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Lessons from the Queensland Rainforests: Steps towards sustainability.

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Summary

Commercial timber harvesting commenced in the tropical rainforests of north Queensland in 1873 and ceased in 1988 following their inclusion on the World Heritage List. The evolution of forest policy, management and research is reviewed, and strengths and weaknesses are highlighted. Between 1950-85, eight estimates of the sustainable yield varied ten-fold. Discrepancies were due to different assumptions regarding management, and to errors in estimating net productive areas and growth rates. During 1950-85, the allowable cut (130,000-207,000 m^3/ann) exceeded sustained yield estimates (60,000-180,000 m^3/ann), but the actual harvest (90,000-205,000 m^3/ann) remained less than the allowable cut. The allowable cut was reduced to a sustainable level in 1986, and commercial logging ceased in 1988. It is not certain that the harvest during 1980s was sustainable, but several indicators suggest that it probably was sustainable. Lessons for other tropical timber producers are highlighted.

Introduction

A century of timber harvesting ended in 1988 when the tropical rainforests of Queensland were included on the World Heritage List. The management system devised for these forests was considered to be "the most complete example of sustainable management . . . found anywhere in the tropics" (Poore *et al*. 1989, p. 197). Timber harvesting in these forests has now ceased, but the experience gained should not be lost. This paper highlights some strengths and weaknesses of the silvicultural and management systems employed in these forests in the hope that others may learn from these experiences.

There are small pockets of rainforest along most of the coast and coastal ranges of Queensland, but these develop into substantial areas of high forest only where the great dividing range draws close to the coast and precipitates high rainfall (Bell et al. 1987, McDonald and Elsol 1984, Adam 1992). The most significant areas are the tablelands behind the city of Cairns, between 16 and 19° south. Although timber was harvested from other tropical and subtropical rainforests in Queensland, this review will concentrate on these forests between Townsville and the Daintree River.

Social and Historic Context

Australia is an old continent, but a young nation. Geologically and floristically, it is an ancient land, with poor soils and many primitive flowering plants (Rainforest Conservation Society 1986). Aboriginals may have occupied this continent for more than 40,000 years, and must have helped to shape the rainforests (Kershaw 1986), but the greatest changes have occurred since white settlement.

Although the Dutch visited north Queensland in the 1600s, it was Captain Cook who claimed "New South Wales" for the British Crown in 1770. Australia has recognised few aboriginal land claims, and much land (and most of the forest) remains under government control. Sydney Cove was founded in 1788, and the Colony of Queensland became independent in 1859, but the first settlement in this region began only in 1869 with the commencement of sugar cane growing (Frawley 1991a). Soon after, in 1873, the explorer Dalrymple made an important journey of discovery, finding several river valleys rich in the prized timber, red cedar (*Toona australis*). Cedar getters quickly followed and exploited this resource. Exports of 200,000 cubic metres were reported (Bolton 1963), and by 1900 cedar accounted for 72% of Queensland's export earnings. Unfortunately, the enthusiasm of the cedar getters exceeded the transport infrastructure, and much timber was wasted (Birtles 1982, Adam 1992). There was little regulation of the harvest, and timber licences permitted unrestricted harvesting. It was 1885 before a royalty system was introduced and timber was "priced" (Frawley 1991a).

Table 1. Forest Reserves in Queensland.

Year	State Forest (hectares)	National Park (hectares)	Timber Reserve† (hectares)
1900	0	0	640,000
1910	324,820	10,787	1,133,755
1930	747,773	63,000	1,375,708
1960	2,072,064	341,000	1,237,246
1988	3,973,000	3,522,129	531,000

† Timber reserve is a less secure form of tenure.

The sugar boom of the 1880s hastened both development and destruction. The decade saw a twenty-fold increase in the area under sugar cane cultivation, a ten-fold increase in registered sawmills, and the destruction of much of the coastal lowland rainforest. Land speculation was rife, and only 2% of the alienated land was cultivated. This caused little concern, as the seemingly endless forests were viewed as a hindrance to settlement, and the agricultural possibilities seen with great optimism. The rainforest soils were thought of uncritically as "rich scrub soils" suitable for all forms of agriculture, and some 60 million cubic metres of prime timber were destroyed to make way for agriculture (Thomas 1931). Despite evidence to the contrary, these attitudes remained entrenched for more than 50 years. As recently as 1954, vast areas were offered for agricultural "development" (mainly sugar on the coast and dairying on the tableland) without any assessment of land capability, potential markets or economic prospects (Frawley 1991a). Fortunately, these events coincided with the rise of professional forestry in Australia, and the region did not follow the same fate of the "Big Scrub" of northern New South Wales, which was almost entirely destroyed.

The issue of forest conservation and management was raised not by the government, but by the timber industry, who felt threatened by the encroachment of agriculture. In 1889, Richard Hyne, sawmiller and Member of Parliament, proposed permanent forest reserves, the creation of a Forestry Department and the establishment of plantations (Frawley 1991b). That attempt failed, but a Forestry Branch was formed within the Lands Department in 1900, and in 1906 a State Forests and National Parks Act was passed — the first of its kind in Australia. In 1911, Queensland appointed an Oxford graduate, N.W. Jolly, who was the first professionally qualified forester appointed to an Australian Forest Service. In his first annual report, Jolly outlined two fundamental principles: the need to determine an annual cut based on the area and productivity of the forest rather than the demands of industry, and the importance of sufficient regeneration. Jolly recognised the dangers of speculative and exaggerated estimates of growth, and regulated yields by area until growth and yield plots could provide reliable growth data (Carron 1983).

Despite these initiatives, the next decades were not easy for the fledgling Forest Service. There remained the unquestioned belief that rainforest lands should be made available for farming, and the government was reluctant to set aside as State Forest or National Park any land that might be suitable for farming (Table 1). The Land Act of 1910 enshrined the policy that all suitable rural lands should be alienated and developed into "family farms" (Frawley 1988). A Royal Commission (Payne *et al*. 1931) found that "Queensland needs no forestry science. . . . The productive wealth of the country at present suffers from the fact that there are too many rather than too few trees". So forest reserves were created only on the rugged residual lands, and the majority of log supplies continued to come from land clearing (94% in 1920, 73% in 1930).

E.H.F. Swain, outspoken director (1918-32) of the Queensland Forest Service, challenged these views, and argued for more rational land use planning. Forestry, he argued, was also land settlement, and provided that forest areas were given security against alienation, they could be scientifically managed to support a local economy in perpetuity. This was preferable to incautious alienation and slow development by speculators and struggling farmers (Swain 1931). Swain's view conflicted with government policy (Payne *et al*. 1931), and he was dismissed for his efforts. Fortunately, his efforts led to several reforms and ultimately retained much forest cover (Frawley 1988). Attitudes gradually changed, and by 1960 there was a greater community recognition of the value of the rainforest resource and its increasing scarcity (Sloan *et al*. 1962).

Rainforest alienation for agriculture virtually ceased by the mid-1960s, but frontier attitudes prevailed within the timber industry, which exerted considerable political influence to maintain low royalties and high quotas. This period saw the introduction of heavy earth moving machinery, and the associated problems of soil erosion and excessive canopy disturbance, and it was some years before the Department of Forestry asserted control and effective supervision. It was probably during the late 1960s and early 70s that environmental impacts of harvesting were greatest (e.g., Bruijnzeel 1992, Cassells 1992).

Global attention focused on the rainforests during 1970s, partly the result of several books documenting the rapid destruction of these forests (e.g., Myers 1980). Well organized protests campaigned against several proposed logging operations in subtropical and temperate Australian forests (e.g., Terania Creek in 1978). The Australian Conservation Foundation (1981) adopted as policy that rainforest logging should cease, and proposed to the Queensland Government the creation of a "Greater Daintree National Park". In 1980, this area was included on the Register of the National Estate, a Federal Government initiative. Contrary to these initiatives, the Queensland Government supported developers in 1983 during construction of a 30 km unsurveyed four-wheel-drive road through the Cape Tribulation rainforests, until then effectively a wilderness area. After protracted negotiations between the State and Federal governments, the latter acted unilaterally in 1988, nominating the north Queensland rainforests for the UNESCO World Heritage List and enacting legislation prohibiting commercial forestry operations within the proposed area. Over 80% of the 'original' rainforest (i.e., existing when Europeans arrived) still remains, but the proportion varies greatly by forest type (e.g., 47% lowland, 95% foothill, 86% upland; Winter *et al*. 1984).

The Queensland National Party was defeated in the 1989 elections after more than 30 years in government. The new government is more supportive of conservation initiatives, and has conducted an inquiry into forestry in other areas. The Federal Government also initiated the first National Forest Inventory, and a Resource Assessment Commission to look into the sustainability of all primary industries.

The Queensland experience parallels developments in many other places, and may show what the future has in store for other tropical countries. By drawing on this experience, other countries may avoid some of the pitfalls and gain some helpful insights.

Forest Management in North Queensland

The main thrust of rainforest management in Queensland has varied over the years with community attitudes and government policies. During the first forty years, the Forest Service was preoccupied with rational land use planning and the creation of secure forest reserves. Jolly (Conservator 1911-18) emphasized the need to regulate the harvest and foster regeneration. Swain (1918-32) stressed silviculture and utilization. Grenning (1932-64) was noted for his support for plantation tree breeding (Carron 1983).

Swain emphasized that silviculture is the basis of forestry, that forest production depends upon effective silviculture, and that this in turn depends upon good utilization. Accordingly, he promoted research into utilization, and soon had documented the properties of 200 species (Swain 1928a). These efforts yielded spectacular rewards, revealing many 'cinderella timbers' including Queensland walnut (*Endiandra palmerstonii*) once despised and rejected by sawmillers (Cilento 1959), later highly prized and subject to special quotas. The Second World War (1939-1945) stimulated efforts to increase production and utilization, and the number of species exploited commercially increased substantially during this period (Table 2).

Table 2. Commercial Species.

1885	1 (cedar)
1900	10
1930	26
1940	36
1945	100+
1986	124 compulsory & 37 optional

Government logging operations commenced in 1919, with the timber sold at auction. Some sawmills purchased by the State in 1916 were merged with the Forest Service in 1920. These provided the opportunity to show how sawmilling could be integrated with forestry objectives and provide reliable data for stumpage appraisals. However, this enterprise was terminated in 1933 due to pressure from the sawmilling fraternity (Carron 1983).

A major management objective during the years immediately following the second world war was to maintain high production to support reconstruction efforts. Annual reports during this time stress the great achievement in exceeding all previous harvests, or lament the failure to attain the harvests of previous years. In 1948 a quota was introduced, and set at 207,000 m^3/annum. The original intention of this quota is no longer clear; it was not a sustained yield estimate, although this belief seems to have developed later. It was not determined from inventory data or from growth and yield studies, but was set for individual mills at their maximum log intake during the period 1945-47, and the aggregate represented about two-thirds of the capacity of mills licensed for Crown supplies. It was intended as a "maximum cut prescription" to arrest the overcutting of the forests, but was viewed, at least by the sawmillers, as the guaranteed log supply volume (McLean *et al*. 1959).

Many silvicultural experiments and permanent sample plots were established during the 1950s and 1960s, providing the foundations for much of the later growth and yield research (Anon. 1983). Some early results suggested that silvicultural treatment (viz. girdling or poisioning of non-commercial trees) increased timber production on commercial trees and in 1954 standardized rules for logging and subsequent treatment were adopted. These were soon supplemented with a compulsory species list aimed at increasing the utilization of low-value species. Preliminary results stimulated the belief that 600,000 m^3/annum could be harvested from the 243,000 hectares considered suitable for treatment (Ryley 1960, Volck 1968). While selected experiments suggested yields above 2 m^3/ha/annum, it is unlikely that such yields could be obtained over extensive areas. This ambitious programme was never instituted, and only 5000 ha had been treated by 1972 when work stopped for economic and aesthetic reasons (Volck, pers. comm.).

"Forest Inventory Surveys" had commenced in the sclerophyll forest during the 1940s, and were extended to the rainforests in 1961. Large tracts of forest were sampled systematically, often with a sampling intensity as high as 5 percent. Unfortunately, the data processing infrastructure was limited, and the full value of these data was never realized. During this period, a system of "management by rules" outlined in "Head Office circulars" became established. Specialists prepared prescriptions for a wide range of activities; these were ratified by Head Office and became standard guidelines for all field operations (Carron 1983).

The 1960s brought many problems associated with the introduction of heavy earth-moving machinery. Previously, small machines and modest horsepower exploited skill rather than power, inflicted little damage and created little disturbance. The new bigger, more powerful bulldozers required wider tracks to extract logs, and enabled operators to uproot rather than negotiate obstacles. Unless operators are both skilled and motivated, big machines may create much more soil and canopy disturbance, causing soil erosion and stimulating regeneration by pioneer species. It took some time before forest managers could effectively control these operations, but it is important to reognise that the major limitation was a lack of political will rather than a lack of knowledge or a failure to recognise the problem.

Effective management of these forests was consolidated during the 1980s (Whitmore 1990 p.123, Cassells 1992). Practical treemarking and logging guidelines were revised and implemented (Dale 1985, Ward and Kanowski 1985). Following concern over the 1948 quota (Stocker *et al*. 1977), new yield estimates were prepared, and the annual allowable cut was gradually reduced toward sustainable levels (Figure 2). Efficient inventory techniques were devised and implemented. These corrected deficiencies in the previous inventory surveys, discriminated between the gross and net area for harvesting, and provided information for local management rather than for regional reporting (Vanclay *et al*. 1987, Vanclay 1990a, 1993).

Greater emphasis was placed on financial aspects during the 1980s, and cost-cutting measures curtailed many research and management initiatives. There was a brief attempt to better inform the public about natural forest management for multiple use, but these efforts at education and extension were a reactionary response to criticism from conservation groups, and were not sustained. The emphasis on agroforestry and rehabilitation of degraded agricultural lands has continued following the cessation of timber harvesting. It is unfortunate that the importance of this work was not recognised much earlier. For several decades it was Government policy to promote family farms, and it would have been appropriate for the Forest Service to complement this policy with strong agroforestry and extension programmes.

Forest operations during the 1980s demonstrated that commercial timber harvesting could be conducted with minimal impact if equipment operators adhered to a few simple guidelines (Crome *et al*. 1992). This requires training, incentives and supervision, of machine operators and of their employers.

Rainforest Research in North Queensland

Systematic botanical studies commenced in the 1850s (Mueller 1858) and a comprehensive flora was published in 1883. This flora (Bailey 1883) included 49 families represented in the tropical rainforest, and during the next 40 years, only one more family was added (Francis 1929). An 1889 expedition gathered extensive plant and animal collections (Meston 1889). Swain (1928b) developed an ecological classification and examined regeneration and succession. From the 1930s, ecological studies began to be supported by experimentation rather than simple observation.

The first recorded experiments involved enrichment planting. These trials, initiated in 1903, examined the prospects for planting wild seedlings on snig tracks after logging. By 1914, it was felt that plantations would be more efficient than enrichment planting, and trials with prime timber species such as cedar were initiated. Initial results were disappointing, but some later plantings exhibited impressive growth rates (Nielsen 1989). By 1930, attention had turned to the native conifer *Araucaria cunninghamii*, which has become a major plantation crop in Queensland with some 50,000 hectares established. This success was partly due to the development in 1922 of the metal planting tube, which greatly enhanced planting efficiency (Carron 1983).

Small areas of rainforest were silviculturally treated during 1914-30, and the possibilities for silvicultural intervention were researched more fully with the appointment of a full-time researcher in 1948. Trials focused on the removal of non-commercial trees following logging, thinning of advance growth to favour desired individuals, and enrichment planting with desirable species (Anon. 1983). Results suggested a large stimulus in commercial timber production, but work ceased for economic and aesthetic reasons in the early 1970s.

Growth and yield plots were established as early as 1911, but these focused on stand growth rather than individual tree growth. The first permanent sample plots identifying individual trees were established in 1948, and by 1980 the database comprised 250 plots sampling a good range of site and stand conditions (Vanclay 1990b). Although the plots were not originally intended for growth model development, it became the prime application of these data. The range of conditions represented in the data is fortuitous, and it would have been preferable to sample deliberately for extremes of site and stand condition (Beetson *et al*. 1992).

Hydrological research commenced during the mid-1960s. Studies in catchments logged during conversion to other uses indicated that most of the sediment originated from poorly-located roads and tracks, and from earth and log-filled crossings (Gilmore 1971). New management guidelines drew on these findings, and banned logging during the wet season, prohibited snigging through running streams, stipulated drainage for roads, tracks and loading ramps, and prohibited the use of earth or log-filled stream crossings. Subsequent studies examined runoff and soil hydrological processes (Cassells *et al*. 1985), but were terminated in 1981.

Yield Prediction in North Queensland rainforests.

The 1948 quota of 207,000 m^3/annum was not based on resource estimates, and the McLean Commission (1950) estimated that increment in these forests was about 75,000 m^3/annum (Table 3). Although they drew on limited data, it now appears that their estimate was rather good. Subsequent estimates during the next two decades were much higher. The high yield estimates of Volck (1968) assumed that most of the productive forest zoned for logging (i.e. 243,000 ha) would be silviculturally treated, but this did not eventuate. Discrepancies between other estimates may be attributed to differences in gross and net area estimates, in volume equations and growth estimates, and in methodology and assumptions.

Table 3. Yield Estimates for North Queensland Rainforests.

Author	Year	Crown Forest excl NP	Nett Product Area	Net Area Adjust-ment	Sust. Yield m^3/yr	Nett Yield m^3/ha/y
McLean Commis.	1950				75,000	
Owens	1960		339,000		300,000	0.88
Volck	1968		243,000		600,000	2.47
Waugh	1973	728,000	286,000	0.39	172,000	0.60
Volck	1975	442,000	300,000	0.68	180,000	0.60
Higgins	1977	390,000	183,000	0.47	167,000	0.91
Bragg	1981	443,000	143,000	0.32	88,000	0.62
Preston & Vanclay	1985	439,000	158,000	0.36	60,000	0.38

The first well researched and well documented yield estimates were prepared by Higgins (1977). As well as providing yield estimates, he canvassed many practical aspects of rainforest management. Regrettably, his report was never made public, apparently because his long term prognosis was optimistic and could have thwarted efforts to reduce the harvest (P.J. Kanowski, Director of Forest Management, QFS, pers. comm.). However, Higgins (1977) did make it clear that yields would have to be reduced in the short term to compensate for past overcutting:

"As a result of very heavy cutting on state forests in the past 20 years, the calculated sustainable yield will not be obtainable from rainforest in the next 10 to 20 years. The very heavy cuts that were sustained during the 1940s, 50s and early 60s were supplied mainly from vacant crown land which has since been converted to sugar cane or pasture. An attempt was made to sustain the existing industry from state forests and timber reserves alone in the late 1960s and into the 70s. The rate of cutting was so rapid that a large percentage of the productive accessible area has been cut over within the last 20 years. The amount of forest available for re-cutting in the next 10 years is insufficient to maintain supplies at the present rate for another 10 years. . . . North Queensland's past importance as a supplier of timbers to Queensland seems unlikely to be regained".

Higgins (1977) based his estimates on a simple transition matrix model ("SUFI"), which did not consider stand density or site quality. He apparently intended a comprehensive series of permanent sample plots that would enable the transition matrix for each projection to be compiled from a subset of plots similar to the stand to be projected. Unfortunately, this plot system did not eventuate, perhaps because of the high cost involved in establishing such system. The inability to account for site quality and stand density must have contributed to his high yield estimate (Table 3), since much of the growth data available to him derived from plots on better-than-average sites and plots which had been silviculturally treated.

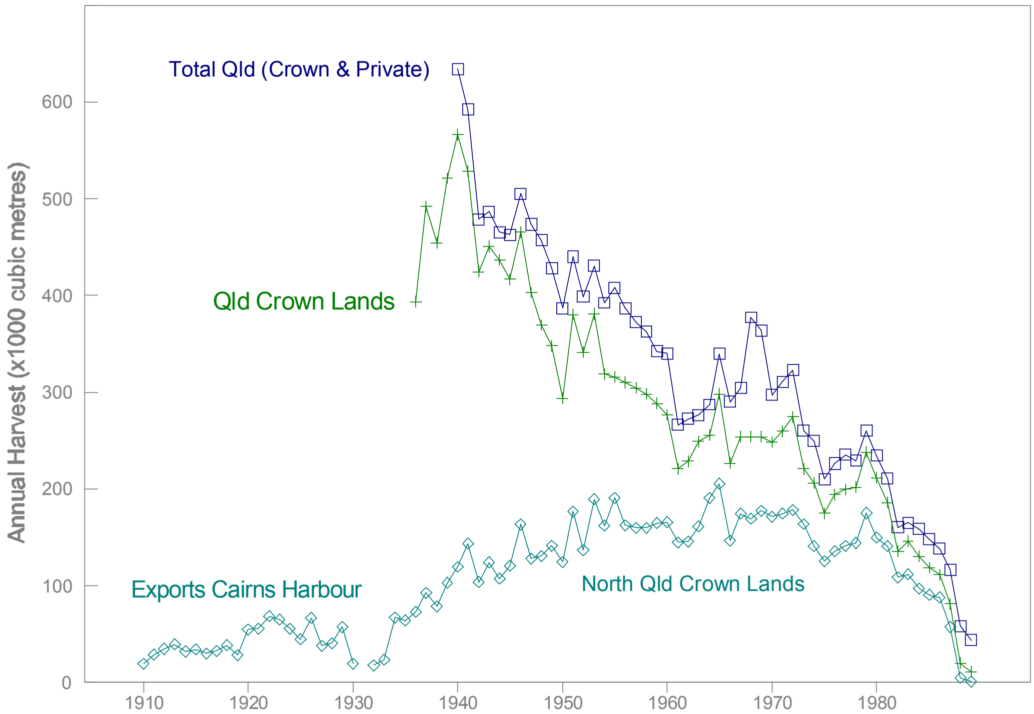

Figure 1. Harvest of rainforest timbers in Queensland. Data from Queensland Forest Service Records, mainly annual reports (see appendix). Optional volumes are not included.

Local field staff recognised some of these deficiencies and commenced an inventory program to provide better data concerning the present status of the resource, and especially of the net productive area. A systematic 2-stage sample provided area data. Points on a 1-km grid were examined on topographic maps and/or air photos, and their accessibility and productivity recorded in a computer database. A sub-sample of these was visited on the ground to correct for any interpretation bias. Plots were established, and the likelihood of harvesting each tree was assessed (given prevailing prescriptions regarding slope, stream buffers, etc.). Using these data and the traditional method of stand table projection adjusted for stand density, Bragg (1981) estimated the sustained yield as 88,000 m^3/annum. However, his estimates did not lead to revised quotas (Figure 2).

During the 1980s, it became Departmental policy that the allowable cut should be formally reviewed every five years, so estimates were revised during 1985-86. This revision drew upon Bragg's updated area database, but all other inputs were re-examined. Preston and Vanclay (1988) devised a simple index of site quality, developed a dynamic growth simulation model, revised harvesting predictions, and used new volume equations. This study suggested that a harvest of 60,000 m^3/annum could be sustained from the forest area zoned for logging. The apparent increase in net productive area (Table 3) was due to a revised definition. Previously this referred to the area that could support a harvest every cycle; the revised methodology examined areas that could support a harvest in any cycle. The Queensland Forest Service published these calculations (Preston and Vanclay 1988), the first time such data were made available to the public. Subsequent enhancements to the site assessment procedure (i.e. use of indicator species to provide an objective way to quantify site; Vanclay 1989) and growth modelling methodology (i.e. development of a tree-list model with species-specific growth equations; Vanclay and Preston 1989, Vanclay 1994a) have led to similar yield estimates (e.g. Vanclay 1994b).

Table 3 reveals a five-fold range in yield estimates (excluding Volck's 1968 estimate which assumed silvicultural treatment of large areas of forest); it is noteworthy that the area estimates contribute as much variation as do the growth estimates. The 1975 and 1981 estimates draw on the same gross area, but have a two-fold discrepancy in net productive area. This problem of estimating the net productive area is common to many tropical timber producers, but can be reconciled through remote sensing and efficient inventory. Reliable growth estimates can only be obtained from careful permanent plot remeasurements, and these should not be neglected (Vanclay 1994a).

Timber Production during 1910-1988.

Some critics have argued that the volume harvested from these rainforests exhibited a steady downward trend not indicative of a sustainable harvest (e.g., RAC 1992, p.G50). However, they refer to state-wide data, rather than the more elusive north Queensland data, which exhibit a different trend (Figure 1). Instead of a steady decline, these data exhibit an increase to 1950, a fluctuating but stable harvest to 1980, followed by a rapid decline until the cessation of harvesting in 1988. The contrasting trends reflect different management objectives. The rainforests of north Queensland were managed as natural forests, but the araucarian vine forests of southern Queensland were exploited and replaced with plantations (Frawley 1991b), and by the 1950s the pine 'scrubs' were 'mined out' (Grenning 1957).

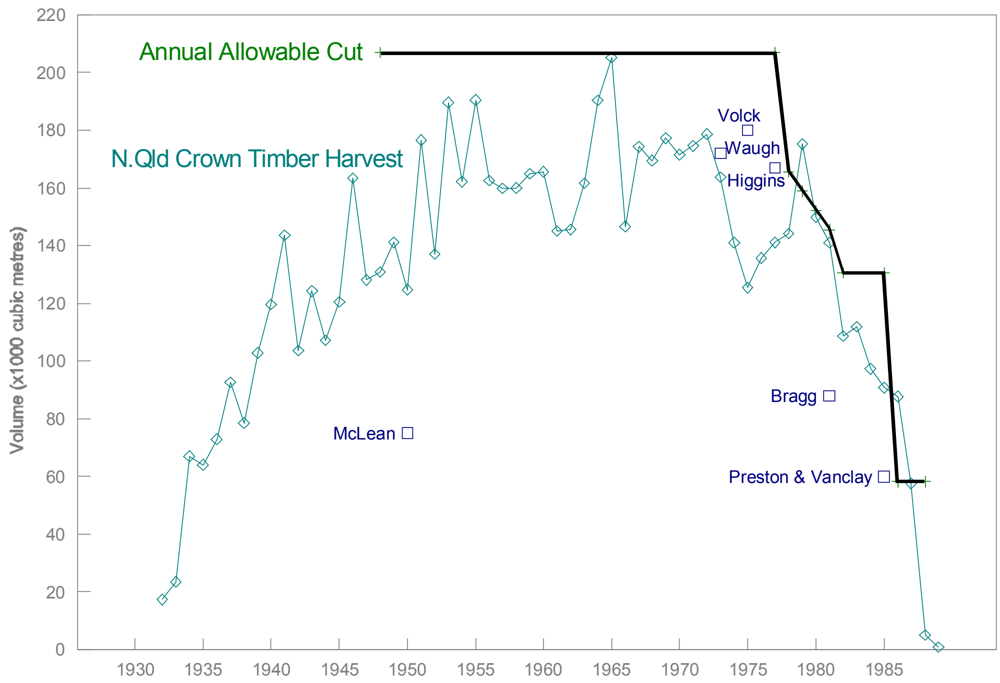

Figure 2. Sustained yield estimates, allowable cut and actual timber harvests from north Queensland Crown lands during 1932-89.

The decline in the harvest during the 1980s was not due to the exhaustion of the resource, but due in part to the reduction in area available for harvesting. The reduction in productive forest area was partly due to the conversion of land to other uses (both agriculture/pasture and national park, see Table 1), and partly due to revised estimates of the accessibility and productivity of the permanent forest estate. These estimates drew on new data which revealed that the proportion of the area zoned for logging which was either inaccessible or unproductive (in a commercial sense; i.e. did not carry sufficient volume of commerical species to warrant the construction of access roads, etc; see Table 3), was considerably higher than previously anticipated.

Figure 2 illustrates the sustained yield estimates, the annual allowable cut, and the actual timber harvest. The sustainable yield is a scientific estimate, which is quantitative and refutable, and is based on inventory data, growth estimates and clearly stated assumptions. The allowable cut should be based on this yield estimate, but was sometimes adjusted for forest conversion, political convenience and other objectives. If the productive capacity of the forest is not impaired (e.g., by soil compaction and erosion), the harvest may exceed the sustained yield for a short time, but these short-term gains must be offset by a reduced harvest in the future to allow the growing stock to recover. In practice, the setting of an allowable cut may be a political decision, but responsibile scientists and forest managers should discriminate clearly between an objective sustained yield estimate and a politically expedient allowable cut or quota.

The actual harvest from the forest may be subject to the vagaries of markets and prices, and may be much more capricious than yield estimates and quotas. To provide some flexibility for fluctuations in timber demand, it was policy in Queensland that the annual harvest could exceed the allowable cut in any year, provided that the five-year average did not exceed the allocation to any purchaser.

During the early years of forestry in Queensland, the goal of forest management (having secured the forest estate) was to maximize timber production to support regional development; this objective is especially apparent in war-time and post-war annual reports. By the late 1940s, it became clear that timber harvests could not continue to escalate, and a quota was established. Initially the quota (207000 m^3/ann) exceeded the estimated annual volume increment, as it was felt that the standing volume could sustain the large harvest desired for regional development. This optimistic quota could not be maintained, and by the late 1970s, a supply crisis was looming (Higgins 1977). This led to the first serious attempts to quantify the sustained yield and several gradual reductions in the allowable cut towards sustainable levels. These three phases of yield regulation policy are evident in Figure 2.

Was it Sustainable?

It is difficult to assess the sustainability of a harvest at any point in time. Ultimately, sustainability can be proved only by demonstrating repeated commercial harvesting over a long period, coupled with detailed monitoring and inventory to demonstrate that the poductive potential is not declining and that future

✓	Local community financially secure
✓	Secure permanent forest estate
✓	Minimal soil erosion
✓	Protect streams & steep slopes
✓	Timber species regenerate
☹	Representative national parks
✓	Stable harvesting prescription
✓	Non-declining even-flow harvest
☹	Management supported by research
✓	Economically viable
☹	Public & decision makers informed
☹	Community input in policy & planning

Box 1. Appraisal of Queensland rainforest management in the 1980s.

options are not lost. An efficient but less satisfactory alternative is to examine the prognosis with simulation studies. Computer simulations of timber harvesting suggested that a viable timber harvest could be sustained for more than 400 years (Vanclay and Preston 1989, Vanclay 1994b). Permanent plots that have been repeatedly harvested show no evidence of any decline in productivity. On the contrary, they provide evidence to support the assertion that any productivity decline can not exceed six percent per harvest (Vanclay 1990b). But we still know rather little about many key processes of rainforest functioning (e.g., Webb and Kikkawa 1990, Goudberg and Bonell 1991), so any harvesting of timber and other products should proceed cautiously and conservatively.

More important than these theoretical simulation studies is the need to maintain the highest standards within practical constraints, to monitor and critically appraise operations, and to improve practices as new opportunities evolve. In this context, Queensland operations may be assessed as sometimes good, sometimes lacking, but showing a progressive improvement. By the mid-1980s, operations were reasonable, but a critical appraisal (Box 1) leaves some room for improvement.

The first requirement for sustainability is security. The local community must be secure; while people go hungry encroachment cannot be prevented. The forest estate should be secure, protected by the law and respected by the community. The second requirement is for adequate environmental controls. Stream buffers and steep slopes should be protected from harvesting. Forest operations should provoke little erosion and soil compaction, and should be succeeded by adequate regeneration of species removed in harvesting (i.e. not only commercial species, but especially species which may have pivotal roles in providing food for pollinators and seed dispersers, or in nutrient cycling). Invasion by weeds (exotic species, indigenous vines, palms or bamboos) may be the first symptom of a silviculture unsuited to the forest, and thus of unsustainable harvesting practices. Generally, these requirements were satisfied in Queensland, except in a few places where vines or the exotic shrub *Lantana camara* posed some problems.

It is prudent to preserve examples of all habitats in national parks or other conservation reserves. Although national parks protected 20% of Queensland's tropical rainforest, they did not represent all habitats. By 1979 some 87% of rainforest formations were "reasonably well conserved" (Specht 1981, up from 50% in 1971), but the national parks system still fell well short of adequate representation for rainforest ecosystem (Working Group on Rainforest Conservation 1985). Most deficiencies occurred in the lowland rainforests which were threatened by agriculture, urban development and tourism, rather than by timber production. Specific deficiencies were noted by Webb (1966, 1987).

Harvesting prescriptions should be stable, as continual erosion of the cutting limits is a sure sign of overcutting. Some revisions to enhance practices or improve economics may be acceptable, provided that changes are supported by research. Practical and economic issues may preclude a non-declining even-flow on an annual basis, but the several-year running average harvest should be stable, smooth and close to the estimated sustainable yield.

Management should be supported by research and monitoring. Research should address a range of issues, ranging from taxonomy and forest dynamics to silviculture and applied harvesting research. Queensland had a promising research program during the 1970s, but this was curtailed in the 1980s and many questions remained unresolved (e.g. Goudberg and Bonell 1991).

Timber harvesting should be economically viable. Financial data relating to the Queensland rainforests were rarely made publicly available, but Higgins (1977) stated that during 1975-76 expenditure on rainforest management was AUD$730,000 and that revenue was $1,271,000. For many years, royalties were kept artificially low, but Harris (1987) estimated that value-adding by the timber industry amounted to $25 million per annum.

The forest is a communal asset, and the community should have a say in policy, planning and management. For such input to be meaningful, the public must first understand the possibilities and objectives of management. This demands considerable effort from forest managers in education and community liaison. Ultimately, many decisions influencing the fate of the forests are political, and foresters must inform politicians and other decision makers about possibilities and consequences. It is noteworthy that sustainability begins and ends with the local and wider community (see Box 1).

We will never know for sure, if timber harvesting in these forests was sustainable, as all commercial timber operations ceased following the inclusion of these forests on the World Heritage List. However, we can monitor the long-term impacts of past logging on the recovery and dynamics of these forests to evaluate the implications for others. These tropical forests are unique in having many permanent plots with a long and uninterrupted measurement history (Vanclay 1990b), coupled with other comprehensive research and management data. These data provide a good insight into the dynamics of these forests and their response to exploitation, and the implications should be applicable to other tropical timber-producers in the region. Remeasurement and analysis of these plots should continue so that the full implications of this unique database to be explored.

Lessons for Others

Perhaps the most important lesson from Queensland, is that community attitudes change, sometimes quickly. There is a growing appreciation that rainforests are a valuable asset to be used wisely. Waste and destruction will hasten this change in attitude and will strengthen the demands for complete preservation (e.g., Watson 1990, Adam 1992). However, the Queensland experience shows that rainforests can be managed wisely, profitably and sustainably, if a few simple guidelines are followed.

In Queensland, many commercial species were 'small gap' species, so an appropriate silviculture was a single tree selection system with minimal disturbance. Such a system is desirable for many other reasons, including soil and biodiversity conservation, but should only be used where it is compatible with specific species requirements. In forests dominated by pioneer species (e.g., *Tectona, Swietenia*), other systems may be preferable.

Success or failure of such a system lies in harvesting, including the felling, extraction and hauling of timber. The harvest must be planned and supervised to minimize damage, to minimize the number and length of roads and tracks, and ensure their optimal placement. Felling direction should be controlled to avoid damage to residual trees, and this demands skilled operators. Soil disturbance should be minimized in all operations, especially during extraction of logs from the stump to the loading site; this requires appropriate equipment and skilled operators. Roads should be designed and placed to avoid steep grades and streams. Good drainage systems for all roads and tracks are essential to minimize erosion, both during and on completion of operations. Success depends both on what you log, and what you do not log. Do not log stream buffers, steep slopes, conservation areas, connecting corridors or during the wet season.

Finally, harvesting, like all aspects of forestry, is about people as much about trees. Success requires training, incentives and supervision. It also means public relations. Explain to people what you are doing, why and how you are doing it. Listen to what they say, to their hopes and aspirations. And learn to discuss in an amicable way, and to compromise, before small issues become big problems. Your forest depends on it!

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Appendix

The following data were used to compile the figures. These data were compiled from Queensland Forest Service records. For some years, alternative data sources indicated conflicting estimates. The official statistics published in Forest Service Annual Reports was assumed to be the more reliable and unless otherwise indicated, data are drawn from these records. In some years, the marketing system classified tree species and logs as compulsory and non-compulsory (i.e., lower quality; Preston and Vanclay 1988), and only compulsory volumes are tabulated here. Optional logs usually comprised a small percentage of the harvest. The metric system was adopted in 1974. Earlier harvests were reported in super feet, and have been converted using the identity: 1 super foot = 0.003005 cubic metre. In Australia, the financial year is from 1 July to 30 June and so spans two calendar years. In this paper, data relate to financial years, and are reported by the date at the start of the year (viz. data for 1944-45 are tabulated under 1944).

Most of these data derive from published Forest Service Annual Reports. Data on the Crown harvest in north Queensland during 1944-74 (but excluding 1949) were provided by Mr P.J. Kanowski (previously Director, Marketing Division, QFS) from unpublished Forest Service Records. Data on the north Queensland Crown harvest in 1949 were provided by K.J. Frawley (pers. comm.).

Year	Queensland Total	North Qld Total	North Qld Crown
1932			17399
1933			23484
1934			67074
1935			64059
1936		393634	72969
1937		491836	92708
1938		454763	78490
1939		521301	102916

1940	634235	565928	119580
1941	592406	528459	143649
1942	478697	424607	103653
1943	486642	450660	124243
1944	465827	436614	107158
1945	462731	416845	120532
1946	505240	465321	163463
1947	473834	402865	128093
1948	457334	369603	130882
1949	428113	347754	141120
1950	387089	293955	124685
1951	440127	380202	176564
1952	398950	341563	136995
1953	430638	380836	189600
1954	392309	318764	162113
1955	408151	315723	190396
1956	386993	310176	162535
1957	372650	304088	159819
1958	362749	298069	159989
1959	342372	288708	164959
1960	340157	276634	165570
1961	266396	220913	145128
1962	272650	228635	145635
1963	276460	249289	161593
1964	287353	255683	190365
1965	339565	298090	205248
1966	290142	226700	146707
1967	304148	253898	174344
1968	377563	254181	169471
1969	363878	253956	177310
1970	297315	248625	171513
1971	311042	259542	174591
1972	323071	274669	178602
1973	260489	220944	163673
1974	249764	205955	141006
1975	210163	174975	125526
1976	226173	194197	135693
1977	235441	199679	141143
1978	229201	201830	144233
1979	260242	238289	175162
1980	234191	211456	149800
1981	210638	186023	140949
1982	160782	135488	108680
1983	165166	146072	111944
1984	158600	130388	97303
1985	148047	118740	90831
1986	138458	111427	87688
1987	116626	81415	57603
1988	58268	19977	5093
1989	44035	11230	825