CHAPTER 1

THE NATURE OF THIS STUDY

INTRODUCTION

This thesis focuses on an extensive area of callitris pine and eucalypt forest and woodland known as "The Pilliga Scrub" which lies between Coonabarabran and Narrabri in north-western New South Wales. The region is relatively little known scientifically but the recent history of the forest has been the subject of considerable controversy as to whether or not there has been extensive environmental change from grasslands to the present scrub as a result of European land management since the late nineteenth century. The authentication of this change is only documented at a non-scientific level and in a major book by Rolls (1981). The story of environmental change is however, widely accepted and underpins the present State Forests' management philosophy. If State Forests (formerly Forestry Commission of New South Wales) are to adequately manage the area into the next century they require a sound understanding of the present forest environment and its recent history. The primary objective of this thesis is to make a contribution to that understanding.

The management of ecosystems requires knowledge from studies of present day patterns and current ecological and physical processes together with investigations of pattern and processes of the past. With this knowledge it should be possible to detect underlying trends as well as to predict rates, directions and magnitudes of change in complex and dynamic systems (Clark 1990). In short, an understanding of environmental history is integral to present and future land management decisions.

THE NATURE OF POST-EUROPEAN ENVIRONMENTAL CHANGES

The arrival of the Europeans in Australia in the late eighteenth century saw the establishment of new land uses such as the extensive grazing of native pastures by domestic herbivores and intensive agriculture. With these new land uses came the far-reaching consequences of land degradation. The Aborigines were displaced, and grazing, cultivation, mining and urban development modified, disrupted or even destroyed ecosystems. European settlement introduced new plants and animals, caused devegetation, soil changes, plant and animal extinctions and population changes to the original organisms as well as a greatly altering the frequency and intensity of bushfires (Adamson & Fox 1982).

The history and effects of this settlement upon the Australian environment have been extensively reviewed by many authors including; Hamilton 1892; Benbow 1901; Anderson 1941; Harrington *et al* 1979; Doing 1981; Rolls, 1981; Adamson & Fox 1982; Benson 1987; Pickard 1990, 1991; and Denny 1992. Land degradation is now widespread across the continent and is particularly evident in the semi-arid areas of marginal agriculture where it can be seen in the extent of wind and water erosion, depletion and simplification of native pastures, exotic weed invasion, expansion of woody shrubs, loss of tree cover, breakdown in soil structure, soil compaction, soil salinity and induced soil acidity. All of these types of land degradation have been quantified to some extent in New South Wales by Graham *et al* (1988).

The present and future conservation and management of Australia's natural vegetation therefore requires a sound knowledge of how the vegetation has changed through space and time as well as understanding the reasons for these changes (Fox & Recher 1986). A particular example and the subject of this research is the present vegetation pattern within the central part of the Pilliga State Forests.

THE PILLIGA FORESTS

Location

The State Forests of the Pilliga cover an area of 390,000 ha and constitute the largest single mass of dedicated native forest remaining in New South Wales (Fig. 1-1). The forests are located within the North Western Slopes and North Western Plains phytogeographical regions (as defined by Moore 1973, see Fig. 2-2) on the foothills and plains which extend north from the Warrumbungle Ranges and west from the Nandewar Ranges, and are bounded in the north by the Namoi River valley.

The forest area lies at the boundary of the sub-humid eastern region and the semi-arid lowlands of the west (Gentilli 1972). This geographical location places the forests in a marginal area between the temperate forests of the east and the semi-arid woodlands of the west, meaning that this area of the state has probably been particularly sensitive to climatic shifts over time.

The vegetation today comprises a mosaic of cypress pine, box and ironbark open forests and woodlands and broom plains. Most of the region has remained uncleared in at least this century, due to the low agricultural value of the soils and to the regeneration ability of the pine and other woody vegetation under particular environmental conditions.

For many years the area has been referred to as the Pilliga

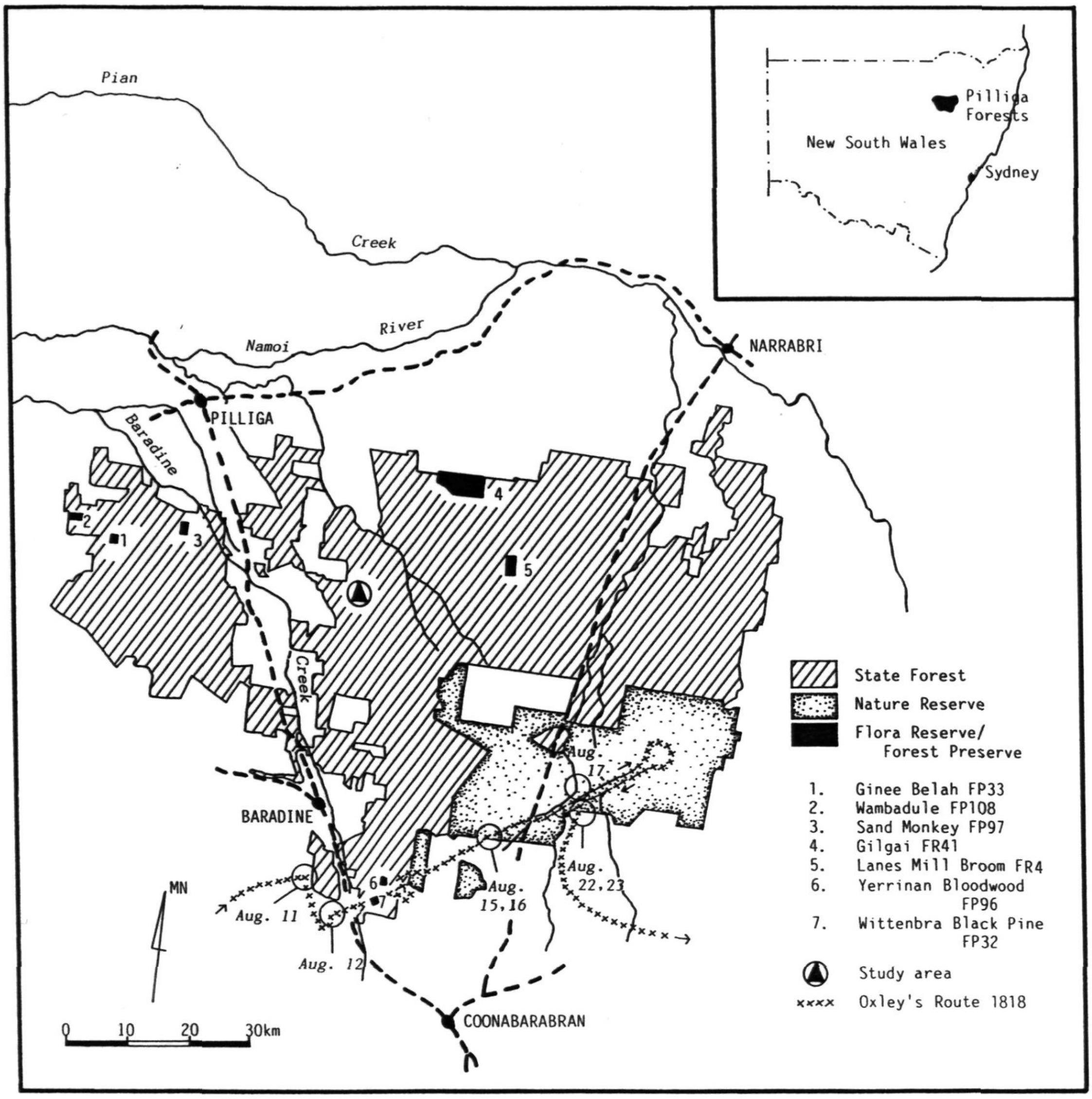

Figure 1-1. Location of the Pilliga State Forests, New South Wales, showing location of the study area, conservation reserves, and the approximate route of Oxley's 1818 expedition.

Scrub, and as Fry (1909) and Jensen (1912) comment, the forest area comprises many kinds of country, but none of which actually constitutes scrub in the sense used in the northern rivers area of New South Wales. In the northern rivers area, the vegetation was, and still is in part, dominated by temperate rainforests and wet sclerophlyll forests. The earliest reference to the use of the word 'scrub' for the Pilliga can be found in Oxley (1820:p. 268), where he writes "The whole was a mere scrub covered with dwarf ironbarks, apple trees, and small gums;...". The term was in general use during the 1880s when Parliamentary reports concerning the spread of pine and other scrubs (Anon. 1881; Anon. 1883) were made. State Forests (Forestry Commission 1987) report that the Pilliga forests represent failed grazing settlements, because of a number of factors including changes in fire regimes after settlement, rural recession and a series of unfavourable years which led to the regeneration of pine and other woody species, which was referred to as 'scrub'.

The original area of the Pilliga Scrub is unclear but a number of estimates have been put forward. Fry (1909) and Vincent (circa 1939) give a figure of 1.8 million acres (728,450 hectares - ha). Jensen (1912) gives 2 million acres (809,388 ha) whilst de Beuzeville (1915a) believed it to cover 2.5 million acres (1,011,736 ha). Whatever the case may be, the existing forests of the Pilliga Scrub now represent about half of the original forest cover.

Regional geology and geomorphology

The surface geology of the region comprises upper Jurassic Pilliga Sandstone. This non-marine quartz-lithic sandstone is associated with conglomerate, siltstone and occasional shale beds. The sandstone sometimes displays crossbedding, indicative of its fluviatile origin. The strata have a shallow north-west regional dip and form part of the intake aquifers which feed the Coonamble Embayment - Surat Section of the Great Artesian Basin (Brown, Campbell & Crook 1977).

To the south, the Warrumbungle Ranges rise to over 1,000 m above sea level (Mt Wambelaong 1,206 m) and comprise basalts, trachyte and pyroclastic volcanic remnants from volcanoes active in the mid-Miocene some 16.6 - 13.5 Million years ago (K/Ar) (McDougall *et al* 1974).

To the east outcropping early Jurassic Garrawilla Volcanics comprising dolerite and basalt sills and flows are present. These basalts are interbedded with the Jurassic sediments (Geological Survey of New South Wales 1968).

Outcropping Pilliga Sandstone is common in the southern and eastern sections of the forests whilst to the north and northwest the sandstone beds are covered by extensive Quaternary sediments derived from the sandstone and deposited by dendritic streams draining north and west. The streams of the region are wide and sand-bedded (Riley & Taylor 1978). The sediments become finer towards the Namoi River valley where extensive clearing for agriculture has occurred.

Mitchell *et al* (1982) recognised one land system for the area which was subdivided into two sub-systems - the Pilliga Uplands and the Pilliga Alluvials. In the Pilliga Uplands three units were identified; the Bugaldie, Cubbo and Broom Plain Units, and three other units were defined in the Pilliga Alluvials; the Gwabegar, Belah Forest and Brigalow Scrub Units. This landscape classification provides a useful framework for an appreciation of the region and a summary of the descriptive data for each of these units is given in Chapter 3.

Regional Soils

Soils of the region generally belong to the Great Soil Groups of solodics (members of the Ultisol soil order - Soil Survey Staff 1975). That is, the soil profiles show a marked texture contrast (duplex in the sense of Northcote 1979), with fine sandy loam topsoils over harsh clay subsoils. Soils derived from the Pilliga Sandstone are highly siliceous and are characterised by a dense growth of trees and shrubs with high species diversity and species composition similar to that occurring on Hawkesbury Sandstone in the Sydney district (Kenny 1964). Soil fertility is generally low except in the limited areas of basaltic rocks. More details of the soils in the study area are given in Chapter 3.

European settlement and land use

The southern edge of the Pilliga Scrub, part of which is now included in the Pilliga Nature Reserve, was explored by John Oxley in 1818 (Oxley 1820) (Fig. 1-1). Subsequently the expeditions of Mitchell (1839) and Sturt (1833) covered similar areas to the north of the study region, and in the period of the late 1830s to the 1840s a large proportion of the area, particularly along main rivers and creeks where water was reliable, was settled by squatters and graziers from the Hunter Valley, Wallerawang and Mudgee districts (Rolls 1981). Cattle grazing predominated from this time to about the mid-1870s when cattle were replaced by sheep which became the dominant domesticated animal (Vincent circa 1939).

By the late 1880s many of the runs taken up in the 1840s were abandoned, and over the following 20 to 30 years, the area was declared timber reserves. The first reserve within the present Pilliga forests, called 'Robertson', was declared in 1877 and comprised sections of 'Coghill' and 'Molly' Runs (Rolls 1981, p. 183) (Fig. 1-2). The year 1877 also saw the appointment of the first Forest Ranger for the area, and in the following year a minimum cutting diameter of 60 cm (2 feet) was introduced for cypress pine (Forestry Commission 1987). These limits were set in order to prevent unrestricted timber exploitation.

Rolls (1981) reports that the first steam sawmill was located in Narrabri in 1875, however, up to the late 1890s, timber for local use was sawn by hand in sawpits.

Present day activities within the forests include cypress pine and ironbark sawlog production, ironbark sleeper cutting, brushcutting for urban fencing, fence post production, gravel extraction, honey production, agistment grazing of cattle and horses, tourism, recreation, research and education. The most important economic activity is timber production, dominantly cypress pine sawlogs and ironbark sleepers.

Figures for past sawlog and sleeper yields have been documented in the Managemant Plan for the Pilliga Management Area (Forestry Commission 1987). Current timber production is 45,000 m^3 of cypress pine sawlogs per year, 6,000 m^3 of ironbark sawlogs per year, and 12,000 sleepers for the State Rail Authority of New South Wales (Carey pers. comm. 1995).

Because of its size and great floral diversity the Pilliga Scrub has a high conservation value for flora and fauna and provides a wildlife corridor linking the Nandewar Ranges (Mt Kaputar National Park) in the north-east with the Warrumbungle National Park and associated forested lands to the south.

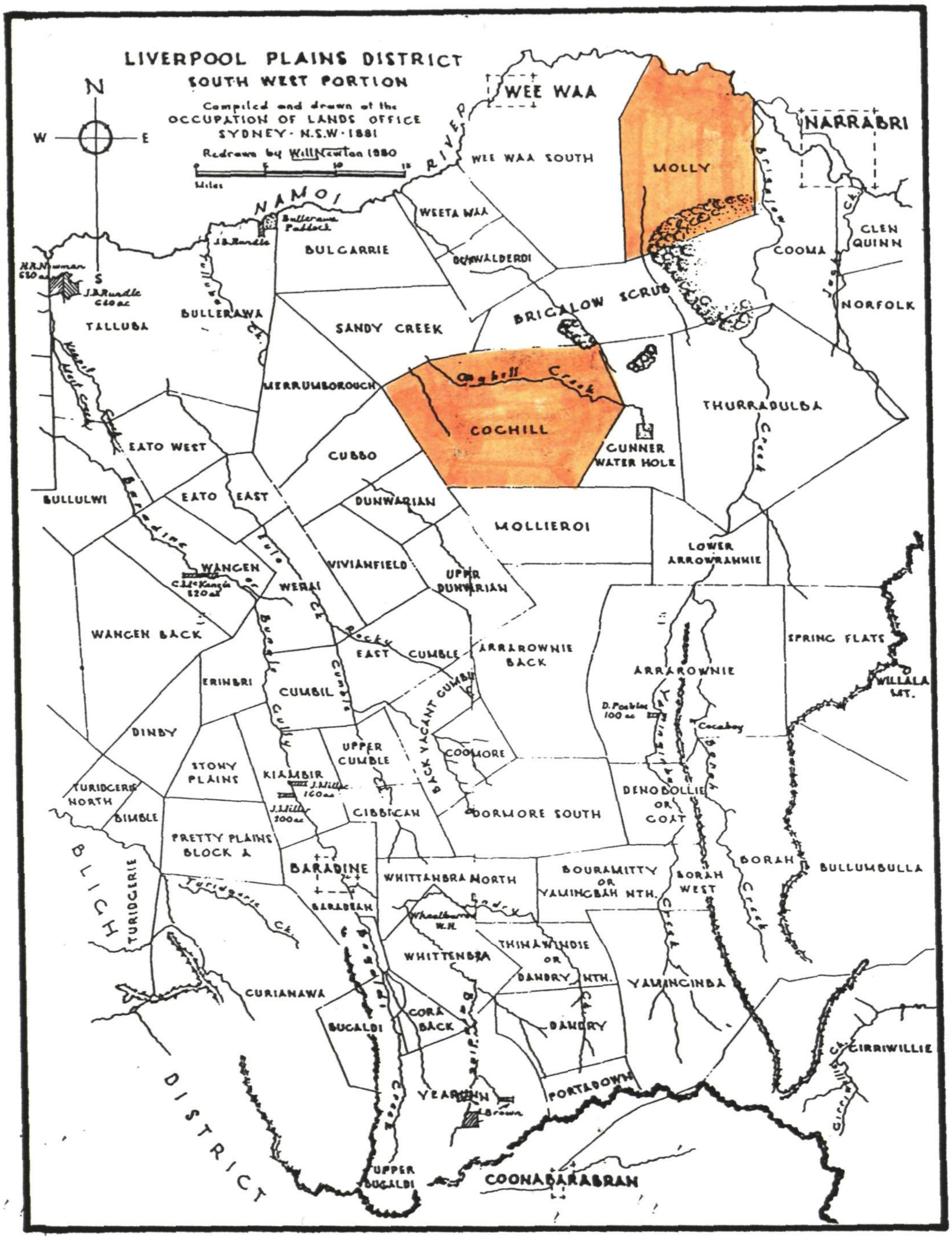

Figure 1-2. 'Coghill' and 'Molly' Runs, sections of each formed part of the first forest reserve established in 1877 (Rolls 1981). (Map reproduced from Rolls 1981).

Approximately 9.4% of the Pilliga Scrub (based on an original size of 809,388 ha or 2 million acres) is reserved within the Pilliga Nature Reserve (75,910 ha) administered by the National Parks and Wildlife Service of New South Wales, with an additional 3,395 ha held in five Forest Preserves and two Flora Reserves (Fig. 1-1) administered by State Forests. These conservation areas have mainly been selected on the basis of their low timber values and/or unusual soil or vegetation conditions and cannot be regarded as representative of the Pilliga Scrub as a whole. The reserves were established under the National Parks and Wildlife Act (1974) or the Forestry Act (1916) and the Forestry (Amendment) Act (1935) of New South Wales which created the title of National Forest and can only be revoked by an Act of Parliament.

Introduced flora and fauna

Like the rest of Australia, the Pilliga Scrub has not been immune to the introduction of exotic flora and fauna. Rabbits, introduced during the late 1890s have been the most serious animal introduction because of their rapid population growth and heavy impact on native vegetation. By the 1920s rabbits were in plague proportions and destroyed most small cypress regeneration and other tree and shrub species (Forestry Commission 1987). Attempts to control them by fencing and poisoning have been haphazard and largely ineffective and only the introduction of the *Myxomatosis* virus during the 1950s has had any real effect on populations.

Other feral animals found in the forest include; horses, goats, pigs, foxes and cats all of which have probably been significant in changing vegetation and affecting the habitat values of ground dwelling native animals.

An apiculture industry has operated within the forests for more than 50 years, and there are currently 600 bee sites regularly rented (Forestry Commission 1987). The effect of the Italian honey bee on the forest flora and fauna is largely unknown, but the work of Pike & Balzer (1985) indicate that they may compete with native pollinators and could have an impact on the distribution and abundance of some plant species.

Some introduced plant species present noxious weed problems, namely; *Opuntia stricta*, Prickly Pear and *Opuntia aurantiaca*, Tiger Pear. Both these species are now biologically controlled by the Cactoblastis and Cochineal insects respectively, although it has been reported that Cochineal may not be as effective as first thought (Hosking no date). Cochineal can control Tiger Pear when environmental conditions favour an increase in its population, that is, temperatures close to 30^{0}C and low humidity. Hot wet conditions appear to be unfavourable.

Other weed species include *Xanthium* sp., Cockleburr, *Sclerolaena* spp., Copperburrs, and *Parthenium hysterophorus*, Parthenium weed, which are thought to have been introduced along roadsides on the Newell Highway and into Pilliga East State Forest.

According to State Forests (Forestry Commission 1987) introduced plant species do not constitute a threat to the silvicultural well-being of the forest.

THE FOREST TODAY - CURRENT PERCEPTIONS OF VEGETATION CHANGE SINCE WHITE SETTLEMENT

Like other settled areas of Australia, the present forest country of the Pilliga Scrub has been subject to the effects of settlement from as early as the 1830s and 1840s. The history of settlement can be traced from anecdotal evidence and historical records, and has been described by Vincent (circa 1939). More recently, the origin of the structure of the present forest country has been described by Rolls (1981) in his book A Million Wild Acres. As Pickard (1982) comments, Rolls (1981) has used a combination of primary source documents, folk history from descendents living within the district and social history to piece together a narrative version of events in the district since settlement. This work has been widely acclaimed as an Australian classic (Murray 1984) and has clearly been extensively researched and well written but unfortunately it is often difficult or even impossible to confirm some of the historic and factual claims made in the text because the referencing is inadequate.

One of Rolls' key themes is that the present forests of the Pilliga are an artefact of 150 years of European land management. This general model of environmental change has become a widely recognized 'matter of fact' in the mind of the general public and has been uncritically accepted as a self evident truth in many subsequent publications including the regional management plans of State Forests (see for example; Forestry Commission 1987; Chiswell 1982; Cooney 1986; Austin & Williams 1988).

A critical appraisal of this model and more particularly the use of it by others is an important part of this thesis and the model is therefore presented here in some detail. Mitchell (1991) and Norris *et al* (1991) have challenged the uncritical acceptance of parts of the model with particular reference to the central region of the forests east of Baradine Creek.

Prior to European settlement according to Rolls (1981), the present forest country comprised a mosaic of open woodland and grassy plains that was maintained in this condition through regular burning by the Aborigines. Rolls (1981) makes numerous references to regular fires lit by the Aboriginal inhabitants (Rolls 1981: p248), even going as far as commenting on Oxley's (1820) description of a forest of small burnt ironbarks (Oxley 1820: p263), stating that this fire was also lit by the Aborigines (Rolls 1981: 7). Rolls (1981) suggests that tree density was an average of eight mature cypress pine and ironbark trees to the hectare (Rolls 1981: p1; p245). No source is acknowledged for this precise statement and extensive research for this thesis has been unable find any documentary evidence to confirm it.

The role of fire, and predation by rufous rat kangaroos are alleged to be factors controlling cypress pine regeneration (Rolls 1981). In Chapter 1: p7 the first reference to rufous rat kangaroos is presented, although the original source (Oxley 1820) described them only as 'kangaroo rats'. It is possible that the rat kangaroo Oxley saw could have been one of three species, namely the Rufous Bettong (*Aepyprymnus rufescens*), the Brush-tailed Bettong (*Bettongia penicillata*), or the Eastern Bettong (*Bettongia gaimardi*). The distribution of all three species includes the Pilliga but the latter two are now much reduced in their natural range due to agricultural clearing and the impact of gazing animals (Strahan 1983).

Settlement followed exploration, and was more or less complete by the late 1830-1840s, at least along the major rivers and creeks.

Initially, the early settlers and graziers excluded fire and maintained heavy stocking levels, particularly from the mid-1840s to the early 1870s (Rolls 1981: p182). Palatable grasses were greatly reduced in number due to grazing pressure and trampling by cloven-hoofed stock encouraging the growth of unpalatable native species including *Stipa* and *Aristida* (Rolls 1981: p28-29). The rufous rat-kangaroo had been replaced by cattle and sheep so that acacia scrub and cypress pine increased in number (Rolls 1981: p182). Trampling affected the soil surface conditions, changing it from a spongy soil full of humus to a hard compacted bare earth (Rolls 1981: p28; p129).

During the period between 1879 and 1887 there was above average rainfall enabling regrowth of forest species (Rolls 1981: p205). Following this, stocking rates were greatly reduced for economic reasons and the re-introduction of fire by the graziers to try and encourage favourable grass growth had the effect of favouring extensive pine regeneration as a result of years of stored pine seed (Rolls 1981: p184) in the soil. Dense regrowth led to the eventual abandonment of many of the grazing runs. No similar pine regeneration event is believed to have occurred until after the wet year of 1950, the fire of 1951 and the reduction of rabbit numbers by *Myxomatosis*. As a result, Rolls argues, the forests have existed in their present condition only since the 1950s (Rolls 1981: p205).

THESIS AIMS

The original direction of this research was to investigate the soils-vegetation relationships in the Pilliga forests. However, as the forests cover a large area, some 3,900 km^2, and having a number of diverse plant communities, it was decided to narrow this broad investigation and concentrate on one particular area.

The central part of the forests, east of Baradine Creek was selected as this area has long been regarded as poor and scrubby (Forestry Commission 1987). From a vegetation and soils point of view this area is of interest because it is here that the Cubbo and Gwabegar sub-units of the Pilliga Land System merge. It is a boundary zone between the low hills with sandstone outcrops and the edge of the alluvial sandplain that stretches north and west towards the black soil floodplains of the Namoi River, and it contains examples of all the main vegetation communities of the larger area.

The purpose of this thesis then is to develop a better understanding of this environment, to establish an ecological history in the short, medium and long term for the central parts of the Pilliga Scrub in order to put current processes into an historical perspective and to determine the validity of published and widely held perceptions about vegetation change in this part of the forest.

The specific aims of this thesis are as follows:

1. To improve understanding of the relationship between vegetation, soil, topography, climate and fire in the central part of the forest.
2. To research primary source material in order to test or confirm the model of recent vegetation change presented by Rolls (1981).
3. To use the data collected in points 1 and 2 to evaluate the published perceptions and significance of historical vegetation change.
4. To combine the information from the above points to evaluate and guide present and future forest management within the central part of the forest.

A particular study area (Fig. 1-1) within the central section of the forests was chosen because it had a number of vegetation, soil and topographical environments in close proximity all of which are otherwise widely distributed through the forest. The study area is located along Dunwerian Road and Pine Road within Pilliga East State Forest (SF 266, dedicated December 1916) and Euligal State Forest (SF 810, dedicated March 1927).

The hypothesis

The vegetation of the study area displays striking contrasts in physiognomy and species composition resulting in sharp boundaries between vegetation communities (Plate 1-1). This suggests that a number of edaphic conditions may be influencing vegetation distribution.

It has long been recognised that vegetation, soil and climate are closely related and numerous publications dealing with vegetation communities and their distribution usually include details regarding associated soil types (Zimmer 1946; Beadle 1948; Florence 1964; Curtis 1975; Cunningham *et al* 1981, Eldridge 1988).

Given the uniformity of climate in the Pilliga, it could be expected that the main determinant of vegetation structure and floristics will be the nature of the substrate together with topographic and drainage conditions. Vegetation patterns could be linked to variations in soil moisture which is controlled by subtle topographic soil differences, particularly as the Pilliga area receives low rainfall and surface flow events are infrequent.

This expectation provided a testable hypothesis for the study. It is suggested that vegetation patterns are closely linked to

Plate 1-1. Aerial view of a broom plain near the study area illustrating abrupt boundaries between communities. Approximate width of the plain is 150m.

variations in soil moisture which in turn will be controlled by subtle topographic and soil differences. Further, other important factors to consider are soil erosion, the possible effects of soil salinity, the abundance, distribution and activity of soil fauna, and the effects of fire.

Methodology

A number of approaches were required to address the aims and hypothesis for this thesis, and these are outlined in the following.

A review of forest pre-history was necessary in order to put the present Pilliga Scrub vegetation into perspective. Tertiary and Quaternary studies for eastern Australia help to shed light upon the development of the forest vegetation over this time span, leading up to European settlement of the region. The long term instrumental climatic record, the *El Nino* - Southern Oscillation phenomenon and present climate of the forest area are also important factors in the understanding of forest dynamics, especially for the regeneration of *Callitris glaucophylla* (White Cypress Pine), the major economic timber for the region. Climate and fire histories were determined as reliably as existing records and field evidence would allow.

The effects of Aboriginal occupation needed to be considered in terms of changes to forest structure resulting from their hunting practices, in particular, their use of 'fire stick farming'. Further, the consequences of fire, both naturally occurring and human induced (hazard reduction burning for forest management, and deliberate or accidental fires) also has significant impacts on the vegetation, for example the regeneration of fire sensitive species which include *Callitris glaucophylla*.

A review of previous studies including land systems, soil and vegetation provided base information which could be drawn upon for this thesis, complimenting field work investigating soils and vegetation of the study area.

Knowledge of the forest's settlement history, land use and management was developed as far as possible from primary source documents such as maps and other archival data pertaining to the region's early settlement. There are a number of published works highlightling the importance of using such documents for scientific studies because of the information they contain, such as vegetation descriptions, development and management (Jeans 1978; Sheail 1983; Oxley 1987a, 1987b; Lunney & Leary 1988; Pickard 1993). For the Pilliga region this information comes in many forms both published and unpublished, and includes several explorers' journals, various land surveys, travellers' descriptions, railway surveys, sketches, early photographs, and biographies. These materials were located in the; State Archives, State Library, Department of Lands (now the Department of Conservation and Land Management (C.& L.M.), and at the Baradine office of State Forests.

The effects of management by State Forests since the early 20th century are not discussed in detail. Forest management history is another topic in itself and although State Forests have constructed roads, issued licences to cut ironbark sleepers and broombush, and for bee keeping, the study area does not possess major pine stands, there have been no major silvicutural treatments and overall impacts of these management acts are minor.

Soil data collection included detailed soil profile descriptions, drainage conditions, local topography and aspect, soil moisture and soil conductivity measurement.

Plant communities within the study area were surveyed in order; to establish the structure of the vegetation (growth form, height and foliage cover) and to determine the floristics (all the plant species that make up the vegetation of a given area). This information was recorded by selecting sampling areas (quadrats) within each of the different communities and a detailed description of the vegetation was recorded.

This thesis describes the results of this research and is organised in the following way:

* The local environment and the pre-history of the Pilliga Scrub is presented in Chapter 2.
* Chapter 3 describes the present forest, the study area and the methodology used for field work.
* The European history, from 1818, is presented in Chapter 4.
* Chapters 5 and 6 present the results and analysis from the field work.
* Chapter 7 concludes the thesis, reviewing the present position and establishes directions for future research and management.

CHAPTER 2

ENVIRONMENTAL PERSPECTIVES

INTRODUCTION

This Chapter describes the general environment of the Pilliga region and sets the scene for analysis of the alleged environmental changes.

THE FOREST ENVIRONMENT

Geology and Geomorphology

The central and southern parts of the Pilliga forests are dominated by the Upper Jurassic Pilliga Sandstone (Kenny 1964; Packham 1969). The total thickness of quartz-lithic sandstones, conglomerates and occasional shales ranges from 300 to 800 m; there is a general thickening of beds into the Coonamble Embayment of the Great Artesian Basin and the unit has a regional dip to the north-west of about 5° (Forestry Commission 1987).

Sedimentation was non-marine and more or less continuous through to the mid-Cretaceous (Packham 1969) and it has been suggested that deposition of the sandstone was in a braided river system (Arditto 1982). The sedimentary rocks do not appear to contain organic remains, apart from the occasional pieces of silicified branches and logs (Arditto 1982). The Pilliga Sandstone outcrops extensively around the south-east and eastern margin of the Coonamble Lobe, disappearing below Tertiary - Quaternary alluvial sediments to the north-west.

In the study area sandstone outcrop is limited to low ridges and is sometimes exposed along shallow road cuttings on the upper slopes. The lower slopes and creeks are covered and filled with colluvial and alluvial sands. These fluvial depositonal areas are a complex of low-angle coalescing alluvial fans and terraces (Mitchell *et al* 1982). Discrete areas of sand are present in close proximity to the larger modern stream lines and although their relationship in the landscape is unclear at present, they may be considered to be overbank deposits, source bordering dunes or possibly prior stream channels. Anastomising abandoned stream patterns are evident on air photos and satellite imagery and many are marked on the ground by slightly higher sinuous lines of deep yellow sands locally known as 'sand monkeys'. Figure 2-1 illustrates these sediment distribution patterns as observed in the study area and also maps areas of sandstone outcrop and *in-situ* soils.

In the central portion of the forest including the study area, total relief is only about 100 m and slopes on the long shallow hillslopes do not exceed 5 degrees. Stream fall is typically only 5 m per km and the sandy bed load is only moved during occasional high flow events. Soil development is closely linked to parent material and topographic position and is discussed in more detail in Chapter 5.

EVOLUTION OF THE AUSTRALIAN FLORA

The development of Australia's environment and its vegetation over the last 65 million years (my) has been extensively reviewed by numerous authors such as; Bowler 1976, 1982; Bowler *et al* 1976; Barlow 1981; Christophel 1981; Galloway & Kemp 1981; Kershaw 1981; Walker & Singh 1981; Martin 1981, 1987, 1991; Lange 1982; Singh 1982; Sluiter & Kershaw 1982; Truswell & Harris 1982; Wasson 1982; Holmes *et al* 1983; Hope 1984; White 1986; Frakes *et al* 1987; Clark 1990; Thom 1992; and

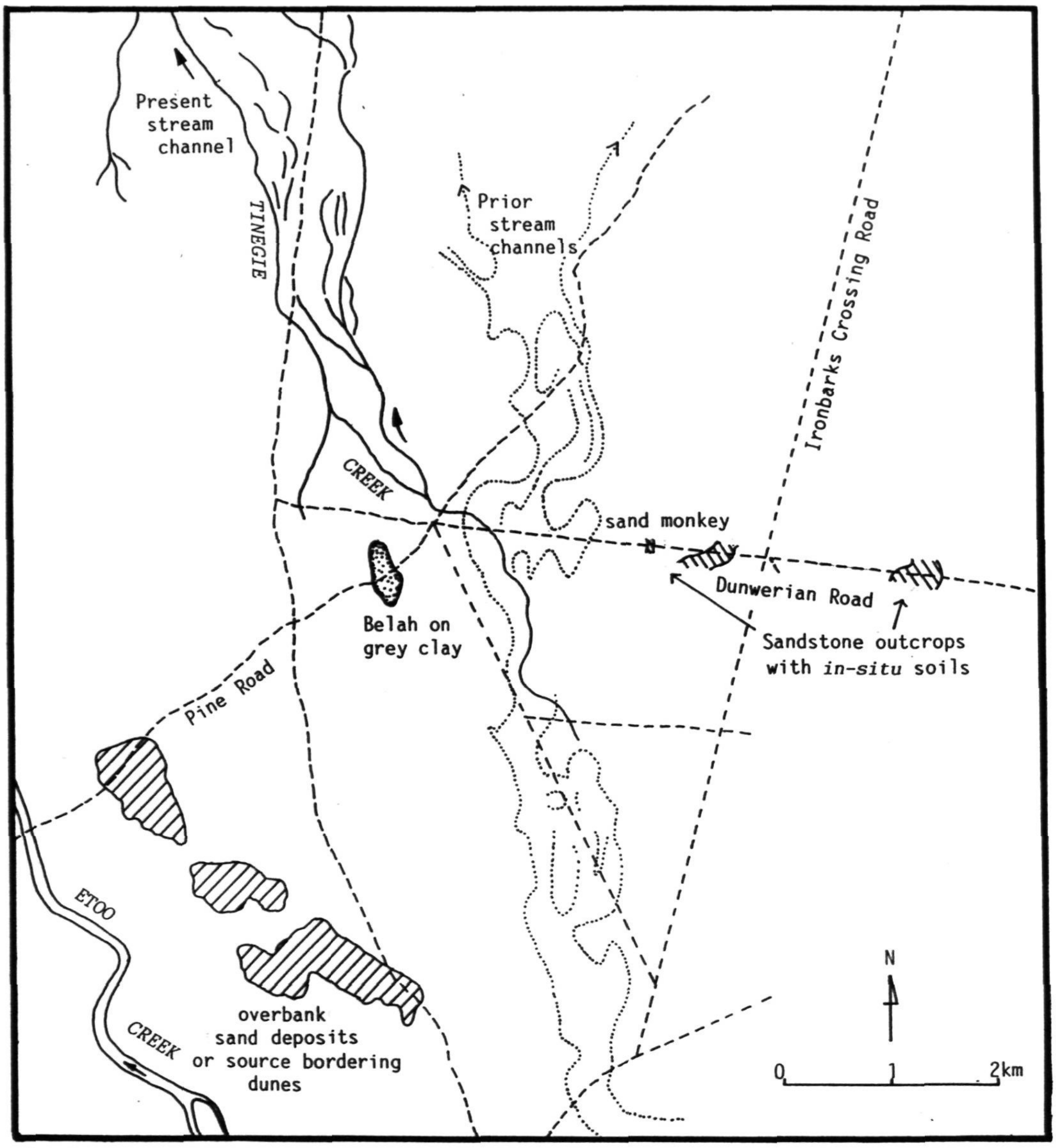

Figure 2-1. Anastomising stream patterns and other features as found within the study area.

Kirkpatrick 1994. At the broadest scale this story begins with the breakup of Gondwana during Cretaceous times. At the beginning of the Eocene the Australian continental plate began its drift northward, separating from Antarctica approximately 54 my BP (before present) as the South East Indian Ridge developed and the Tasman Rise was breached. One immediate consequence of the opening of the Southern Ocean was the alteration of global oceanic circulation patterns resulting in climatic change on continental Australia (Walker & Singh 1981). Mountain building along Australia's Eastern margin may have added to the climatic complexity of the continent and maintained a relatively wet eastern seaboard.

Rainforests of Gondwanic origin expanded and diversified over much of the continent through the early Tertiary. These forests were gradually replaced over the last 20 my as the climates changed further. Seasonal rainfall regimes with dry periods were established, particularly in the centre of the continent. Fire also became an important environmental factor. Over time the closed forests became more restricted in their distribution and were replaced by sclerophyll and drought adapted species (Walker & Singh 1981; Truswell & Harris 1982; Kershaw 1988). The flora has thus evolved in response to fluctuations in temperature, to increasingly frequent periods of aridity, periodic fire and to the development of a range of extreme soil types (Carnahan 1986).

More recently, during the late Pleistocene, the vegetation has been under the direct and indirect influence of humans for at least 40,000 years (Tindale 1981; Allen 1989; Bowler 1989). Through hunting, gathering and burning, and through the use of local resources generally it seems certain that the Aboriginal peoples have had some influence on the pattern of vegetation within the different ecosystems, and it seems likely that major impacts were initiated by changes in fire regimes. Together with this there have been other environmental changes over the last 40,000 years as the environment became colder towards the last glacial maximum around 20,000 - 16,000 years Before present (BP) and then warmed to the present interglacial (Clark 1990).

QUATERNARY ENVIRONMENTS

At present, the Pilliga forests lies near the boundary of sub-humid and semi-arid climatic zones (Gentilli 1972) and so have probably been very sensitive to fluctuations in climate in the geologically recent past.

Quaternary vegetation and environments in New South Wales and other areas of Australia have been described by authors such as; Bowler *et al* 1976; Kershaw 1981; Singh 1982; Bowler & Wasson 1983; Bowler 1989; Dodson & Wright 1989; Singh & Luly 1991; Dodson *et al* 1992; White 1994; and Hope 1994. Apart from Dodson & Wright (1989) the difficulty with considering all these studies arises from the fact that most are located at considerable distances from the Pilliga region and the effects of climatic change during the Quaternary may have been expressed differently in those areas. Nevertheless, a general summary of Quaternary climatic history can provide insights into the likely nature of changes in the Pilliga and is given below.

Throughout most of the Quaternary, terrestrial environments in New South Wales were colder and drier than at present (Clark 1990). Continental Australia had become seasonally arid, during the last 700,000 years, and the closed forests inherited from Gondwana became isolated remnants occupying areas that remained suitable for their survival (White 1994, Clark 1990). The main direction of evolution of Australia's modern flora involved a change from closed forests to open woodland to grasslands to deserts and the evolution of sclerophyll-type vegetation that became well adapted to arid conditions, fire, and poor soils (Gill 1981). Climatic change within the Quaternary was generally much more rapid and extreme than during previous geologic times, and this had a profound affect on the vegetation. Interglacial periods were warmer and wetter, whilst cold, glacial periods were arid. True aridity with active inland sand dunes only occurred in the Quaternary (Bowler 1976, 1982).

Over much of arid and semi-arid Australia trees and shrubs are found that belong to genera in which most species grow in rainforest environments. It appears that these species from the arid and semi-arid zone are derived from basically rainforest families, and are believed to be relics from a time when much of the continent was covered with rainforest, though the species themselves, of course, do not necessarily date from that time. Examples of such plants that now grow in the study area are *Atalaya hemiglauca* (Sapindaceae), *Pittosporum phylliraeoides* (Pittosporaceae) and *Geijera parviflora* (Rutaceae).

A few chenopods are also present; for example, one species in particular, *Sclerolaena diacantha*, usually grows in a semi-arid to arid area. Its presence within the Pilliga, although within its natural range, may be a reflection of past environments (c.f. Dodson & Wright 1989) but its distribution here could also be attributed to travelling stock (Jacobs pers. comm. 1995) Another unusual plant within the Pilliga is *Triodia mitchellii* var. *breviloba* (Poaceae). Most members of this genus are found in arid grasslands, but this species grows both in the Pilliga and in eastern Queensland. Perhaps what we are seeing in the study area can be best thought of as a collection of species, many of which can be regarded as relics from one or more fluctuations in the vegetation/climatic relationships of the past (Jacobs pers. comm. 1995).

Palaeoclimatic and palaeoenvironmental reconstruction for the Quaternary in Australia, as for anywhere, is based on observations and descriptions of what exists now. However, the fossil record, both spatial and temporal, is often very patchy and this is a significant factor limiting the reliability of the reconstruction of past environments. This is particularly important in terms of environmental history if this is to be used as a part of the knowledge base to be drawn upon when deciding the future management of ecosystems (Clark, 1990).

Reconstructing the Quaternary for the Pilliga region can be attempted by drawing from a number of other works in comparable environments even though some of these are rather distant. The studies include those by Martin (1987) on the Lachlan River, Wright (1986) describing flora at Lime Springs and Trinkey, Dodson *et al* (1993) describing vegetation history at Cuddie Springs and the one study that relates more closely to the Pilliga forests; that of Dodson & Wright (1989). These last authors investigated pollen samples, soils and sediments from Ulungra Springs, a site approximately 155 km south of the study area. As with the study area, the geology around the Springs is dominated by Jurassic Pilliga Sandstone. There is also some Triassic Narrabeen Sandstone, lithic sandstone, shale, claystone and conglomerate lenses. The present vegetation of the area is similar to the forests of the Pilliga, that is, open forest and woodland dominated by *Eucalyptus crebra, Allocasuarina leuhmannii* and *Callitris glaucophylla* with an understorey of diverse shrubs and ground cover species.

Dodson & Wright (1989) made an interpretation of the environmental history for the region over the last 30,000 years from sediments collected from two exposed pit faces at Ulungra Springs, one adjacent to a spring-fed soak and the other 210 m to the north which sampled sediments away from the present soak. Radiocarbon dates gave similar ages to the basal sediments of each pit although the depth of these units varies greatly (Pit 1 350cm 29,440 ± 470 yr BP, and Pit 2 550cm 27,300 ± 500 yr BP).

The pattern of terrestrial vegetation over this time has apparently shifted from subhumid forest (about 30,000 yr BP), changing to woodland, shrubland, and arid vegetation then back to forest in the Holocene. These results indicate that the vegetation cover around 30,000 years ago was similar to that of today. A very open semi-arid shrubland dominated by chenopods then followed and this seems to have survived from 25,000 yr BP to 10,500 yr BP. Shrub taxa such as species of *Lomandra, Xanthorrhoea, Gonocarpus, Hibbertia* and *Bossiaea* persisted throughout the record implying that environmental change had a greater effect on trees than on the shrubs. These shrub genera are common within the present day vegetation of the study area.

From the work at Ulungra Springs and other research Dodson *et al* (1992) have produced maps based on (i) archaeological site distribution and habitat reconstructions as well as (ii) palaeoecological site distributions and habitat reconstructions for eastern Australia from 25,000 BP to the present. The study area is located in the western edge of these reconstructions but the scale of the maps do not allow detailed interpretation of the changing environment in any particular region.

Perhaps a more direct picture on vegetation change in the Pilliga during the Quaternary can be drawn from the few studies located in the northern tablelands, north western slopes and the north western plains (Wright 1986; Dodson & Wright 1989; Dodson *et al* 1986, Dodson *et al* 1993) (Fig. 2-2). These studies, in effect, give a cross section of vegetation change for the last 30,000 years over a topographic and climatic gradient. Table 2-1 summarizes the interpretations of these studies.

PRESENT FLORA OF THE FOREST

The present day vegetation of the forest has been generally described by many authors including; Oxley (1820); Cambage (1904); Fry (1909); Jensen (1912); de Beuzeville (1915a, 1915b); Maiden & Cleland (1920); Rupp (1932 - species list only); Blue Gum (1954); Lindsay (1967 - these maps are still being used); Anon (1972); Peasley (1975); Rolls (1981); Chiswell (1982); Mitchell *et al* (1982); Forestry Commission (1987); and Austin & Williams (1988).

The vegetation comprises mixed cypress pine and eucalypt forests and woodlands with, for the most part, a shrubby understorey. *Callitris glaucophylla* ((Thompson & Johnson 1986), syn. *C. glauca, C. columellaris*) is widespread on a range of soils, excluding the heaviest soil types where *Allocasuarina cristata, Eucalyptus pilligaensis* and several other box species and *Myoporum mitchellii* also grow. *Eucalyptus crebra* is found on deep sandy soils often with *Callitris glaucophylla* and this association is very common throughout the forests

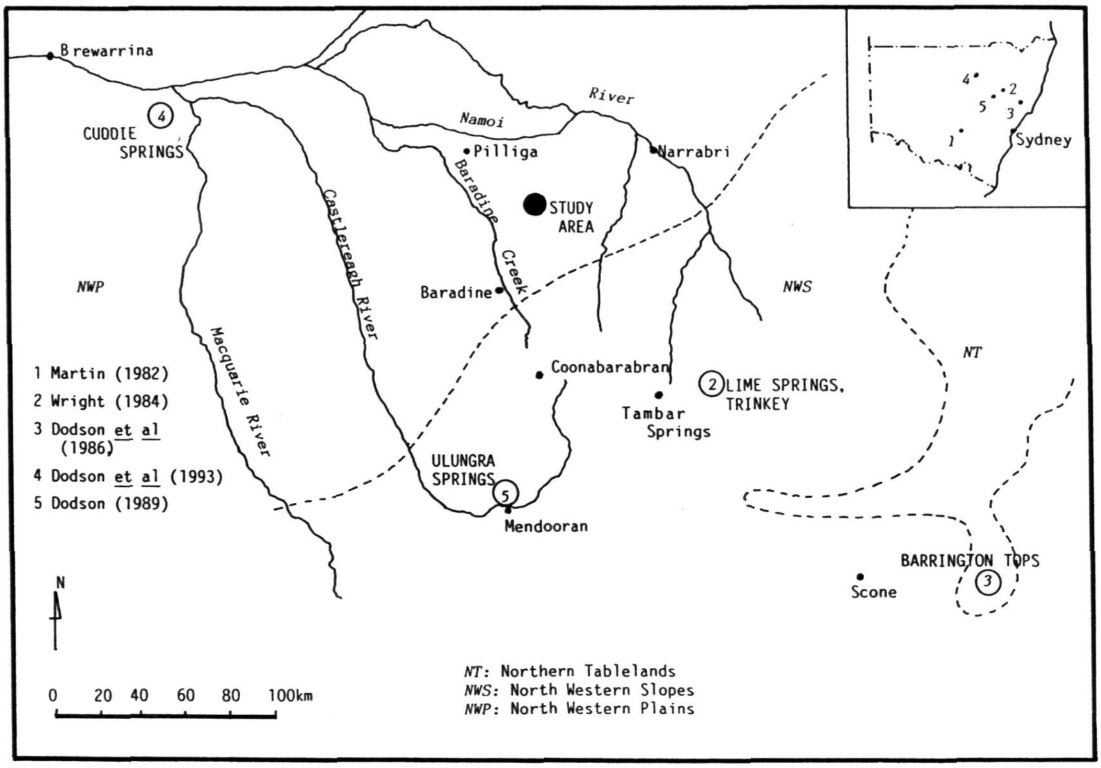

Figure 2-2. Location of Quaternary study sites in northern New South Wales. Phytogeographical region boundaries.

Table 2-1: A comparison of Quaternary vegetation reconstructions for Cuddie Springs, Ulungra Springs, Lime Springs, Trinkey and Barrington Tops (cf. Fig 2-2)

***** no data

SEMI-ARID				COOL TEMPERATE
	NORTH WESTERN PLAINS	NORTH WESTERN SLOPES		NORTHERN TABLELANDS
Yrs bp	Cuddie Springs	Ulungra Springs	Lime Springs and Trinkey	Barrington Tops
30k	Lower rainfall. Shrubland dominated by chenopods, scattered acacias, casuarina and eremophila shrubs or small trees. Trees rare, diverse understorey of herbs.	******	******	******
27.3k ± 500	******	Semi-arid woodlands, Vegetation similar to the present. *Eucalyptus* and *Angophora* with under-storey of Poaceae, Asteraceae. *Plantago*, shrubs of *Bossiaea*, *Leptospermum/Baekea*, *Dodonaea*, *Lomandra/Xanthorrhoea*.	******	******
26k	******	******	Age of Buff Silt Unit, no pollen. The presence of silt a possible sign of arid conditions.	******
25k	******	Tree pollen scarce.	******	******
20k - 19k	Vegetation deteriorating - loss of taxa decrease in shrub & grass cover, but increase in chenopod taxa as glacial maximum approaches.	Aridity increasing. Treeless open shrub steppe; high values for chenopods, Asteracece, Poaceae.	20,000-6,000 yrs age for Black Silt Unit. No pollen, but stone artifacts & megafauna present throughout this Unit.	******
			19,300 ± 500 years is date for black sandy clays at Lime Springs. No pollen, believed	

Table 2-1 Continued

	NORTH WESTERN PLAINS	NORTH WESTERN SLOPES		NORTHERN TABLELANDS
	Cuddie Springs	**Ulungra Springs**	**Lime Springs and Trinkey**	**Barrington Tops**
			to have been destroyed by the deposition of overlying 'parna' unit. 18,000 years thought to be high level of ground water discharge.	Before 11,000 yrs an open eucalypt forest/woodland with grassland & high Asteraceae (Tubuliflorae) content present in north west.
10k	******	A return to modern vegetation cover. Chenopodiaceae, *Plantago*, Liguliflora & Tubuliflora decline suggesting return to woodland formation.	******	11,000-9,000 yrs forest surrounding development of *Nothofagus moorei* forest suggesting increased rainfall.
6k	******	******	Grey Silt Unit dating, no pollen but possible indication of aridity	7,300-3,200 yrs greater extent of wet eucalypt forest in north west
5k	Trees & chenopods: few Asteraceae and Poaceae species.	Modern vegetation cover.	******	6,500-3,500 yrs greater extent of cool temperate rainforest in south & east. Greater rates of growth from 3,500 yrs
3.5 - 2.5k	******		******	Rainforest contraction & development of more open *Eucalypt* forest with *Poa sieberana* understorey indicating lower temperatures & rainfall
1k	******		******	small expansion of *N. moorei* rainforest & wet eucalypt forest
0.5k	*Eucalyptus largiflorens* *E. microtheca* woodland	Open forest & woodlands of *Callitris*, *Eucalyptus* and *Allocasuarina*	******	******

(Plate 2-1).

Other species of *Eucalyptus, Angophora* and *Allocasuarina* are present, and the many understorey species include those belonging to the genera; *Acacia, Melaleuca, Dodonaea, Calytrix, Grevillea* and *Phebalium.* In the central part of the forest area broom plains dominated by *Melaleuca uncinata, Micromyrtus sessilis* and *Calytrix tetragona* are common, as well as scattered patches of *Eucalyptus* (Subsection Symphiomyrtus) *viridis.*

More detailed descriptions of the vegetation are presented in Chapter 6.

CLIMATE

Instrumental climatic record

From the period of instrumental records (a little more than 100 years), there is evidence of widespread variation in the annual and seasonal rainfall patterns over most of Australia. The few recording stations that go back to the mid-1800s suggest that most of eastern Australia was wetter in the late nineteenth century than the first half of the twentieth century (Hobbs 1988). A return to wetter conditions, that is, a significant increase in annual and summer rainfall in central New South Wales for example, began around 1945-1946 (Pittock 1975; Cornish 1977), and this general pattern can be seen in Figure 2-3. Hobbs (1988) concluded that the instrumental record demonstrates evidence of annual and seasonal rainfall variability, but whether the period of instrumental record is considered to be representative over the longer term is open to question. Since 1945-1946 annual rainfalls have increased by 10-20 per cent over most of south-eastern Australia (Hobbs 1988).

Plate 2-1 *Eucalyptus crebra* - *Callitris glaucophylla* woodlands, a common association in the study area (Site V13).

The closest meteorological station to the study area having the longest instrumental record is Narrabri (80 km to the northeast); the first year of recording being 1871. Figure 2-3 presents the annual rainfall and the 10 year running mean for Narrabri Bowling Club (054120, this station is now not operating) and Narrabri Post Office (053030) for the years 1891-1959 and 1961-1990 respectively (giving a combined record of 99 years), Baradine Forestry Station (053002) for the years 1944-1990 (46 years) and Pilliga Post Office Station (052023) for the years 1883-1990 (107 years). The long term mean for each of these stations is 656.6mm for Narrabri Post Office, 587.0mm for Baradine Post Office and 553.0mm for Pilliga Post Office. Moderate to very strong ENSO years compiled from several authors (Glantz *et al* 1991; Diaz & Markgraf 1992) are also given.

***El Nino* - Southern Oscillation Phenomenon (ENSO)**

The Southern Oscillation is a global phenomenon involving a negative correlation between pressure over Indonesia and pressure over the southern Pacific. It is related to fluctuations in the intensity of the east-west Walker Cell, and associated with it are large interannual variations in sea surface temperatures, rainfall and wind strength over much of the Pacific. The Southern Oscillation is related to the *El Nino* which is the occasional severe warming of the equatorial eastern Pacific, and together they are referred to as ENSO (McBride & Nicholls 1983; Nicholls 1988, 1989).

In recent years it has been recognized that ENSO is one of the most important controls on medium term (decadal) climatic variation in the Australian region (Wright 1985, Nicholls 1988, 1989). Droughts in Australia usually coincide with *El Nino* events; probable *El Nino* events

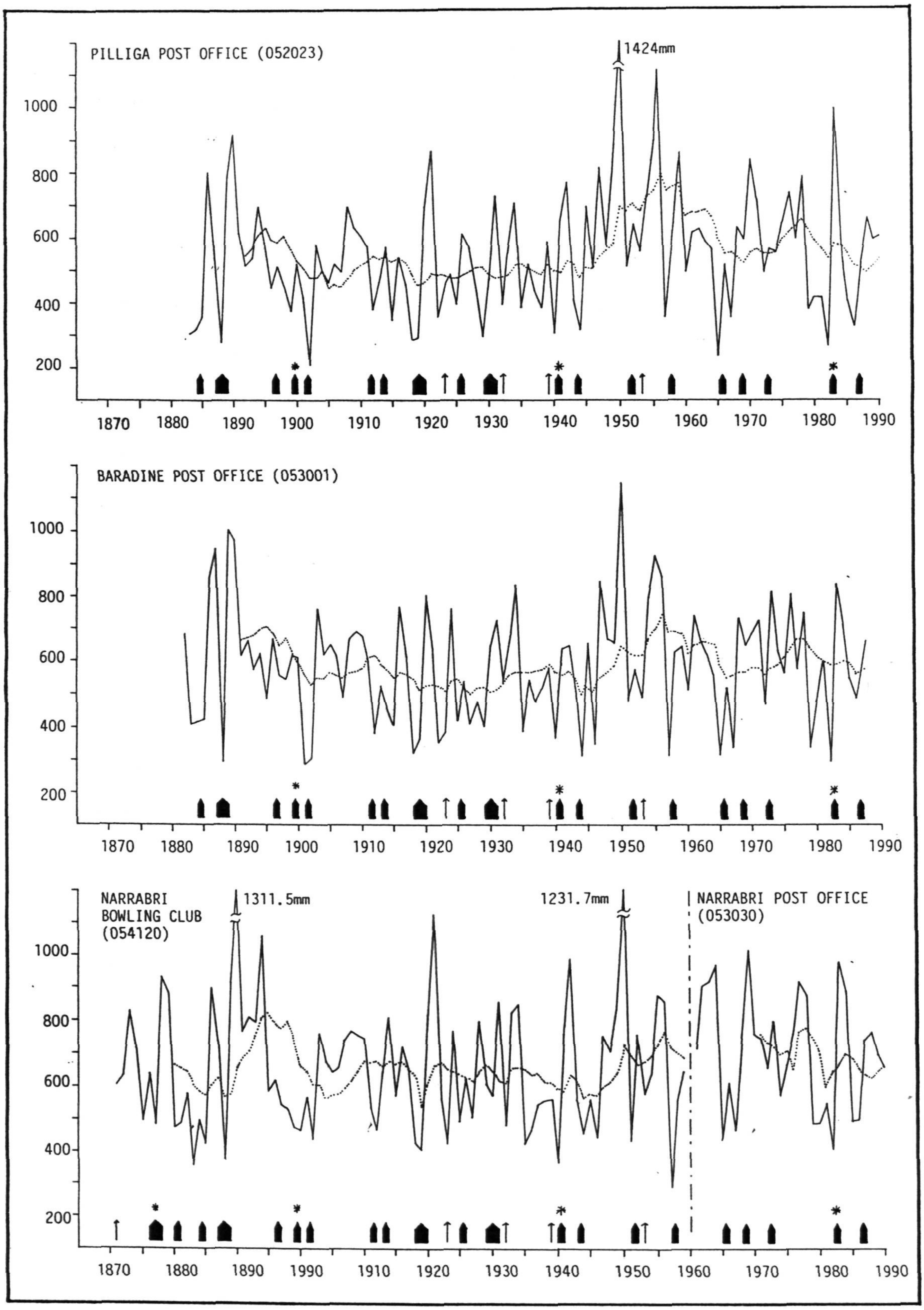

Figure 2-3 Mean annual rainfall for Pilliga Post Office, Baradine Post Office and Narrabri Bowling Club/Narrabri Post Office for the period of instrumental recording (—— annual rainfall, ········ 10 year running mean). ENSO events indicated (↑ moderate, strong, very strong ENSO events).

from 1871 are indicated on Figure 2-3 (Glantz *et al* 1991; Diaz & Markgraf 1992). The Southern Oscillation Index, or SOI, is used to describe the intensity of the Southern Oscillation; major droughts in Australia usually accompany large negative values of the index.

The question of how long ENSO has been operating has been addressed by Nicholls (1989) who has been studying the effects of *El Nino* on a wide range of Australian activities, history and the native flora and fauna. Nicholls (1991) found relationships between ENSO events and native vegetation adaptation responses, particularly in semi-arid species/communities. Some of the responses that may be attributable to ENSO include the absence of succulents in the arid flora. Although requiring little moisture succulents do require regular rainfall. Seedling establishment dependent on extended wet periods is another strategy, for example, *Acacia aneura* requires heavy summer rains for flowering and follow-up heavy winter rains to set the seed produced. Drought tolerance and avoidance, fire resistance and dependence are other strategies which may also be ENSO related (Nicholls 1991).

PRESENT CLIMATE

The Pilliga region lies on the boundary of the Western Slopes sub-region of the Sub-humid Eastern Region and Semi-arid Lowlands as defined by Gentilli (1972) following Thornwaite (1931) and Koppen (1936) (cited in Gentilli 1972). To the west of the study area, between Baradine and Coonamble, there is a steep climatic gradient with an increase in frequency of arid years. Presently, the climate is warm sub-humid with variable rainfall. Climatic averages for Baradine, 35 km south of the study area are given in Table 2-2.

Rainfall

Rainfall is low to moderate and varies across the forest from about 700mm in the east and south to 459 mm in the north west. Rainfall distribution throughout the year is bi-modal with the main period in December - January and a second maximum in June. Figure 2-4 displays average monthly rainfall records for Baradine Forestry Station. August and September are usually the driest months. There is a great variability in annual rainfall and in its seasonal incidence. The forests therefore have to withstand periods of severe drought and some periods of extended saturation (Forestry Commission 1987). Thunderstorms are frequent and hail may occur.

During the period of fieldwork rain gauges were installed within the study area to gain a more accurate picture of the local rainfall.

Temperature

January and February are the hottest months. Northerly and westerly winds may cause even higher temperatures with 45^0C being not uncommon. The mean maximum summer temperature 35^0C and mean minimun temperature is 20^0C.

Winters are mild with July usually the coldest month. The mean maximum winter temperature is 16^0C whilst mean minimum temperature is 4.5^0C. Frosts are common in winter, and there may be 27-29 frost days per year (Bureau of Meterology, 1996).

Evaporation

No records of evaporation rates are available for Narrabri (053030) or Baradine (053002) (Bureau of Meteorology 1996) but it is estimated that it would exceed 1500 mm/year in the study area with a

Table 2-2. Climatic averages for Baradine Forestry Station 053002, Latitude 30°57' S, Longitude 19°4' E. Elevation 302.0 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
DAILY TEMP. MEAN DEG. C (21 years of record)													
Max.	33.1	32.5	30.1	25.9	20.7	17.2	16.3	18.0	21.1	25.7	29.2	32.2	25.2
Min .	18.2	18.1	15.2	10.2	6.4	3.6	2.0	3.3	5.9	1o.2	13.0	16.0	10.0
RAINFALL MEAN mm	92	75	50	34	48	41	36	44	42	60	50	53	625
RAINDAYS	7	6	5	4	5	6	6	6	6	7	6	6	70

Source: *Climatic Averages Australia.*
Meteorology Survey July 1988
Bureau of Meteorology.

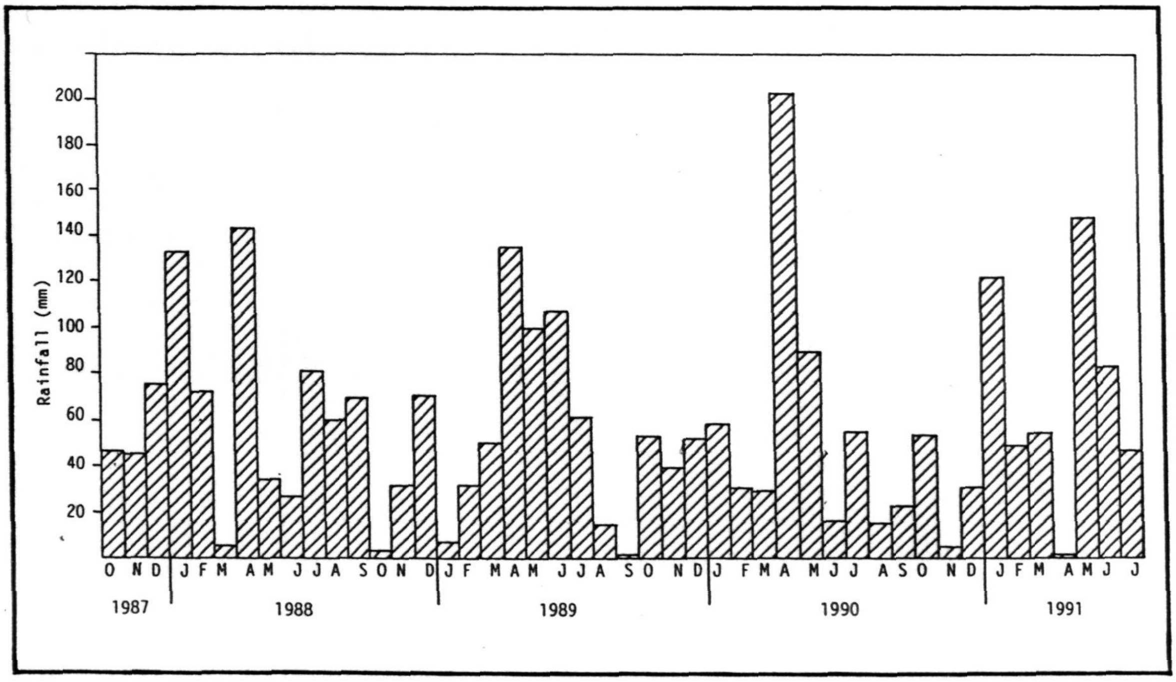

Figure 2-4 Monthly rainfall for Baradine forestry (Station 053002) during the period of field study.

peak of about 225 mm in December (Bureau of Meterology 1972).

Stream flow occurs only after unusually heavy rain periods. Plate 2-2a and 2-2b illustrate stream flow in July 1989 following a very wet April (135.2 mm), May (99.5 mm) and June (107.6 mm). Such flows occur 2-3 times per year on average but dry periods of up to 4 years without stream flow are common.

Significance of climate in Cypress Pine regeneration

Lindsay (1948) reported that there was an apparent lack of Cypress pine regeneration during the early part of this century. Climatic conditions during this time were generally drier than the years preceeding (Fig. 2-3) and this may have been an important factor in discouraging regeneration. Successful cypress pine regeneration occurs during autumn to early winter and is dependent upon good soil moisture following high rainfall in the year following flowering. The timing of this rainfall is critical because if it is is either too early or too late, i.e. summer or spring, then regeneration rates will be low due to high temperatures or declining seed viability respectiviely. The natural regeneration cycle of cypress pine is discussed further in Chapter 4.

LAND USE - ABORIGINAL

Members of the Gamilaroi (syn. Kamilaroi) tribe or linguistic group as recognised by the Australian Institute of Aboriginal and Torres Strait Islander Studies inhabited the Pilliga region, occupying an area from Black Mountain to Gunnedah, Merriwa and Cassilis in the east and south and extending to the Queensland border in the north (Warrumbungle Historical Society no date). Figure 2-5a illustrates

Plate 2-2a Stream flow in Etoo Creek at Aloes Well, Pilliga Forest Way in June 1989.

Plate 2-2b Stream flow in Rocky Creek, Pilliga Forest Way in June 1989.

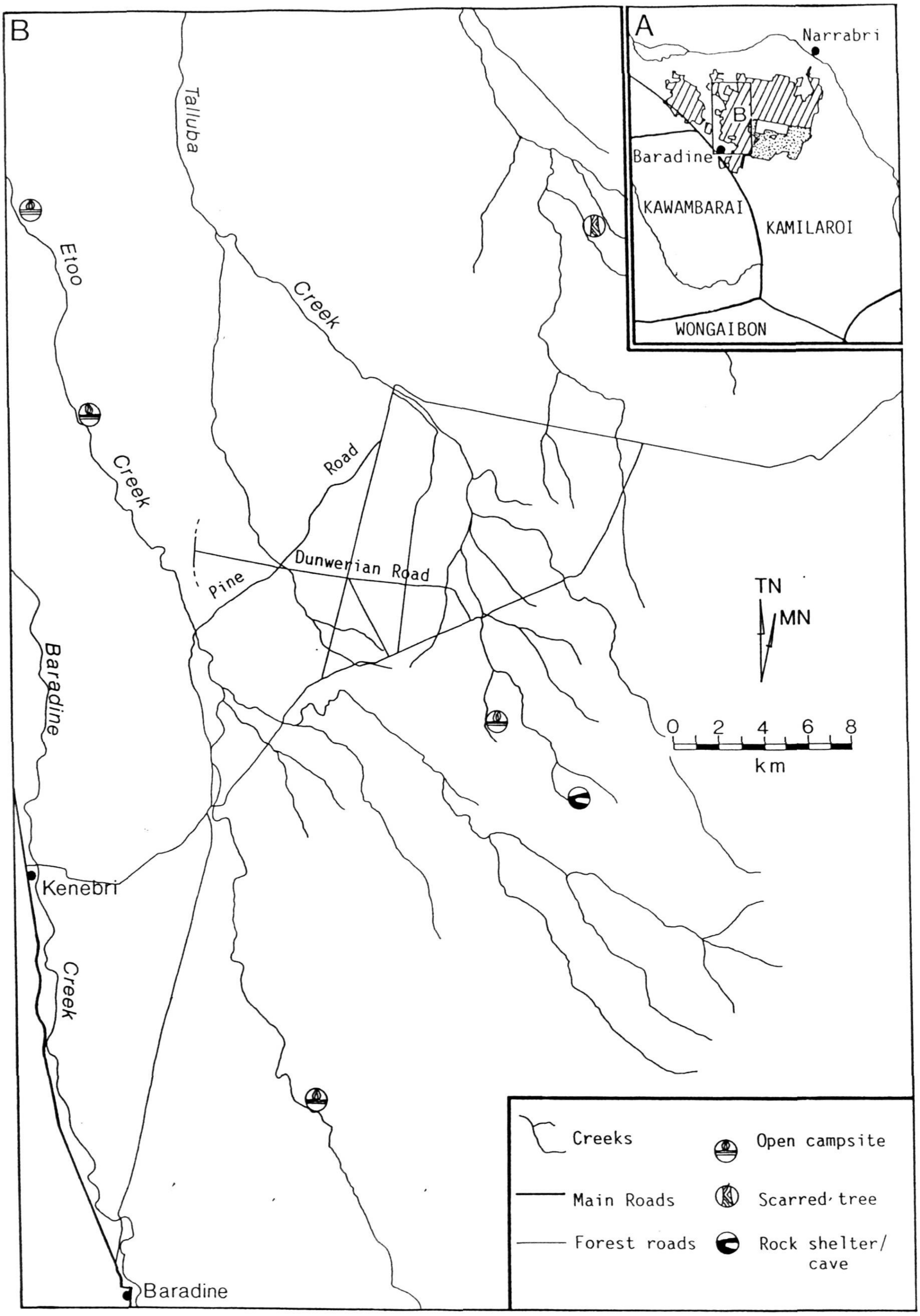

Figure 2-5. 2-5A: Aboriginal tribal divisions (after Tindale 1974).
2-5B: Aboriginal sites recorded within vicinity of the study area (Geering pers. comm.).

the tribal divisions in northern New South Wales (Tindale 1974).

Whilst exploring country to the south-west and south of the main forest area and just south of the area of this study, the explorer John Oxley (1820) made observations on the presence of Aboriginal people along his route. However, when travelling through country that now lies within the Pilliga Nature Reserve (Fig. 1-1) he commented that the Aborigines who had been following his party were nowhere to be seen and that the physical evidence of their occupation within the area was lacking.

Until recently, there has been limited documented evidence of the occurrence of Aboriginal archaeological sites within the forests (Bowdler 1983; Balme 1986; Forestry Commission 1987) and only two sites had been recorded within close proximity to the study area. These are a rock shelter/cave at Salt Caves, and an open campsite in the vicinity of Mags Crossing (Rolls 1981). Balme (1986) concluded that evidence for major use of the Pilliga was poor and that the few artifacts discovered did not shed much light on any human activities associated with them. Further, she suggested that the lack of grindstone fragments may signify that the processing of hard plant foods was not important. The apparent absence of complex campsites and a wide range of site types lead Balme to conjecture that hunting may have been the reason for entering the forests due to the number of medium to large mammals present. In short, Balme (1986) believed that Aboriginal utilisation of the resources of the Pilliga was transitory and limited.

From the above studies two observations can be made to possibly account for the scarcity of archaeological sites. Firstly, the lack of intensive research undertaken as acknowledged by Balme (1986) and the Forestry Commission (1987), and secondly, whilst forestry/logging operations are not as intensive as in other State Forests this activity has possibly damaged or destroyed some sites.

More recently Roberts (1991) investigated the Aboriginal resources of the Pilliga Forests. Roberts recorded many more archaeological sites than were previously known. For example, 89 new sites have been found, 62 scarred trees have been recorded (as opposed to only one in all the previous works), and he found that open campsites were much larger than originally thought and that they contain many more artefacts. Some of these open campsites contain fragments indicating stone manufacture and repair which suggests that these sites were used as base camps thus being used over the longer periods of time. Further, as grindstone fragments were found at a number of sites, it seems likely that both hunting and gathering were common activities. In summary, Roberts suggested that prehistoric occupation was more widespread and by implication, it probably had a greater impact on the forest than had previously been appreciated. Figure 2-5b illustrates known aboriginal sites within close proximity to the study area after the work of Roberts (1991) and from K. Geering (pers. comm. 1991).

FIRE

Aboriginal use of fire

There is considerable debate in the literature concerning the nature and effects of Aboriginal 'fire stick farming' and its influence in shaping the Australian environment (Hughes & Sullivan 1981; Clark 1983; Kershaw 1986; Bowman & Brown 1986).

Oxley (1820) when travelling through what is now the Pilliga Nature Reserve describes areas of recently burnt country: August 18 - '...we entered a very thick forest of small iron barks which had been lately burnt...' (Oxley 1820: p268). This is the only reference Oxley makes to fires (not necessarily lit by the Aborigines) within the region (apart from the campfires of Aborigines following his party) since he spent only about 12 days within the present boundaries of the State Forests and the Pilliga Nature Reserve under extremely trying conditions.

Based on stone artefact typology Geering (pers comm. 1991) believes that the possible aniquity of Aboriginal occupation within the forests may be within the order of 5,000 to 6,000 years. Such a period is certainly long enough for their activities to have had an impact on forest structure and composition and consequently the removal of Aborigines from the forests after white settlement may have altered existing fire regimes which in turn may have resulted in some recent changes to the forests. Until more substantive evidence, such as pollen and charcoal is recovered from datable sediments, this point must remain speculative.

Fires and European settlement

The main source of information regarding the history of post-settlement fires is Rolls (1981), and a summary is presented here. It is believed that at the time of settlement (1830s - 1840s) the forest area comprised a mosaic of open woodland and grassy plains maintained by regular fires lit by the Aboriginal inhabitants (Rolls 1981: p127). The early graziers excluded fire and by the 1870s there had apparently been no regular burning for about 25 years (Rolls 1981: p182). As a result the forest structure began to alter as cypress pine regeneration began. Wire and spear grasses (*Aristida* and *Stipa* species respectively) were also more common as more palatable grass species were grazed more heavily. The graziers then began to burn in an effort to control these unfavourable grasses and pine scrub encroachment. This burning, together with some apparently favourable weather conditions, promoted continual cypress pine and shrub regeneration (Rolls 1981: p182-184). It is unclear if this is really the case or that a combination of factors, including fire may have promoted regeneration.

Harrington & Driver (1995) discuss the relationship between the introduction of European stock and the reduction in burning with the increase in density of woody plants such as *Dodonaea attenuata*. The re-introduction of burning and reduction in grazing return semi-arid grasslands to their former more open condition. This may be the case for the greater Pilliga in the change from 'fire-stick farming' to European management, but other studies (Dodson 1989; Dodson *et al* 1992) indicate that the shrubby component of the vegetation has been present for much longer than the span of human occupation.

Early foresters had a different appreciation of fire. At the 1st Regional Conference of Forestry (circa. 1915) W.W. de Beuzeville commented that '... to render waste lands viable for timber production, one must totally exclude fire.' (de Beuzeville circa 1915).

Recent fire history

Serious fires affected the forest in 1951, 1974 and 1982, the latter burning some 105,870 ha of the State Forest (King 1984). The approximate boundaries of these and other major fires from 1951 to 1982 have been mapped from air photos, satellite imagery and State Forests records (Mitchell *et al* 1982). State Forests at Baradine hold up to date records so that a complete fire history of the area for the last

45 years is known.

The major cause of wildfires in summer are from dry electrical storms (Forestry Commission 1987). Lightning strikes are often difficult to detect in the central Pilliga because of its large area, level topography and vegetation cover restricting visibility, and the absence of people. Given the right conditions an undetected lightning strike may cause a major outbreak 2 to 7 days after a storm has passed (Forestry Commission 1987).

As with any fire, the extent of damage depends on the intensity of the fire and the type of vegetation carrying the fire. For example, *Acacia triptera* is a common and widespread shrub species within the forests, and can often be found in large clumps throughout the broom plains. This species burns readily and produces extremely high temperatures. Flame heights are high even under mild weather conditions (Nicholson pers. comm. 1989).

Cypress pine provides a major income source for the region and as this species is very susceptible to fire, State Forests implement control burns at strategic sites within viable stands, particularly cypress regeneration stands as these are the most susceptible to loss and damage. Large area hazard reduction has also been carried out in non-pine stands in the central Pilliga. A fine fuel load of 5 tonnes per ha is considered the maximum acceptable level before hazard reduction burns are implemented (Nicholson pers. comm. 1989).

Other economically important species are resilient to the effects of wildfire. For example, the above-ground vegetative parts of *Melaleuca uncinata* are destroyed by fire but plants regenerate profusely from lignotubers. *Eucalyptus crebra* will survive most intense fires due to its thick insulating bark, and after fire it will resprout from epicormic buds.

Fire and soils

When a fire burns through bushland the litter layer and soil surface are changed. The stable slowly decomposing organic layer is destroyed, becoming a thin bed of ash. This affects soil nutrient availability, litter fauna populations, soil moisture levels, and plant germination rates (Hurditch 1986).

There are a number of physical and chemical consequences due to fire (Jeffrey 1987) including the following: loss of soil nutrients by volatilisation (between 25% and 60% of nitrogen for example); ash is removed by wind and surface run-off; the soluble nutrients within the ash, mineralised by fire, may be deeply leached (Shea *et al* 1981). A reduction in water-holding capacity can occur increasing runoff, and on slopes, the soil stability is decreased which creates a tendency for downslope movement of sediment.

In areas of heavy fuel, prolonged burning may result which leads to higher soil temperatures. Information regarding the spatial and temporal variations which occur in soil temperatures under a free running fire are not definitive (Gill 1981) but it appears that maximum soil surface temperatures can range from 75^0C and higher. If this is the case, then fires will have a deleterious effect on the seed viability of fire sensitive species such as cypress pine.

SUMMARY

The last 30,000 years have seen climatically driven shifts in the vegetation of the Pilliga forests. A shift from subhumid forest around 30,000 years BP to woodland, shrubland then arid vegetation was followed by a shift back to vegetation similar to that of 30,000 years BP in the Holocene, that is a return to forest and woodlands with a shrubby component in the understorey. During the more arid phase (25,000 - 10,500 yrs BP) an open semi-arid chenopod shrubland dominated, although shrub taxa such as *Lomandra, Gonocarpus, Hibbertia, Xanthorrhoea* and *Bossiaea* were also present indicating that the shift to more arid conditions had a greater effect on tree species than shrubs.

During the Holocene, around 5,000 to 6,000 years BP or possibly earlier, it is believed that Aboriginal tribes were present within the forests. Through their use of fire for hunting, and from naturally occurring wildfires, the shrubby component of the understorey may have been modified, the forests and woodlands possibly becoming more open in structure (Rolls 1981). From Oxley (1820) it is clear that the forest, at least where he traversed, comprised both open and shrubby understorey areas which is possibly consistent with what little we know about the patterns of fire.

Australia's vegetation is adapted to ENSO-related characteristics of Australian rainfall particularly in semi-arid areas where the influence of ENSO is strong (Nicholls 1991). The climate over most of Australia is characterised by widespread variability both seasonally and annually, and the vegetation has evolved in response to this (c.f. Lacey 1973).

The present climate of the Pilliga is warm sub-humid and the variable rainfalls display a yearly bimodal distribution. Further, the forests over time have been subjected to prolonged droughts and extended periods of saturation.

Fire (and aridity) have been considered an important part of the development of Australia's flora. There is considerable debate as to the extent to which Aboriginal 'fire-stick farming' has influenced the structure of many rangeland communities (Hughes & Sullivan 1981; Clark 1983; Kershaw 1986). However, the extent of their use of fire and the incidence of naturally occurring fires (lightning strikes) within the Pilliga forests is unclear but the exclusion of fire by early settlers for approximately 25 years (Rolls 1981) probably had some effect on the changes to forests structure. This point remains speculative.

State Forests implement hazard-reduction burns for the protection of fire sensitive species such as the economically important cypress pine. Fire is a damaging agent for existing pine stands as well as for cypress pine seed stored in the surface soil, which may be destroyed by excessive temperatures resulting in a reduction of regeneration.

The present condition of the forests should be seen as a result of the influences of climatic and environmental conditions throughout the Quaternary to the present, and the presence of Aboriginal and European peoples and their utilisation of the forest resources.