Livestock, Land Cover, and Environmental History: The Tablelands of New South Wales, Australia, 1820–1920

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For southeastern Australia, arrival of the First Fleet in 1788 raises similar issues in environmental history as the 1492 landing of Columbus in the Americas. But Anglo-Australian settlement is younger and better documented, both in terms of scientific proxy data and historical sources, which include data on stocking rates that generally were light. Environmental concerns were voiced early, and a lively debate continues both among professionals and the lay public, with Australian geographers playing a major academic and applied role. This article addresses environmental degradation often attributed to early pastoralism (and implicit clearance) in the Tablelands of New South Wales. Methods include: (1) comparison of well-reported travel itineraries of 1817–1833 with modern land cover and stream channels; (2) critical reviews of high-resolution pollen profiles and the issues of Aboriginal vs. Anglo-Australian fire ecology; and (3) identification of soil erosion and gullying both before and after Anglo-Australian intrusion. The results indicate that (a) land cover of the Tablelands is little changed since prior to Contact, although some species are less common, while invasive genera of legumes have modified the ground cover; (b) the charcoal trace in pollen profiles prior to Contact supports an ecological impact of regular Aboriginal burning and rare, catastrophic fires; and (c) most stream channels were already entrenched (“gullied”) well before 1840, with repeated cut-and-fill cycles during the late Holocene, but before Contact. Land impairment has not been a major problem on the Tablelands, although the last two centuries have experienced cumulative and complex environmental change. This unexpected empirical picture suggests that, until high-technology intervention, increasing periodicity/magnitude of extreme drought/precipitation events had been the overriding trend in interior New South Wales, perhaps reinforced by burning. There is no support for an apocalyptic model of colonial environmental history. Key Words: Australia, pastoral degradation, vegetation change, fire ecology, gulling, climatic perturbations.

The Environmental Dialectic in Australia

Australia has been the focus of environmental debate since a scant twenty years after the arrival of the First Fleet in 1788. This multivocal discourse has had many forms, involving the agents of government, the educated public, and academia. The impression obtains that this engagement was deeper and more persistent than it was in other British colonies, perhaps because so many of the early officials were drawn from a meritocracy emerging from the Napoleonic wars, naval and military in the main part, and skilled in engineering and the sciences. The reports of various commissions addressing the consequences and causes of recurrent drought catastrophes were articulate and perceptive. A similar bent for applied research is evident among the large number of professionals today working on environmental and ecological issues, commonly within government agencies that serve intermediary roles. In fact, federal and state agencies dealing with land capabilities, rangelands, wildlife, and forestry were in place well before Earth Day 1970 and have addressed conservation as much as applied technology. Last but not least, there is an ongoing negotiation about environmental understanding between the Aboriginal peoples and the newer Australians.

But environmental sensitivity was only one facet among contested priorities, centered on the economics of labor, survival, and wealth accumulation, as early settlers strove to create new homes in Australia’s unfamiliar environment. One segment of that vigorous, continuing dialectic is revealed in the first-person literature of the early “explorers,” who charted that physical and biotic environment. Mainly levelheaded and competent, their attitudes toward nature and to the indigenous inhabitants were, in the context of the time, relatively benign, despite their colonial goals of settlement expansion and economic development. Their writings provide a unique documentation of Australian environments at the time of Aboriginal-European
Contact. They also cast a mainly favorable light on the efforts of countless civil servants, who, across two centuries, attempted to steer the fitful growth of the colony in a rational manner, with at least a latent concern for what today would be called sustainable economic exploitation.\(^1\)

Although not synchronized with the transatlantic confrontation of 1492, the much more recent encounter of Europeans with Australia deserves greater comparative attention. Within Australia today, there are a number of competing environmental narratives (Mercer 2000; Powell 2000), of which the most voluble are voices that view Anglo-Australians, past or present, as reckless destroyers of the land (e.g., from different positions, Bolton 1981; M. Williams, McCarthy, and Pickup 1995; MacKenzie 1997; White 1997; Horton 2000; but compare Reynolds and Smith 2002). To outside investigators, such as the authors, it comes as a surprise that the Australian environment beyond the arid interior should be on the brink of desertification.

One major collection of papers on the Australian ecosystems begins with a politician's introduction asserting that 65 percent of the original tree cover has been removed since 1788, and that up to 75 percent of the rainforest has been cleared (Saunders, Hopkins and How 1990, v). However, against the "natural" benchmark of AUSLIG (1997a), Graetz, Wilson, and Campbell (1995) offer very different figures, based on digitally processed satellite imagery: only 9 percent of the originally closed forest has been lost and 35 percent of all other kinds of forests and woodlands cleared, with an additional 21 percent thinned. These glaring discrepancies illustrate the chasm between advocacy and more pragmatic reasoning. The "facts" themselves are differently constructed.

Even measures of current rainforest loss are inconsistent from year to year, or state to state, with expansion in one and retraction in another, simply as a result of changing definitions (Young 1996, 23–24). A second problem in measurement comes from identifying a possibly isolated incidence of land degradation, such as gullying or salt encrustation, and then generalizing it to an entire spatial sampling unit; when the aggregate results are assembled on a small national map, it may give the impression that half of the cultivated land of Australia is degraded (Young 1996, 36).

Beyond these questions of consistency and scale, there are methodological issues of how change is measured, and against which datum? With care, broad inferences can be made between aerial photography or satellite imagery from different years, but that only gives a time depth of several decades. Can one reconstruct change since the time of initial European settlement? Here the best modeling approaches are no substitute for historical investigation, and even then, apparent change may be difficult to interpret.

Aboriginal land use had significant impact, and biological response during the transition to and experimental changes of European land management is incompletely understood. Countless spells of catastrophic drought have intermittently favored erosion and biotic degradation. Such climatic perturbations, which now amplify human impacts on the environment, originally kept Australian ecosystems in flux, that is, in a metastable rather than stable equilibrium, linked to high, rather than low, resiliency. That poses theoretical and practical problems in regard to the "original" condition of the environment (e.g., Hopkins, How, and Saunders 1990; Taylor 1990; Smith and Pickup 1993; Walker 1993; Ludwig and Tongway 1997), such as the use of classic successional models, the separation of short-term variability from longer-term or "irreversible" change, the isolation of anthropic and climatic inputs prior to the industrial-scale environmental impacts after 1940, or the unresolved differences or similarities between Aboriginal and European fire ecology. The notion of some "pristine datum" may therefore be illusory.

In Australia, the concept of "land degradation" is increasingly accepted as change in terrestrial ecosystems that reduces or destroys the capacity of land for sustainable human use (Christie 1993, 314). This includes both physical and biological resources and, implicitly but less comfortably, biological and economic sustainability. But physical and biological criteria for disturbance or deterioration set different thresholds since, at the scale of land cover, vegetation change is potentially reversible, whereas destroyed soils are essentially nonrenewable. But both kinds of change are interconnected: soil erosion that leads to hydrological disequilibrium, with gullying or alluviation, implies biotic impairment, even in default of firm criteria to discern biotic degradation or define biotic disequilibrium. At this scale, soil erosion (even without major soil destruction) is a sensitive and visible indicator of an ecosystem in trouble to a degree that agronomists and various applied scientists will be concerned. This basic concept of land impairment underlies the article, given that there is no generally accepted definition of degradation. We are, however, cognizant that many biologists prefer a floristic approach, whether for selective attrition of high-diversity forests or displacement of native plants by exotic or adventist species in the ground cover (see Benson 1991). The case for such change in ground cover poses a dilemma because, like the spread of Africanized grasses in parts of
the Americas, cultivation of introduced grasses and legumes in Australia increases productivity and soil protection. On the other hand, the invasion of native pastures by exotic weeds reduces productivity and qualifies as a form of biotic degradation.

“Degradation,” despite its intuitive and, at times, alarming reality, is very much a relative concept, specific to a particular mode of investigation and its stated parameters. Honest disagreements about identification and interpretation will therefore persist. But that also opens the door to claims that 60 percent of Australian rangelands are “desertified,” since desertification is now, all too broadly, defined as moderate or severe land degradation in relatively dry areas as a result of human activities as well as adverse climatic trends or periodicities (see M. Williams et al. 1995). It is true that Australia is a continent of ecological extremes. But, by global standards, it would be difficult indeed to demonstrate that the rangelands of Australia are environmentally devastated.

That “Plague of Sheep”

Against this difficult and contested background, Elinor Melville (1992, chapter 3) has written an essay arguing that the Anglo-Australian introduction of livestock rapidly and directly led to environmental transformation, including reduced density and height of vegetation cover, increasing soil aridity, and a shift to arid-land biota. Deforestation, high stocking rates, and modification of fire patterns further reduced biodiversity and led to watershed deterioration, severe flooding, and soil erosion. These processes were reinforced by drought and its attendant fires to “produce an environment that stabilizes for shorter periods . . . at decreasing levels of productivity” (Melville 1992, 77).

Melville’s remarkable claim for the destruction of eastern New South Wales by sheep grazing “in the first fifty years” after 1788 (Melville 1992, 77) is based primarily on two historical sources, Gardner (1854) and Strzelecki (1845). Gardner’s unpublished manuscript is a compendium of miscellaneous notations and sketches, with very limited applicability to environmental history. In effect, he blamed the droughts of 1838–1839 and 1848–1849 on livestock overgrazing (Gardner 1854, 3, 27, 113, 115), and, quite curiously, believed that the reduced peak flood levels of the Hunter River (Figure 1) in 1832, 1840, 1851, and 1857 (at 23–29 ft.), compared with those of presettlement times (1820 at 37 ft.), reflected the impact of desiccation due to overgrazing (Gardner 1854, 3). Strzelecki, on the other hand, published a major study on the hard-rock geology and soil types of southeastern Australia, based on a two-year stay.

His comments on what he saw as catastrophic environmental degradation actually describe the visible effects of a major drought in 1838 (Strzelecki 1845, 365–69, 433–37), for which he had no prior experience. Neither of these authors was able to identify cause and effect, nor understand the extreme perturbations characteristic of Australian climate.

While an ascientific environmental historian may feel comfortable in considering incidental historical perspectives as valid diagnoses, there fortunately are counterexamples of a more scientific methodology, such as Heathcote’s (1965) classic Back of Bourke. He evaluates a large array of nineteenth-century observations and government analyses for a part of western New South Wales; this information is used in conjunction with drought and flood chronologies, changing land tenure policies, and pastoral practices to outline a more contextual picture of landscape transformation. Examples of similarly professional studies in the United States also illustrate our point: Earle (1988), Blumler (1995), Peacock (1998), Knox (1999), or Trimble and Crosson (2000).

In criticizing the premises of Melville’s essay, we are not setting up a straw horse. She uses it as an authoritative case study to explicate how she believes that the sixteenth century “ungulate irruption” of Spanish sheep and cattle introduced to Mexico effectively degraded that environment within a similarly short span of time.2 Melville’s book received the Bolton Prize for 1995 from the Conference of Latin American Historians. At issue then is a very real question of how “environmental history” is practiced.

Although a Mediterranean-style transhumance was once followed in Highland Britain, this is not what was transferred to and readapted in Australia. It has been argued that stock raising was introduced to Australia by mainly urban settlers, who had little prior experience with livestock and even less familiarity with a very different environment (Strzelecki 1845, 366). That is simplistic because sheep in Australia were primarily run by wealthy absentee owners, on the margins of the settled domain, through the agency of ex-convict shepherds, many of whom were political exiles from Ireland and had stronger rural roots than their unfortunate counterparts from among England’s industrial proletariat. Sheep in Lowland Britain were run by gentlemen-farmers, who read eighteenth-century manuals on efficient farming and raised sheep on prime pastures that had been withdrawn from farming through “enclosure.”

In Australia, sheep were the preoccupation of a new landed class looking for large profits in quality wool. They adapted to the novel conditions of the continent.
by having their flocks shepherded on natural pastures during the day and guarded in folds from wild dogs by night (Jeans 1972, 90–1). The animals were grazed in the grassy, open valleys but reputedly did not use the rough, wooded, or scrubby uplands; at the same time, the evolving pattern of property titles or claims eventually left little room for transhumance. By the late 1800s, stocking rates in New South Wales (see Butlin 1962) did matter, and overgrazing became a potential problem. Indeed, the fact that the high initial stocking rates eventually had to be scaled back suggests an experimental phase in the economics and ecology of pastoralism that resulted in drastic readjustment.

The goal of this paper is to examine whether early Anglo-Australian stock raising led to the degree of environmental degradation claimed, for example, by Melville, and if so, when, and whether overgrazing was the primary problem. To this end, we use several lines of evidence, beginning with first-hand, detailed accounts of the land cover during the early Contact period. These insights are amplified by means of the pollen record and evaluated with respect to the role of fire ecology before and after Contact. Finally, we turn to the relationships between soil erosion and changing stream behavior, and their possible link to ground cover. The concluding discussion integrates the multiple data sets with respect to long-term landscape stability or change, proposing a nonequilibrium model for “gullying,” and briefly addressing the consequences of environmental perturbations for Anglo-Australian settlement.

The investigation is focused on three regions misleadingly known as the Tablelands of New South Wales. These are neither vast plateaus nor a homogeneous geomorphic region. Rather, the designation is one of several applied during the nineteenth century to identify a number of interior areas first occupied by the second wave of Anglo-Australian settlement, c.1820–1850 (see Perry 1963; Jeans 1972; Harriman and Clifford 1987; Powell 1988). These lay beyond the sandstone plateau of the Blue Mountains or the heavily forested coastal slopes of the Great Escarpment (see Ollier 1982). The settlers were pastoral, and what attracted them was a land cover...
of grassy, open woodland with a subhumid climate. Most areas are high-lying plains in the headwaters of the Murray-Darling drainage, frequently interrupted by small or large chains of low mountains, trending north–south. The western margins are approximately defined by semiarid, shrubby woodlands or scrub, except to the southwest, where the Tablelands merge with the great alluvial surfaces of the Riverina (Figure 1). As used here for convenience, the Tablelands are an ecological and historical construct.

Early Travel Reports on the Bathurst Plains

For the first twenty-five years of the New South Wales colony, it is widely held that settlement was bottled up in the coastal valleys around Sydney, separated from the interior by the dense vegetation and rugged canyons of the Blue Mountains. In fact, although the mountains were crossed several times soon after 1798, official acknowledgement of the opportunities in the interior (C. Cunningham 1996) awaited George Evans, the deputy surveyor-general of New South Wales, who blazed a trail across this wilderness in 1813 and penetrated to the edge of a grassy, fertile landscape that became known as the Bathurst Plains. After a rough road was finished in early 1815, some of the government herds were moved to the area and a few leaseholds allocated. Despite recurrent drought, indifferent productivity, and unequal access to land at the coast, colonists only began to move into the Hunter Valley, north of Sydney, into the Goulburn Plains to the southwest, and to the Bathurst Plains during the 1820s (see Perry 1963, Figure 5). Between 1821 and 1828 that part of the Anglo-Australian population living beyond the 1813 limits of the colony increased from 1.2 to 21 percent (Perry 1963, Table 1), with over 2,000 settlers in the wider Bathurst area, known as the Central Tablelands or Western Districts.

In 1829, all of the land on the Bathurst Plains had been granted, with a few strips reserved by the government and some scattered holdings beyond (Perry 1963, Figure 10). By 1834, the Bathurst core had expanded southwest, with a second nucleus of grants around Blayney (Jeans 1972, Figure 23), and most of the area around Orange was subdivided by 1839. In 1828, some 119,000 ha had been granted, with 16 percent of that classified as “cleared” but only 1.4 percent of it cultivated (Perry 1963, Tables 2–4). However, the numbers of livestock on the Central Tablelands greatly exceeded those of the settlers, with cattle in 1821–1828 up from 5,900 to 49,300, and sheep up from 27,800 to 172,900 (Perry 1963, Tables 5–6; Jeans 1972, Table 3). But various travelers during the 1820s and 1830s reported livestock far from squatter stations or land actually leased, implying that stocking rates were nominal during the early decades of “frontier pastoralism.” That presumably changed as the numbers of sheep in the Central Tablelands grew to 610,000 in 1866, but to 7.6 million in 1891, before “crashing” back to 2.2 million in 1902 (Butlin 1962, Tables I and II, “mid-central” division).

Against this background of settlement and pastoral expansion, the question is, to what degree was the environment impacted? According to biologists Goldney and Bowie (1990, 427, 433), this is “one of the oldest and most disturbed people-dominated agricultural regions in Australia,” with the Central Tablelands claimed to be 50 percent deforested. We disagree, based on an historical reconstruction of the vegetation cover, derived from the earliest travelers, and complemented by our observations of the soil landscape. The Bathurst Plains here serve as a model to identify and illuminate the nature of the evidence for Figure 2, while Figure 3 gives a key to the symbols used. The major tree types reported are identified in Table 1, using the vernacular names and listing the hallmarks for the main categories for eucalypts. Species vary according to region.

Good descriptions of the Bathurst Plains were provided by several observers: (a) George Evans (December 1813) (in Lee 1925, 157–63, with annotated map), (b)

<table>
<thead>
<tr>
<th>Table 1. Principal Tree Types Reported by Early Travelers in the Tablelands of N.S.W., with Characteristics and Preferred Habitats (based in part on Cronin 1997, Holliday 2002) (Obsolete Common Names in Quotation Marks)</th>
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<tbody>
<tr>
<td><strong>Eucalypts (Myrtaceae)</strong></td>
</tr>
<tr>
<td>Gum (River red, “Blue”). <em>E. camaldulensis</em></td>
</tr>
<tr>
<td>Bark peels down to near base, trunk smooth and light gray; blue-green foliage. Very tall. Mainly riparian.</td>
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<tr>
<td>Box (Yellow). <em>E. melliodora</em></td>
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<tr>
<td>Rough bark on trunk, upper branches smooth and off-white. Tall. Good quality soils, rolling topography.</td>
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<tr>
<td>Stringybark (Red). <em>E. macrotheca</em></td>
</tr>
<tr>
<td>Bark peels in long, thin strips. Medium to tall. Well drained, hilly sites.</td>
</tr>
<tr>
<td>Ironbark (Red). <em>E. sideroxylon</em></td>
</tr>
<tr>
<td>Dark, rough, deeply-furrowed bark. Medium to tall. On shallow upland soils.</td>
</tr>
<tr>
<td>Apple (Rough barked). <em>Angophora floribunda</em></td>
</tr>
<tr>
<td>Wattle (Silver, “Weeping”). <em>Acacia dealbata</em></td>
</tr>
<tr>
<td>Drooping, like weeping willow. Small to tall. Clay floodplains.</td>
</tr>
<tr>
<td>River-Oak (&quot;Swamp&quot;). <em>Casuarina cunninghamii</em></td>
</tr>
<tr>
<td>Lustrous green, tamarisk-like foliage. Tall. Riparian.</td>
</tr>
<tr>
<td>Cypress Pine (White). <em>Callitris glauca</em></td>
</tr>
<tr>
<td>Evident member of cypress family. Medium to tall. Rolling hills, light soils.</td>
</tr>
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</table>
Henry Anthill (1965) in May 1815, in the company of Evans and the governor, and (c) Allan Cunningham, a botanist from the Kew Herbarium (April and August 1817) (fully published in Lee 1925, 180–86, 298–301), who accompanied (d) the surveyor-general, John Oxley, in turn responsible for another narrative (Oxley 1820, 2–3, 202). The original trail from Sydney crossed the Fish River, after emerging from the deep, wet valleys and thickly forested ranges of the Great Escarpment. Moving west from the Fish, the country was hilly, with a grassy “open forest” of small timber that extended southward. The Bundaleer Downs (“Sidmouth Valley”) were a beautiful grassland, thinly timbered, and with a stretch of “boggy” ground near the Fish River, while grassy, open woodland was visible to the south. After a tract of “diminutive forest,” extensive grassland (“fine open grazing lands”) continued to the open floodplain of the Campbell River. Turning NNW, the road crossed gentle hills with open forest and grassy valleys, until the plain of the Macquarie River was reached 12 km south of Bathurst.

As extracted from overlapping itineraries, this stretch south of the Fish River was a mosaic of grassland and grassy open woodland, but the plains around Bathurst were “a clear and open tract of campaign country,” the only trees being river-oaks (Casuarina, Table 1) along the stream banks (Cunningham in Lee 1925, 182–83). The grass was so thick and tall that it could be mowed, the best Evans had seen in the colony, and the gentle hills were only thinly wooded, “the trees being far apart” (Evans in Lee 1925, 161). On the hills just southwest of Bathurst, Cunningham (in Lee 1925, 183–84) found an impoverished flora (“very inconsiderable”), but a more complex association in the riparian zone around Dunkeld, where there also were blue gums; however, fire-wood had to be carted in, from distances of 8 or 9 km, as it also did in 1839 (Meredith 1846, 85).
Traveling ENE from Bathurst, Cunningham (in Lee 1925, 184–85) moved from the grassy upland to the “sterile scrubby” valley of Winburndale Rivulet, which was 3.5 m wide, yet deep and flowing too fast to cross, with reeds growing on its banks. This suggests a gully-like stream, which is exactly what is found today: a 3.5-m deep channel below a former alluvial flat that has a brownish gray cumulic soil with an accelerator mass spectrometry (AMS) date of 1700 ± 85 years before present (AA52058); remnants of a younger, “inset” fill support a river-oak with a girth of 600 cm, and a cover mantle of recent flood gravel/sand, which includes a fresh, river-oak branch that gave a “modern” age (A12436). South of Bathurst, the topsoil on the hills and in the bottoms was loamy, over a wet clay, and the vegetation grassy, trees being small and stunted and thinly scattered over the stony hills (Cunningham in Lee 1925, 185–86; Oxley 1820, 3). West of Bathurst, the open landscape ended with the steeper hills west of Dunkeld; further downstream the Macquarie River was bounded by rocky bluffs and wound between “forest hills”; and on Pine Ridge, near Pine Hill, there were cypress pines (see Table 1) 1.2 m in diameter, although surrounded by a more grassy landscape (Evans in Lee, 161–62).

Coming to Bathurst via Mitchell’s new road in mid-1834, the German traveler Charles von Hügel (1994, 343) descended from the watershed pass “through sparse forest in sandy soil,” before reaching the edge of an undulating plain “clear of forest.” Or as Mrs. Charles Meredith (1846, 82–83) noted in 1839, there was neither grove nor tree, and “scarcely a bush,” as a catastrophic drought had turned the grassland into “dreary desert plains” (Meredith, 108). Such reports from subsequent decades, including some French narratives (Havard and Havard 1938), give a consistent picture of the Bathurst Plains.

These multiple descriptions provide a sharp environmental image of the district at the time of the Contact. The original Bathurst Plains formed a nearly treeless grassland, enclosed by higher ground that was thinly wooded. As Anglo-Australian settlement began, the Plains were closely demarcated by the contiguous block of land grants and “reserves,” mapped for 1829 by Perry (1963; Figure 10). They also correspond well with the Bathurst, Raglan, and Macquarie soils on granite (mapped by Kovac, Murphy, and Lawrie 1990) (at 1:250,000). This grassland, as open as the Serengeti or the Illinois prairie, covered an area of 550 km²—large enough to depict on a 1:5,000,000 million scale map. But the AUSLIG (1997a) land-cover reconstruction for “1788,” a nominal date for Aboriginal-European Contact, shows the Bathurst district as a medium-tall eucalypt woodland (10–30 percent foliage or canopy cover) with a grassy understory, and the sector east of the Campbell River as “open forest,” with 30–70 percent canopy and a shrubby understory. By AUSLIG criteria, the former should instead have been classified as “grassland” (G3 instead of eM2G), and the latter as “woodland” with 10–30 percent canopy and grassy understory (eM2G instead of eM32). The difference is substantial and raises questions as to the reliability of this “authoritative” benchmark widely used in southeastern Australia to assess vegetation change since Contact.

Why were the Bathurst Plains essentially treeless? Although a little lower than adjacent parts of the Central Tablelands, precipitation is not substantially less—550–800 mm compared with 700–800 mm—with only the Macquarie floodplain receiving less than surrounding upland plains. Frosts as a result of cold-air drainage are more common in the district, but nowhere near a threshold that might affect tree growth, as opposed to grass dormancy. Prehistoric burning, discussed below, will have enhanced the extent and definition of the grassland habitat. Most convincing as to the latent role of fire is the low diversity of the flora noted by Cunningham in 1817.

It is striking that the Bathurst grasslands in 1817 were tightly linked to gently sloping or level surfaces and a single substrate, granodiorite. That signals a primary role to edaphic factors, namely soil type, subsoil drainage, and topographic expression. Critical is that the granodiorite weathered to quartz sand and a clayey residue derived from plagioclase feldspars. Although the topsoils tend toward sandy loams, the subsoils are compact sandy clays, often resting on thick accumulations of much older clays. Convex inflections of topography, on upper slopes,
are well enough drained, and the subsoils are less heavy, favoring percolation of water. But concave, lower slopes or level surfaces are poorly drained, and the dense, clayey subsoils are only slowly permeable. As a result, soil water migrates horizontally, at the base of the A horizon, to form “perched” water tables with seasonal waterlogging under anaerobic conditions in the B horizon. These are inimical to tree rooting. Furthermore, the soda derived from weathering of sodium feldspars is washed out of slope soils to concentrate in the bottom lands, further inhibiting tree growth, except in the case of young alluvium.

In a soil landscape with abundant clay and extensively affected by varying degrees of periodic waterlogging, it is the dense, anaerobic, and sometimes sodic subsoils that pose the major impediment to tree-root penetration. That is why trees reappear on steeper and sandier slopes. Such edaphic factors not only account for the original grasslands of the Bathurst Plains but help explain other vegetation mosaics of the Central Tablelands. Oxley (1820, 2) described the Bathurst area as extensive “downs,” with thinly wooded hills, admirably adapted for sheep grazing. In southern England, “downs” are treeless, undulating uplands on permeable chalk. In Australia, the term began to be used for grassy and open undulating topographies ideal for sheep, but, unlike the downs of Britain, which reflect excessive permeability and droughty substrates, the downs of Australia are a result of poor subsoil drainage.

Despite the rolling topography and the inherent erodibility of the local soils (Kovac, Murphy, and Lawrie 1990), there is little evidence of historical soil erosion. We examined a sensitive set of bottom exposures at Dunkeld, some 10 km west of Bathurst, and below a 6-km-long rocky slope, with 3° to 8° gradients and locally scarred by modern sheet erosion. At the base of that incline, the floodplain of Rocks Creek is not covered by soil sediment, but has an intact profile, with a gray topsoil of 30 cm over a reddish-brown, clay loam Bt horizon of 30 to 50 cm, resting on a sandy loam with some groundwater motting. Toward the valley center, this older alluvium is replaced at the same level by a younger fill, with several buried, gray floodplain (“cumulic”) soils, under only 20 cm of fresh colluvium with leaf debris. The buried soils imply a time depth of several millennia, rather than a century or two. There is evidence for very recent soil erosion, within a time span of decades, but no apparent record of an erosional response to the first century of Anglo-Australian land use: both Rocks and Evans Plains creeks are deeply incised (Figure 2), but their entrenchment may well predate Contact, since Cunningham (in Lee 1925, 298–99) in 1817 was inconvenienced here by “several deep gullies running into the (Macquarie) river.” More recent gullies are evident in upper Georges Plains Creek. These are discontinuous, separated by reedy wetland tracts, and cut into Holocene alluvium; some of these gullies are older, however, with smoothened and vegetated faces alongside a small, wet floodplain.

**Original Land Cover of the Central Tablelands**

Reconstruction of the land cover of the Bathurst Plains, using descriptions of the earliest European travelers, is a familiar enough methodology. Seeking to understand these distributions in edaphic terms and discussing them in the light of complementary environmental evidence for landscape change is more novel. Further, by synthesizing the data in a regional environmental context, we avoid the disconnected overgeneralizations of Ryan, Ryan, and Starr (1995) and the sometimes specious riposte of Benson and Redpath (1997). What follows is an analysis of the land cover mosaic reported by Allan Cunningham in other sectors of the Central Tablelands included in Figure 2. We revisited the route of these itineraries, but the areas of modern, residual woodland—mainly open forest—represented in Figure 2 are simplified from the distribution of “medium” and “dense” vegetation shown on the topographic maps, corresponding to the AUSLIG (1997b) categories of 30–70 percent and 70–100 percent canopy cover. Figure 2 does not show open woodland (“scattered” vegetation) with 10–30 percent canopy, which accounts for more than half of the unshaded areas. Comments on nineteenth century gullies or modern soil erosion are included for each travel segment.

**From Bathurst to the Lachlan River.** Oxley and Cunningham left Bathurst on 20 April 1817, striking south along the divide of the Macquarie and Lachlan watersheds, moving from more open vegetation to one “much wooded with ill-grown gum and stringybark trees,” although grass was good and common (Oxley 1820, 3–4). Cunningham (in Lee 1925, 186) specifies hills covered with “brush or undershrub,” with “fine lofty trees apparently generally hollow and decayed at their base.” This suggests that “dieback,” believed by some writers to be a modern scourge, is a much more complex phenomenon.

Turning west, they moved through grassy country, thickly wooded with “dwarf timber” with “brusby spots,” before reaching the grassy valley of Mandurama Ponds, with a richer flora; westward was a very open forest, “thickly clothed with grass,” and “brushwood” on the ridges that eventually changed to scrub country. The
valley of Limestone Creek had a rich flora, and the setting was grassy, with very open timber but no undergrowth. Beyond, they encountered a tract of recently fired grassland, then crossed a mosaic of scrub and “high grassy lands,” and, subsequently, a “rich forest country.” The extensive, old alluvial plain near the Lachlan River was flat and mainly open, but sometimes scrubby, until they reached the fringing woodland of the Lachlan, which was grassy, the only tall timber growing immediately on the “very high” banks (Cunningham in Lee 1925, 187–91; Oxley 1820, 4–8). 

The densest, often brushy, woodland they encountered on this leg is largely open today, indicating that 10 or 15 km at the northern edge of the Copperhannia Nature Preserve have been cleared. The former mosaic of woodland and grass in the Limestone and Mandurama valleys has also been thinned. A microhistorical study by Fry (1994) near Kenyu, south of Cowra (Figure 2), illustrates this process. Grazing pressures here increased rapidly after the 1860s, with fencing, ringbarking, and clearing by the mid-1880s, as landholders switched from sheep to more wheat growing, prior to the “collapse” of the 1890s. But most of the tree species identified in 1820 by acting surveyor-general James Meehan are present today (Cambage 1921, 252; Fry, 103).

The Bathurst-Lachlan itinerary illustrates a different picture, of clearance or thinning, where the broad lines of vegetation change given by AUSLIG (1997a, b) are essentially correct. But sheep were less directly involved than a more complex agricultural transformation that climaxed about 1890. Nonetheless, damage by soil erosion is modest, even in the hilly country southwest of Blayney. The reddish clay soils on long slopes with scattered tree cover are essentially intact, with some light erosion by sheetwash and rill cutting. Occasionally, the sandy loams of the hillcrests may be eroded, with limited sheets of colluvial wash accumulating over intact soil profiles. Although the valley sediments have been gullied, the active floodplains are reedy and formed by an organic “inset” fill, a meter thick, precluding recent channel incision.

From Wellington to Bathurst. Oxley and Cunningham reentered the area covered by Figure 2 in August 1817, coming from the west. East of Wambangalang Creek (“Elizabeth Vale”), with its fringing reed grass (*Phragmites*), the valleys were grassy, with an unidentified eucalypt, stringybark, and acacia on the often grassy hills. The Little River (“Molle's Rivulet”) channel had high, vertical walls of red earth, interrupted by “several deep gullies” (SR: SZ 7, reel 46, 16 August 1817); reed-grass was well developed, with a floating aquatic fern (*Azolla*) and a variety of riverine plants; the high dry grass had been fired by the natives, and small ironbark and stringybark grew on the hills. Moving southeasterly, they crossed a less hilly area, more brushy now with acacia, but still grassy and with evidence of another recent burn; Curra Creek was swampy before it entered a narrow gorge through the Catombal Range, named Glen Finlas, where they found a rich flora, evidently protected from fire; the surrounding mountains had large cypress pine (Cunningham in Lee 1925, 284–91).

On the other side, the glen opened up to the spacious valley of the Bell River, with a luxuriant grass cover on black soil, lightly wooded; again, reed grass, *Azolla*, and a shallow, meter-deep channel, with scattered large river-oaks on its banks. They followed the Macquarie down to Ponto Hill (“Hove’s Rock”), noting high shelving and rocky banks, a bed with sand and cobbles, the riparian edge marked by blue gum, large river-oak and apple, with woodland back from the edge of the broad floodplain, grassy with evidence of fires; the gently winding river had a uniform width of 40 yards (36 m) and flood marks at 5 m above water level. The channel was interrupted by “long strips of islands” (Cunningham in Lee 1925, 288–91; Oxley 1820, 188–91; also Sturt 1834, 7–10). This indicates a river with a strong proportion of bedload and high peak discharge, but during the drought year 1828, the Bell was dry and the Macquarie scarcely flowing (Sturt, 7). Given the relatively even annual distribution of rainfall, this underscores the high variability of discharge events from year to year, prior to Contact. Today, the river only deposits mud on its shelving banks downstream of the Burrendong Dam.

Although the riparian woodland has been lost and replaced with a scattering of younger trees, the AUSLIG (1997a) reconstruction for 1788 does not match the descriptions of 1817. It shows the Wambangalang basin as a two-story woodland with 30–70 percent canopy cover (eM3L) (Figure 4A), whereas it was actually reported as grassy and lightly wooded. The stretch between the Little River and Glen Finlas is given as medium-tall woodland with 10–30 percent canopy cover, although Cunningham described it as brushy, which, in his terminology, implies smaller trees. Except for steep, stony slopes, where grazing may produce terracettes, soil erosion is insignificant. The upper Bell River has sloping, grassy valley floors that show modest bank collapse and local gullying in channel proximity.

Cunningham and Oxley left the deep, winding valley of the Macquarie to follow the western interfluves in the direction of Orange. The initial reaches were open and grassy, with small timber of bastard box and stringybark scattered on the hillsides; the tall grasses were, in part,
Figure 4. A. AUSLIG (1997a) vegetation reconstruction for Central Tablelands “1788.” Upper stratum: M2, Medium height trees, 10–30 percent canopy cover; M3, 30–70 percent cover. Lower stratum: G, grasses; Z, shrubs; L, low trees. B. Reconstruction for “1788” (1813–1831, this study). F (dark gray), forest hills; GW (white), grassy woodland; G (light gray), grass. W, M, B, O, C stand for names of settlements.

burnt, and only the rougher ground was brushy (Cunningham in Lee 1925, 293–95; Oxley 1820, 194–97). Yet AUSLIG (1997a) includes this reach squarely within its category eM3Z, i.e., shrubby open forest with 30–70 percent canopy (Figure 4A). The stretch further south crossed rougher ground, with small grassy basins and diminutive ironbark and stringybark on the stony ridges and brushy spots between valleys. Entering the “glens” in lower Lewis Ponds Creek, they found a flood mark at +5.5 m; the valley upstream was “very swampy and covered with very long grass,” and had a flood mark at 1.8 m; slopes were thinly wooded; the rough interfluve southeasterwards to Pine Hill had low grassy hills, stringybarks on stony ridges, and larger blue gums along stream banks (Cunningham in Lee 1925, 295–98; Oxley 1820, 197–202). The vegetation cover reported in this itinerary closely matches the contemporary scattered and medium-dense tree cover, allowing for some thinning. Notable is that high species diversity—including a variety of acacias and flowering plants, some of them coastal—was limited to patches of bushy scrub on broken terrain, where it normally would be spared from grass fires.

The Ravine Country. The middle Macquarie Basin and that of the Turon drainage are deeply dissected to form a low, mountainous terrain, with a modern mosaic of wooded ranges and grassy valleys. Evans first penetrated these ravines in December 1813, following the west bank of the Macquarie for some 20 km downstream of Bathurst (Figure 2). His major impression was that of a “barren” landscape, i.e., rocky and with a sparse cover of vegetation. In one sector he saw tall gums and box, and before he turned back, he noted a large tract of “open” country extending back from both sides of the river (Evans in Lee 1925, 162–63 and map). That closely describes the present land cover.

Cunningham made a short trip northward from Bathurst at the end of 1822, and the valleys he followed to Lawson’s Creek were consistently grassy, the ridges rocky and brushy, the hillslopes grassy with small timber; “well wooded” areas were discontinuous, but his lists of grasses, herbs, shrubs, and trees are as complex as from any area he studied (see Cunningham, in Lee 1925, 493–500).

In April 1823, Cunningham resumed his travels northward, describing the lightly timbered, grassy plain of the upper Cudgegong River, already grazed by cattle, and then crossed the swampy Lawsons Creek valley to cut north across rough ridges and wet valleys (Cunningham 1825, 142–44). On the return trip in June he came down to Mudgee through open woods from the north and northeast, encountering cattle trails 15 km from the furthest cattle station. The extensive riverine plains had wooded flats with apple, but these continued “clear of timber” to the base of the hills (A. Cunningham 1825, 186–90). In a generalized way, these trajectories across the ravine country reveal a land cover little different from that of today.

Discussion. The grass-woodland mosaic reported by the earliest travelers reflects edaphic factors: Trees
do not generally root in seasonally waterlogged clay soils, except in the riparian zone, where excess water drains directly into the channel. Indeed, riparian woodlands should be densest on the banks of deep channels for this very reason. Fire will have primarily accentuated eco-
tonal contrasts.

The areas reconstructed by AUSLIG (1997a) as “open forest” (30–70 percent canopy) for “1788” (Figure 4A) were less extensive than claimed, even allowing for generalization at the scale of presentation. More often, they also had a grassy rather than shrubby understory. In some areas, such as along the northern margins of the Copperhannia Nature Preserve, tree density was high but stature “diminutive,” that is, a “bushland,” as much of this area remains today. A quantitative definition of 10–30-m-tall trees is therefore open to question. In general, grassy valleys or swales were reported with clockwork regularity by all the earliest travelers (Figure 4B), and wooded hills were commonly also labeled as grassy and included in repetitive descriptions of “excellent,” “fine,” or “tolerable” grazing country. While this is a macroscale approach, Fensham and Fairfax (1997) illustrate how the voluminous surveyors’ notes and cadastral maps can be used to reconstruct land cover in detail, but can do so only after initial settlement.

The level land of the Central Tablelands was suited for a grazing economy without landscape modification; in our view, thinning or clearing were largely unnecessary for pasturing purposes. Stocking rates have also not been a general problem in the region. The midcentral division of Butlin (1962) covers an area of close to 60 million ha, where sheep peaked at 7.6 million in 1891 and fluctuated at 8 to 12 million during the last seventy-five years. Assuming that 25 percent of the terrain is unsuitable, this implies stocking rates of 5.9 ha per sheep in 1891 and 3.75 to 5.6 ha per sheep in recent times—when there certainly is no evidence of overstocking. That does not preclude local overstocking, particularly where sheep are constrained from normal mobility by fencing or when drought parches the pastures. The pernicious effect of fencing and drought in combination is to destroy produc-
tive perennial grasses. Since Cunningham mentions only a “brome” grass (probably a Poa), it is difficult to reconstruct the former diversity of native grasses in the Central Tablelands. They have now been largely displaced by sown exotic grasses and nitrogen-binding legumes on soil of low natural fertility (see Kovacs, Murphy, and Lawrie 1990, 59–63, 273–76, 287–90).

Agriculture has remained concentrated along an axis of relatively level land between Bathurst, Blayney, and Orange, where the original landscape was either open or only lightly wooded. “Clearance” is therefore a relative word in regard to the expansion of cultivation, with a very different meaning than nineteenth-century clear-
cutting in the Upper Midwest or northeastern United States. It also was fundamentally different from Aus-
tralian deforestation for logging purposes. The tree cover of the Central Tablelands has indeed been “thinned,” but the broad outlines of land cover as described 180 years ago remain quite apparent in the landscape today.

Soil erosion, in effect, serves as a proxy for the dis-
ruption of ground cover. Whether as sheetwash on upper slopes or gullying in the bottoms, soil erosion today is localized and rarely far advanced in the Central Table-
lands. Yet gullying was already evident in 1817, and a parallel manuscript investigates key alluvial settings de-
scribed by the early travelers to argue that many large and small streams were already entrenched to approxi-
mately their present dimensions during the early 1800s, when channel floors often were gravelly, as they are to-
day (Butzer and Helgren n.d.). Compared with soil erosion in the southeastern United States, soil erosion is “light” rather than “heavy.” The soil cover today is by no means “degraded.” Reflecting complex responses to dif-
ferent thresholds, there has been damaging soil erosion in some parts of southeastern New South Wales since Contact times, but that is not the case in the Central Tablelands.

Modern siltation in various reservoirs of the Table-
lands has been interpreted as evidence for ongoing soil erosion, but that ignores the high peak discharges and overbank flooding of the Macquarie River prior to An-
glo-Australian intrusion. At reduced scales, this pattern was projected to lower-order streams, e.g., 5.5-m flood crests downstream (with a gravel channel) and 1.8-m upstream along Lewis Ponds Creek (with an uncinsed, swampy valley today). Such figures do not represent an isolated flood event, being replicated in different drain-
ages and reported by various travelers across fifteen years or so. They suggest flood volumes five or ten times greater than channel capacity at bankfull stage, at a scale comparable to hurricane-induced flooding in the eastern United States.

Finally, the botanical observations of Cunningham must be carefully weighed against the ahistorical infer-
ences of those biologists who use phytosociological as-
sumptions to reconstruct “undisturbed” vegetation, of-
ten based on surviving relict patches, in order to posit species loss or the fragmentation of biotic associa-
tions. The salient fact is that Cunningham found only a few sites with high species diversity (Figure 4B), all in areas sheltered from fire, e.g., the Macquarie flood plain, Limestone Creek, Glen Finlas, and the Ravine Country.
Land Cover and “Gullying” of the Liverpool Plains, 1818–1831

During the 1800s, the Liverpool Plains were widely regarded as a spectacular pasture country, lying directly northwest of the Hunter River Valley and marking the southern part of the Northern Tablelands. If we include the Peel River plain, these plains form a roughly circular area some 110 km in diameter, enclosed or broken by low ranges that rise 300–800 m above a flat basin of Quaternary sediments (Figure 5). The soil cover is dominated by deep, reddish black clays, prone to shrinking and cracking as they dry out. Such fertile vertisols extend across bedrock-floored piedmonts and even up steeper hillslopes. They accumulated over long periods of time from weathering and erosion of the surrounding volcanic rocks (alkali basalts) of early Tertiary age.

The Narratives. Oxley crossed the northern perimeter of the plains in late 1818, coming from the west via Garrawilla Creek (Figure 5). Coxs Creek had recent flood marks at 4.5 m, but “still within the banks,” where the modern channel is 5 m below the plain, with inset fills at 2 and 3.5 m. Away from the fringing river-oaks, vast plains, clear of trees, stretched to the north and southeast, in part, still wet long after the last rains; a rich organic soil extended even up the hillslopes; clusters of hills rose above the plains like islands in a sea, with occasional clumps or lines of timber on “gentle eminences.” Even the hills were grassy and only thinly wooded, with apple, box, several gums, and, more locally, weeping wattle and cypress. He crossed the plains to the Mooki River, “the heights of the banks from fifteen to twenty feet,” compared with 5–6 m today and indicating no further deepening since. Eastward, the piedmonts of the Melville Range had open forest, the hills were grassy and open, again with apple, box, and gums, while cypress was more common on the mountains. At the eastern terminus, the hills and mountains northeast of Tamworth were “covered with excellent grass to their very summits,” as was the Cockburn valley, while box, stringybark, and cypress were the main trees (Oxley 1820, 275–87).

Cunningham enters the picture in June 1823, first negotiating a pass across the Liverpool Range, which

Figure 5. Land cover of the Liverpool Plains “1788,” as documented 1818–1832 (this study). The flat clay plains are vertisolic and were treeless except for watercourses. Modern distribution of medium-dense woodland is shaded. 1, Dartbrook; 2, Jacks Creek; 3, Warrah Cr.; 4, Borambil Cr.; 5, Barrabulaba Cr.
marks the southern perimeter. The mountains were “lightly timbered” or had “open forest,” and his view northward to the Coxs River included a stream marked by a line of acacia, amid an expanse of brown grass and herbage that except for “an occasional line of small trees,” was “perfectly clear of brush or scrubs” (Cunningham 1825, 176–77). He returned in May 1825 to follow Coxs River down to near its confluence with the Namoi, describing great strips of level, open, and timberless country, stretching for 80 km, with only “a few straggling trees” of acacia or white gum, covering 600 km² and offering “rich grazing land for cattle,” while the drier margins would “afford healthful, sound walks for sheep”; the soil was a “rich loam,” and the lowestmost tracts were still flooded from the previous summer’s rains, and marsh plants, as well as eight distinct grasses, were noted; the western piedmonts had ironbark and cypress, with tall stringybark, box, and some white gum along the lower river (Cunningham in Lee 1925, 540–43).

In May of 1827, Cunningham crossed the Liverpool Plains by a different route on his way to Queensland. It was a drought year, and surface water was scarce. He descended from the head of Dart Brook, encountering tall trees and dense bush, before entering an open bush of box and ironbark along upper Jacks Creek; Warrah Creek was lined with river-oak, and the drying bed had only pools of water or masses of tall reeds, between steep banks of black earth; eventually, the flats opened up to meadow land 5 km wide. Striking directly north along the western edge of the mountains, Curra bulula Creek was found to be “reedy” near “the base of the open forest,” but later it passed through a “confined, bushy valley”; the next stream northward was small and rocky, with shaded banks and abundant grass; and the Melville range was “thickly wooded and seemingly grassy.” Approaching the Namoi River near Carroll, he found an expanse of brushy, drooping acacia; the alluvial plain was open, with deep-cracking ground, the broad riverine fringe wooded with large apple; flood debris was lodged in timbers at a meter above the flats and 10 m above low water; the 50 m wide river was forded at “a pebbly fall,” amid a grassy forest of large blue gum; for some distance to the north, there were only stunted ironbark and cypress (Cunningham in Lee 1925, 546–53). On his return trip, he noted that the Namoi floodplain below Gunnedah was a maze of “flats, wooded lands, and scrub watered by shallow channels,” with flood marks 8 m above the river (Cunningham in Lee 1925, 579–80).

Surveyor-general Thomas Mitchell crossed the Liverpool Plains in December–January 1831–1832, coming up from the Hunter Valley. Mitchell found the southern footslopes of the Liverpool Range “well covered with grass,” “already eaten short by sheep.” Ascending up the long pass now followed by the New England Highway, he noted that “the adjacent mountains afforded excellent sheep pasture,” making no mention of forests. Emerging at the northern end of the pass, there was a “wide expanse of open level country,” “clear of trees” to the horizon, with rich soils, good grass, and grazing cattle, “adding pastoral beauty to what had recently been a desert” (Mitchell 1838, 24–27), i.e., during his visit of 1828, at the end of the severe drought also experienced by Cunningham (in Lee 1925, 547), who writes of “desert woods” or “poor and hungry” land.

Colly Creek, a minor tributary (“Nuzabella rivulet”) near its junction with Borambil Creek, was found to be entrenched 5.5 m, exposing “rich soil” in the banks, and with a gravel bed (exactly as today), near a camp site where the long grass “reached to the heads of the horses,” but in part had just been burnt. Quirindi Creek was noted for “the steepness of its banks.” The plain near Currabubula Creek was “open and grassy,” with a “thiny wooded plain,” and “good grass and a thin cover of box” east of the Melville Range on the level stretch to Tamworth (Mitchell 1838, 33), the approximate site of the last cattle station.

Now turning northwest, down the Peel River, Mitchell observed that Sandy Creek (“Goora gulley”) had steep banks and a bed of gravel and sand, as today (see further below). He intersected Cunningham’s route at the Namoï, coming down from the tall grass of the plain, across a valley with weeping wattle to the floodplain, where 50-foot (15 m) banks were followed by tall blue gums and dense river-oak. On the other bank of the Namoi, he passed through a forest of cypress with river-oak undergrowth, before following an extensive plain with deeply cracked vertisols. Further west, approaching Boggabri, he found the level stretches north of Namoi variably wooded, often thickly so, with an unidentified eucalypt and river-oak; the Namoi River here was 14.5 m below the banks to water, which flowed 3.5 m deep (Mitchell 1838, 27–51). Once again, north of Boggabri, the “country smoked in all directions” (Mitchell 1838, 52).

The last of the early travelers on the Liverpool Plains was the impresario and Arctic explorer Edward Parry. His journal provides incidental but useful information on land cover in places not visited by the major explorers (see Campbell 1923). A fitting overview of an era is given by a letter of May 1843 by the German scientist Ludwig Leichhardt (1968, 651): “the Liverpool Plains—an extensive level country, showing black soil covered with grass, with Compositae and Leguminosae, formerly the bottom of a large inland lake, with hills and ridges rising like islands.”
Evaluation. The travel narratives for the Liverpool Plains reveal a complex environment at the time of Anglo-Australian Contact. Large parts were almost flat and essentially treeless, particularly in the drainages of the Coxs and Mooki rivers. The beveled plain on Paleozoic rocks west of Tamworth was a very open woodland. The innumerable rocky hills or discontinuous ranges that rose above the sea of grass on the clay plains were lightly wooded but commonly grassy, with open woodlands extending onto the gently sloping piedmonts. The landscape context of grass versus open woodland, and of their delimitation, is clear. The flat, treeless grasslands were prone to extensive flooding during the rainy season, but commonly lacked surface water during the dry seasons of drought years, similar to the flood savannas of Africa. The protracted and extensive fires noted during the last weeks of the dry season were specific to the grass-woodland mosaic of the piedmonts and floodplains. These were the environments most consistently used by the Aboriginal inhabitants, and it was here that indigenous burning would have favored open, grassy woodlands without a shrubby understory.

We also note the different perceptions of the Liverpool Plains during drought and wet years: lush pastures in 1831 contrasted with the “desert” of three or four years earlier, supporting modern anecdotal evidence of the rapid recovery of the land when the rains return after a severe drought. The stress of periodic drought may explain the decline of cattle from 205,000 to 93,000 from 1847–1854 and an increase of sheep from 187,000 to 301,000 from 1844–1854 (Gardner 1854, 113–16); today, sheep number close to a million. Depending on how the “plains” were defined in 1854, the combined stocking rate in “sheep equivalents” would have been 10–12 ha per sheep.

Surprising are the number of occasions on which the early travelers commented on entrenched stream and river channels. Where figures are given, the depths of these steep-banked channels are identical to those that we studied (for details, see Butzer and Helgren n.d.). Within the channel of Borambil Creek, we measured great river-oaks, with girths of up to 292 cm, growing at 75 cm above the floor and at the base of a bank 5.5 m high. Where it was crossed by Mitchell, Sandy Creek is a 5.5-m gully, into which water backs up from the adjacent Peel River; a +2-m inset fill within that gully supports a mature eucalypt and projects to a young alluvial fill of the Peel that has a humate AMS date of 275 ± 35 years (AA52058), as well as a dead blue gum with a girth of 570 cm, further downstream. In fact, the Peel has been reentrenching itself down to its late Pleistocene lag gravels in stages: the highest (+5.5 m), dark gray, clayey, cumulic soil (preceded by five such paleosols), which directly underlies the floodplain at Sandy Creek, has an AMS date of 2310 ± 40 years (AA52057); a younger, but lower, clayey alluvium (+3.5 m) is dated 1120 ± 35 years (AA55992), and there is another, light-brown alluvial fill dated 700 ± 30 (AA55993). In other words, there are four distinct bodies of alluvium dating between 2310 and 275 years ago, separated by three periods of entrenchment, each of which exposed the lag gravel on the floor of the Peel channel. It is all too easy to mistake “gullying” or a “young” alluvium for evidence of “historical” soil erosion.

Discussion. The historical record, supported by the alluvial history, indicates that many streams on the Liverpool Plains were entrenched (“gullied”) prior to 1818–1831. Furthermore, four cut-and-fill cycles during the last 2,000 years indicate repeated hydrological disequilibrium, well prior to Anglo-Australian intrusion. Channel downcutting after 1831 has ranged from essentially none to a maximum of 2.5 m along the Peel River. Whatever “gullied” there has been during historical times has been minor or localized, mainly at slope inflections along tributaries of the Peel.

The Liverpool Plains are not widely cleared, nor are their land cover and soils degraded. They remain a major center of agricultural and cattle production, the vertisols still organic and fertile. These self-mulching soils allow root dehydration when they crack open during the dry season, especially where they are deepest, on level ground. That continues to inhibit tree growth, even in areas that are not seasonally flooded. Notwithstanding the historical evidence, the AUSLIG (1997a) map of “original” vegetation identifies only about 1800 km² of grassland in the Liverpool Plains (Figure 6A). If that were true, a vast area of 6000 km² of presumed eucalypt woodland would have been cleared or thinned to grassland or crops (see AUSLIG 1997a versus 1997b). Our historical examination, grounded in the testimony of the first travelers, rather than on satellite-based extrapolations, suggests 4700 km² of original grasslands (hardly a “small proportion,” as per Benson and Redpath 1997, 305); some 3000 km² of the basin lands have been cleared or thinned, mainly west or north of the Peel River (Figure 6B). Further, AUSLIG (1997a, b) suggest a substantial thinning of the montane woodlands, although the substantial areas designated as medium-dense woodland on the 1:100,000 topographic maps, conform to the present reality. We did, however, observe that apple, prominent in some areas during 1827–1832, now is rare, while wattle and cypress pine are less common.
Palynology and Land Cover Change

Our vegetation reconstruction for the Contact period in the Central Tablelands and Liverpool Plains provides a critical datum, but it does not illustrate the dynamics of biotic change before or after the early 1800s. It is possible, for example, that woodlands had been extensively cleared by about 1900 but have reexpanded since, or that dominants have been selectively displaced. To examine this, we turn to palynology, a different line of evidence, involving different assumptions. Although the number of sites in the Tablelands with palynological studies remains small, these are increasing rapidly in Victoria and coastal New South Wales.

Kershaw, Bulman, and Busby (1994) assembled seventy-one pollen diagrams from southeastern Australia to compare modern and pre-European pollen spectra. The results are noteworthy in that thirty-nine of these show no differences of statistical significance, including a variety of sites now within heavily disturbed agricultural areas. This is explained by broad taxonomic pollen groups that are insufficiently sensitive to allow identification of change within grassland and open woodland environments.

The Lake George Record. One of the most widely cited (or misrepresented) palynological studies in Australia comes from Lake George, a semipermanent water body in a closed basin (floor elevation 674m) located 38 km NE of Canberra (Figure 7). In 1820 the lake was full and situated within a vast grassy plain, next to grassy woodland, above a fault escarpment to the west (Cambage 1921, 259–60). This basic land-cover pattern has changed but little across some 200,000 years, with herbaceous taxa consistently accounting for 70 percent or more of the pollen count (Singh and Geissler 1985).
During the last, Pleistocene, cold-climate cycle, there were strong fluctuations of dominant tree pollen types, among sclerophyll genera (representing low, open woodlands) and cool-temperate rainforest genera (representing patches of tall, closed woodland). But the cool-temperate forms had disappeared by the early Holocene, as eucalypts became the dominant class of trees. During the early Holocene, there was a high component of woody shrubs, but by 5,000 years ago, the land cover had stabilized along the lines described in 1820 (Singh and Geissler 1985).

Fine-resolution sampling of the youngest part of the Lake George cores shows changing concentrations of charcoal particles that assume special significance as a conditional record of fire frequency or intensity in the vicinity (see R. Clark 1982; Green et al. 1988). A plot of a constant sedimentation rate against the more consistent calibrated 14C dates confirmed the estimates of Singh and Geissler (1985, 420, Table 2, Figure 12) that the four pollen spectra and nine charcoal estimates of the top 10 cm of the core span the last 1,600 years; since none of these spectra include nonnative taxa, they may all predate Anglo-Australian settlement. Even as pollen of trees and shrubs increased slightly, charcoal production climbed rapidly to a peak around CE 1000; a second peak, perhaps 400 years later, doubled the charcoal count again; after a minor decrease, a similar peak was regained, all apparently before tangible Anglo-Australian disturbance. Without taking such crude temporal estimates at face value, our point is that intense fires in the vicinity increased rapidly during the last two millennia, perhaps peaking dramatically during the early 1800s.

Modern pollen traps fairly consistently record pine and Paterson's Curse or Echium, two nonnative genera, with tree representation much the same as in the uppermost core; pollen from a moss cushion in the adjacent woodland further included traces of elm and Cerealia, with 12.4 percent Rumex, an introduced pasture weed with indigenous relatives present only as traces in the cores (Singh and Geissler 1985, 420–21, Figure 12).

**Wet Lagoon.** A high-resolution picture of the intrusion of nonnative plants is provided by Dodson (1986), who examined 1 cm increments of the top 20 cm of a core in Wet Lagoon, 20 km north of Lake George and in a similar environment (Table 1). Nonnative pollen types first appear at the same time that a sedge swamp was permanently established at this site, and the firm organic matting probably excludes contamination through livestock trampling. Low pollen productivity below the mat suggests repeated drying out, so that the sedge swamp should mark a sustained wetter interval. Lake George, 7 m deep in 1822, was dry by the 1840s, but mainly deep 1863–1896 (Singh and Geissler, 1985, Figure 3). If the sedge mat of Wet Lagoon first formed during the 1860s, it would record some 120 years of sequential disturbance. That estimate would place the appearance of Echium toward 1930, the time when it was declared a major noxious weed in southeastern Australia (Parsons 1981, 184). Eucalypts at Wet Lagoon began to decline and weeds increased as the sedge mat formed (Dodson, 1986); a brief explosion of woody, myrtleaceous shrubs (c.1890–1920?) may reflect a lull in Anglo-Australian burning. This was followed by a charcoal maximum and increasing counts of grasses (probably including wetland forms) and then an explosion of weedy plants, perhaps implying renewed pasture degradation.

Whatever the exact dating, Wet Lagoon records a surprisingly complex picture of biotic change across a critical century. It suggests that the early decades of livestock grazing had little effect on land cover, but, eventually, there was sufficient pasture deterioration to allow invasive weeds to establish themselves. A study of the local land-use history is called for to elucidate the ecological details.

**Pollen Cores Near Gwyra.** The Wet Lagoon sequence only represents a proxy, local land-use history that has heuristic rather than generalizing value. This is forcefully

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**Table 2.** Nonnative Pollen Indicators in Wet Lagoon, Goulburn District, N.S.W. Top 20 cm of Profile, by 1 cm Increments (Modified after Dodson 1986, Figs. 8–9)

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<td>Rumex decline</td>
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<td>Eucalyptus increase</td>
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<td>Grasses peak</td>
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<td>Charcoal peak; Rumex secondary maximum</td>
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<td>- 5</td>
<td>Peak of Plantago lanceolata; first Echium</td>
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<td>- 6</td>
<td>Grasses and charcoal increasing; Rumex maximum</td>
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<td>- 7</td>
<td>Eucalyptus declining rapidly; sedge and woody shrubs peaking; pine established</td>
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<td>- 8</td>
<td>Woody shrubs expanding rapidly</td>
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<td>- 9</td>
<td>Explosion of woody shrubs begins; trace pine</td>
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<td>- 10</td>
<td>Sharp Rumex decline</td>
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<td>- 11</td>
<td>First Rumex peak</td>
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<td>- 12</td>
<td>First traces of pine and Plantago lanceolata [Establishment of sedge swamp (1860s)]; abrupt increase in pollen productivity</td>
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<td>Trace Rumex</td>
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brought home by the exacting studies of Gale et al. (1995), Gale and Pisanu (2001), and Gale and Haworth (2002) in Little Llangothlin Lagoon, near Guyra on the New England Tablelands. Based on lead isotope ($^{210}$Pb) dating, these authors identify a major discontinuity in geochemical indicators, organic matter, and pollen assemblages between apparent dates of about 1806 and 1836, after which time, sedimentation rates should have increased by several orders of magnitude 1836–1861. The problem is that the “unsupported” $^{210}$Pb values for the intervening 60 cm (−0.52 to −1.20 cm in the 90 mm core) are negative, requiring an independent method of calibration for the lower parts of the core. The authors choose to use initial European settlement in the area (1837) to verify a date of 1836 for the end of the environmental discontinuity (Gale and Haworth 2002, Figure 3). However, if the three AMS dates from the bottom are adopted for independent calibration and plotted on a curve with the lead-isotope date of 1861 (at −0.48 m), the base of the geochemistry curves at −2 m should date to very roughly 2,000 years ago; in that case, there was no accelerated sedimentation, and the discontinuity would be centuries older.

In any event, the discontinuity predates Anglo-Australian settlement. The related proxy data are best explained by a sudden hydrological “crisis”: an abrupt 65 percent decrease in sodium and potassium and major short-term increases in phosphorus and organic matter (fivefold!). There also are brief jumps in sedges and grasses (reed grass?) and, more incomprehensibly, total replacement of river-oak by another species of Casuarina. We suggest a catastrophic flood event(s), which freshened up the lake and introduced masses of soil ions, previously in basin storage. Of course this interpretation would also involve a considerable influx of silt, deficient in $^{210}$Pb. In any case, such abrupt changes could hardly be triggered by sheep grazing with local stocking rates of one sheep to 3.9–5.3 ha in 1857, and next to no cattle (Haworth et al. 1999). This is supported by constant sedimentation rates, despite significant changes in land use c. 1890–1980, in nearby Black Mountain Lagoon (Haworth et al. 1999). Exotic weeds (Plantago) only became prominent around 1910, and pine, first appearing during the 1850s, displaced Casuarina as the dominant tree about 1930. River-oak, heavily selected for its usefulness by the settlers, was ecologically replaced by European willows.

**Regional Discussion.** It is productive to review more briefly some further pollen profiles from adjacent regions. Bondi Lake is in a national park near the New South Wales south coast, 10 km to the south of the Bega River (Dodson et al. 1993). Pine and disturbance plants first show up systematically during the last 120 years, but the indigenous forests did not decline, at least not locally. Charcoal production about 2,000 to 300 years ago was twice that of the last two centuries, and forest composition was less stable in pre-European times. Although the sedimentation rate increased after Anglo-Australian settlement, eutrophic status had already been increasing previously; it has only become serious during the last few decades.

A number of other pollen profiles help illuminate the dynamism of local ecosystems. In the Hawkesbury Valley, a national park 50 km NW of Sydney, early to mid-Holocene pollen records show that repeated fires were linked with accelerated sedimentation; fine resolution study confirms that anthropogenic fire was important in controlling rainforest distribution in the deeply incised, valley refuges. But the late Holocene record shows a marked increase of charcoal after 1800 (Dodson and Thom 1992; Johnson 2000). In a coastal swamp of Ku-ring-gai Chase National Park, 25 km north of Sydney (Kodela and Dodson 1988), the picture is reversed: charcoal influx and concentrations were highest 3,000 to 1,300 years ago, declining during the last 200 years, possibly as a result of Aboriginal displacement and European presence (e.g., the appearance of nonnative plants). Declining eucalypt pollen suggests a drier climate since 1,700 years. On the Barrington Tops (Dodson, Greenwood and Jones 1986), above the Great Escarpment at 1160–1450 m elevation, various charcoal peaks are dated between 2,200 and 230 years ago, independent of any moisture trends, suggesting a nonclimatic explanation for the increased frequency and intensity of fires. More recent disappearance of mountain grasslands in southeastern Queensland may also be a result of Aboriginal displacement (Fenshaw and Fairfax 1996).

A more conspicuous Contact horizon is apparent in Lake Curlip, on the coastal plain of easternmost Victoria (Boon and Dodson 1992); Anglo-Australian settlement here began about 1870, with logging and forest thinning for cattle pasturage favoring expansion of understory scrub, and, eventually, a charcoal maximum and accelerated sedimentation rates after 1900. Charcoal peaks in pre-European times were more modest, but favored increases in phosphorus and eucalypt pollen as trees profited from nutrients released by ash. That may explain why phosphorus and organic concentration in the Murray-Darling drainage began to increase more than 300 years ago, as recorded in coastal Lake Alexandrina, South Australia (Barnett 1994). A last case in point comes from Lake Keilambete, in southwestern Victoria.
(Mooney and Dodson 2001). Here the sedimentation rates, charcoal, and grasses increased during the twentieth century, while eucalypts declined, but charcoal concentrations about 1,800 years ago were twice as great.

Palynologists in Australia have made notable progress in identifying and addressing the nature of ecological transformation after 1788. The biotic changes, apparently, were as complex and protracted as the geomorphic/hydrological ones. There were no ecological "crashes" within a decade or two, contrary to some of the anecdotal literature. Instead there was an "unraveling" across a century or more, in a stop-and-go interplay of inputs and feedback processes. Further, it appears that prehistoric biotic environments of southeastern Australia were not in a "steady state" equilibrium in an environment prone to severe periodic drought or heavy precipitation.

**Implications of Fire Ecology Before and After Contact**

Periodic fires have long played a significant role in the selection and patterning of Australia's land cover. For post-Contact times it is widely believed that fire suppression, the resulting fuel buildup, and the inevitable destructive fires, have increased its impact, leading to policy changes and perhaps further complicating surprises. Such issues resonate in the United States (see Arno and Allison-Bunnell 2002; also Vale 2002, for a possible indigenous role), with similar implications for political conflict over fire control and logging interests. But in Australia there is an added dimension, the matter of Aboriginal use of fire as a tool.

Human settlement in Australia began 50 or 60 thousand years ago, and some believe that people contributed to extinction of the Australian megafauna about 40 to 50 thousand years ago, perhaps through the deliberate use of fire in hunting, or inadvertent, increased habitat fragmentation as a result of more fire in the wake of human presence (see Miller et al. 1999; Roberts et al. 2001; Kershaw et al. 2002). One way or other, the Aboriginal use of fire is a critical part of examining Australian fire ecology (Head 2000), and several basic questions can be identified: (a) Was Aboriginal burning beneficial in preventing fuel buildup and if so, how is/was it done, and should it be reinstated today? (b) Did Aboriginal application of fire change the physiognomy, composition, and boundaries of biotic units? Even partial answers are relevant for ecological evolution and plant and animal sociology, not to mention policy decisions. And (c) did fire ecology play a significant role in determining the equilibrium or nonequilibrium character of Australian environments?

Wildfires in bush or forest depend not only on fuel, climate, and weather, but also on ignition. Lightning strikes have facilitated expansion of grassland and savanna since mid-Tertiary times, with the prominence of fire increasing in warmer climate zones, changing in response to different types of vegetation, and, in the short term, becoming more frequent during dry years (J. S. Clark et al. 1997, Part IV). But in Australia, ethnohistorical documentation (Hallam 1975) and ethnographic observations (Lewis 1989; Head 1994; Russell-Smith et al. 1997; Bowman 1998) show that fire is or was both a tool and a cultural manifestation of Aboriginal societies (Kohen 1995, chapter 7):

- Fire is used to drive game, clear undergrowth for visibility, and maintain open tracks;
- Old stands of perennial grass are removed by burning after they turn to cellulose, bringing forth fresh grass attractive to game; fire also produces new seeds for collecting, and makes wild yams and other tubers accessible;
- Fire serves a variety of defensive, signaling, domestic, and social purposes and is central to a number of rituals;
- "Corrective" burning is applied at intervals to areas long unburnt ("unclean") and the appropriate season is picked so as to avoid intense or unchecked fires.

In effect, the many economic and ritual uses of fire were integrated into a larger, deliberate strategy of environmental management (Russell-Smith et al. 1997) that implicitly imposed a particular esthetic on the landscape. That esthetic was shared by early Anglo-Australians, who repeatedly lauded the park-like appearance of the open woodlands (see Ryan et al. 1995, under "Forest Land"). It was fire that favored a grassy understory by periodically destroying woody shrubs (Bowman 1998).

The politically correct truism is that Aboriginal people set low-intensity and "controlled" mosaic fires, whereas Anglo-Australians burned at the wrong season or allowed excessive fuel accumulation by inhibiting burning, which eventually provoked destructive conflagrations. Indeed, fire intensities range widely: "low" intensity fires are limited to burning ground-level litter, grass, and shrubs, whereas "high" intensity ones are orders of magnitude hotter, the flames scorching or charring tree trunks and burning their crowns (Bradstock, Williams, and Gill 2002). An ethnic dichotomy of
controlled, light Aboriginal burning versus runaway, high-intensity Anglo-Australian fires has been popularized by Pyne (1991) and appears to be believed by some in Australia.

But even among modern Aboriginal groups in Northern Australia, there is a gap between theory and practice. For example, sacred locations are usually protected from fire, but sometimes they are burned over unintentionally; fires are unchecked and, lacking the technology to extinguish them, always allowed to burn themselves out; fire can also be used casually, as when five boys burned 23 km$^2$ of land to catch three feral cats (Gould 1971; Nicholson 1981, 69; Bowman 1998). Indeed, there is only one ethnohistorical testimony for people stopping flames from moving in the wrong direction. Granted that Aboriginal peoples had much more experience in a fire management that was deeply, culturally grounded, that case must be tempered with realism. Given shifting winds and a tinder-dry woodland, the January 2003 firestorm in Canberra (ignited by lightning) burned over 1000 km$^2$ in a single day, advancing on a 35 km front (Lavoren 2003), despite the best industrial technology. Neither can the U. S. Park Service master a “controlled burn” when wind speeds increase abruptly, as they did with the August 2000 fire disaster at Los Alamos, New Mexico.

Anglo-Australian burning probably replicated indigenous methods. An early settler in Victoria noted that the Aboriginal people “constantly set fire to the grass and trees” so that “almost every part of (southeastern Australia) was swept over by a fierce fire, on an average, once in every five years” (Curr 1883, 356). Curr also described Anglo-Australian methods of burning: each year sections that had not been grazed for some time were burnt off to generate a more nourishing pasture; on a hot windy day, burning branches would be dragged along a line at the windward end of the portions to be fired; sometimes the procedure was less than successful, but, on occasion, the flames “rushed up the tall stems of a thousand Eucalypts, the leaves of which shrivelled like old parchment” (Curr 355–56) — suggesting scorching rather than charring, i.e., moderate-intensity fires. Such a practice sufficiently resembles Aboriginal burning to suggest that it was actually learned from resident Aborigines.

We doubt that the nineteenth-century graziers relished conflagrations any more than the Aborigines did. The difference would have been a matter of information: Where to burn and under what conditions? To use fire or to suppress it? For some 150 years, Australians, like their American counterparts, have preferred to believe that bushfires could be suppressed, only to be surprised when ignition of the accumulating fuel creates a disastrous fire.

The net result has been that, in some areas, a thick understory of potentially combustible woody shrubs has invaded once-grassy woodlands, while rainforest has expanded into adjacent open woodland (Fenshamb and Fairfax 1996; Bowman 1998). Much the same is suggested in the Wet Lagoon pollen record (Table 2). Biologists largely agree that recurrent fire, or the absence thereof, will effect tangible changes in ecotonal boundaries, in the patchiness of grass versus trees, or in the density of tree stands. In so doing, however, they implicitly accept that prehistoric fire helped determine the physiognomic structure and boundary details of the land cover first encountered on the Tablelands by Anglo-Australians.11

Burning practices or spontaneous fires, on a time scale of millennia, also played a role in selecting fire-tolerant woodland genera, but whether they changed the regional distribution of dominant arboreal species is uncertain but possible (see Morcom and Westbrooke 1998; Thomas et al. 2001). Across geological time spans, Singh and Geissler (1985) and Kershaw et al. (2002) offer a plausible scenario of how fire-adapted eucalypt forest and scrub became the dominant arboreal land cover of Australia, during the late Tertiary and Pleistocene, in response to fire and repeated bouts of increasing aridity. Whether a greater frequency of late Pleistocene fires, as inferred from the charcoal trace (Kershaw et al. 2002), was related to a demonstrated, early human presence is controversial (Bowman 1998). For all we know, familiar Aboriginal burning practices may only have emerged during late Holocene times.

There is much variability among the charcoal traces of different pollen sites. In some cases, the post-Contact fire record was more prominent than its prehistoric counterpart, in others it was much the same. This is not a function of method, because, in the Snowy Mountains, both oral testimony and dendrochronologically dated fire-scar frequencies show significant differences in recent fire frequency and the timing of major burns from one site to another (see Banks 1989; Pulsford, Banks, and Hodges 1992). This reflects complex spatial and vertical patterning of topography, land cover, and land use in a fine-grained regional landscape. At a macro-scale, a quantitative study of Aboriginal fires in nineteenth century Queensland suggests that burning was more frequent in the eastern coastal sectors, while overall fire frequency and its seasonality varied according to twenty-four land-cover types (Fenshamb 1997; but see Vigilante 2001 regarding methodological problems). The point is that (a) resource productivity, seasonality, and predictability...
vary spatially, (b) the complexity of spatial patterning increases in finer-grained landscapes, and (c) Anglo-Australians and Aboriginal peoples selected different resources and practiced different forms of mobility, in fine- or coarse-grained landscapes. We should therefore not expect historical and prehistoric burning to focus on the same places. Nor should we assume that Aboriginal land-cover modification was uniform or universal.

Both the historical and prehistoric charcoal traces include one or more striking peaks that may reflect either single, catastrophic events or a temporal cluster of major fires. A fairly complete record of bushfires in the state of Victoria includes three categories beyond routine burning: (a) catastrophic fires that destroyed thousands of km² in 1851, 1898, and 1939; (b) major fires that burned over more than 100 km² once every decade; and (c) more localized but also destructive fires every year or so (Gill 1981). According to Aboriginal testimony, the 1851 fire swept from the Murray River to the coast in two weeks (Morcom and Westbrooke 1998). Whether deliberately set, or a result of accident or lightning, fires like that of 1851 or the Canberra firestorm of 2003 should have had significant impact on land cover, perhaps with a geomorphic response. They also suggest that discrete, major peaks in the charcoal record at intervals of centuries may reflect stochastic events falling outside the framework of regular burning by Aboriginal peoples.

Low- and moderate-intensity fires are mainly beneficial for soil. They release nutrients from the litter, stimulating the germination and early development of nitrogen-fixing plants such as acacias, river-oaks, and understory legumes (see Bradstock, Williams, and Gill 2002; Green et al. 1988). And within months of a scorching fire, eucalypts will sprout countless exocormic shoots on their trunks and branches. But high-intensity fires oxidize soil organic matter and intensify water-repellant properties; the unprotected, hydrophobic surface soil aggregates are highly erodible until a ground cover is reestablished (Bradstock, Williams, and Gill 2002; Prosser 1990; Saynor et al. 1994).¹²

High-intensity fires that remove ground cover also char trees and make soil vulnerable to major precipitation events are the most likely to affect large areas. Yet severe, long-term droughts can also destroy ground cover, thin out canopies, and parch soil aggregates; their impact, however, is regional, affecting several watersheds, and such droughts are much more frequent than destructive fires. Burning may, in some cases, contribute to hydrological change, but it is more likely to be a co-agency, to reinforce the coupling of intense drought and excessive rains—a secondary input to the complex processes that trigger geomorphological disequilibrium.

The Southern Tablelands: Soil Erosion and Alluvial Histories

The Central and Southern Tablelands share similar soils, rapid changes of Paleozoic lithologies, and a parallel settlement history. But the upper Murrumbidgee Basin, around Canberra, has greater relief as well as more Quaternary sediment in storage. We now examine potential Anglo-Australian soil erosion through the proxy of recent stream behavior and gullying in the upper Murrumbidgee Basin, based in part on exemplary Australian research that has focused on change during the short time span of two centuries.

Contradictory Evidence about Nineteenth Century Gullies. The earliest travel reports suggest that only the highest-order rivers had well-defined, rocky channels running below extended floodplains (Currie 1825; Sturt 1834, 20–32; Lhotsky 1835). Smaller streams had poorly defined channels, except where incised at the margins of major floodplains; typically, lower-order valley bottoms tended to be marshy and heavily vegetated with grass and reeds; water during the dry season was limited to elliptical scour-pools. Described as “chains of ponds” (Eyles 1977b) or “swampy meadows” (Prosser 1991), these shallow waterways moved across cohesive, organic A-horizons, resting on yellowish B-horizons of dispersible clays.

Such profiles are called duplex soils by most Australian pedologists (Northcote et al. 1975; they include at least some of the “texture-contrast” soils of Paton et al. 1995, 2–5), yet the mottled yellow clay subsoils are sediments, interbedded with lenses of sand or gravel, displaying disconformities and locally dating between about 30,000 and 3000 BP (Gillespie et al. 1992; Wray, Young and Price 1993; Wasson et al. 1998). The surface horizons represent cumulic soils (dark, gray, clay loams); high organic contents may have been enhanced by downslope movement and accumulation on swampy valley floors, densely covered by herbaceous plants (Wasson et al. 1998). Such accumulations of surficial “Black Clay” are widespread in the upper Murrumbidgee drainage and span the last 2,900 years (Eyles 1977a; Gillespie et al. 1992; Wasson et al. 1998). Typically up to 2 m thick, they may continue to accumulate in the undissected segments of some small watersheds.
The dark color and clayey texture of the apparently low-energy Black Clays mask evidence for significant energy flux. In the Wangrah Creek drainage (50 km², 800 m local relief), the Black Clay backfills older gullies to a depth of 6 m and includes scours through and massive lenses of cobbles (Prosser et al. 1994). The Lanyon Creek fan near Tharwa has multiple channel lenses of sand and imbricated gravel, interbedded with clays (Gillespie et al. 1992, 30). The scour pools in Black Clay bottoms apparently were large features (6–19 m wide, 20–150 m long, and several meters deep (Lhotsky 1835, 25–26; Eyles 1977a, b; Prosser 1991), separated by riffles with a head of 50–100 cm, stabilized by reeds. Such undulating channel floors would minimize velocity variations during high discharges and may be inherently unstable. Latent instability is also suggested by two mid-Holocene intervals of gully ing along the length of Wangrah Creek (Prosser, Chappell, and Gillespie 1994).

Did these “pristine” stream systems crash, and, if so, when? Detailed surveyor plans show that Jerrabomberra Creek was intact in 1840, but one tributary had a fresh 7 m-deep gully in 1848, and deep gullies were present in another tributary catchment by 1878; in 1907 the trunk channel was entrenched 3.6 m (Wasson et al. 1998, 294–95). The 1842 survey plan for Wangrah Creek shows a channel of ponds, but by 1910, the major floodplains were gullied (Prosser 1991, 146). Near Michelago, the old tradition suggests that Margarets Creek was gullied at some time between 1861 and 1900, with discontinuous gullies along Michelago and Teatree Creeks; gullying became continuous and extended to low-order tributaries 1920–1960 (Starr 1989). Malong Creek was a chain of ponds in 1835, but it converted to a sandy gully after the 1860s (Hancock 1972, 107–8).

This picture suggests discontinuous gullying by 1848, major gullying after the 1860s, and renewed gullying or entrenching of intermediate-age fills after 1920. But there are significant exceptions. In 1823, Currie (1825, 375) encamped “on the bank of a gully” south of Michelago (Ryries Creek). The Bredbo River in 1823 had “bullrushes growing on the banks” (Currie, 377 and map), but Stewart Ryrie’s pencil sketch of 1840 (prior to significant, local pastoral activity) shows the Bredbo as a large, discontinuous gully above a channel splay at its confluence with Deep Creek and an undercut bank on its eastern side (see Dover 1994, Plate 7.2); this is exactly how it looks today. Even though stream channels functioning as chains of ponds did not necessarily lack steep banks; thus, Burra Creek during the first decades of settlement was 1–2 m deep, compared with 2.8 m today (Eyles 1977c).

There was, then, no simultaneous hydrological “crash” in the upper Murrumbidgee drainage. In some sectors, gullying had begun prior to Anglo-Australian settlement. The chains of ponds notwithstanding, streams around 1830 were in a metastable equilibrium, not a “steady state.” Discontinuous gullying appeared along some streams after the 1860s, when lands were allocated to a larger number of settlers, to partly displace the land-grabbing, wealthy “squatters” of the first wave of pastoral occupancy. With denser occupancy, especially on hillslopes, gullies were initiated along steeper stretches at points of local disturbance, where roads cut across vegetated channels, or when farmers plowed swampy meadows in order to drain them (Starr 1989; Prosser 1991; Lane 1997; Wasson et al. 1998). Sand sags built up directly below discontinuous gullying (Prosser, Chappell, and Gillespie 1994). Then, as the gullies eroded headward and linked with others to form an entrenched trunk channel, a fresh slug of sediment shot out across Black Clay floodplains in the lowermost valleys. Designated as “Post-Settlement Alluvium” (PSA), this consists of 30–200 cm of stratified, yellowish brown, loamy to gravelly fill.

The PSA includes early-twentieth-century trash such as fencing wire, pottery, bones (pig, cattle, and horse), and pollen of *Echium* in the case of Jerrabomberra Creek (Wasson et al. 1998). Fencing wire came into use during the 1880s (Hancock 1972, 122) but was only adopted gradually, while *Echium* became a widespread pest during the 1920s. In Margarets Creek, the PSA was deposited as a channel plug across a log bridge still functioning c. 1915 (Starr 1989, Figure 11). In the larger Tarcutta drainage, nearer Wagga Wagga, the PSA embeds old tires (twentieth century?) in addition to bottles and fencing wire (Page and Carden 1998, 307); even so, Tarcutta Creek retained extensive tracts of pools and swampy meadows into the 1930s or 1940s, a continuous gully system formed only after deliberate swamp destruction and channel straightening. In the Tumut watershed, pools and swamps were drained or filled in after c. 1960, with sediment dislodged by the construction of Forestry Service roads in the upper watershed (Lane 1997). These details suggest that much, if not most, of the PSA dates to the 1900s.

**Some “Post-Settlement Alluvium” Is Much Older.** Puzzled by the many exposures that appeared to conform to the description of PSA, we did eight cross-sections along 13 km of Margarets Creek and recorded a profile at the junction of Ryries and Michelago creeks. What we found is that similar brown loams or clay loams form two distinct overbank units overlapping the top of the Black Clay, as well as one or two inset fills within the channel.
The first overbank loam may have two cumulic soils and, at the mouth of Ryries Creek, has a humate AMS date of 1365 ± 35 years (AA52059), statistically indistinguishable from a date of 1270 ± 30 years (AA56115) for the youngest unit of the Black Clay below. The second overbank loam in some settings has an umbric epipedon and a cambic B-horizon, soil properties quite unlikely to form in a century or two. In proximity of long slopes, this younger overbank unit takes on a more colluvial character or merges with thin alluvial sheets debouching from small valleys, while in channel proximity, there may be lines or lags of cobble gravel, suggesting high-energy spillover from a then higher-lying channel. Magnetic susceptibility readings at the Ryries section indicate a fairly smooth continuity between the Black Clay and the two overbank units. Both overbank deposits suggest that older material in temporary storage was remobilized across the whole floodplain as part of an environmental disequilibrium affecting ground cover, erosion, and deposition. After about 1200 years ago, dark, gray vertisols no longer formed on the floodplain, implying that the related chain of pools were disappearing. Significantly, in the valleys around Michelago, the overbank loams appear off-white when dry and give the impression of great spreads of PSA, in response to historical soil erosion. But that is not so.

The inset fills of Margarets and Ryries creeks are much younger than the overbank loams. They commonly consist of thin-bedded loams and sandy loams, interbedded with gravel and resting on Pleistocene lag cobbles; occasional concentrations of clay peds indicate bank undermining; with ochric epipedons, structure is weak; the surface is normally stabilized by a mat of grass, and branches of European willow are incorporated in the Ryrie's section. Although 1–2.5 m thick and fluctuating in elevation, sediment volume of the inset fills, limited to the channel margins, is small. In one sector another low, gravel inset, with a soil matrix and an ochric epipedon, supports a mature willow. The inset fills mainly represent channel plugs and splays, formed by surges of headward gully erosion that create or extend discontinuous gullies, all within the trunk channel. This is a true post-settlement alluvium, and it was preceded and/or accompanied by 2 to 5 m of channel entrenchment, with the small volume of sediment eroded from the bed, rather than the surrounding slopes. That is the sum of historical alluvial change, greater than on the Liverpool Plains, but very modest in terms of landscape damage, with the exception of a few, straight and narrow gullies on slopes.

A reconstruction of sediment volume eroded, or in temporary storage, in the Jerrabomberra catchment (Wasson et al.) shows that only 5 percent of the total sediment flux was derived from unchanneled slopes; the remainder came from channel entrenchment and bank erosion. Contrary to a widespread belief, pastoral land use did not promote slope erosion (Wasson et al. 1998, 307). Livestock, cultivation, burning, and woodland clearance were components of a more complex process that disrupted the hydrology, with higher peak discharges and channel incision, yet did not destroy the soil mantle over most of these watersheds.

This relatively conservative evaluation of soil erosion in the upper Murrumbidgee drainage can be usefully complemented by a comparative look at the steep, forested coastal catchment of the Bega River, some 150 km SSE of Canberra and which has another well-documented land-use history (Lunney and Leary 1988). A key factor in this case study (Brooks and Brierley 1997; Fryirs and Brierley 1998; also Brierley and Murn 1997) is the abundance of sandy, granite-derived sediment in storage. In 1851, the lower Bega had high, cohesive banks, whereas in 1865, its major tributary, the Wolumla, had a swampy valley floor. By 1896, the lower Bega channel had been transformed to a wide, shallow, and sandy bedload system; thirty years later, the cross-sectional area was three times that of 1851, with sand sheets now spreading across the old floodplain (a bedload wave in the sense of Erskine 1994), and flood-cycle deposits accumulating at a rate of seventeen times greater than during earlier millennia. Unaffected by the first thirty years of cattle grazing, destabilization is attributed to radical forest clearance of the intermediate and lower country 1870–1920, facilitated by direct channel bank erosion due to cattle trails down to water.

Reexamination of the lower Bega and Wolumla valleys put a different light on this interpretation since the river flows directly on bedrock 10 km upstream of Bega. That explains the exceptionally wide expanse of sand further downstream since the channel could only accommodate higher peak discharges by lateral expansion. In point of fact, the ground cover and soil landscape of the basin is in exceptionally good condition. There also are “PSA-like” overbank deposits, midway up Wolumla Creek, but subdivided by a strong cumulic soil, that recall the sequence at Michelago.

The potential impact of heavy precipitation events in both the upper Murrumbidgee and Bega catchments deserves closer attention because high-magnitude floods 1949–1978 remodeled channels of the Hunter River Basin, north of Sydney (Erskine and Warner 1999). Hydrological response to Anglo-Australian land use along the Hunter River (see Perry 1963, chap. 5) was slow, with a first meander cut-off in 1877 and sandy
overbank deposition after 1913, even though extensive bank erosion due to destruction of riparian forests was already apparent by 1870 (Erskine and Warner 1988). A state of high-magnitude and frequency floods after 1949 reduced channel sinuosity, increased the cross-sectional area, and entrained coarse bed load from in-channel sources. The same flood-dominated decades had analogous effects on the adjacent Macdonald River, a drainage minimally impacted by Anglo-Australian land use and one that has retained a 95 percent forest cover (Erskine 1986). The analogs with our observations at Michelago raise the possibility that the post-settlement inset fills of Margarets and Michelago creeks were primarily a response to high magnitude/frequency floods.

Concluding Discussion

The vehemence of Benson and Redpath’s reaction to a sixteen-page pamphlet published by a local conservation board (Ryan, Ryan, and Starr 1995) is partly a matter of environmental politics: the offending authors’ views might set off an antiecological movement (see Benson and Redpath, 318). But minimalizing a very complex transformation serves little purpose. The early Australian graziers and farmers loved their “sunburnt land,” despite its “flood and fire and famine,” learning by trial and error. Aboriginal wisdom was equally predicated on a long and painful trajectory of gaining experience. Australia has more than its share of beautiful environments, and its peoples have more than enough reason to protect it from careless or short-sighted exploitation. A hypercritical judgement of the Anglo-Australian settlement experience should not be required as an incentive for sound ecological behavior, when most of the damage that has been done and continues to happen is a consequence of high-technology intervention.

Australia is, if anything, pragmatic, and wide segments of society at all levels are profoundly concerned, supporting beneficial land management policies in spite of current government indifference. The national environmental movement, Landcare, is decidedly mainstream and enjoys strong support by farmers. Geographers,15 who share the major part of student training in environmental and resource studies with ecologists, send graduates to small towns or regional centers to organize and coordinate conservation efforts. The point is a more nuanced understanding of the present, in light of the past and with an eye on the future.

The present study attempts to show that the environmental history of the Tablelands 1820–1920 was very complex indeed.

Land Cover Change or Stability? The testimony of the first travelers overwhelmingly suggests that the modern vegetation physiognomy is much as it was in 1820. That does not preclude that some areas were subsequently cleared, but have often seen woodland recovery, nor that some genera such as river-oak, cypress pine, apple, or acacia are less common as a result of selective cutting. But in terms of land cover, the net change is surprisingly limited on the Tablelands or in the Ravine Country. There no longer are tracts with six-foot grasses, but ground cover is remarkably good, except in drought years, although sown exotic grasses or legumes have replaced native genera and exotic weeds introduced during the first century. The outcome is imperfect, but these are not degraded landscapes.

Ethnographic and ethnohistorical evidence leaves no doubt that the Aboriginal peoples burned vegetation, particularly grass and woody undergrowth, on a regular if judicious basis. Biologists for the main part concede that this practice kept woodlands open and grassy, affected ecotonal mosaics, and favored fire-tolerant genera of trees. The pollen and charcoal record suggests that in the “dry forests” of southeastern Australia fire became more common during the last 2,500 years (see also Kershaw et al. 2002, Figure 1.7). The magnitude of some of the charcoal peaks also argues for occasional catastrophic fires, possibly ignited in part by lightning. In conjunction with the archaeological evidence (Lourandos 1997, 301–23), this implies a more intensive use of land and resources, or more sedentary behavior, perhaps reflecting denser populations, long-term Aboriginal population growth, or new land use strategies.

Fire, as a deliberate humanizing process, favored the park-like woodlands commented on favorably by the early explorers and settlers. So, in the late 1820s, Sturt (1834, xxviii–xxx) pointed out the general lack of litter and undergrowth, which he attributed to “the ravages of fire,” with the result that a horseman could gallop through the open forests in perfect safety. Later in the century, anonymous artists captured much the same image in popular prints of simple cattle stations showing widely spaced, old-growth trees in a parkland setting. Fire may also have reduced species diversity, given that Cunningham found richer species associations in areas of broken topography (Figure 4B) that would tend to shelter plants from fire.

Gullies vs. Cut-and-Fill Cycles. Many larger and smaller channels in the study area were already deeply entrenched (“gullied”) when first seen by Anglo-Australian explorers, and such gravel-floored channels have considerable antiquity. In several cases, we
demonstrated two or more cut-and-fill cycles during, perhaps, the last 1,200 years. This places a sharper perspective on the scour troughs or massive cobble lenses within the seemingly homogeneous Black Clays of the last three millennia, in the upper Murrumbidgee Basin. Similarly, the multiple cumulic soils and scour troughs recorded in the banks of the Peel River and its minor tributaries represent cut-and-fill cycles of late Holocene, but pre-Contact, age.

That does not dispute that some low-order streams were not entrenched at the time of Contact. Some are still not gullied, however, as on the plains west of Tamworth or in the upper Murrumbidgee. Much ado is made of “chains of ponds,” where thick stands of reeds or sedges tend to modulate and mask the impact of periodic flood surges. They reflect a long history of suspended sediment transfer in low-gradient watersheds, in which the recurrence interval of high-magnitude events was sufficiently long to allow the vegetative mat to recuperate after flood damage. But chains of ponds are currently held up as an ideal type in what is, in fact, a broad spectrum of “reedy streams.” We have seen overgrown reedy streams that periodically undercut their outside meanderbends. We have also seen segments of reedy streams linking discontinuous gullies, some of which are old and “healed,” and others that are more fresh. In each variant, the channel is primarily modeled by high-magnitude events; what differs is the threshold of disequilibrium.

Given the extreme periodicities of Australian climate, a combination of sustained drought and fire stress would impair ground-cover and channel-floor vegetation; if followed by very heavy rains, the resulting peak discharges can tear out the vegetative armoring of part of a channel, destabilizing the stream system by creating a discontinuous gully. Given the violent oscillations of severe drought and excessive rainfall, against the stochastic possibility of major fires, it is fair to say that pre-Contact streams were metastable. Nonetheless, the specific disequilibrium thresholds vary from stream to stream, and climatic events play out differently from one watershed to another. It is not surprising, therefore, that no two alluvial histories are identical. But, as in Europe and North America, stream systems in Australia were more sensitive to periodic environmental stress than are the vegetation patterns recorded in pollen profiles.

The recurrence of cut-and-fill cycles through most of the Holocene, as recorded along the Peel River and the Wangrah drainage, provides a clear and compact proxy record of environmental periodicities and disequilibria, previously only suspected on the basis of a medley of more discrete evidence from a much larger area (Holdaway et al. 2002, Table 2), or the increasing but strongly fluctuating incidence of large elolian sand grains deposited in Blue Lake, Snowy Mountains, during the last several millennia (Stanley and De Dekker 2002). The fact that dark cumulic soils no longer formed after about 1000 to 1200 years ago, resulting in the accumulation of mainly lighter-colored mineral sediments, further suggests an overall negative shift in oscillating or dynamic equilibrium. A simple, event-driven, nonequilibrium model can be used to illustrate the complexity and dynamics of such fluvial systems.

A Nonequilibrium Model for “Gullying”. In rough terms, stream behavior can fluctuate between longer periods of mainly low-energy discharge, with only incremental change (“steady-state equilibrium”), and shorter periods of repeated, high-energy discharges and abrupt change, marked by channelized erosion (entrenchment) and spatially differentiated, channel or overbank sediment accumulation. However these two “states” each have several trajectories, and the channel or floodplain is only one linear mosaic of a more complex watershed, with different processes affecting various changes on the upper and lower slopes.

Multiyear drought perturbations increase the latent instability of an initial “steady” state (above) by seriously impairing land/ground cover and soil stability. Subsequently, heavy rains trigger pulses of fluvial energy that impact the soil landscape, triggering sediment mobilization and transfer; runoff is rapid and peaks early, concentrating as excessive discharge in channels that must accommodate great volumes of water by deepening or widening (“gullying”). Soil-water profiles drop, and channel flow becomes more episodic, leaving an unvegetated stream bed vulnerable to subsequent floods. This disequilibrium (“crash”) is followed at intervals by further flood surges that adjust the channel gradient and banks, and, perhaps, add sediment from storage on the lower slopes to form sediment accumulations (“inset fills”) along the margins of the channel floor.

Over the remainder of the watershed, the return of the rains stimulates regenerative feedbacks, as vegetation and other organic carbon reserves recover with an appropriate time lag. As ground cover improves, rainfall impact on soil is reduced, percolation increases, soil moisture reserves are replenished, and peak discharges reduced. But this enhances the competitive ability of woody shrubs, unless they are curtailed by fire. Finally, the system returns to a “steady” state.

This nonequilibrium model provides a sketch of what actually happens during the course of a “cut-and-fill” cycle in the Tablelands. It has analogs to current
threshold-and-state models for rangeland ecology (see Walker 1993; Dodd 1994; Ludwig and Tongway 1997), but the trigger is a rainfall perturbation rather than overgrazing. Our point is that overgrazing or other ground cover disturbance does not “cause” gullyling, but it can enable it. Overgrazing, like catastrophic fires, enhances the destabilizing role of multiyear droughts. But the trigger remains excessive precipitation.

Although most of the soil erosion in New South Wales takes place in small, upland watersheds (Wasson 1994), the soil removed by sheetwash and rilling is only carried short distances, much of it remaining in storage on lower slopes; the sediment yield carried into impoundments on the larger rivers comes mainly from gullyling and channel erosion (Wasson, Olive, and Rosewell 1996). Our own observations, including a soil toposequence at Michelago, confirm that slope soils are remarkably stable and that geomorphic dynamism is largely limited to the channels. Soil erosion and gullyling, whatever their scale and frequency, do matter. But because of their visibility to the untrained eye, the tendency is to overestimate their significance for land impairment, as Stocking (1996) has already argued in the case of Africa.

The Consequences of Environmental Perturbations for Anglo-Australian Settlement. It remains to consider how the early settlers coped with an environment subject to such extreme periodicities. The best-known landscape painters of the 1860s to 90s, working mainly in the mesic environment around Melbourne and for an elite audience, sought to capture the essence of Australia but, steeped in European tradition, projected a peaceful, arcanian view of still, gliding streams or luminous eucalypts. The reality was a great deal more harsh.

Table 2 suggests that, at least in the Goulburn area, the first decades of grazing by Anglo-Australian livestock did not, despite a long string of dry years, punctuated by severe droughts (1826–1828, 1838–1839, 1849–1850), degrade native pastures sufficiently to favor the establishment of nonnative weeds. But by the 1860s, the interior of New South Wales was lurching to an environmental crisis. The number of sheep was increasing exponentially, fencing had begun to impede transhumant drovers from moving their animals to submontane drought pastures (or even to markets), periodic drought ravaged overutilized pastures, and the new “homestead” legislation attracted increasing numbers of small farmers to try their luck on very small lots (e.g., O. B. Williams 1962; Heathcote 1965; Dovers 1994). These pressures continued to build as the number of sheep in New South Wales increased from 6.2 million in 1862 to 55.5 million in 1892. Perversely, long runs of wet years (1859–1864, 1870–1880, 1889–1895, see Foley 1957) stimulated livestock expansion, despite the intervening dry years (1865–1869, 1880–1886). The bubble burst with the devastating droughts that began in 1896 and recurred across the next twenty years. By 1902, the number of sheep in New South Wales had been involuntarily reduced by 52 percent, truly a socioeconomic disaster. Yet evaluations by professionals and government commissions continued to resist the idea that built-in climatic extremes were involved, blaming the events on human actions (Heathcote 1965, 28–29, 53). A positive outcome of the tragedy was a new public attention, at all levels, to environmental issues.

Heathcote (1965, 57) makes the point that recovery of the sheep industry, back to 51.6 million head by 1910 (Burlin 1962, Table 1), implies that there was no permanent ecological deterioration “in the sense of a steady decline of capacity.” That does not, however, take into account biotic substitutions and the increase of nonnative ground cover to replace native pasture grasses (see Boyd, Stubbs, and Averrill 1999). At Wet Lagoon it appears that the ground cover was in a state of rapid flux by perhaps the 1870s, with abundant evidence for pasture deterioration and possibly a period of fire suppression.

An extreme case near Wannon, southwestern Victoria, illustrates the association between gullyling, drought, fire, sodic soils, and rampant overstocking. Environmental change began with a severe frost in 1844 that killed the local acacias, subsequently burnt over (Robertson 1897 [1853]). Then, the native pasture began to deteriorate, leading to soil slumping; about 1850, the marshy, grassy valley floors began to die off as a result of increasingly saline spring flow, resulting in the formation of gullies two or three meters deep by 1853, with collapse of riparian trees. “Saline spring flow” indicates unusually sodic, duplex soils, which is consonant with widespread piping (“tunnel erosion”) on duplex soils in Victoria (unlike the Tablelands) and the common association of piping and gullyling (Boucher and Powell 1994). Saline seepage implies a rigorous drought with limited freshwater dilution, presumably the major drought of 1849–150, followed by the almost inevitable rainy years. Robertson (1897) reports that his flocks had increased from 1,000 sheep to between 8,000 and 10,000 head during the decade of the 1840s, on a run of 4780 ha—a very high stocking rate of only 1.7–2.1 ha per animal (compared with 5.9 ha per sheep in the Central Tablelands 1891). As stubborn as Robertson was, he still resisted resowing his ruined land with leguminous ground cover in 1853. This is a worst-case scenario that has
heuristic value in showing how extreme overgrazing can lower the equilibrium threshold.

Anglo-Australian land impairment was not a quasi-instantaneous process, but one of complex change, compounded by an increasing number of "positive" feedbacks as patterns of land use continued to change. By 1890, rampant overstocking in New South Wales had taken its toll, but that was already compounded by an equally experimental expansion of agriculture. The result was a fundamental reevaluation of land use strategies— and an accompanying dislocation of rural folk—much as on the American Great Plains following the Dust Bowl disaster of the 1930s (see Worster 1979). In this context, livestock grazing during the early stages of settlement expansion was not a primary factor in change, but only the first of several. The big picture today is a cumulative one of two centuries of transition, culminating in the full application of industrial technology. Rivers have been rerouted, floodplains overirrigated, semiarid shrublands torn up, and coastal forests converted to wood chips. Yet amid such subregional threats to the environment, that process has left large areas such as the Tablelands of New South Wales as ecologically sound as any part of the United States, putting the lie to the apocalyptic model of colonial environmental history (MacKenzie 1997). In part, this reflects the cumulative experience and environmental attitudes of the descendants of the first settlers to cross the Blue Mountains.

The landscape of southeastern Australia is unintelligible without reference to its inherent climatic periodicities, of devastating droughts and excessive rains. This confused the first generations of livestock graziers, who raised their hopes during five or ten years of good rains and hunkered down when years of declining rainfall or severe drought followed. The potential productivity of the land rose or fell by wide margins, as the capacity of natural resources to support livestock or cultivation oscillated between what were different equilibrium states. The indigenous biota had evolved with such periodic but unpredictable shifts, their resilience tempered by the repetitive stress that promotes diversity and renewal processes (Scheffer et al. 2001). The environmental history of the Tablelands is therefore constructed by the resulting, dynamic interplay of successive Aboriginal and Anglo-Australian cultural systems with the natural environment.

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Notes

1. Although construction of the environmental debate in the postcolonial anglophone world has common threads (Lowenthal 1997; Dunlap 1999), we would attribute a greater role to the background and perceptiveness of the initial intellectual and political leadership that came to the different colonies. In Australia, the environmental role of its Aboriginal inhabitants has also played a critical role in (re)defining that debate (Head 2000).

2. An extended project in Central Mexico uses physical and biotic information included in land-grant documents to reconstruct the environment on the eve of first pastoral settlement (Butzer and Butzer 1993, 1997). Complementary field and archival work show that the environment changed little during the next two or three centuries, although disturbance was already apparent near indigenous settlements at the time of European contact. Spanish settlers in Mexico practiced traditional, transhumant pastoralism, an activity long tested ecologically in the Mediterranean world (Butzer and Butzer 1995; Butzer 1988, 1996).

3. We use "Anglo-Australian" instead of "Euro-Australian," given that the Australian territories of the nineteenth century were almost exclusively anglophone, despite the derivation of the colonists from different parts of the British Isles.

4. The version of Cunningham published by Lee is accurate and mainly complete, as verified from microfilms of the originals, found in State Records New South Wales, Kingswood (in SZ 7–15, reels 46 and 47, and SZ 20, reel 2744). Complementary references are given as SR, adding particulars.

5. See also the 1815 painting by John Lewin, reproduced in Benson and Redpath (1997, 284).

6. For modern residual woodlands on Figures 2 and 4B, see the rendition of medium or dense vegetation in Australia 1:100,000 Topographic Survey, Series R651, sheets Dubbo (8633, 1982); Wellington (8632, 1982); Euchareena (8732, 1976); Mudgee (8832, 1977); Molong (8631, 1982); Orange (8731, 1977); Bathurst (8831, 1977); Cowra (8630, 1982); Blayney (8730, 1981); and Oberon (8830, 1982). On the 1:50,000 maps, the demarcation of woodland
is identical, but for the incomplete 1:25,000 set, medium-dense woodland is significantly expanded in the form of "islands" within "scattered" vegetation, i.e., open woodlands with 10–30 percent canopy.

7. What Cunningham means by "brush" is apparent from the associations he uses: brush and underbrush, or dwarf timber/diminutive trees and brushy, i.e., low trees with a relatively dense understorey. Scrub appears to mean low trees in rocky habitats. Several tracts of scrubby woodland were noted in the Central Tablelands by Cunningham in 1817, at least some of which lack an edaphic explanation, as did the "diminutive" trees of the Copperbannah bushland. Some such instances may represent secondary scrub following intense pre-Contact burns. It also is suggestive that the pockets of rich floras noted in the early 1800s were found in topographically secluded areas less likely to have been swept by fire.

8. For modern residual woodland and forest shown on Figures 5 and 6B, see Australia: 1:100,000 Topographic Survey, Series R 651, sheets Boggabri (8936, 1969); Manilla (9036, 1969); Tambor Springs (8835, 1970); Curlew (8935, 1969); Tamworth (9035, 1975); Coolah (8834, 1973); Blackville (8934, 1970); and Murrurundi (9034, 1970). For geological coverage, see New South Wales 1:250,000 Geological Survey sheets Narrabri (SH 55–12, 1971), Gilgandra (SH 55–16, 1968), Manilla (SH 56–9, 1973), and Tamworth (SH 56–13, 1971).

9. In the monsoonal climates of northern Australia, the least desirable time for "controlled" burning is late in the dry season (Southern hemisphere spring); in southeastern Australia, however, fuel moisture content is lowest in late summer and autumn. The traditional Aboriginal burning peak early in the dry season curtailed the destructive spread of late fires by the lack of continuity of fuel (Braithwaite 1991).

10. An example of the latter was reported from the Blue Mountains in October 1839, after the Aboriginal inhabitants had already been displaced. "The trees, huge masses of charcoal to all appearance, had no branches till very near the summit, and those bore only a few scattered tufts of rusty leaves" (Meredith 1846, 70). But Aboriginal fires around Sydney in the early 1790s had a similar impact: "two thirds of trees in the wood were very much scorched by fire, some were burnt quite black to the top" (S. Clark and McLaughlin 1986, 103). European settlement probably did not significantly change fire regimes in the Blue Mountains (C. Cunningham 1984). For example, an account of February 1824 from the Bathurst district seems to imply continued burning [by Aborigines?] to clear pastures: "It is by burning ... that the forests' undergradhsm is cleared to convert them into pastures, and we often saw the flames rising on different points of the surrounding ... country" (French Journal of Rene Lesson, published by Havard and Havard 1836, 284–85). The best contemporary painting is that of John Lyceert (see Hoorn 1993), showing Aborigines using fire to hunt kangaroos, c. 1820. The fire is burning into the wind in a tract of close woodland.

11. Ideally, this discussion should include the question of changing ground cover across some two centuries (e.g., Norton 1972), but the travel reports on the complex associations of grasses (see Wheeler, Jacobs, and Norton 1982; Kahn and Heard 1997) at the time of Contact are spotty or their taxonomy confusing. Similarly, palynology cannot distinguish the many different kinds of grasses. Residual modern distributions suggest that Themeda australis (T. triandra, or kangaroo grass), Poa poiformis (blue tussock grass), and Spha arisglis (plains grass) once were dominant in the southern parts of the Tablelands; as a result of overgrazing, it is thought that these were replaced by two species of Danthonia (wallaby grass); continuing grazing pressures led to the displacement of these perennials by mainly nonnative annuals and legumes (Medicago and Trifolium), and, ultimately, with invasion by weeds such as Ranex and Echium (Plumb 1982, 8; Mott and Groves 1994). Kangaroo grass is fire sensitive whereas Danthonia is not (Mott and Groves, 1994, but, ironically, the unaltered pastures had a low carrying capacity, whereas the intrusive legumes increased productivity (Plumb 1982). Since Themeda is a C4 grass and Danthonia has a C3 photosynthetic pathway, carbon isotopes of successive layers of humus in deep soil profiles should help determine whether the Themeda association was or was not once dominant.

12. The accumulating body of experimental data underscores that grazing on native or sown grass is among the least destructive forms of Anglo-Australian land use. The greatest destruction of all is set in train by ground-cover disturbance in the wake of logging activities (Neil and Fogarty 1991; Saynor et al. 1994; Loughran and Elliott 1996; Erskine and Saynor 1996; also R. Clark 1986).

13. A map reproduced in Commonwealth of Australia (1996, 6–28) purports to show very high gully densities in the Central Tablelands. We are puzzled by this depiction, which, at least in some sectors, seems to confuse gully density with drainage density, suggesting air photo or satellite interpretation without ground truthing. Perhaps the most spectacular gully system in southeastern Australia, at Bungonia, near Goulburn, was already seen and commented on as "ramified" by Allan Cunningham 27 April 1842 (SR: SZ, 1746, original p. 123).

14. After Dorothy Mackellar’s evocative poem My Country, published 1908 (see Mackellar 1990, 9). Despite a stifling, upper-class home environment, Mackellar traveled regularly to her family’s rural estates.

15. The great majority of the palynological and geomorphologic studies related to environmental history are by geographers, often working in university units that are becoming multidisciplinary and that proclaim their goals under labels such as "resource management and environmental studies," "human and environmental studies," or simply "environment." The Australian National University counterpart now offers a course in organizational sociology. Historical geographers have also placed strong emphasis on environmental themes. Today, almost every issue of Australia’s two geography journals includes an article or two on different facets of ecological/environmental history.

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