Soil erosion hazard

coverage
currrency
frequency

Indicator 4.1a (interim indicator)
Area and per cent of forest land systematically assessed for soil erosion hazard, and for which site-varying scientifically-based measures to protect soil and water values are implemented

Rationale
This indicator aims to demonstrate that soil erosion risk has been explicitly addressed in forest management planning and field operations.

At the national level there is no numerical measure of the area of forest assessed for soil erosion. Jurisdictions apply various measures to protect soil and water values to suit differing conditions.

Protecting soil and water values in forested areas is critical to maintaining most other forest values and thus is an essential part of sustainable forest management. Knowledge of the causes of soil erosion and trends in its severity can be used to adapt forest management practices so as to limit erosion to acceptably low levels. Systematic assessment of soil erosion hazard and the implementation of site-specific measures to protect soil and water values demonstrate a commitment to the protection of these values. The target for this indicator is therefore all of the forest estate, with the initial focus on areas of high erosion risk.

It is important to realise that this indicator aims to demonstrate that soil erosion risk has been explicitly addressed in forest management planning and field operations. In other words, it records efforts to protect soils from erosion, not whether the efforts have actually been effective. Progressively, the effectiveness of any protective measures will need to be assessed, with modifications applied as required.

Soil erosion hazard is the term used to describe how likely it is for soil in a given area to erode. It depends on the inherent properties of the soil, the topography, vegetative cover and soil disturbance, and rainfall intensity.

Limited data exists nationally for the area systematically assessed for soil erosion hazard. In some States—such as New South Wales, Victoria and Tasmania—data are available for all areas of harvested native forest. In the Australian Capital Territory, New South Wales and South Australia, plantations are also assessed.

Snig track with erosion control barriers

Evaluation could consist of field observations such as the extent of sheet or rill erosion, research findings, or targeted monitoring focusing on situations of high erosion-risk.

Scale is an important factor in relation to soil erosion. From a soil fertility point of view, even downslope movement of soil within a harvesting area is detrimental. Management prescriptions, such as the use of cross-banks (drains) on log extraction tracks, can minimise downslope movement. For this reason, the spacing between cross-drains is reduced in high-risk situations.

Buffer and filter strips along watercourses and drainage lines can be used to prevent the transport of soil into streams, which might otherwise damage aquatic ecosystems. Undisturbed buffers protect larger streams and, where there is minimum ground disturbance, filter strips shield drainage lines. Buffers are increased where there is an increased risk of erosion—such as with high overland flow or on steep slopes.

In production environments of New South Wales, filter strips are placed on all streams, which are not to be disturbed during harvesting, and buffer strips are placed on unmapped drainage depressions, which allows tree felling operations and machinery access. Other states and territories use similar methods.

Fire can greatly increase the susceptibility of soils to erosion by reducing the protective cover that accumulated litter and vegetation provide. Judicious fuel reduction burning or effective fire suppression can limit the spread and impact of wildfires and thus soil erosion hazard. On the other hand, fuel reduction burns on impermeable soils in steep terrain may increase soil erosion risk. Careful assessment of erosion risk is thus important in nature conservation reserves as well as in multiple-use forests and plantations.

Where soil erosion hazard is high, special management considerations or exclusions are implemented as part of the planning and conduct of operations. Roads are a point source of sediment in catchments, so that particular attention is given to planning and maintaining road networks. Recreation activities in multiple-use forests and nature conservation reserves can contribute to erosion—for example, from vehicle tracks and walking trails—and are managed in some jurisdictions. Codes of forest practice generally require that the more erodible portions of harvesting areas—landings, snig tracks and access roads—are rehabilitated after completion of harvesting operations. For example, in Queensland, Victoria and Tasmania, log landings are drained, bark heaps dispersed, soils ripped and topsoil replaced prior to the commencement of regeneration or replanting activities. Audits are used to assess compliance with the codes of forest practice.

Further reading

Ryan, P.J., Murphy, S. and McKenzie, N. (1998). Assessing Soil Erosion Hazard for Australian Forest Management. Final Report on Project 98.801, Forest Wood Products Research and Development Corporation, Melbourne.

Grant, J.C., Laffan, M.D., Hill, R.B. and Neilsen, W.A. (1995). Forest Soils of Tasmania. Forestry Tasmania, Hobart.

DNRE (1996). Victorian Code of Forest Practices for Timber Production. Department of Natural Resources and Environment, Melbourne.

The State of Queensland Environmental Protection Agency (2002). Code of Practice for Native Forest Timber Production, Brisbane.

Protection of soil and water by forests

coverage
currrency
frequency

Indicator 4.1b

Area and per cent of forest land (including plantations) managed primarily for protective functions, for example, watersheds, flood mitigation, landslide prevention and riparian zones

Rationale

Forests provide many ecosystem services and functions. The provision of soil and water protection is one of them. Management activities should ensure these are maintained.

Some figures suggest that up to 50 per cent of forested land may be managed for protective functions. However, many of these areas may have other primary functions, with soil and water protection being ancillary. Forest protective functions are rarely mapped and therefore are difficult to quantify.

This indicator refers to the area and proportion of forested land managed primarily for soil and water protection. In this context 'primary' is defined as a legal designation for soil and water protection, and does not include areas under general management, of which soil and water protection are one of a set of multiple management outcomes. Forest management responsibilities rest with the State and Territory governments, all of which have legislation in place requiring management standards relating to watershed protection, areas vulnerable to erosion and slope instability, and riparian zones to be met. In addition to legislation, codes of practice set out activities to be undertaken in or near waterways, in erosion hazard areas or in water management catchments. Table 65 indicates the area of forest managed primarily for protective functions. This shows that, in the States included, historically more than 50 per cent of forested land is collectively managed for protective functions.

Table 65: Forest managed primarily for protective functions in multiple-use forest in New South Wales, Victoria, Western Australia and Tasmania ('000 ha)

	Area protected	Area of forest for which data are available
Multiple-use forest	3 562	6 654

Source: Commonwealth of Australia (1997)

Designated water supply catchments provide water for urban and rural use. To maintain water quality, legislation exists in each State and Territory to control land use activities in these catchments, which are generally public land, such as nature conservation reserve or multiple-use forest.

Restrictions may be imposed on:

- the level, type and location of recreational activities;
- timing of forest management practices (such as during wet weather);
- methods of road construction and spatial distribution of roads; and
- management of fuels, grease and oils.

Table 66: Examples of area (ha) by sample forest protection categories

	Tasmania	New South Wales	Victoria
Protection category			
Water supply	–	9 102	51 000
Slope	150 000	77 580	538 000
Riparian	35 000	221 460	488 000

Source: National Forest Inventory (2003)

In Victoria, 51 000 hectares of forest are protected as water supply catchments and in New South Wales 9 100 hectares of multiple-use forests are zoned primarily for water catchment protection (Table 66). Data are not available from other States and Territories.

Compared to open woodland or grassland, forested areas are characterised by higher leaf area and evapotranspiration rates and deeper organic soil layers and rooting systems. As a result, runoff is generally reduced in forested catchments and the mean annual streamflow and mean annual flood peaks are less. Flooding is a function of climatic and biophysical controls at a catchment scale, including drainage density, slope, shape, soil type and depth, and vegetation type/density. Mitigation of flooding through forest management in vulnerable catchments will relate to harvesting patterns, intensity and timing relative to the hydrological year. However, there are no data from routine monitoring on which to report.

The delivery of sediments to waterways can occur in response to erosional and/or slope instability processes. Erosion is a function of catchment morphology, soil properties, rainfall factors and slope gradient. Slope instability is determined by increased loads (including water and snow), soil moisture content, loss of soil structure due to shock or vibration, undermining, loss of soil cohesion, and the gradient of the slope. Forest codes of practice and management plans, or specific legislation in each State and Territory, define appropriate measures to minimise risk. These include practices which limit or prohibit harvesting during periods of high rainfall or on steep slopes. In some codes of practice, steep slopes associated with high hazard risks for erodibility and slope instability may be specified (for example, 30° in Victoria and New South Wales), while others vary according to parent material (11° to 19° in relation to landslide susceptibility in Tasmania). Data are not available for most States and Territories. However, in Victoria 538 000 hectares of steep forested land is protected, in multiple-use forests of New South Wales 77 600 hectares are protected from water pollution hazard or extreme erosion risk, and the area mapped in Tasmania for landslide protection is 150 000 hectares.

Riparian zones comprise the vegetation and soils immediately adjacent to streams. These zones are important for maintenance of habitat and biodiversity, streambank stabilisation and the trapping of sediment mobilised from upslope positions. The removal of riparian vegetation can have profound effects in terms of water quality, stream morphology, habitat and biodiversity—both at the site and beyond. In forested areas, particularly where harvesting occurs, riparian zones are considered to be buffer or filter strips that protect waterways. The width of these strips, which should take account of soil properties and slope, varies between the States and Territories according to the forests codes of practice (indicator 7.1d), licences, and plans of management, but is generally 5–60 metres.

The width of buffers will affect the proportion of forest set aside to protect waterways. However, it should be noted that the condition of the riparian zone—and hence its capacity to protect waterways—is not only dependent on width, but also on the type of cover and its composition, connectivity and structural integrity. There is also a relationship with the intensity of disturbance created by the activity being undertaken. Generally data are not available for reporting, although in Victoria 9.8 per cent (488 000 hectares) of riparian vegetation in forests within Regional Forest Agreement areas is protected from forestry activities. In Tasmania 35 000 hectares have been mapped as streamside reserves and this area is expected to increase as a result of future planning. In New South Wales, 184 500 hectares of multiple-use forests are reserved from harvesting as filter strips, with another 37 000 hectares in which modified harvesting is permitted. Furthermore, specific set-back distances apply in certain areas not specified by the New South Wales Integrated Forestry Operations Approvals. Additional information referring to condition of riparian zones is available in New South Wales through the Stressed Rivers Report at a catchment scale; however, this is not quantified according to land tenure or use.

Further reading

Commonwealth of Australia (1997). Australia's First Approximation Report for the Montreal Process. Montreal Process Implementation Group, Canberra.

DLWC (1998). Stressed Rivers Assessment Report: NSW State Summary 1998. Department of Land and Water Conservation, New South Wales.

Native forest and plantations for production and water quality maintenance, Cotter Dam, ACT

coverage
currrency
frequency

Stream flow in forested catchments

Indicator 4.1c

Percent of stream kilometres in forested catchments in which stream flow and timing has significantly deviated from the historic range of variation

Rationale

This indicator aims to measure the effects of forest management and other factors on water flow and variation in flow. This is important for stream health and for water supply for human use.

Studies show that stream flow increases after forest harvesting, decreases with regrowth or plantation establishment and increases again in older forests. Attempts to quantify changes in stream flow in forested catchments are problematic.

Human activities since European settlement have altered the natural flows of many river systems with resulting environmental and economic effects. Some of the consequences include reduced stream flow or changes to the seasonality of flows, including the length of time during which there are low flows or no flows.

Catchments in Australia are used for more than water supply and storage. Although streams may rise in forested or wooded uplands, they can also flow through private and public land, which may be forested, agricultural, grazed or urban. It should also be noted that while forest management practices such as harvesting may occur in one part of a catchment, other land use and management practices may be going on elsewhere in the same catchment.

In some cases, the impacts of one form of land use may add or subtract to the impacts of another, such as when increased runoff after forest harvesting is offset by farm dam development. Under these circumstances, it is difficult to isolate the impacts of one type of land use on stream flow. In addition, the occurrence of bushfires and the high degree of rainfall variability—which may result in stream flow varying between years by as much as 70 per cent—complicate the difficulty of trying to characterise the system. In some States, streams have been monitored for several decades; however, there has been no systematic and consistent analysis that provides an assessment of the temporal and spatial variability of stream flow.

Studies have been undertaken in forested areas in which the impacts of forest management in one catchment are measured and compared with an adjacent, undisturbed catchment. Although most studies have focussed on mountain ash forests in Victoria, other studies have been undertaken on mixed species forests, and are in progress in hoop pine plantations in Queensland. These studies demonstrate that:

- stream flow increases after forest harvesting, in response to higher runoff after the removal of vegetation from ground surfaces; and
- stream flow decreases in proportion to the density of regrowth in the catchment and returns to pre-harvesting levels after 4–8 years, depending on forest type.

However, other studies show that forest management has little impact on stream flow. Significant variations of flow have occurred in three streams out of a total of 14 monitored in a Victorian study, although the conclusions drawn suggest that the major impact on yield is probably wildfire—dating from 1939—rather than forest management. It should be noted that there are a number of significant constraints in this study due to problems with data reliability and continuity.

In addition to impacts imposed during harvesting in forested catchments, stream flow may be modified by the construction of storage dams. These structures retain water until controlled releases contribute water downstream, and affect the timing of flows.

Further reading

Cornish, P.M. (1993). The effects of logging and forest regeneration on water yields in a moist eucalyptus forest in New South Wales, Australia. Journal of Hydrology. 150 (2–4): 301–22.

Harper, P.B. and Lacey, S.T., (1995). A review of findings from the Yambulla Catchments Hydrological Research Project, 1979–1990. State Forests of NSW, Pennant Hills.

Lane, P. and McKenna, P. (in press). Retrospective Stream Flow Analysis. Final Report to Forest Management Branch. Department of Sustainability and Environment, Forests Science Centre, Heidelberg.

Nandekumar, N. and Mein, R.G. (1993). Analysis of Paired Catchments Data to Determine the Hydrologic Effects of Change in Vegetative Cover on Yield. Technical Report to Land and Water Resources Research and Development Corporation and Department of Conservation and Natural Resources. Department of Civil Engineering, Monash University, Clayton.

O'Shaughnessy, P.J., Fletcher, T., and Bren, L., (1999). The Effects of Forest Harvesting on Water Yield and Quality in the Lerderderg Catchment. Research Report to Department of Conservation and Natural Resources, Melbourne.

Smith, D.I. (1999). Water in Australia. Oxford University Press, Melbourne.

Dead river red gum (*Eucalyptus camaldulensis*) following flooding of Murray river for Yarrawonga Dam, Mulwala, NSW

coverage
currrency
frequency

Soil organic matter

Indicator 4.1d (interim indicator)

The total quantity of organic carbon in the forest floor (greater than 25 millimetres diameter components) and in the surface 30 centimetres of soil

Rationale

The quantity and type of soil organic matter helps describe a soil's physical, chemical and biological status, which in turn affect many important ecosystem processes. This indicator aims to measure soil organic matter that can impact on soil fertility.

There are no broad operational data available for soil carbon or organic matter change in Australian forests. Certain forest practices can alter soil organic matter.

Soil organic matter is important because it provides for the storage and release of key nutrients and is important in ecosystem carbon cycling. It also affects soil physical and hydrological properties and provides substrates for soil biota. Broad scale land clearing, primarily for agriculture, has had the most dramatic impact on soil organic matter but many forest operations may also change the quantity and features of soil organic matter. Characteristics of soil organic matter are particular to each forest ecosystem. The interim indicator aims to provide a surrogate for the physical, chemical and biological properties important for soil fertility.

Protecting soils in forested areas is critical to maintaining most other forest values and thus is an essential part of sustainable forest management. To assist in this, the plantation forest industry has developed chopper rolling as standard practice. Chopper rolling is used to crush the residues from clear felling operations *in situ* to retain nutrients and organic matter.

Knowledge of the trends and causes of change in organic matter and other important soil chemical properties can be used to adapt management practices where required. However, for the following reasons, there are no broad operational data available for soil carbon or organic matter change in Australian forests.

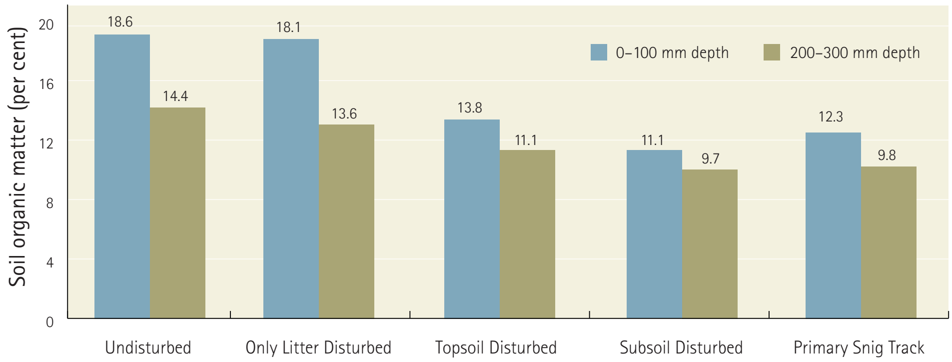
Chopper rolling to retain organic matter, South Australia

Total soil organic carbon is composed of several components that vary greatly in their properties and contribution to soil fertility. Australian forest soils may contain significant quantities of relatively inert (stable) carbon in the form of charcoal, and there is no simple and cheap way of separating this from the organic components when total soil carbon is measured. Direct measurements of carbon are a better indicator of change in the productivity of plantations than 'loss-on-ignition', which is sometimes used.

Soil organic matter (SOM) is also costly to monitor, and changes are not simple to interpret in terms of ecosystem functioning (apart from impacts on soil carbon stocks, which are important for greenhouse accounting). The importance of a change in soil organic matter varies with forest ecosystem type and management objective.

There appears to be good potential to use soil disturbance classes as a surrogate for SOM change (Figure 41 and case study). This would be a more cost-effective approach to monitoring, but it needs further calibration.

Figure 40: Relationship between soil disturbance category and soil organic matter content on the general harvest area and snig tracks 10 years after clearfelling mountain ash (*Eucalyptus regnans*) forest

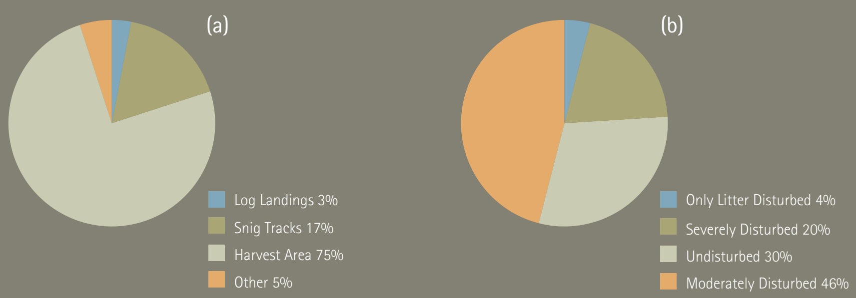


Source: Lacey *et al.* (2002)

Case study

Research during the last decade in mountain ash forest in the Victorian Central Highlands has provided a potential means to monitor soil change in harvested forests in the future. A field survey technique for assessing soil disturbance during harvesting and regeneration has been developed. This method has been used to survey the proportion of harvesting areas affected by operational categories (Figure 41a) and varying levels of associated soil disturbance (Figure 41b). Results show that clearfelling affects most of a site, causing about 66 per cent of the area to experience moderate to severe soil disturbance.

Figure 41: Proportion of logging coupe area (mean of 20 operational coupes) occupied by (a) different operational categories or (b) soil disturbance categories, following clearfelling of mountain ash forest in the Victorian Central Highlands



Source: Lacey *et al.* (2002)

Further reading

Bauhus, J., Khanna, P., Hopmans, P., Ludwig, B. and Weston, C. (2002). Evaluation of soil organic matter as a meaningful indicator of important soil properties and processes in native forest ecosystems. Final Report on Project 99.803 to Forest Wood Products Research and Development Corporation, Melbourne.

Carlyle, C., Snowdon, P., Polglase, P., Nambiar, S., Smith, T., Simpson, J. and Bubb, K. (2002). Soil-based information for developing sustainable plantation management in Australia. Final Report on Project 99.801 to Forest Wood Products Research and Development Corporation, Melbourne.

Lacey, S., Rab, M.A. and McCormack, R.J. (2002). Effects of forest harvesting on soil physical properties: Developing and evaluating meaningful soil indicators for sustainable management in southeastern Australia. Final Report on Project 99.805 to Forest Wood Products Research and Development Corporation, Melbourne.

Pennington, P. and Laffan, M. (2001). Procedures for the measurement of changes in soil physical properties following logging of wet *Eucalyptus obliqua* forests. Final Report on Project 99.804 to Forest Wood Products Research and Development Corporation, Melbourne.

Rab, M.A. (1999). Measures and operating standards for assessing Montreal Process soil sustainability indicators with reference to Victorian central highlands forests. Forest Ecology and Management 117: 53–73.

Raison, R.J. and Rab, M.A. (2001). Guiding concepts for the application of indicators to interpret change in soil properties and processes in forests. Pp. 231–258 in: R.J. Raison, A.G. Brown and D.W. Flinn (eds) Criteria and Indicators for Sustainable Forest Management. IUFRO Research Series, No. 7. CABI, Wallingford.

Whitford, K. (2001). Evaluation of key soil indicators of sustainability in Australian Mediterranean Forests. Final Report on Project 99.802 to Forest Wood Products Research and Development Corporation, Melbourne.

Sampling organic matter

Soil physical damage

coverage
currrency
frequency

Indicator 4.1e (interim indicator)
Proportion of harvested forest area with significant change in bulk density of any horizon of the surface (0–30 centimetres) soil

Rationale
To measure the extent of soil physical change induced by human activities that might adversely affect soil fertility and thus other ecosystem processes.

Certain forest operations can result in changes to soil bulk density, but there is insufficient data to report fully on this indicator. Codes of practice in most jurisdictions limit these impacts.

Protecting soils in managed forests is critical to maintaining most other forest values and thus is an essential part of sustainable forest management. Knowledge of the trend and causes of detrimental soil compaction can be used to adapt management practices to avoid further soil damage, or to guide ameliorative activities.

This indicator measures the extent of soil physical change induced by human activities that might adversely affect soil fertility and thus other ecosystem processes. Balancing soil physical properties is important in maintaining soil fertility and hydrological processes.

Changes in soil physical properties can affect important ecosystem processes such as infiltration of water, aeration and growth of plant roots. The indicator focuses on bulk density (which reflects soil pore space), and the impacts of forest harvesting, because these are recognised as having the potential to adversely affect soil physical properties.

Recovery from significant soil compaction is slow in the field. This raises concerns about the potential for cumulative impacts between rotations.

The intensity of harvesting can influence the level of impact on soil physical properties. Roads, tracks and log landings have the greatest potential to impact on the soil physical properties and should therefore be minimised. Severely compacted areas may need to be re-habilitated following completion of harvesting. Codes of practice are in place in most jurisdictions to minimise these impacts.

Research based on this indicator has shown that bulk density may be a valuable measure of soil disturbance but it is too costly at the operational level for practical application. It has been proposed that a target of 20 per cent of harvested areas in a management unit be surveyed for soil disturbance.

Currently there are no comprehensive national data on the effects of forest harvesting on soil bulk density. However, the degree of soil disturbance can be calibrated with soil density and carbon content for contrasting forest ecosystems and harvesting regimes (e.g., Table 67; Figure 42).

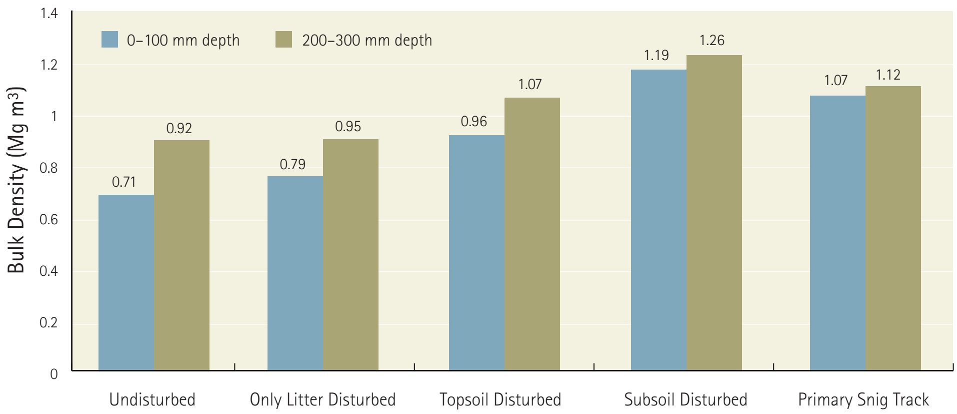
Cording of snig track to avoid rutting by machinery

Table 67: Effects of soil disturbance on bulk soil density following harvest of two mature messmate stringybark (*Eucalyptus obliqua*) forests in Tasmania

	Disturbance Level		
	None/Light	Moderate (Topsoil)	Severe (Subsoil)
		(i) Dolerite soil	
Fine earth bulk density (g cm^{-3})	0.61	0.62	0.80
Organic C (%)	*4.5*	*4.6*	*3.3*
		(ii) Granite soil	
Fine earth bulk density (g cm^{-3})	0.60	0.70	0.85
Organic C (%)	*6.8*	*6.5*	*3.9*

Source: Pennington and Laffan (2001)

Figure 42: Relationship between soil disturbance category and soil bulk density on the general logging area 10 years after clearfelling mountain ash (*Eucalyptus regnans*) forest



Source: Lacey *et al.* (2002)

Further reading

Lacey, S., Rab, M.A. and McCormack, R.J. (2002). Effects of forest harvesting on soil physical properties: developing and evaluating meaningful soil indicators for sustainable management in southeastern Australia. Final Report on Project 99.805 to Forest Wood Products Research and Development Corporation, Melbourne.

Pennington, P. and Laffan, M. (2001). Procedures for the measurement of changes in soil physical properties following logging of wet *Eucalyptus obliqua* forests. Final Report on Project 99.804 to Forest Wood Products Research and Development Corporation, Melbourne.

Rab, M.A. (1999). Measures and operating standards for assessing Montreal Process soil sustainability indicators with reference to Victorian central highlands forests. Forest Ecology and Management 117: 53–73.

Biodiversity of water bodies

coverage
currrency
frequency

Indicator 4.1f

Per cent of water bodies in forested areas (e.g., stream kilometres, lake hectares) with significant change in biological diversity from the historic range of variability

Rationale

The in-stream fauna reflects the quality of the habitat and water. This in turn, reflects the impacts of off-stream management activities, so that aquatic biodiversity is a good measure of the success of protective management prescriptions.

Biodiversity in water bodies can be assessed in various ways. Most jurisdictions assess biodiversity in major water bodies, but often these give 'snapshot' results and longer term monitoring is needed to establish temporal and spatial trends.

There are several different rapid appraisal methods by which the ecological health of a river or stream can be assessed. However, several States and Territories use the interactive computer package AusRivAS (Australian River Assessment System). AusRivAS was developed under the National River Health Program of the Commonwealth Government in 1994. It involves the environmental protection agencies at a State level and is centrally administered by the Australian Government Department of the Environment and Heritage and Land and Water Australia.

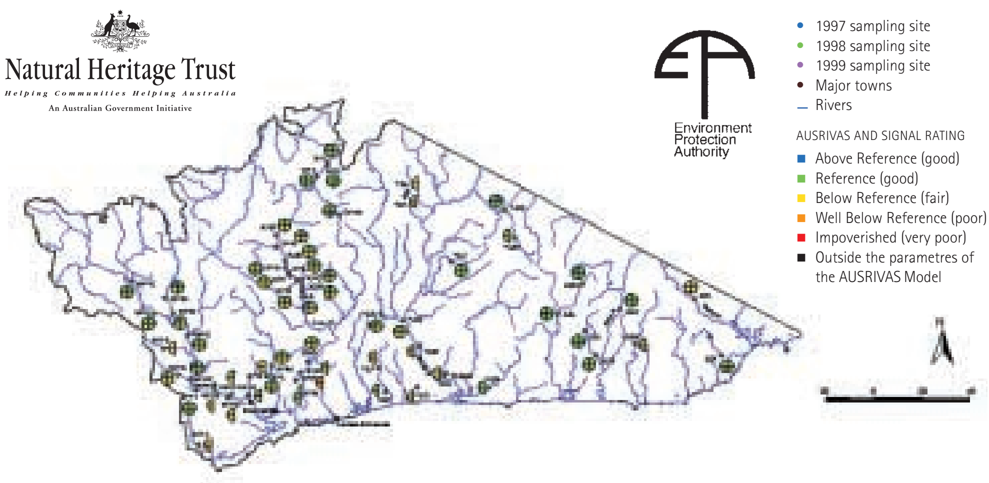
AusRivAS is based on comparisons between test and reference sites. The reference sites are selected to represent the best available sites for each type of river, but do not necessarily represent pristine conditions. In some cases reference sites may refer to rivers with modified hydrology, water quality and in-stream habitat. An additional limitation is that models are developed for bioregions and not for catchments. Medium to long-term data are not yet available to distinguish variance in biological diversity from the historic range of variability. Importantly, stream monitoring does not specifically target forested areas and sites are often located within regions with multiple land uses where off-site impacts from other landuse and land management practices can be expressed. One-third (21 900 kilometres) of the total river length assessed at a national scale, and including all land uses, is to some degree impaired. Impairment refers to a loss of between 20 per cent and 100 per cent of the various kinds of aquatic invertebrates that should live there.

Examination of the data at a State-by-State/Territory level suggests that New South Wales has the poorest aquatic biota condition—approximately 50 per cent of the river length is assessed as having impaired biota. This compares with greater than 35 per cent in the Australian Capital Territory and Western Australia, and between 12–24 per cent of the river length assessed in the remaining States and Territories having impaired biota.

It should be noted that aquatic habitat condition is related to water quality and water quantity in terms of sediment and nutrient loads, and to the delivery of pollutants from upslope or up-catchment locations. Therefore, impacts to river health will be particularly evident in catchments characterised by low tree density and/or ground cover, erodible soils, high rainfall erosivity, intensive agriculture or urban development. In addition, where salinisation or soil acidification is widespread, water quality may be impacted by the inflow of surface or shallow groundwater with high salt loads or low pH. Therefore, the distribution of specific catchment conditions needs to be identified both spatially and temporally in order to assess any direct correlations between river health, soil characteristics, climate and/or landuse.

In Victoria, SIGNAL (Stream Invertebrate Grade Number – Average Level method) is also used to measure river health by indicating the nature of disturbance or impact at a site in terms of the sensitivity of macroinvertebrates to stream salinisation and organic pollution. Index of Stream Condition benchmarking—which is partly based on AusRivAS and SIGNAL data and includes other criteria relating to hydrology, channel morphology and the riparian zone—has been undertaken in Victoria. Results for the overall condition of streams—with condition of biota representing only one set of criteria—indicate that 34 per cent of Victoria's major rivers and streams are in very poor or poor condition and only 22 per cent are in good or excellent condition. However, this assessment does not identify forested areas specifically. Mapping of the biological health of streams in the East Gippsland region (1997–99) provides some data for largely forested catchments (Figure 43), which can be compared with a multiple land-use catchment dominated by agriculture and grazing (Figure 44).

Figure 43: AusRivAS and SIGNAL monitoring results for stream health in East Gippsland, Victoria

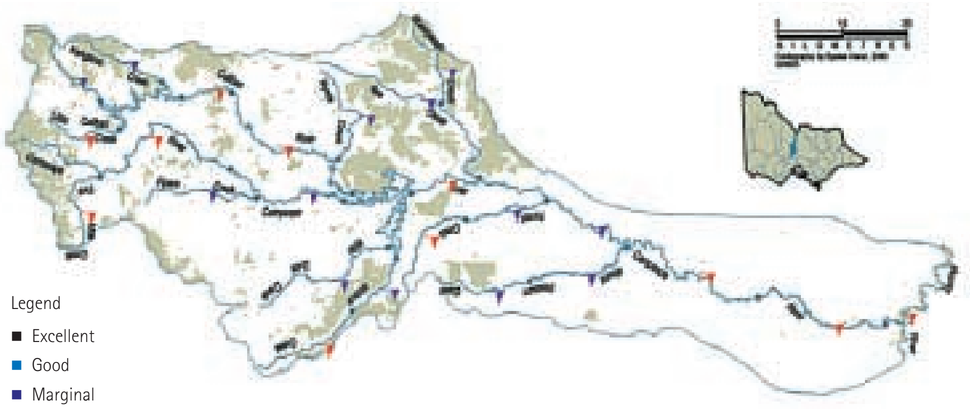


Source: Victoria, Environmental Protection Authority (2002).

In the south-east region of New South Wales, single snap shot AusRivAS monitoring indicates that Local Government Areas with a significant proportion of forested catchments—for example, Snowy River Shire, Bega Valley Shire and Bombala Shire—have a majority of their streams in good condition. This is in contrast to Local Government Areas characterised by agricultural, grazing or urban landuses.

AusRivAS monitoring represents, at best, broad comparative information for river health and biodiversity in multiple land use catchments where certain landuse or land tenure is dominant. In South Australia, AusRivAS monitoring of invertebrates, one-off surveys of fish in specific areas, and annual censuses of frogs are undertaken. However, it is estimated that fewer than 15 per cent of streams and lakes within forested areas in South Australia are monitored for biological diversity, with no data currently available to determine any temporal changes with reference to the historic range of variability.

Figure 44: AusRivAS ratings on stream health for the Campaspe catchment, Victoria



Legend

- Excellent
- Good
- Marginal
- Poor
- Very poor
- Not available

Source: Victorian Water Resource Data Warehouse (2003).

Overlaid mapping of landuse and tenure with longer term AusRivAS data is required before meaningful relationships and trends will be evident. Since AusRivAS is a national program co-ordinated through the Australian Government Department of the Environment and Heritage, overlaid mapping of landuse and land tenure for forest coverage on a State/Territory basis should be possible in the future. However, longer term data are required to establish temporal as well as spatial trends in river health (as defined by biodiversity). The limitations of AusRivAS also need to be acknowledged and addressed.

Willows (*Salix* spp.) planted for stream bank stabilisation

Further reading

Anderson, J.R. (1993) State of the Rivers Project. Report 1. Development and Validation of the Methodology. Department of Primary Industries, Queensland.

ACT Commissioner for the Environment. (2000). Australian Capital Region State of the Environment Report, Canberra.

Barmuta, L.A., Chessmand, B.C., and Hart, B.T. (1998). Interpreting the Outputs from AusRivAS. Occasional Paper 2/98. National River Health Program, Land and Water Resources Research and Development Corporation, Canberra.

Davies, P.E. (2000). Development of a national river bioassessment system (AusRivAS) in Australia. In J.F. Wright, D.W. Sutcliffe and Fruse, M.T. (eds) Assessing the Biological Quality of Fresh Waters: RIVPACS and Other Techniques. Freshwater Biological Association, Cumbria.

Davies, P.E., Chessman, B.C., Metzeling, L., Tiller, D., and Dixon, L. (1994). River Bioassessment Manual. Monitoring River Health Initiative, National River Processes and Management Program, Commonwealth of Australia, Canberra.

DLWC (2002). Assessing Conservation Value and Health in New South Wales Rivers. Centre for Natural Resources, New South Wales Department of Land and Water Conservation, Parramatta.

Krasnicki, T., Pinto, R. and Read, M. (2001). Australia-wide Assessment of River Health: Tasmania Program. Technical Report No. WRA 01/2001. Department of Primary Industries, Water and Environment, Hobart.

Victorian Water Resource Data Warehouse (2003). AusRivAS ratings on stream health for the Campaspe catchment, Victoria. http://www.vicwaterdata.net/home.asp

Physio-chemical properties of water bodies

coverage
currrency
frequency

Indicator 4.1g

Per cent of water bodies in forest areas—e.g., stream kilometres, lake hectares—with significant variance from the historic range of variability in pH, dissolved oxygen, levels of chemicals (electrical conductivity), sedimentation or temperature change

Rationale

To use the physio-chemical parameters to assess the health of the aquatic environment and the quality of water for human use (drinking, irrigation, recreation) and ecosystem health.

Although some monitoring is carried out in most jurisdictions there are insufficient data to report fully on this indicator.

Monitoring and analysis of certain key physical and chemical variables in water can provide information on the ecological health of water bodies and how forestry operations or management practices are affecting water quality. This is important both because of human use of water, and in determining the health of the aquatic environment in a forested area. This indicator is closely related to indicator 4.1f.

Water quality is monitored across the States and Territories to assess river condition and health and to determine whether water for different uses, including drinking water, satisfies set criteria. Guidelines, which define threshold values of physico-chemical parameters, are provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Responsibility for monitoring and/or analysing data is varied and includes State/Territory agencies, statutory authorities, catchment management authorities, local government and community groups—such as those participating in Waterwatch.

In Victoria, the environmental condition of 950 stream reaches, representing 18 000 kilometres of major rivers and tributaries, has been assessed using the Index of Stream Condition (ISC). Assessment is based on 19 indicators relating to hydrology, streamside zone, physical form of the channel, water quality and aquatic life. Results show regional differences but, in general, pH is decreasing, there is a slight increase in turbidity, a decrease in salinity and a slight decrease in total nitrogen. Only 56 of the total 950 stream reaches fully meet the criteria for ecologically healthy rivers as defined by the ISC classification.

In New South Wales, the Stressed Rivers Report and the Interim Environmental Objectives developed by the Environment Protection Authority provide frameworks for either describing the current health of river systems or for developing management tools to optimise river health in the future (Figure 45 and Table 68). Although some data provide snapshots of the current status for some rivers, temporal trends are not evident yet due to the limited time series available. Regional State of the Environment reporting for the Australian Capital Region including the Australian Capital Territory and the south east region of New South Wales has compiled data for water quality since 1990. Some trends are beginning to emerge, particularly in relation to

Water sampling

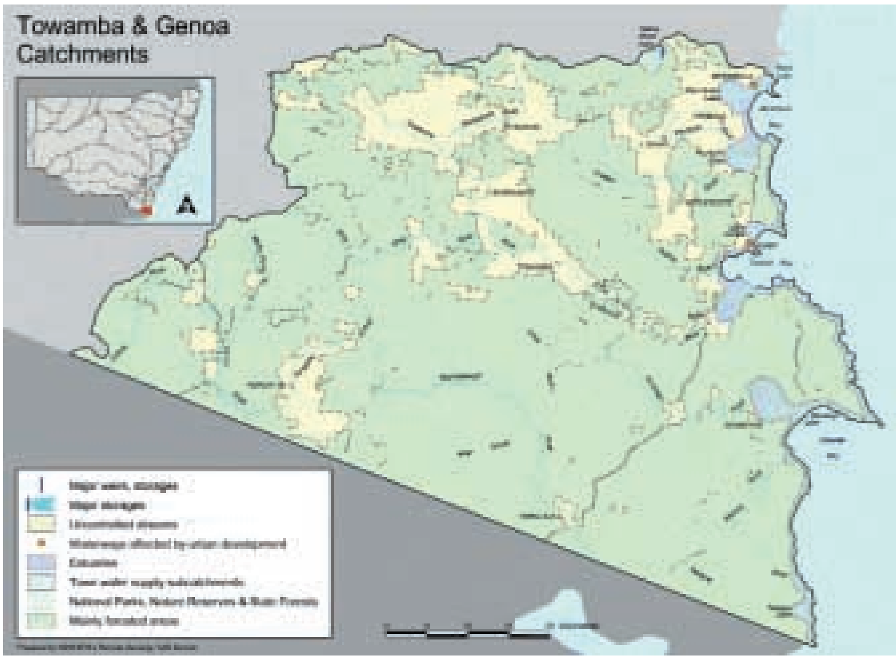
temperature, nutrients and salinity, but these are not conclusive without appropriate analysis using tools which take into account variability that may be due to seasonality, climate, landuse and non-constant variance.

State Forests of New South Wales has been conducting hydrology research projects for more than 25 years, investigating the impacts of forest management activities on water quality and quantity. At present State Forests operates more than 35 stream gauging and water quality monitoring stations in a number of State Forests' regions. Results of research projects and water quality monitoring have shown that runoff containing fine sediment from unsealed roads is the major potential source of water pollution in a managed forest environment.

Further research by State Forests, universities, CSIRO and the Cooperative Research Centre for Catchment Hydrology has demonstrated that due to strict sediment control measures State Forests' management activities do not have an adverse impact on water quality.

In Queensland, the State of the Rivers project uses the Anderson Method of rapid appraisal of stream condition. However this does not assess hydrology, water quality or aquatic biota. In Western Australia, ongoing Statewide monitoring is being undertaken, and increasing trends have been identified in relation to salinity, but there are no measurement programs to record changes in other chemical properties relating to this indicator, or sedimentation.

Figure 45: Land tenure and water resources in the Towamba/Genoa River catchment, New South Wales



Source: New South Wales Environment Protection Authority (2000).

It is clear from the data and additional information available that while water quality monitoring is undertaken in each of the States and Territories, and catchment management planning is a major activity, there is no specific focus on the contribution of forest to catchment condition at a broad scale. Research undertaken in small forested catchments indicates that water quality varies in response to the design, spatial distribution and use of roads, harvesting, wildfire and climate. The effects of these activities vary according to soil erodibility, rainfall erosivity, slope, antecedent soil moisture conditions and vegetation characteristics. State codes of practice and licenses provide prescriptions to protect water quality through appropriate design, use and distribution of roads and water crossings.

Table 68: Stress classifications for Towamba catchment, New South Wales for selected streams shown in Figure 32

Sub-catchment	Overall stress classification	Full development stress classification	Hydrology stress rating	Environmental stress rating
Pambula River	S3 (medium environmental stress, high extraction)	Unresolved	High	Medium
Towamba River	S5 (high environmental stress, low extraction)	S5	Low	High
Mid Towamba River	U3 (medium environmental stress, low extraction)	U3	Low	Medium
Mataganah Creek	U3 (medium environmental stress, low extraction)	S4	Low	Medium
Wonboyn River	U3 (medium environmental stress, low extraction)	U2	Low	Medium
Nullica Creek	U4 (low environmental stress, low extraction)	Unresolved	Low	Low
Wog Wog River	Unresolved	Unresolved	Low	Low

Source: Department of Land and Water Conservation, New South Wales (1998)

However, system responses to complex processes operating in multiple land use large catchments have not been investigated, so extrapolation of these research findings is not feasible. Relevant research has also not been undertaken in forested catchments where minimal disturbance occurs.

Further reading

Anderson, J.R. (1993) State of the Rivers Project. Report 1. Development and Validation of the Methodology. Department of Primary Industries, Queensland.

ANZECC (2000). National Water Quality Management Strategy. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council, Canberra.

Cornish, P.M. (1992). Water quality following logging on the Tantawanglo research catchment. Report to Tantawanglo Technical Committee. Forestry Commission of New South Wales, Pennant Hills.

Department of Natural Resources and Environment. (2002) Victorian River Health Strategy. Department of Natural Resources and Environment, Melbourne.

DLWC (1998). Stressed Rivers Assessment Report: NSW State Summary 1998. Department of Land and Water Conservation, New South Wales.

Doeg, T.J. and Koehn, J.D. (1990). A Review of Australian Studies on the Effects of Forestry Practices on Aquatic Values. SSP Technical Report no. 5. Fisheries Division, Department of Conservation and Environment.

New South Wales Environment Protection Authority. (2000). Towamba and Genoa River Catchments, Catchment at a glance http://www.epa.nsw.gov.au/ieo/Towamba

Harper, P.B. and Lacey, S.T. (1995). A review of findings from the Yambulla Catchments Hydrological Research Project, 1979–1990. State Forests of New South Wales, Pennant Hills.

O'Shaughnessy, P.J. and Jayasuriya, M.D.A. (1991). Water Supply Catchment Hydrology Research: Status Report 1991. Melbourne Water, Melbourne.

coverage
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frequency

Persistent toxic substances

Indicator 4.1h

Area and per cent of forest land experiencing an accumulation of persistent toxic substances

Rationale

Toxic substances can adversely affect important ecological processes in forest ecosystems. They may also be transported in water or sediments. Knowledge of the trend and cause of accumulated toxic substances can be used to design corrective measures that lower future risks.

While guidelines have been developed that deal with the use of toxic and persistent substances, no national data are collected for this indicator.

Currently there is no systematic monitoring of forest soil pollution in Australia, except for limited areas where bio-solids and treated effluent are applied.

An important mechanism to avoid soil pollution in forests is outlined in guidelines contained in codes of forest practice. These guidelines in codes deal with the use of pesticides, chemicals, the application of fertilisers and the careful storage and use of fuel or oil.

In forested areas one issue of concern is the impact on the environment of the application of heavy loads of fire retardant chemicals, as part of fire suppression activities. Fire retardants contain high concentrations of nutrients—nitrogen, phosphorus and sulphur—as well as very small amounts of performance additives. Minimising the use of retardants in areas where there is a high risk of transport to streams following fires, or where there are sensitive ecosystems and water supply catchments, can mitigate risks to the environment.

Case study

The New South Wales Environment Protection Authority (EPA) has produced comprehensive environmental guidelines for the use and disposal of bio-solid products. Bio-solids can be applied to forests, but in doing so, there is a strong emphasis on the protection of soil and water values, particularly from nitrate leaching. The guidelines require analysis of the bio-solid to determine the pathogen and heavy metal contamination levels. This is followed by the requirement to meet appropriate application and management practices. Ongoing monitoring of soil and water contaminant levels is required. Land application is varied according to the sensitivity of the area to loss of ecological, natural, cultural or heritage values. Buffer zones are required around sensitive areas, and there are limits on the quantity and frequency of bio-solid application. Each application must be licensed by the EPA.

Guidelines for the disposal of bio-solid products are being refined, based on research by State Forests New South Wales. Research has been conducted on the effects of bio-solid application rate on growth and soil nutrient change in pine plantations. It determined that the release of organic nitrogen from decomposing bio-solids under a pine stand were much higher than indicated in the EPA guidelines. Significant leaching of nitrate occurred from aerobically-digested bio-solids at one site, indicating the need for monitoring to provide data to support more site-specific management.

Further reading

Beese, F.O. and Ludwig, B. (2001). Indicators to guide management for multiple forest use. Pp. 199–213 in R.J. Raison, A.G. Brown and D.W. Flinn (eds) Criteria and Indicators for Sustainable Forest Management. IUFRO Research Series, No. 7. CABI, Wallingford.

EPA (1997). Use and Disposal of Biosolid Products: Environmental guidelines. Environmental Protection Agency, Chatswood.

Forest Practices Board (2000). Tasmanian Forest Practices Code, Tasmaina.

Gould, J.S., Khanna, P.K., Hutchings, P.T., Cheney, N.P., and Raison, R.J. (1999). Assessment of the Effectiveness and Environmental Risk of Use of Retardants to Assist in Wildfire Control in Victoria. Client Report No. 672. CSIRO Forestry and Forest Products, Canberra.

Innes, J.L. and Karnosky, D.F. (2001). Impacts of environmental stress on forest health: the need for more accurate indicators. Pp. 215–230 in R.J. Raison, A.G. Brown and D.W. Flinn (eds) Criteria and Indicators for Sustainable Forest Management. IUFRO Research Series, No. 7. CABI, Wallingford.

Robinson, M.B. (1999). Nitrogen Dynamics After Application of Biosolids to a *Pinus radiata* Plantation. PhD Thesis, University Melbourne, Melbourne.