16 Future Scenarios for Tropical Montane and South Temperate Forest Biodiversity in Latin America

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Aerial photograph illustrating riparian native forest surrounded by a matrix of agricultural land in Region X, Chile. Photo: Cristian Echeverría

Summary

This chapter presents results of a scenario-building exercise, designed to explore future trends in forest biodiversity in four forest areas, and the potential implications for policy development and implementation. An expert consultation conducted in a workshop environment identified 11 principal pressures responsible for biodiversity loss in Latin America, namely land-cover change, fire, invasive species, browsing animals, pollution, mining, development of infrastructure (roads, pipelines, dams), logging/fuelwood extraction, habitat fragmentation, climate change and loss of keystone species and ecological structures. The relative importance of these different pressures was assessed in each of four study areas, namely Central Veracruz (Mexico), the Highlands of Chiapas (Mexico), Rio Maule-Cobquecura (Region VII, Chile) and Los Muermos-Ancud (Region X, Chile). Scores were generated for each area describing both variation in intensity of the pressures over time and their potential impacts on different components of biodiversity. The scoring process was used to support development of three scenario narratives for each area, namely *business as usual*, *deepening conservation crisis* and *effective conservation*. Recommendations for policy development and implementation are presented for each study area, based on these scenarios. The results indicate that action on global commitments to reduce biodiversity loss must take account of the geographical variation in the relative importance of different pressures and their varying impacts on different biodiversity components. Policy developments and practical conservation action will need to be tailored for individual areas, defined at the sub-national level.

Introduction

The development of effective conservation strategies and plans requires information not only on current status and trends in biodiversity, but on how biodiversity might change in the future. For example, if a species is declining in abundance, then a conservation intervention might be planned based on an assumption that this decline is likely to continue unless some form of action is taken. Models of ecological dynamics provide a set of tools for exploring potential future trends in the structure and composition of ecological communities (see Chapters 9–11). However, such models are based on a range of assumptions and uncertainties, which make it difficult to predict the future with any degree of accuracy. Conservation plans tend to ignore such uncertainties, and fail to consider the possibility of novel situations or surprises occurring, despite their potential importance (Scott, 1998). As a result, conservation planning may often risk costly failure (Holling and Meffe, 1996).

Scenario planning offers a tool for supporting conservation decision making under such uncertain conditions. A scenario can be defined in this context as an account of a plausible future (Peterson *et al.*, 2003). The development of scenarios is a recognized tool in business planning and economic forecasting (Wack, 1985a, b; Schwartz, 1991; van der Heijden, 1996), but only recently has it begun to be applied to biodiversity conservation. Peterson *et al.* (2003) provide a valuable introduction to the use of scenarios in this context. A first attempt to develop global biodiversity scenarios was presented by Sala *et al.* (2000), and elaborated further by Chapin *et al.* (2001). Scenarios are increasingly being used in environmental assessments at global and regional scales, such as the Millennium Ecosystem Assessment (http://www.maweb.org/)

(Carpenter *et al.*, 2005), the Global Environment Outlook (http://www.unep.org/geo/) (UNEP, 2003) and the International Assessment on Agricultural Science, Technology and Knowledge Development (http://www.agassessment.org). This reflects their value in communicating complex scientific information to policy makers.

Scenarios can be used to explore the uncertainty surrounding the future consequences of a decision, by developing a small number of contrasting scenarios. Generally, scenarios are developed by a group of people in a workshop who engage in a systemic process of collecting, discussing and analysing information. The scenarios may draw upon a variety of quantitative and qualitative data, such as the results of ecological surveys and outputs from modelling exercises. Peterson *et al.* (2003) suggest that the major benefits of scenario planning for conservation are: (i) increased understanding of key uncertainties; (ii) incorporation of alternative perspectives into conservation planning; and (iii) greater resilience of decisions to surprise events.

This chapter presents the results of a scenario-building exercise undertaken for four forested regions of Latin America. The aim was to identify and start to quantify present and potential future human impacts on genetic, species and habitat components of biodiversity. The goal was to identify priorities for conservation action and produce recommendations for policy makers.

Development of Scenarios

Scenarios were developed in a workshop activity involving a team of researchers drawn from a variety of different ecological fields, who were invited to provide an expert assessment of current and potential future pressures and their potential impacts on biodiversity. The exercise covered the forested parts of four study areas: Central Veracruz (Mexico), the Highlands of Chiapas (Mexico), Rio Maule-Cobquecura (Region VII, Chile) and Los Muermos-Ancud (Region X, Chile). The four regions were assessed separately by different groups of experts, both because the intensity of the pressures experienced differs between regions, and because the impact of a similar intensity of pressure varies between forest ecosystems. Two separate workshop activities were undertaken: (i) a scoring exercise, considering the processes influencing biodiversity and their potential impacts; and (ii) the development of scenario narratives.

Scoring exercise

Working in four regional groups, researchers were invited to identify a list of pressures (or processes influencing biodiversity) considered to be important in the forests with which they were familiar. They were then asked to perform a numerical scoring exercise, to indicate the likely intensity of each pressure at three dates: 2005 (the present time), 2010 and 2050. Intensity was scored as mean intensity over the forested parts of the study area, using a five-point scale: *Zero* (0), *Relatively Low* (1), *Moderate* (2), *Relatively High* (3) and *Very High* (4). For land-cover change, this would equate to: Zero, 0%; Low, 1–25%; Moderate, 26–50%; High, 51–75%; and Very High, 76–100% of the forest area converted to another land-cover type. Whilst land-cover change does not vary in intensity at a given location, other pressures may vary in intensity at a given location (i.e. fires may be either low or high temperature; logging can be selective or total). For these, the following guidance for scoring was developed:

Zero: no area of the region affected by the pressure under consideration.
Low: either a small area (<25%) at high intensity, or larger area at low intensity affected.
Moderate: either a moderate area (26–50%) at high intensity, or larger area at low intensity affected.
High: either a large area (51–75%) at high intensity or larger area at low intensity affected.
Very High: a very large area (>75%) at high intensity affected.

Participants were asked to refer to research results or supporting data if available, but otherwise to provide an estimate based on their expert judgement. Participants were then asked to estimate the potential impact of each intensity value of the pressure on each of the three components of biodiversity (genetic, species and habitat diversity). The scoring system for these impacts was as follows: *Zero* (0), *Low* (1), *Moderate* (2), *Relatively High* (3), *Very High* (4), *Complete Loss of Biodiversity* (5). This part of the exercise recognizes that different pressures have different relative impacts on biodiversity, and this may also vary between study areas and forest types. For example, fire of a moderate intensity might be expected to have a far greater impact on a montane cloud forest than on a lowland tropical dry forest, as in the latter case many species may have evolved in the presence of fire and display adaptations to it (Chapter 13). This is further illustrated by the results obtained. In 2005 in the Highlands of Chiapas, there was considered to be a high level of land-cover change. This was estimated to have a very high impact on habitat diversity, a moderate impact on species diversity and a moderate impact on genetic diversity. In comparison, in the Rio Maule-Cobquecura region, there was also considered to be a high level of land-cover change in 2005. This was estimated to have a very high impact on genetic diversity, and to be leading to a complete loss of both species and habitat diversity.

Development of narratives

The scoring exercise was used to prompt a discussion, within each group of experts in the workshop, leading to the development of scenario narratives for each of the study areas. To support this process, researchers were asked to consider the following questions:

- How might different pressures interact?
- What are the underlying factors responsible for these pressures, and how might they be addressed?

- Which specific species and habitats/ecosystems are at particular risk, and from which pressures?
- What specific recommendations can be made for policy makers, including those in national and local government, conservation organizations and the private sector?

For each region, three contrasting and yet plausible scenario narratives were then developed: *business as usual*, *deepening conservation crisis* and *effective conservation*. These were defined as follows:

1. *Business as usual*. What might happen to biodiversity if things continue as they are at present?
2. *Deepening extinction crisis*. What might happen to biodiversity if the current situation deteriorates? Why might this occur?
3. *Effective conservation*. What might happen to biodiversity if effective conservation action were to be implemented? How might this be brought about?

Under each scenario, the experts were invited to consider the following questions:

- What will happen to the pressures (and underlying drivers) responsible for biodiversity change?
- What will the impacts be on different components of biodiversity?
- What are the implications for human responses, including policy development and implementation, and practical conservation action?

Each regional group of experts was also invited to suggest one or more possible surprise events that would modify the course of the narrative scenarios, and to note the critical uncertainties for the future of that forest area. Interactions between pressures were considered in the narratives, but not in the preceding numerical exercise. The narratives and results of the scoring exercise are presented below, considering each of the four study areas individually.

Scenarios for Central Veracruz (Mexico)

Present trends and pressures

The major pressures and drivers (or ultimate causes) of biodiversity loss in the tropical montane cloud forest region between 1000 and 2000 m altitude in Central Veracruz were identified as operating at local, national and global scales. Land-cover change is currently the most significant direct cause of biodiversity loss in the area, followed by infrastructural development, logging/fuelwood extraction and habitat fragmentation (Table 16.1). At a global scale, underlying drivers include fluctuations in international markets, including those for coffee, sugar cane and beef, and the impacts on markets of international treaties such as the North American Free Trade Agreement (NAFTA).

Table 16.1. Results of a numerical scoring exercise to indicate the likely intensity of different pressures at three dates: 2005 (the present time), 2010 and 2050, in four study areas: Central Veracruz (Mexico), Highlands of Chiapas (Mexico), Rio Maule-Cobquecura (Region VII, Chile) and Los Lagos (Region X, Chile). Intensity was scored as mean intensity over the forested parts of the study area, using a five-point scale: *Zero* (0), *Relatively Low* (1), *Moderate* (2), *Relatively High* (3), *Very High* (4) (see text for details). The values presented here relate to the 'business as usual' scenario; in other words, projected future values are those based on current trends.

	Study area and year											
	Veracruz			Chiapas			Maule (VII)			Lagos (X)		
Pressure	2005	2010	2050	2005	2010	2050	2005	2010	2050	2005	2010	2050
Land-cover change	3	2	2	4	3	1	4	3	1	3	3	2
Fire	0	0	0	1	1	1	3	3	2	3	3	3
Invasive species	0	0	0	0	0	0	3	3	2	2	3	3
Browsing animals	1	2	0	1	0	0	2	2	2	4	4	3
Pollution	0	0	0	0	0	0	4	4	4	1	1	2
Mining	1	1	0	0	0	0	0	0	0	0	0	0
Infrastructure (roads, pipelines, dams)	2	2	2	1	1	1	1	1	1	1	2	3
Logging/fuelwood extraction	2	3	2	2	3	2	2	1	1	4	4	3
Fragmentation	2	2	3	4	3	2	4	4	3	4	4	3
Climate change	1	2	3	0	0	1	2	4	4	1	2	2
Loss of keystone species and structures	1	1	2	0	0	0	4	4	4	2	3	4

Mega-projects such as the Plan Puebla Panama pose a specific threat to regional biodiversity through plans for an expanded infrastructure of ports, roads, airports and railways, with associated land-use changes. National-scale drivers include subsidies for forest clearance for economically productive purposes, and a lack of enforcement of environmental legislation, including that on the implementation of environmental impact assessment studies.

Local-scale direct drivers include unsustainable harvests of forest products, through both selective logging and the collection of orchids, bromeliads and birds, infrastructure development and strip mining for gravel and sand. As forest cover disappears, biodiversity conservation depends strongly on species survival in other land uses. However, traditional agroecosystems (such as shade coffee, home gardens and traditional intercropping systems (*milpas*)) that harbour wild forest species are being transformed to low- or eroded-diversity systems (such as sugar cane, non-shade coffee, pastures or urban areas). Indirect drivers include population growth (especially in large cities), a lack of security in land tenure, a culture of land clearing and the social and economic marginalization of local people. This final factor is also leading to migration from rural areas and land abandonment, which can have a positive effect on biodiversity.

Scenarios

From 2005 to 2050, under a *business as usual* scenario, there are few changes in environmental legislation and subsidies. However, community groups continue to exert pressure on the government to implement the existing laws. New protected areas are created, but receive little planning or financial support, and so their impact on biodiversity conservation is limited.

Most pressures remain unchanged (Table 16.1), with an initial increase in the rate of logging, and a long-term increase in the rate of fragmentation. Initially, the rapid loss of undisturbed forest cover continues. Many forest fragments may not disappear in the short term, but will experience accelerated changes in structure and composition as a result of the selective removal of certain tree sizes and non-timber products, and of cattle grazing, especially close to forest edges. In 2005, there was already evidence that the hydrological system (rivers and springs) is affected by forest loss and degradation, and that small wetland areas are disappearing (Bruijnzeel, 2001). There is some evidence that deforestation will slow as the most accessible forest cover is removed, with the remaining forests being restricted to steeper slopes (Manson *et al.*, 2007). As a result of economic pressures, some large areas of agricultural land were being abandoned in 2005, resulting in an increase in old-field systems and secondary forests.

Within the reduced area of forest, patterns of fragmentation remain relatively unchanged under a *business as usual* scenario. Most forest fragments are currently small. Given the intensity of the land use under this scenario, the level of isolation of forest patches remains relatively high, thus reducing the level of gene flow between populations. Thus, endogamy and gene drift reduce genetic diversity, especially for species that require large habitats. To some degree, the impact of forest conversion on biodiversity depends on the dominant land use in the region. Some agroecosystems (e.g. shade coffee) harbour more forest biodiversity and conserve more ecosystem services than others (e.g. sugar cane or pasture); these systems also offer better connectivity between forest patches.

Species with very specific habitat requirements, especially including shade-tolerant primary forest species preferring high humidity conditions, continue to be threatened by these pressures. Whilst a large number of endemic forest species are present, local extinctions are difficult to document and had not been observed in the region by 2005. The long lifespan of many tree species means that an extinction debt can build up through limited regeneration opportunities, even though viable adult individuals are still present (Hanski and Ovaskainen, 2002; Helm *et al.*, 2006).

In a *deepening extinction crisis* scenario, changes in international markets lead to a dramatic increase in intensive land use such as sugar cane plantations, cattle pasture and urban areas. The associated increase in use of agrochemicals leads to high levels of pollution in water, soils and air, and resulting species loss in non-forest ecosystems. Forest fragments become smaller, more isolated and more disturbed, with edge effect penetration increasing. Eventually, only remnant fragments on very steep slopes and in protected reserves remain. In response to the decreased area of exploitable forest, groups illegally extracting timber, firewood and non-timber products from the remaining forests become better organized, more powerful and more difficult to control. The more frequent drier and warmer weather resulting from global warming and the increased concentration of human activity lead to fire becoming an important pressure within these patches.

Light-demanding and invasive species colonize the small, degraded forest patches, and most plant species dependent upon forest interior conditions become locally extinct. Animal species share a similar fate as a result of reduced opportunities for dispersal and reproduction. The remaining populations of native species suffer from founder effects and inbreeding.

As soil fertility, water quality and quantity decline, policy makers are eventually forced to act. The resulting reforestation programme is too late to save much of the region's biodiversity, with the new forests being little more than plantations.

An *effective conservation* scenario arises when markets for ecosystem services become increasingly important. The main drivers of biodiversity loss are controlled, as economic opportunities relating to water capture, carbon sequestration and ecotourism become more attractive than agricultural activities. Secondary succession becomes possible within degraded land areas, and much lost forest is recovered. Protected areas finally receive adequate government support in the form of staff, budgets and management plans, and are linked together with the remaining forest fragments through biological corridors.

Agricultural subsidies are redirected to sustainable organic agriculture. There is an increase in certified forestry (including plantations), which involves the implementation of management plans that pay attention to biodiversity conservation. The use of native species and application of ecological knowledge within the forestry sector reduces the costs of restoration efforts and ensures that most, if not all, forest structure and forest types are conserved. Traditional ecological knowledge is incorporated directly into management plans for forests, plantations and diversified farming. Finally, the development of other industries in the region reduces pressure on forest resources.

As a result of these timely developments, the populations of many species, including those thought to have become locally extinct, begin to recover. Gene flow between fragments increases, and the risk of random extinctions reduces.

Xalapa is declared a model sustainable city according to the UNESCO criteria. Politicians learn that conservation pays, and that balancing biodiversity conservation and productivity is both possible and very popular, as societal benefits rather than private interests are maximized.

Surprise events and critical uncertainties

Possible surprises

- Volcanic activity increases in unexpected locations, affecting land uses/land cover.
- A strong earthquake results in the destruction of human infrastructure; reconstruction costs are too high and population densities are drastically reduced.
- Water sources available to Xalapa are reduced and the city is forced to adopt drastic measures to take advantage of local water sources including local rivers, springs and rainwater (cisterns). At present, 60% of Xalapa's water supply comes from the state of Puebla.
- A major highway is built in the area of the remnant cloud forest fragments, thus affecting the biodiversity and hydrology of the region.
- A fall in the price of coffee drastically changes regional land uses; for example, an increase in the production of sugar cane would reduce biodiversity and increase forest fragmentation.
- New legislation in relation to payment for environmental services focuses on the sustainable use of forest natural resources.
- Large areas of forest are protected and restored by private interests, without government support, either with conservation in mind or in the expectation of ecosystem services payments.

Critical uncertainties

Global warming may lead to regional climate change such that large areas of cloud forest are succeeded by a different type of forest or become more attractive for different land uses. Even with a smaller magnitude of change, cloud forest species may be outcompeted by species originally belonging to other ecosystems.

Recommendations

- A network of connected protected cloud forest areas could be created and administered and managed by local owners.
- Considerably more financial, professional and governmental support could be provided for the current protected areas.
- An environmental zoning assessment could support land-use planning.
- Intensification of cattle ranching could reduce the overall land area required.
- Sustainable land use could be encouraged through:
  - Investment in organic coffee production and marketing.
  - Promotion of sustainable use of non-timber forest products.
  - Promotion of sustainable ecotourism.

Scenarios for the Highlands of Chiapas (Mexico)

Present trends and pressures

Land-cover change and habitat fragmentation are currently the most significant causes of biodiversity loss in the area, with logging/fuelwood extraction ranking as the next most important pressure (Table 16.1). The intensities of these pressures are determined by a suite of indirect drivers related to population density and growth rates, markets, culture, land tenure, weak and disorganized environmental governance, and a lack of institutional reliability and trust. Poor, marginalized people in this region have little incentive to conserve forests. There is a lack of markets for forest products, and a culture favouring agricultural activity over forestry, so that forest is perceived as potential agricultural land rather than a resource in itself. Indigenous groups place a particular cultural value on maizefields.

Scenarios

In a *business as usual* scenario, deforestation, fragmentation and loss of biodiversity continue at present rates until forest area becomes a limiting factor (Table 16.1). As the area of agriculture land increases, the agriculture frontier expands, and there is a concomitant decrease in biodiversity. The structure and composition of remaining forests is simplified as a result of fragmentation, edge effects and increased accessibility. The most dominant habitats are then pastures, maizefields and agroecosystems; there are fewer areas recovering from agriculture, and a reduction in overall habitat diversity.

Species of Andean and Neotropical affinity are often replaced in the landscape by species of Holarctic origin, although some native opportunistic and pioneer species will continue to be widespread. Species of limited range are particularly vulnerable to losses in genetic diversity as populations are lost. The effect on tree species is delayed in comparison to species with shorter life cycles (Helm *et al.*, 2006).

By 2050, as the same trends continue, there is an economic and social collapse, with accompanying emigration, and abandonment of rural areas. In particular, men emigrate in search of viable employment, breaking up family units. Policy changes occur in response, with the NGO sector playing a key role, but it is too late to alter the land-use changes and their impacts.

Rural conditions have been poor since before the social conflict in 1994, which led to the Zapatista uprising. Indigenous peoples continue to be marginalized, and suffer high rates of poverty. These conditions have driven the accelerated process of forest area loss (González-Espinosa, 2005; Cayuela *et al.*, 2006). A *deepening extinction crisis* could be produced if levels of conflict were to rise again. The processes described in the *business as usual* scenario would be accelerated, and the breakdown of the regional economy occur more rapidly.

For an *effective conservation* scenario to come into being, novel social and resource management policies, with national investment in ecosystem restoration are required. People are enabled to make use of the forest as an important resource rather than converting it to agriculture. Payments for environmental services such as water and carbon storage, and taxation of polluting industries, help to bring this about. Interventions to create these economic opportunities are needs-based, apply locally appropriate approaches developed through participation and foster equal opportunities, including between genders. As the economic situation improves, population growth rates decline, decreasing the level of pressure on natural resources.

Under this scenario, all components of biodiversity are better conserved. The productive role of biodiversity is better recognized as new products are discovered and exploited, and ecological and conservation values are integrated into international ecosystem service markets. Species-oriented restoration is rapid, and we expect the gradual recovery of ecosystems over time.

Surprise events and critical uncertainties

Possible surprises

- One or more earthquakes could create such destruction in the cities that urban populations migrate to rural areas, increasing the rate of forest loss and pressure on biodiversity.
- Erosion and mud slides produced by increased precipitation and changes in the rain regimes could lead to direct loss of forest area, and loss of crops resulting in increased poverty and land-cover change.
- Forest health could suffer as a result of desiccation and loss of biodiversity, allowing insects (e.g. bark drillers) or new plant diseases to have serious effects on tree canopy dominants.
- A new indigenous uprising could result in land invasions, resulting land-cover changes, new black markets for rural products and migration from conflict areas to forests.

- An increase in the level of drug production and traffic could lead to deforestation for marijuana cultivation.

Critical uncertainties

The long-term impacts of fire on vegetation cover and the forest's ability to recover following anthropogenic disturbance are uncertain.

Recommendations

- Invest in local development, employment and welfare; simultaneously enforce relevant legislation on forests and narcotic cultivation.
- Promote a new rurality, with new relationships between natural areas and development, between cities and rural areas.
- Redevelop political institutions, seeking a regulated autonomy within a national legal framework, to help satisfy indigenous people's demands for self-governance.
- Promote the peaceful coexistence of cultures, with education towards political, cultural and religious tolerance.
- Establish predictive models that relate climate variables, fire occurrence and vulnerability, in order to inform the regulation of fire setting in agricultural areas adjacent to wild lands.
- Identify areas vulnerable to mud slides, and initiate preventive forest restoration and hydrological management.

Scenarios for Rio Maule-Cobquecura (Region VII, Chile)

Present trends and pressures

Land-cover change, pollution, loss of keystone species and habitat fragmentation are currently the most significant causes of biodiversity loss in the area, with fire and invasive species ranking as the next most important pressures (Table 16.1).

Scenarios

Under a *business as usual* scenario, each of the major pressures continues to be important, with intensity only reducing by 2050 because the area of forest available to be affected has been so substantially reduced (Table 16.1). The area and spatial continuity of exotic pine plantations expands. The scarcity of land available for commercial afforestation in the western portion of the Rio Maule-Cobquecura region means that the process of conversion of native forests to plantations shifts to the eastern slope of the Coastal range. Here, there are reductions in the area of mixed sclerophyllous Mediterranean-type forests and shrublands, which harbour several endemic tree species. Firewood and timber for charcoal continue to be harvested from the remaining forest.

The increasing plantation area and connectivity of plantations leads to an increase in the area and severity of anthropogenic fires. Reduced precipitation as a result of climate change, and an increased frequency and intensity of ENSO-driven droughts (La Niña events) also leads to increased fire frequency. As the area of native forest decreases, the area affected by fire also decreases, but the proportional area affected remains high.

Other effects of the massive expansion of forest plantations include reductions in river flow and water availability, and an increase in soil erosion associated with the 12–20-year clear-cut cycle (Varas and Riquelme, 2002; CIREN, 2004; CONAMA, 2004). Together, these pressures lead to biodiversity losses in riparian habitats, wetlands, rivers and streams.

Rates of forest fragmentation and its impacts on genetic and species diversity initially increase, and then decrease as the area of native forest available for conversion is reduced. Invasive animals and plants increase in number as native forest fragments become smaller and are surrounded by a matrix of non-native plantations. These invaders include *Canis domesticus* (dog), *Pinus radiata* (Monterey pine), *Teline monspessulana* (broom) and *Acacia dealbata* (silver wattle).

The combination of land-use change, fire, logging and fragmentation leads to local extinctions and regional reductions in genetic biodiversity, especially for threatened species. The most threatened groups include amphibians, freshwater fish, crustaceans, aquatic insects, some mammal species such as *Pudu pudu* (pudu deer) and birds.

A *deepening extinction crisis* scenario results from a rise in the international price of wood pulp, bringing about a faster expansion of forest plantations, and related pressures on wetlands, rivers and streams. Large timber companies gain control of ever-increasing areas of land. In this market-oriented scenario, there is a strong pressure to weaken the legislation protecting the threatened species and habitats of Chile. An increase in the level of various threats that are present at low levels, such as infrastructure development, mining and industrial pollution, could also lead to a deepening extinction crisis.

In an *effective conservation* scenario, subsidies for exotic plantations are replaced with financial incentives for the sustainable management of forest ecosystems, and the restoration of native forests in priority areas. This policy change results from new legislation intended to implement biodiversity conservation and sustainable development targets. One major aim is to restore the area of native forest to 1975 levels, with managed forest plantations also established to provide access to firewood and non-timber forest products. Technical assistance is provided to landowners, forest certification employed more effectively and applied ecological research promoted. By 2050, there is an improvement in the conservation status of all biodiversity elements, with the exception of some irrecoverable losses of genetic diversity in threatened species.

Surprise events and critical uncertainties

Possible surprises

- A huge wildfire is looking increasingly possible, as a result of: (i) the massive expansion of contiguous fire-prone exotic pine and eucalyptus plantations; and (ii) reductions in precipitation and intensification of droughts in the region.
- The introduction of new invasive insect species and fungal diseases could affect the native plant and animal species. On the other hand, if these new pests or fungi preferentially infest pine or eucalyptus plantations, this could facilitate the recovery of native tree species.
- An earthquake could trigger landslides and debris flows, devastating some of the current forest stands that would be replaced by pioneer species. This happened after the Valdivia Earthquake of 1960.
- A tsunami would not only greatly disturb coastal marine and estuarine ecosystems, but in combination with subsidence from earthquakes could increase the area covered by wetlands, as was also seen after the Valdivia Earthquake of 1960.
- A large volcanic eruption could destroy thousands of hectares of forests and Andean grasslands and shrublands, covering them in tephra and pumice. This happened in 1957, after the eruption of Quizapu Volcano in the Andes of the Rio Maule-Cobquecura region. Snow persistence would be reduced, and the albedo and nutrient loss would significantly increase. Under the new Mediterranean-type climate, stream-flow variability between summer and winter would increase.

Critical uncertainties

The intensification of global climatic change might lead not only to temperature increases but to an increased inter-annual and intra-annual variability in precipitation, with a trend towards reduced annual totals. This Mediterranean-type climate would cause a decrease in water availability, with water restrictions imposed in summer.

Recommendations

- Forest conservation and research goals could include:
  - A base inventory of biodiversity for the region, with ongoing monitoring planned and implemented.
  - Better dialogue, collaboration and negotiation for conflict resolution between the various stakeholders dealing with the management and conservation of native forests including: the government, forest companies, rural communities, researchers and NGOs at national, regional, municipal and local levels.
  - Landscape planning, including the establishment of a network of new protected areas to improve the connectivity at a landscape scale,

would help to conserve all the remaining forest and shrub fragments, wetlands, Andean grasslands and shrublands.
  - The targeted restoration of those species, habitats and ecosystems that are assigned a high conservation priority would increase the chances of their long-term persistence in the region.
- For success in this region, the main change needed is the approval of a Law on Native Forests, which would bring economic incentives to the sustainable management and conservation of native forests. This law has been discussed since 1992, and its approval is considered the single most important policy measure towards forest conservation in Chile.
- A complementary goal is the elimination of the subsidies to exotic plantations in this region, since there is a need to reduce the planted area, which is already excessive and incompatible with maintaining a desirable level of biodiversity and ecosystem services as a basis for economic development and population welfare.
- Over 90% of the plantations are owned by two major private holdings, and virtually all of them are certified through existing certification systems (i.e. FSC, ISO 14001, Certfor). Therefore, the standards and procedures of certifiers need to be revisited, with the full participation of forest conservationists and researchers. Both accountability and compliance with certification, including adequate criteria to ensure the conservation of biodiversity, are crucial.
- Adequate planning of the roads, dams, irrigation channels and other infrastructure is also needed, in order to reverse unnecessary fragmentation caused by poorly planned works. A better coordination of the government services in charge of forests and biodiversity (CONAF, CONAMA) with the Public Works Ministry and the private sector is necessary.
- The use of pesticides, herbicides and other agrochemicals should be reduced in the forest plantations, and the most toxic agrochemicals should be eliminated.
- Opportunities for alternative projects involving the local and rural communities need to be promoted, in order to reverse deforestation trends and to promote socio-economic development in rural communities. These projects could include agroforestry, ecotourism, conservation and restoration programmes, and the sustainable use of native forests and other ecosystems, for example through the harvesting of non-timber forest products (NTFPs).
- The budget and resources devoted to the prevention and extinction of wildfires need to be strengthened, emphasizing the protection of native forests, and allocating a high priority to areas with threatened flora and fauna, or threatened ecosystems.
- The local education system, from kindergarten to high school, should promote awareness of the importance and uniqueness of the biodiversity of the Rio Maule-Cobquecura region, and how to effectively contribute to its conservation. Training at university level, and of professionals, workers, rural communities and other target groups, should also be considered, as well as public campaigns focused on critical issues such as fire prevention. The aim is to improve the attitudes and behaviour

of the population towards the conservation and sustainable use of the resources in the region.

- Measures to improve regional natural hazard response could include:
  - Working to better prevent and suppress wildfires in areas of high conservation value.
  - Improvement of the current germplasm banks and *ex situ* conservation efforts for the most threatened native species.
  - Further studies on long-term climatic variability using data derived from tree-rings, pollen, charcoal and lake sediments.
  - The development of better geological hazard maps for earthquakes, debris flows and volcanism.
  - Design action plans and expert systems to respond to natural hazards and to reduce the vulnerability of biodiversity, human populations and economic activities to such hazards, in coordination with the government institution that deals with hazards (Oficina Nacional de Emergencia – ONEMI).

Scenarios for Los Lagos (Region X, Chile)

Present trends and pressures

Browsing by livestock, logging/fuelwood extraction and habitat fragmentation are currently the most significant causes of biodiversity loss in the area, with land-cover change and fire ranking as the next most important pressures (Table 16.1).

Scenarios

Under a *business as usual* scenario each of the major drivers continues to be important in 2010 (Table 16.1). Fire frequency in natural forests remains high, as the expansion of fire-prone eucalyptus plantations continues. The fires that are used to convert native forests to pasture land also have a tendency to spread beyond their intended area.

Within natural forest areas, selective felling for timber using mobile sawmills continues, leaving only the less commercial trees. Emergent trees are lost, and structural diversity decreases. These levels of extraction will increase the probabilities of fires, presence of invasive species and cattle grazing in the understorey. As logging levels approach clearcutting, forest areas are converted to arborescent shrubland.

The extraction of peat and *Sphagnum* mosses from bogs and moorland also increases, being enabled by new mining laws, and leads to considerable biodiversity loss and erosion.

The commercial success of the Puelo and Huilo-Huilo hydroelectric dams results in plans for many more being drawn up. Visitor numbers decline at the Huilo-Huilo nature reserve, but energy companies are unconvinced by tourism arguments. Riverine fragmentation increases, overall water velocity decreases, and local extinctions of aquatic species result.

Invasive species spread through the landscape, as forest fragments become smaller and surrounded by invaded spaces. Non-native plant species already gaining a hold in the region in 2005 include *Ulex europaeus* (gorse), *Sarotamnus scoparius* (broom), *Rubus constrictus* (blackberry) and *Acer platanoides* (Norwegian maple). Invasive animal species include *Canis domesticus* (dog), *Mustela visori* (American mink) and *Salmo trutta* (brown trout).

By 2050, the levels of pressure from land-cover change, fire, logging and fragmentation all decrease, primarily because habitat loss leaves little native forest to be affected. The overall impacts on biodiversity of these events are negative. From a genetics perspective, there is a moderately severe impact on threatened species of flora and fauna. At a species level, the rates of loss are moderate to high. The only species to remain widespread in the region are those that are most resilient to change. By 2025, 1% of species are lost from the region. Particularly threatened tree species include *Pilgerodendron uvifera* (ciprés de las Guaytecas), *Persea lingue* (lingue), *Laurelia philippiana* (tepa) and *Eucryphia cordifolia* (ulmo). Vertebrate groups that suffer major losses include nutrias (otters), *Pudu pudu* (Pudú deer), birds, reptiles, fish and amphibians, especially including *Rhinoderma darwinii* (Darwin's frog) and *Bufo rubropunctatus* (red-spotted toad).

Aquatic ecosystem diversity is also affected by the increased area of plantations. Reductions in the availability and quality of water in streams and rivers lead to desiccation of riparian habitats and peat bogs.

A *deepening extinction crisis* scenario is brought about through increases in the market value of woody fibre, *Sphagnum* and other forest products. As fossil fuel prices increase without alternative energy sources coming online, the demand for fuelwood increases pressure on the forests. As there are no incentives to conserve the forest, these extractive pressures speed the rate of loss. If the regional impacts of climate change, water and air pollution are more rapid than anticipated, this will also hasten the rate of loss.

A number of factors combine to produce an *effective conservation* scenario. The promotion of ecotourism and regulation of existing tourism bring sustainable income that is dependent upon nature conservation to the region. Certification schemes for timber extraction, hand-in-hand with education at different levels, technical assistance to landowners and the elimination of subsidies for plantations of non-native species, combine to create an enabling environment for sustainable forestry. With subsidies being redirected to support sustainable management, and legislation being enacted to encourage habitat restoration for the conservation of target threatened species, pine forests are restored to native forests in selected areas. Other plantation areas are managed for long-term fuelwood supply.

Research funding under this scenario is directed towards biodiversity inventory, monitoring, restoration techniques and land-use planning with different future scenarios in mind. The aim might be to restore the area of forest to that existing in 1975, within the framework of a network of protected areas to improve connectivity on a landscape scale. Most elements of biodiversity and associated ecosystem services would be expected to recover under these circumstances, though some losses of genetic diversity are irrecoverable.

Surprise events and critical uncertainties

Possible surprises

- A huge wildfire could result from the combination of the spread of the invasive *Ulex europaeus* and the occurrence of extreme climate events such as prolonged or repeated droughts.
- The approval of legislation favourable to the environment would be surprising, but welcome.
- The approval of mega-projects in the region, bringing infrastructural development and greater market connectivity, would be likely to have additional negative effects on biodiversity.
- The introduction of different non-native plants could bring with it a new disease to which either native species or non-native species are vulnerable, resulting in widespread die-offs in native forests or plantations. A comparable example is the *Phytophthora ramorum* fungus, which is causing 'sudden oak death' in Europe and the USA (Henricot and Prior, 2004).
- An earthquake, perhaps accompanied by a tsunami, or a large volcanic eruption, would have unpredictable but calamitous effects (as described for the Rio Maule-Cobquecura region).
- Low-probability, high-impact events of global resonance could include impact of a large meteorite or spread of a novel disease.

Critical uncertainties

- The rate of future land-use change is extremely uncertain, as a result of the lack of clear governing legislation, and the overwhelming influence of future markets.
- Climate change patterns bring a great source of uncertainty, with models simulating greater climate variability into the future. If climate change results in decreased levels of precipitation and greater variability in precipitation, fires within plantations and natural forests can be expected to become more frequent and stronger in times of drought.
- The effectiveness of policy response measures in preventing biodiversity loss is highly dependent upon the resources invested and the strength of the prevailing pressures. Example measures include *ex situ* conservation including germplasm banks, an improved fire-fighting programme, and *in situ* conservation initiatives including restoration and harvest management.

Recommendations

- Forest conservation and research goals could include:
  - A focus on policy-relevant research, and improved dialogue between researchers and decision makers.

  - Simulation and risk mapping of the potential impacts of extreme events such as large fires, tsunamis or earthquakes.
  - Development of expert systems to respond to wildfire emergencies, in coordination with the government institution that deals with hazards (Oficina Nacional de Emergencia – ONEMI).
- As for the Rio Maule-Cobquecura region, the approval of a Law on Native Forests would provide economic incentives for the sustainable management and conservation of native forests.
- Redirecting subsidies from support to non-native plantations and from agriculture (including the drainage of swamp forests) towards sustainable management of native forest would provide great assistance for forest conservation. Reduction in pesticide use might accompany these changes.
- The expansion of plantation area would then cease. In particular, it would be useful to prevent the establishment of further *Eucalyptus* plantations in the region's seasonally flooded forest areas (*ñadis*).
- The promotion and regulation of forest certification schemes would support sustainable forest management and open different markets to local timber products.
- Investment in new pulp plants, which stimulates demand for plantations, could be ceased, and existing plants could be converted to conform to environmental standards.
- Improved land-use planning, taking multiple benefits of forest into account, would: (i) designate areas for forest restoration with connectivity, watershed management, biodiversity value and a forest coverage target in mind; and (ii) reduce the potential for further unnecessary fragmentation caused by the construction of roads and canals.
- Greater investment in and planning of fire control.
- Alongside these practical measures, education is key to gaining community cooperation with conservation. The local education system could help by disseminating knowledge about the region's unique biodiversity, and its contribution to ecosystem services.
- Opportunities for the rural population to avoid destructive logging and other impacts could be provided through creation of alternative employment, especially in the growing ecotourism industry, and within forest restoration initiatives.

Combining Intensity and Impacts of Pressures: A Modelling Approach

Results from the scoring exercise indicated that, as the intensity of pressures increases, the impacts on biodiversity are generally likely to increase (Table 16.2). However, the impacts of different pressures differed between biodiversity components and between study areas, depending on the pressure concerned. For example, a very high intensity of land-cover change was considered to have at least a very high impact on all three components of biodiversity in Rio Maule-Cobquecura, but only moderate impacts on genetic and species diversity in the Highlands of Chiapas.

Table 16.2. Impacts of different anthropogenic pressures on biodiversity, considering each of the three components of biodiversity (genetic, species and habitat diversity) individually. The scoring system for impacts was as follows: *Zero* (0), *Low* (1), *Moderate* (2), *Relatively High* (3), *Very High* (4), *Complete Loss of Biodiversity* (5). For details of scoring system for intensity of pressures, see text and Table 16.1.

		Study area											
		Veracruz			Chiapas			Maule (VII)			Lagos (X)		
Pressure	Intensity of pressure	Genetic diversity	Species diversity	Habitat diversity	Genetic diversity	Species diversity	Habitat diversity	Genetic diversity	Species diversity	Habitat diversity	Genetic diversity	Species diversity	Habitat diversity
Land-cover change	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	2	1	1	1	1	1	3	3	4	2	2	2
	2	2	1	2	1	1	2	3	4	4	2	2	3
	3	3	2	3	2	2	3	4	4	5	3	3	4
	4	4	3	4	2	2	4	4	5	5	3	3	4
Fire	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	1	1	1	1	2	2	3	3	1	2	3
	2	3	3	1	1	1	3	2	3	3	2	3	4
	3	4	3	4	2	2	4	3	3	4	2	3	4
	4	5	5	4	2	2	4	4	4	4	3	4	4
Invasive species	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	1	1	1	1	2	2	3	2	1	2	2
	2	1	1	1	1	1	3	3	3	3	1	2	2
	3	1	1	2	2	2	3	4	4	4	2	3	3
	4	2	4	2	2	2	4	4	5	5	3	3	3
Browsing animals	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1	2	1	1	2	2
	2	3	2	1	1	1	1	2	2	2	2	3	2
	3	4	3	1	1	1	2	2	3	3	3	4	3
	4	5	4	2	2	2	3	3	4	3	3	4	3
Pollution	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	1	1	0	1	1	1	1	1	1	1	1	1
	2	3	2	1	1	1	1	2	2	2	1	2	2
	3	4	4	3	1	1	2	2	3	3	2	3	3
	4	5	5	4	2	2	2	3	4	4	2	3	4

Continued

Table 16.2. *Continued*

		Study area											
		Veracruz			Chiapas			Maule (VII)			Lagos (X)		
Pressure	Intensity of pressure	Genetic diversity	Species diversity	Habitat diversity	Genetic diversity	Species diversity	Habitat diversity	Genetic diversity	Species diversity	Habitat diversity	Genetic diversity	Species diversity	Habitat diversity
Mining	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	2	2	2	1	2	2
	3	3	1	1	1	1	2	2	3	4	2	3	4
	4	5	5	5	2	2	2	3	4	5	2	4	4
Infrastructure	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	1	1	1	1	1	1	2	2	1	1	2
	2	1	1	1	1	1	1	2	3	2	1	2	3
	3	1	3	2	1	1	2	3	4	4	2	2	3
	4	3	4	3	2	2	2	4	5	5	2	3	4
Logging	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	1	1	1	1	1	1	1	1	2	3	3
	2	2	1	1	2	2	2	2	3	3	3	3	3
	3	3	2	2	2	3	3	3	4	4	3	4	4
	4	5	3	3	3	4	4	3	4	4	3	4	4
Fragmentation	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	1	1	1	1	2	2	2	3	1	3	3
	2	0	1	1	1	2	3	3	3	3	2	3	3
	3	3	2	2	2	3	4	3	4	4	3	4	4
	4	4	3	2	2	4	4	4	4	5	3	4	4
Climate change	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	1	1	1	1	1	2	1	2	2	2	2
	2	1	2	2	1	1	2	2	2	3	2	3	3
	3	2	3	2	2	2	3	3	3	4	3	3	4
	4	4	5	3	2	3	3	4	4	4	3	4	4
Keystone loss	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	2	2	2	1	2	2
	2	2	2	1	2	2	2	2	2	3	2	2	2
	3	3	3	2	2	3	3	3	3	3	3	3	3
	4	4	4	3	3	4	4	4	4	4	3	4	3

Impacts of invasive species were also higher in Rio Maule-Cobquecura than in the other study areas, whereas impacts of mining were considered to be higher in Central Veracruz than in the other areas. In contrast, other pressures such as climate change and loss of keystone species were considered to have similar impacts for a given intensity in all of the study areas. Impacts also differed between biodiversity components; in general, impacts on habitat diversity were considered to be higher than on species or genetic diversity, for a given intensity of a particular pressure. However, these relationships again differed between study areas; for example impacts on genetic diversity were generally considered to be higher in Central Veracruz than in the other study areas.

Such scores of the potential impacts of different pressures can be combined with the scores describing the intensity of pressures. This could potentially provide a tool for projecting trends in biodiversity, based on an assessment of pressures. Such a tool could then be used interactively to examine the potential impact of different policy or management interventions. As a first attempt towards developing such an approach, we constructed a Bayesian Belief Network (BBN) incorporating the results of the scoring exercises. A BBN can be considered as a tool for exploring the probabilistic relationships between (usually categorical) variables. A BBN is constructed first by developing a graphical model illustrating the relationships between the variables of interest. These relationships are then defined in terms of the probabilities associated with the states of the variables concerned. Further information about the method is provided by Castillo *et al.* (1997) and Jensen (2001). An example of the application of BBNs to exploring the sustainable management of Latin American forests is provided by Newton *et al.* (2006).

Four major causes of biodiversity change, as identified during the workshop, were incorporated in the BBN: habitat fragmentation, logging, fire and land-cover change. These four pressures ranked among the most important when scores obtained for the four study areas were pooled together. The BBN was constructed using Hugin Developer 6.3 (Hugin Expert A/S, Aalborg, Denmark). In this model, the impact of the four pressures is considered separately on the three components of biodiversity: genetic, species and habitat diversity. A separate BBN was constructed for each of the four study areas, enabling scores to be integrated in the model for the relative impact of each level of each pressure on each of the three components of biodiversity. The impacts of different pressures were treated additively. The model was then explored using the scores for the estimated intensities of each pressure within each study area for three dates: 2005 (present day), 2010 and 2050. The model was run by selecting the appropriate state of each factor on a scale of 0–4, using the scores provided in the workshop.

The BBN infers outcomes based on the probabilistic relationships represented in the conditional probability tables (CPTs) associated with the individual variables. In this model, the probabilities incorporated in the CPTs were based on the scores provided in the workshop. Using the BBN, it is possible to alter the intensity value of any of the pressures included, to assess the impacts on different components of biodiversity. In this way, it is possible to explore how the impacts vary according to the level of different pressures, and to combine pressures together.

Initial results obtained using the model are presented in Fig. 16.1. These outputs highlight a number of interesting features:

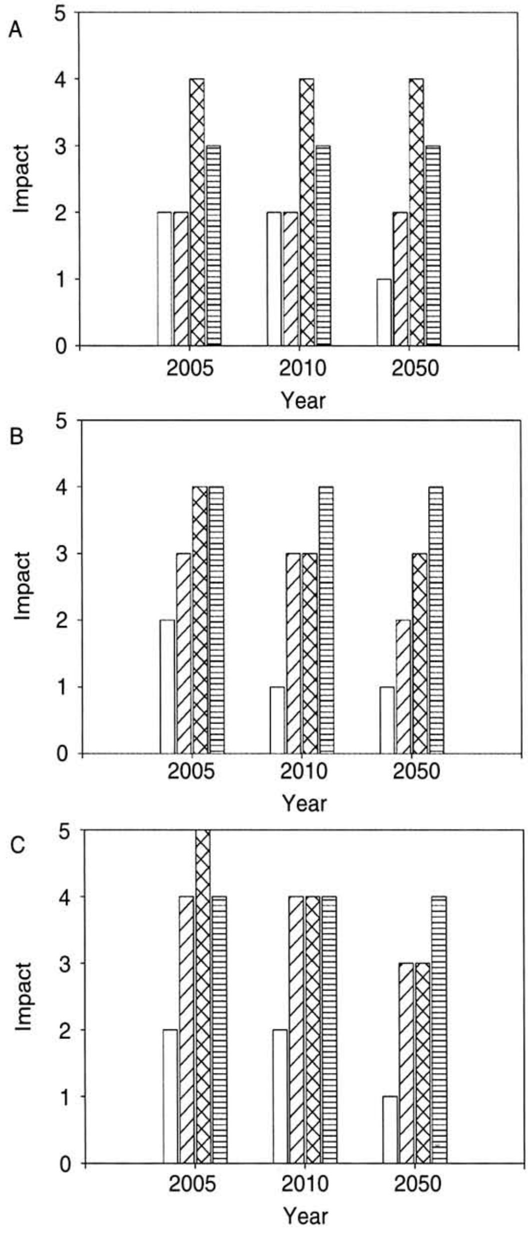

Fig. 16.1. Projected impacts of four combined pressures on different components of biodiversity under the 'business as usual' scenario, based on continuing current trends, using a Bayesian Belief Network (BBN) incorporating workshop scores (see text). Impact scale (loss of biodiversity): *Zero* (0); *Low* (1); *Moderate* (2); *Relatively High* (3); *Very High* (4); *Complete Loss* (5). Impact values presented are those inferred as most likely by the BBN, from combined scores of four pressures: fragmentation, logging, fire and land-cover change. Open bars, Veracruz; hatched bars, Highlands of Chiapas; cross-hatched bars, Rio Maule-Cobquecura; horizontally hatched bars, Los Lagos. Impacts presented relate to (A) genetic diversity, (B) species diversity and (C) habitat diversity.

- Projections differ between the three components of biodiversity. In general, more severe impacts are anticipated on habitat diversity than on genetic diversity, for example.
- Current rates of biodiversity loss appear to be higher, according to the results of this exercise, in the South American study areas (Los Lagos, Rio Maule-Cobquecura) than in the Mexican study areas (the Highlands of Chiapas, Central Veracruz).
- Across three of the four study areas, the impacts of these pressures on biodiversity are projected to diminish with time. This counter-intuitive result is explicable in terms of the current high rates of biodiversity loss. Such high rates of loss cannot be sustained indefinitely into the future: if biodiversity continues to decline at present rates, then by 2050 there will be relatively little left to lose. Therefore rates of loss will decline.

Conclusions

These examples highlight the value of scenarios as a tool for conservation planning, enabling the implications of research results to be communicated in a way that can readily be understood by decision makers. The contrasting narratives produced for each of the four study areas illustrate how the particular circumstances differ between areas, highlighting the need for specific conservation actions to be developed at local or sub-regional scales. While the 'extinction crisis' can be considered as a global phenomenon (Ceballos and Ehrlich, 2002; Thomas *et al.*, 2004), the precise causes of biodiversity loss and the severity of their potential impacts vary substantially from place to place. This variation is perhaps unsurprising given the ecological, political and socio-economic differences between the study areas, but the finding has important implications for policy initiatives developed at the international scale. For example, parties to the Convention on Biological Diversity (CBD) have endorsed a far-reaching Programme of Work relating specifically to conservation of forest biodiversity, which defines broad activities for the assessment and reduction of threats to forest biodiversity and suggests that guidance should be developed and implemented 'to help the selection of suitable forest management practices for specific forest ecosystems' (CBD, 2002). The implication of the current research is that, although the general causes of biodiversity loss may be common to many areas, each forest area will differ in terms of: (i) the precise combination of different pressures; (ii) their varying intensities over space and time; and (iii) their contrasting potential impacts on different components of biodiversity. Distinctive approaches to addressing these problems will therefore need to be developed for each area individually, as illustrated by the recommendations for policy and action presented here.

Peterson *et al.* (2003) suggest the particular circumstances under which scenario-based conservation planning might be preferred, relating to the degree of uncertainty and the degree to which a system can be controlled.

When control of a situation is difficult and uncertainty is high, these authors suggest that scenario planning is an effective approach. The study areas considered here could certainly be considered as meeting these criteria; much of the environmental change that is occurring is uncontrollable and uncertain in terms of outcome. However, in other situations, alternative approaches such as adaptive management planning (Margoluis and Salafsky, 1998; Salfasky *et al.*, 2001, 2002) might be more appropriate. At present, there is little evidence of adaptive management in any of the study areas. This partly reflects a lack of resources and capacity among the institutions that might implement it. As illustrated by the recommendations presented here, the policy environment relating to natural forests is poorly developed, non-existent or even actively antagonistic to conservation. The problem therefore lies deeper than a consideration of the most appropriate approach to conservation planning and management. Rather, the priority is to strengthen the political will, institutional capacity and financial support for forest conservation – whether the institutions be government agencies, conservation NGOs, community-based organizations or private sector enterprises.

Peterson *et al.* (2003) also highlight some of the problems of the scenario-planning approach, such as the reliance on expert opinion. It is conceivable that the predictions of experts may be no better than those of non-experts. Certainly it could be argued that the reliance on one type of expert, namely research scientists with expertise in forest ecology, limits the value of the scenarios presented here. This could be addressed by involving a broader range of stakeholders in scenario-building exercises. Such an approach, implemented at the level of the individual study areas, could provide a useful means of strengthening dialogue between research scientists and other stakeholders, including local communities, government representatives and non-government organizations. Methods could also be used to elicit information from a broader range of experts, for example specialists in mammals, insects or other species groups (see Burgman, 2005). However, it is salutary to consider the extent of uncertainty surrounding biodiversity in these study areas. The precise patterns of distribution, abundance and population trends of the vast majority of species remain poorly defined, and, as a result, it is unclear precisely how many species are currently threatened with extinction. Given this lack of baseline information, estimates of potential future change in biodiversity can remain little more than informed guesswork.

The development of effective conservation strategies depends on a comprehensive assessment of different pressures or threats (Salafsky *et al.*, 2002). It is notable that little progress has been made in developing appropriate methods for assessing such pressures. Wilson *et al.* (2005) provide a recent review of relevant approaches by considering the concept of vulnerability, which may be defined as the likelihood or imminence of biodiversity loss to current or impending threatening processes (Pressey *et al.*, 1996). Wilson *et al.* (2005) differentiate different elements of vulnerability, including the intensity of a threatening process in an area, and the effects of a threatening process on particular features of biodiversity. As described by Wilson *et al.* (2005) and in Chapter 14 of the present volume, spatially explicit statistical or process-based modelling approaches offer methods for assessing the exposure of areas to threatening processes. However, few examples of this approach are available that consider multiple threats (e.g. Miles *et al.*, 2006; ten Brink *et al.*, 2006), and still fewer consider impacts on multiple components of biodiversity. Bayesian Belief Networks, as described here, could potentially provide a tool for such analyses. BBNs possess the advantage of modelling probabilistic relationships, enabling the uncertainty surrounding pressures and their impacts to be explicitly incorporated and explored. Ideally, future developments of this approach might be informed by further quantitative analysis of threatening processes (see Chapter 14), and by information regarding the interactive effects of different pressures on biodiversity. The lack of information about such interactions is one of the most serious areas of uncertainty. It is conceivable that future losses of biodiversity could be substantially more rapid than envisaged here, because of novel interactions that might occur in future (e.g. climate change influencing spread of pests and diseases and interacting with the fire regime).

Use of such analytical approaches could provide a means of further developing biodiversity scenario approaches. For example, Sala *et al.* (2000) adopted a simple multiplication procedure for combining scores describing the magnitude of expected changes in drivers of biodiversity change and their potential impacts. While conceptually simple, this method offers limited scope for analysing or exploring the uncertainty surrounding the scores, which, in common with the current investigation, were based entirely on expert knowledge. Another interesting contrast between the global analysis presented by Sala *et al.* (2000) and the current investigation relates to the pressures (or drivers, *sensu* Sala *et al.*, 2000) that were identified. These authors considered five pressures: land-use change, climate, nitrogen deposition, biotic exchange and atmospheric CO_2. In the current analysis, 11 pressures were identified through discussion as significant current causes of biodiversity loss within the study areas. Atmospheric CO_2 was not included (except with respect to its role in climate change). Given their importance within the areas assessed here, it is surprising that pressures such as habitat fragmentation, overharvesting (i.e. logging), infrastructural development and fire were not considered by Sala *et al.* (2000).

One of the outcomes of the modelling analysis presented here is that the rate of biodiversity loss might actually decline in some areas in coming decades, even if current trends in pressures continue (Fig. 16.1). This reflects the current high rates of biodiversity loss, and the fact that these rates cannot be maintained indefinitely. In other words, the rate of biodiversity loss will decline when there is little biodiversity left to be lost. This has significant implications for the current international policy goal of reduced rate of loss of biodiversity ('the 2010 biodiversity target'), as endorsed by the CBD (Balmford *et al.*, 2005). It is ironic that this policy objective might be met only when its ultimate aim, to conserve biodiversity, has failed.

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