas or reduce them to tiny remnants. Wildfires can invade alpine and subalpine areas and recovery is slow. Human-induced changes could prevent recovery after climate change cycles.

Conclusion

The conifers of the southern hemisphere are a distinctive group occurring in a large range of forms and occupying a large range of ecological niches from tropical rainforest to alpine shrublands and semi-arid woodlands. They have a distinctive place in the paleobotanical history of conifers and have been used (and have great potential) for silvicultural and horticultural use. In the past they have been little studied but this is beginning to change and further study is likely to lead to both a greater understanding of the group and a greater utilization of their unique characteristics.

See also: **Biodiversity**: Endangered Species of Trees. **Entomology**: Bark Beetles. **Medicinal, Food and Aromatic Plants**: Edible Products from the Forest. **Temperate Ecosystems**: Fagaceae; Pines. **Tree Breeding, Practices**: Southern Pine Breeding and Genetic Resources. **Tree Physiology**: Mycorrhizae. **Tropical Ecosystems**: Southern Hemisphere Conifers; Tropical Pine Ecosystems and Genetic Resources.

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Subalpine and Boreal Forests

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Table 1 Some species commonly occurring in subalpine and boreal forests, with their common names

Species	*Common name*
Abies balsamea	Balsam fir
Abies lasiocarpa	Subalpine fir
Abies sibirica	Siberian fir
Betula papyrifera	Paper birch
Juniperus spp.	Juniper spp.
Larix dahurica	Dahurian larch
Larix laricina	Tamarack
Larix lyallii	Subalpine larch
Larix sibirica	Siberian larch
Picea abies	Norway spruce
Picea engelmannii	Engelmann spruce
Picea glauca	White spruce
Picea mariana	Black spruce
Pinus albicaulis	Whitebark pine
Pinus aristata	Bristlecone pine
Pinus banksiana	Jack pine
Pinus contorta	Lodgepole pine
Pinus flexilis	Limber pine
Pinus sibirica	Siberian pine
Pinus sylvestris	Scots pine
Populus balsamifera	Balsam poplar
Populus tremuloides	Trembling aspen
Salix spp.	Willow spp.
Taxus spp.	Yew spp.
Thuja plicata	Western red cedar
Tsuga heterophylla	Western hemlock
Tsuga mertensiana	Mountain hemlock

Introduction

Many biogeographers consider boreal and subalpine forests as one biome, others separate them because, although boreal and subalpine forests share many similar attributes with respect to climate, vegetation, and soil, there are significant differences between the two. In this article the two will be treated separately.

Subalpine forests are high-elevation forests that occur in mountainous regions around the world. Coniferous subalpine forests, however, are largely limited to the northern hemisphere. These forests are found immediately above the northern coniferous forest in the European Alps, the mountains of east-central Europe, the Urals, the Himalayas, the mountains of northeast China, and the Appalachians, the Sierra Nevada, Cascade and Coastal Ranges and the Rocky Mountains of North America.

The majority of subalpine forests are dominated by *Picea*, *Abies*, *Pinus*, and *Larix* species; however, some variation does occur among regions (see **Table 1** for common names of these species). Subalpine forests of the European Alps are characterized by *Picea–Abies* forests at lower elevations and *Larix–Pinus* forests at higher elevations. The mountainous regions of Romania, Yugoslavia, and Bulgaria are characterized by *Abies*, *Larix*, *Picea*, and *Pinus* species, whereas the Urals are dominated by *Abies*, *Picea*, and *Pinus* species. The subalpine forests of the Himalayas are characterized by *Abies* and *Picea* at lower elevations and *Juniperus*, *Larix*, *Pinus*, and *Taxus* species at higher elevations, whereas the mountainous regions of northeast China support *Picea–Abies* species at elevations between 2500 m and 3500 m.

Due to distinct differences in species, climate, and soils, the subalpine forests of the Sierra Nevada and Cascade and Coastal Ranges in North America will be excluded from this description (*see* **Temperate and Mediterranean Forests**: Southern Coniferous Forests; Temperate Broadleaved Deciduous Forest). Additionally, because the Appalachians are often considered temperate and because subalpine forests are only found on the highest peaks, these forests will be covered elsewhere (*see* **Temperate and Mediterranean Forests**: Temperate Broadleaved Deciduous Forest).

In western North America, subalpine forests occur along the entire length of the Rocky Mountains. These subalpine forests will be the focus of this article, where, owing to their similarities with the boreal forest, they are often referred to as mountain, taiga, or boreal forests.