FORESTS IN ENVIRONMENTAL PROTECTION

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Summary

Forests play an important role in environmental protection. There is a long history of protection forests in mountain areas, where they help to prevent soil erosion, landslides and avalanches, and where they are important in maintaining the water quality of rivers draining forested catchments. Special silvicultural methods are required to ensure that these forests are maintained indefinitely. Forests also respond to environmental protection. A major issue is air pollution, which is known to have had significant impacts on some forests. Air pollutants of concern include sulfur dioxide, hydrogen fluoride, heavy metals, and ozone. Control of these pollutants ultimately benefits forests. Forests have a major role to play in the protection of the global carbon cycle. They represent an important sink for atmospheric carbon dioxide, and conversion of forests to other land uses is one of the causes of the increase in atmospheric carbon dioxide concentrations. Reforestation and afforestation could contribute to reducing atmospheric carbon dioxide concentrations, and the use of biofuels could help to reduce demand for fossil fuels.

1. Introduction

The relationship between forests and the environment has been recognized for more than a thousand years, yet forestry practices continue to cause damage to the environment in the form of soil erosion, water quality deterioration, and other adverse effects. Some of the earliest records of problems associated with the removal of forests come from Japan, where logging of the montane *Cryptomeria japonica* forests more than 1000 years ago was accompanied by increases in the incidence of flooding in low-lying areas. Since then, forests have continued to be cut in headwater areas, often with disastrous consequences downstream. The value of forests as a means of environmental protection has, however, slowly been acknowledged. In areas where mass movements are common, and there is a relatively high population density, such as the European Alps and Japan, forests have been formally designated as having protection as their primary role. Elsewhere, the role of forest cover in protecting water sources and other values has also been recognized. Links between forests and the atmosphere have been identified. As the control of pollutants and other substances altering the composition of the atmosphere becomes increasingly important, there has been a growing acknowledgement of the role that forests can play in global environmental protection. Forests are both affected by the pollutants and can themselves play a role in altering the atmospheric composition. Consequently, environmental protection measures taken to protect human health may have beneficial effects on forests. Large-scale afforestation as a means of reducing atmospheric carbon dioxide concentrations has been discussed, and some countries (e.g., Australia) are already encouraging such a policy. In this article, various aspects of the relationship between forests and environmental protection are examined. Examples are given from the boreal, temperate and tropical zones, in order to emphasize that environmental protection is an issue facing forestry in all parts of the world.

2. Protection Forests

Protection forests have as their prime function the protection of the environment. They are common in mountainous areas—where they stabilize slopes, prevent avalanches, and protect water quality, and also in coastal areas, where they stabilize sand dunes. For example, in Austria, 741 452 ha of forestland have been classified as protection forest, representing 19.2% of the total forest area; these protection forests typically occur on steep (average gradient ca. 65%) slopes, and often occur at above 1800 m in altitude. Elsewhere, the information on the amount of protection forest is very fragmented because the definition of protection forest varies between countries. For example, in Greece, 100% of the forests are classified as being managed primarily for soil protection, yet this does not preclude the annual removal of >2 million m^3 (overbark volume) of wood from the forest estate. In many tropical countries, certain forests have been formally designated as protection forests, but this designation is not always adhered to on the ground.An example of the role of protection forests in maintaining water quality is provided by studies in the Oxapampa municipal watershed, near Cerro de Pasco, Peru. The area lies in an area characterized by tropical montane forest, and the landscape consists of steep slopes that are susceptible to erosion. Annual soil losses were compared between areas covered by natural forest, areas with a mixture of crops, pasture and forest, and areas of pasture only. The maximum suspended sediment concentrations reached 76, 226, and 771 mg/L, respectively, in the three land-use types during storm flows. Average annual soil losses from the three land-use types were estimated to be 121, 345 and 542 kg/ha, respectively.

Protection forests present particular problems for management. In Switzerland, in those protection forests where timber extraction is permitted, management has been described as “near-natural,” involving either single-tree selection and continuous cover techniques or very small (<0.1 ha) patch cuts. In the French Alps, the ideal structure of protection forests dominated by *Picea abies* is believed to be uneven-aged stands with gaps. Management activities often aim to increase stand heterogeneity, and uneven-aged stand management has been adopted in some North American protection forests, such as the Quabbin Forest of central Massachusetts, which is an important source of Boston's water supply. However, in some parts of the world, commercial felling within protection forests remains an important economic activity, and management is concentrated more on obtaining the best possible growth, while maintaining a forest cover. Thus, in the Russian Far East, forestry operations take place in the mixed, uneven-aged, protection forests. The fellings are designed to reduce the proportion of *Quercus mongolica*, which is usually the dominant species in the overstory, and other broadleaved species. The management objective is to increase the proportion of *Pinus koraiensis*, a species that has a higher volume increment than *Quercus mongolica*. Such major interventions are not typical of European protection forests, but may be relatively common in areas where protection forests are still seen as an important source of timber.

Often, the frequency and extent of silvicultural intervention is strictly limited by law, a regulation that is based on the assumption that undisturbed forest ecosystems are stable. This is now known to be untrue: forest ecosystems are highly dynamic and subject to regular disturbance. As a disturbed protection forest may no longer fulfill its role, management is usually required to reduce the potential impacts of disturbances. Instances where protection forests lose their protective roles include those damaged by forest fires and by large-scale insect outbreaks, such as occurred in Switzerland as a result of major storms in 1990 and 1999. The 1990 storm caused major problems for foresters throughout Switzerland, and in other alpine countries. The amount of fresh dead wood was such that complete removal was impossible. This resulted in the build-up of bark beetle populations, further aggravating the instability of the forests. The problems may also have been exacerbated by the *laissez-faire* approach to management that has resulted in the stands containing a high proportion of very old trees and inadequate regeneration. In some cases, the associated high levels of dieback and mortality were attributed to air pollution (see below), a convenient explanation that shifts the responsibility for forest instability away from the forest manager. In another example (in the Swiss valley known as the Valais), the *Pinus sylvestris* forests situated on the slopes above the town of Visp have been severely impacted by *Tomicus* spp. This insect species normally does not directly cause the death of trees, as populations are generally insufficient to affect trees severely. The cause of the severity of the pest outbreak in the Valais is uncertain, but may involve a combination of severe climatic stress, damage caused by fumes from a nearby industrial plant, very heavy mistletoe (*Viscum album*) infections, and the creation of good insect breeding habitat in the form of small groups of trees blown over by a severe windstorm. The effect is that the beetles have spread, and many trees have died. Salvage logging has been undertaken by conventional road-based logging, and also by the much more expensive helicopter logging. The challenge now is to ensure that the gaps created by the salvage logging do not result in snow and debris avalanches that might endanger people living in the town below the forest.

Assessments of the ecological stability of protection forests are still undertaken, and form an important step in the development of management prescriptions for such forests. A recent case study of the Ban de Ville forest in Courmayeur (Aosta Valley, Italy), revealed many problems typical of alpine protection forests today. The 143 ha forest faces west, and is situated at altitudes between 1300 and 2300 m. It is dominated by *Picea abies*, although *Larix decidua* becomes increasingly common above 2100 m. Two thirds of the forest was found to be "unstable," with identified problems including unsuitable stand composition, an oversimplified vertical structure and cover, the presence of high densities of wild ungulates, and the presence of forest pests (mainly the bark beetle *Ips typographus*) and diseases (mainly *Heterobasidion annosum*). Steps to reduce these problems included increasing the proportion of *Larix decidua* in the pure *Picea abies* stands and gradually establishing a multi-layered, small group structure similar to that proposed for *Picea abies* protection forests in the French Alps. Reestablishment of protection forests following disturbance can present major problems. The forests grow close to the treeline, and are therefore, close to their ecological limit. The microclimate in a forest is very different to that outside the forest, being more favorable to regeneration. Once the canopy cover is gone, the climatic conditions are much harsher, and it may be very difficult to establish a new tree cover. Consequently, it is almost impossible to reestablish the same species composition in a heavily disturbed protection forest. An example of such a system is the protection forests in the Urseren valley, near Andermatt, Switzerland. Here, the forests currently consist of *Picea abies* and *Larix decidua*, with some *Alnus viridis* scrub. While regeneration is possible within the forest, regeneration would be impossible in the event that the forest cover was destroyed.

A particular problem is sliding snow. In a mature forest, this process is limited by the presence of trees. When these are gone however, the buttressing effect is largely removed and snow avalanches can more easily occur. Additionally, stems of young trees may be severed during avalanching. There are various strategies that can be adopted to reduce the problem. If the trees in a protection forest have died, they can be cut at a height of 50 cm to 1 m above the ground surface, leaving high stumps, and thus some buttressing potential. Alternatively, artificial barriers can be installed, although these may be costly. During the initial planting phase, a variety of techniques may be used to reduce snowslide, including stakes, tripods and horizontal logs 18–20 cm in diameter. In Europe, these barriers can be metal and concrete, but frequently, they are constructed from wood. The wood from the surrounding forest can be used, but more often than not, such wood has a low mean life. For example, the heartwood of *Larix decidua* and *Pinus sylvestris* has a mean life of 8–15 years, which may be insufficient time for sufficient regeneration. The heartwood of *Castanea sativa* and *Robinia pseudoacacia* is more resistant to decay, but usually has to be brought in from elsewhere. It is also possible to ameliorate the impacts of sliding snow by planting trees that are less susceptible to this form of damage. In extreme cases, very few trees are capable of growing, although *Pinus mugo* and *Alnus viridis* have been used successfully in the state of Bavaria in Germany. Clumps of *Larix decidua*, *Fagus sylvatica*, and *Acer pseudoplatanus* have also been used. *Sorbus aria* and *Sorbus aucuparia* are also fairly resistant to damage from snowsliding. These stabilize the snowpack, enabling the more sensitive *Picea abies* and *Abies alba* to be planted. Throughout British Columbia and southeast Alaska, red alder (*Alnus rubra*) vigorously colonizes snow avalanche tracks and is resistant to moderate-sized avalanches. Another problem is the presence of very high populations of game (red deer, roe deer, chamois, and ibex) in some protection forests. These artificially high populations have arisen because of hunting policies that allow very high populations to exist (often involving feeding animals in winter and encouraging more palatable forage). In addition, recreation activities above the treeline are increasingly disturbing animals, so that they spend longer in the forest. The result is very high grazing pressure; in some areas this can severely affect forest regeneration. This problem seems to occur throughout the alpine region, but is particularly apparent in Bavaria (Germany), Austria and Switzerland. It is actually a problem in many other types of European forest, and is not restricted to the Alps.

Protection forests do not only occur in mountainous areas. For example, in China, they are used extensively for protection against erosion in semiarid hill-gully systems. An example is provided by the "Three Norths" protection forest system in the northern part of the country. Plans for this system were passed by the State Council in 1978, with the first stage of development being completed in 1985. In establishing this system, account was taken of the ecological and economic benefits of the scheme, and the importance of rehabilitating and protecting the environment was given greater importance than timber production. In many areas covered by the scheme, forest cover has been increased dramatically. For example, forest cover in one demonstration catchment on the loess plateau in Shanxi has been increased from 9.17% in 1977 to 24.4% in 1988. This is all the more remarkable given that the 8917 km^2 catchment has a population of 450 700 people. In another area, soil loss has been reduced by more than 95%, and runoff has been reduced by 91%. These changes have been accompanied by better agricultural planning, resulting in greater productivity of farmland, greater productivity of animal husbandry, and a 250% increase in per capita income. Integrated development projects of this nature, where protection forests are one component of a series of improvements, are clearly of considerable potential. However, recent large-scale "soil and water conservation" projects on the loess plateau supported by World Bank funding are promoting the production of high cash value agricultural products (both crops and orchards) on large constructed terraces at the apparent expense of the long-term sustainability of semiarid soil resources.

Another area where protection forests are of value is in coastal situations. Protection forests are used to stabilize sand dunes, but they are also used to protect muddy shorelines. In tropical and semitropical areas, mangroves are important as coastal protection forests. Very often, only a very small strip of forest remains. However, to fulfill protective functions, a mangrove forest needs to be quite wide. For example, in Indonesia, a greenbelt 614 m wide between the sea and forest fishponds has been suggested as necessary. Coastal protection forests have been used for a long time. For example, the Etang-Sale forest was established on the island of Réunion in the 1870s in an attempt to stabilize the coastal dunes. The forest was planted with *Casuarina equisetifolia*, although more recently, a variety of other species has been used, including *Acacia auriculiformis*, *Azadirachta indica*, *Eucalyptus camaldulensis* and *Khaya senegalensis*, with *Albizia lebbeck* planted as an understory species to increase the vertical diversity. Coastal protection forests differ from mountain protection forests in that they are often planted on land that has never previously been forested. Consequently, exotic species are more often used than in mountain situations. For example, *Pinus nigra* (a pine species originating in southern Europe) has often been planted on sand dunes in Britain.

Many protection forests are designed to reduce the incidence of mass movements, particularly snow avalanches. However, forests may also help increase slope stability. This is because the roots of trees play an important part in increasing the strength of soils on slopes. If forests are removed, the roots will decay quite rapidly, with root strength normally at a minimum three to 15 years following clear cutting. The reduction in strength may be accompanied by landslides and other forms of slope instability. In addition to landslides, the establishment of forests can also result in splash erosion. If there is very little vegetation cover under the forest, drip from the canopy may be sufficiently large and have sufficient energy to cause erosion of the soil. This is particularly true in some tropical plantations of *Tectona grandis*, especially where the leaf litter is removed. In such situations, it is possible to reduce the erosion by maintaining a ground cover, and by allowing the development of a thin organic horizon. Despite these particular problems, there is a great deal of evidence that a well-managed forest will reduce the amount of surficial erosion, especially if it contains multiple strata (which help reduce the velocity of falling drips). The key to managing erosion in plantations is to maintain the infiltration capacity of the soils during the life cycle of the trees.

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Biographical Sketch

John L. Innes was born in 1957, and is currently FRBC Chair of Forest Management, Department of Forest Resources Management, Faculty of Forestry, University of British Columbia. He has a first degree in Geography from the University of Cambridge (1976–1979) where he was winner of a prize for a dissertation on the bird communities of montane rain forest in Tanzania. He has a Ph.D obtained in 1982 from the University of Cambridge (1979–1980, 1982) and the University of St. Andrews (1981), on *Debris Flow Activity in the Scottish Highlands. (A Study of the Effects of Environmental Change on Mass Movement Activity)*. His career has included: employment by the UK Nature Conservancy Council to undertake detailed censuses of birds on the Tay and Eden Estuaries in Scotland (1976); periodic employment by the UK Institute of Terrestrial Ecology on projects investigating the impact of PCBs on puffins (1977–1979); Part-time lecturer and tutor in Geography at the University of Cambridge (1982–1983); Natural Environment Research Council Research Fellow at University College, Cardiff, Wales (1983–1985)—research on recent environmental changes in Scandinavia, dating glacial fluctuations by lichenometry and dendroclimatology; Senior Research Associate at the Climatic Research Unit of the University of East Anglia investigating growth of native trees in Scandinavia (1985); Lecturer in Physical Geography at the University of Keele (1985–1986), where courses taught included History of Geomorphology, Geomorphological Processes, and Applied Geomorphology; Senior Scientific Officer, UK Forestry Commission Research Division (1986–1992), responsible for forest health surveys and research on the effects of pollution on forests; Head of Forest Ecosystems Department, Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf (1992–1999)—research on ozone impacts on forests; and FRBC Chair of Forest Management, Department of Forest Resources Management, Faculty of Forestry, University of British Columbia (1999–). Research fields have included: Criteria and indicators for sustainable forest management; Forest ecosystems; Climate change; Air pollution impacts; Ozone; and Long-term monitoring. Prof. Innes has been an invited participant/speaker at a large number of conferences worldwide. Other posts have included: coordinator of the IUFRO Task Force on Forests, Climate Change and Air Pollution (1990–1995); coordinator of the IUFRO Task Force on Environmental Change and Forests (1995–); member of Arbeitsgruppe Halogenessigsäuren (Working Group on Halo-acetic Acids) of the Swiss Agency for the Environment, Forests and Landscape (1995–1999); co-opted member of the Scientific Advisory Council, International Geosphere-Biosphere Program (1995–); member of the Salmon Conservation Validation Monitoring Panel, Keystone Centre, Manitoba (1999–2000); member of the Executive Board of IUFRO (2001–); member of the Environmental Fund Technical Steering Committee of the BC Oil and Gas Commission (1999); and member of Forest Renewal BC Research Program's Management of Ecosystem Productivity and Condition Committee (2001). Prof. Innes is a member of the following professional organizations: Institute of Ecology and Environmental Management; Swiss Forestry Society; and Canadian Institute of Forestry.