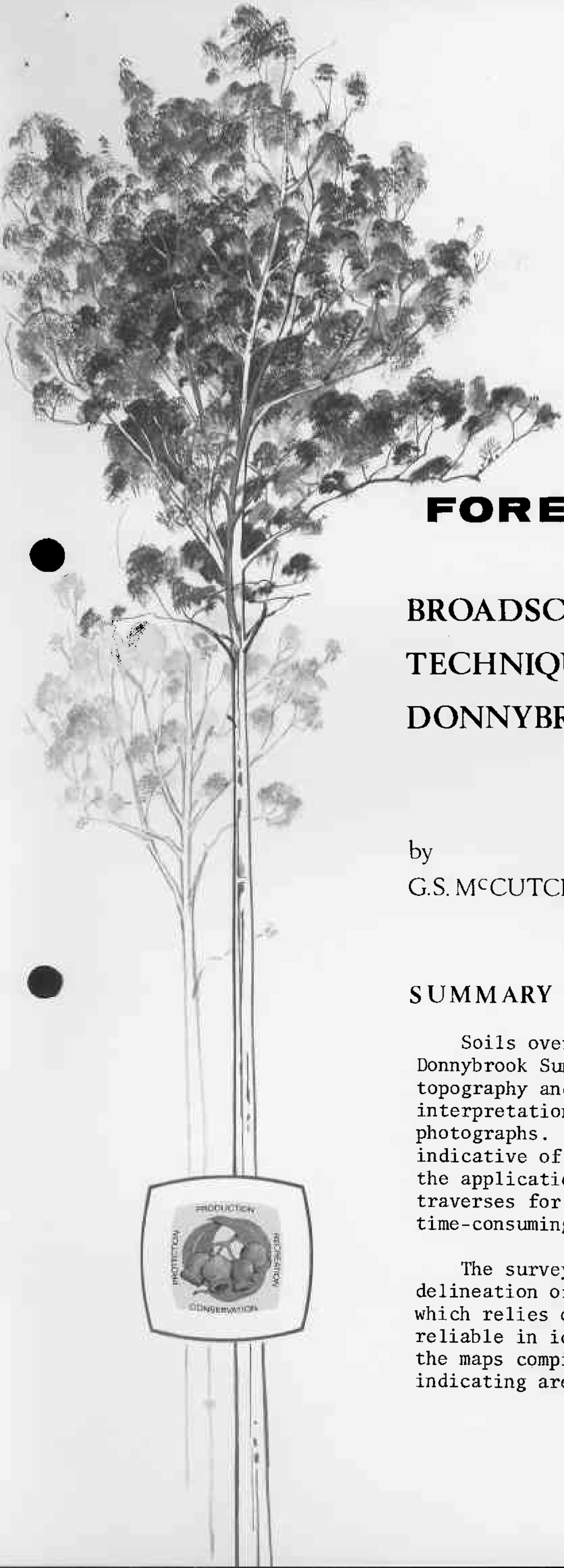

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FORESTS DEPARTMENT
OF WESTERN AUSTRALIA

# BROADSCALE FOREST SITE SURVEY TECHNIQUES USED IN THE DONNYBROOK SUNKLAND

by
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## SUMMARY

Soils over approximately 145 000 ha in the Donnybrook Sunkland, which is characterized by gentle topography and infertile soils, were mapped by interpretation of soil and vegetation units from aerial photographs. The identification of plant species indicative of the different edaphic conditions and the application of various new techniques made field traverses for control of the interpretation less time-consuming.

The surveying method used was more reliable in delineation of soil types than the conventional method which relies on ground traversing alone, but it was less reliable in identification of the soil types. However, the maps compiled were of acceptable reliability in indicating areas suitable for planting with pines.

## INTRODUCTION

In 1975 the Forests Department of Western Australia made public its proposal to convert 60 000 ha of low-quality jarrah (Eucalyptus marginata Sm.) forest in the Donnybrook Sunkland to pine plantation. Before this proposal was published an extensive soil and vegetation survey, involving two intensive field surveys and a broadscale survey based on aerial photograph interpretation, was undertaken to provide the data essential for effective land-use planning in the area. This paper describes the techniques developed to perform the survey.

The Donnybrook Sunkland, also referred to as the Low Plateau (Finkl, 1971 a), comprises approximately 280 000 ha of State Forest in the extreme south-west of Western Australia (Fig. 1).

The geology and geomorphology of the region, which have been described in detail by several authors (Fairbridge, 1953; Finkl, 1971 a and b; Gentilli and Fairbridge, 1951; Prider, 1966; Welch, 1964), can be summarized as follows. After laterization of an undulating landscape on Lower Cretaceous siltstone, erosion and weathering formed the existing soils. Finkl (1971 a) suggests that the laterized surface is coeval with that of the Darling Plateau; it is hence of Pliocene age (Prider, 1966). There are a few exposures of sedimentary rock (Fairbridge, 1953), and in the east there are minor exposures of the intrusive Bunbury Basalt.

The present land surface is mainly gently undulating, between 130 and 180 m in elevation in the north and east and between 70 and 140 m in elevation in the south and west.

The sharply incised valley of the Blackwood River cuts from east to west and divides off the southern third of the region. Valleys of the Blackwood's tributaries near their confluence and of the small rivers draining the northern edge of the area towards the Indian Ocean are also incised. A section of the Margaret River flowing parallel to and just east of the Busselton Fault (a subsidiary fault lying to the east of the Dunsborough Fault at this point but joining it further south) also has steep valley slopes. In general, however, the river valleys slope at less than 5 degrees up to broad ridges.

The soils, which are podzolic, have been named the Chapman Combination (Smith, 1951). The ridge tops are characteristically covered with either block laterite or lateritic gravel in a matrix which is usually sandy but often of heavier texture. Where ridges broaden to small plateaux the laterite is overlain by sand, which is often intensely leached. The slopes surrounding the ridge tops are mantled by sandy soils which either are very highly leached or have iron oxide staining, and there are sometimes outcropping bands of laterite roughly parallel to the ridge tops. The surface slopes of these sandy soils are usually uniform to convex, and in general the leached sands are less steep (sloping less than 2 degrees) than the yellowish sands.

Yellowish-brown loamy soils occur mostly on lower slopes and broad valley floors, and their slope profile is usually uniform to concave.

A narrow belt of silty soil with a strong iron oxide colouration usually occurs at the bottom of valleys, and there is often a massive iron pan at shallow depth. This belt is traversed by the stream channel on a course which may be either fairly direct or meandering.

The soils of the Sunkland area have been sub-divided by the Forests Department into seven main types (Appendix 1), on the following bases: presence or absence of laterite, texture, colour, and depth. The average size of cells of the different soils mapped is approximately 13 ha, and their shape is frequently elongated and with sinuous boundaries rather than compact.

In structural terms (Smith, 1973) the vegetation is predominantly an open forest formation (10 to 30 m high, 30 to 70% projective crown cover). The overstorey species are Eucalyptus marginata Sm. (jarrah) and Eucalyptus calophylla R.Br. (marri), the former being predominant. The crowns of jarrah on the Sunkland area are generally less vigorous than on the Darling Plateau, so that logs are generally smaller. Defects in the timber are also common. The main understorey species are Banksia grandis Willd., Casuarina fraserana Miq., Persoonia longifolia R.Br. and Agonis parviceps Schau.

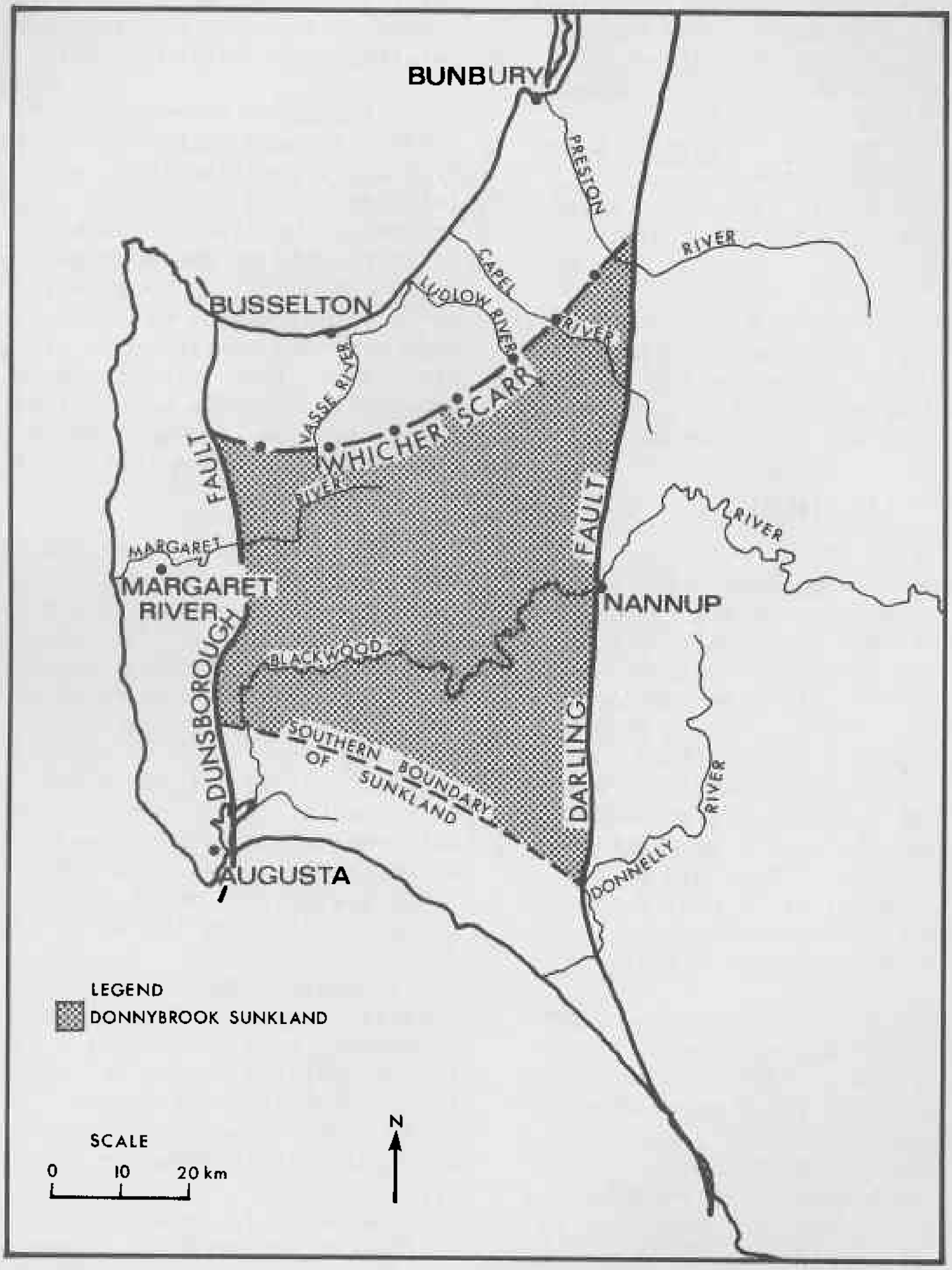


FIGURE 1: Location of the Donnybrook Sunkland, Western Australia.

There is a variety of shrubs and herbs. The families with the greatest percentage cover are the Proteaceae, Myrtaceae, Dilleniceae, Papilionaceae and Epacridaceae.

A less common formation is low open woodland, which comprises two associations. The first, which occurs on freely drained sandy sites, is characterized by Banksia attenuata R.Br., Xylomelum occidentale R.Br. and dense low shrubs. The second, on sites waterlogged in winter, is characterized by Banksia littoralis R.Br. and Melaleuca preissiana Schau. (M. parviflora Lindl.), with dense shrubs of species different from those of the first association.

Along watercourses the shrubs are often taller and denser, although on some broad, flat valley floors and swamps the vegetation forms a closed herbland comprising species of the Cyperaceae and Restionaceae families.

## METHOD

### Field surveys

As a prelude to the broadscale survey an intensive ground survey was carried out over an area of 2900 ha to collect data on the relationship between topography and soils. In addition, all plant species encountered were recorded for an analysis of vegetation species associations. One purpose of this vegetation analysis was to seek correlation between native species associations and the growth of pines on trial plots, as Havel (1968) did on the northern Swan Coastal Plain near Perth, Western Australia. Trial plots were established in the Sunkland in 1971.

However, a more immediate purpose of the vegetation analysis was to relate species composition to edaphic conditions as a tool to expedite field work later during the broadscale survey. Principal component analysis of plant species abundances at each inspection point of the intensive survey led to the definition of six basic vegetation types. Their correlations with some of the soil parameters were studied in further analyses, and in addition field experience helped in identifying the edaphic affinities of each vegetation type. The results of these analyses are discussed in detail in a further Research Paper currently in preparation.

For the broadscale survey, compass traverse lines were placed to sample tracts of apparently laterite-free country and to locate the edges of the laterite bounding these tracts. Traverses started and ended on made roads, preferably but not necessarily at points which would be identifiable on aerial photographs. The spacing between two adjacent traverses or between a traverse and a road roughly parallel to it varied from 1.5 to 4 km.

Information recorded at 100 m intervals along each traverse included soil type and vegetation type, stand basal area (measured using an optical prism) and occurrence of dieback symptoms (dieback is attributed to the pathogen Phytophthora cinnamomi Rands). Topographic details and surface indications of soil type boundaries were recorded continuously along the traverses. Those plant species not previously recorded were collected for identification, and any species known to be rare or of particular botanical interest was noted.

The sub-surface soil examinations, at first carried out using a small spade, were later made with a steel rod of 9.5 mm diameter surrounded by a thin-walled steel tube, each fitted with handles. This tool served as both a depth probe and a sampling device to retrieve a small soil core. A profile was assigned to the soil type on the basis of soil texture and colour at 60 cm depth. This depth was chosen because mathematical analysis showed the occurrence of vegetation species to correlate more closely with texture there than with texture just below the $A_1$ horizon.

In addition to these compass traverses, vehicle traverses were made along tracks accessible to a four-wheel drive vehicle, such as logging tracks and seismic survey lines, as well as along the numerous made roads. Distances were measured by means of a 'Halda' metric odometer. Vegetation types were assessed subjectively, but sub-surface soil examinations were also made at frequent intervals. Features identifiable on aerial photographs and suitable for use as plotting guides (for example, watercourses and track junctions) were recorded. A small stereo-viewer was mounted in the vehicle, and as more recent aerial photographs became available, they were used for navigation as well as for the location of suitable features. These features were also used later as base points in the conversion of recorded distances to actual photographic scale.

## Data plotting

A magnifying stereoscope was used in plotting the field traverses directly on to photographs of 1:40 000 scale. At this scale, in contrast with the more usual scale of 1:15 840, topographic levels were more evident, plotting errors were less frequent, and less frequent re-positioning of the photographs was required during plotting.

It was found most practical to plot the traverses on one half of the effective area of each photograph, leaving the other half clear for interpretation, so that markings could be erased or altered without losing the field data.

With the compass traverses, there was some plotting error because of distortion of scale and linearity towards the outer edges of the photographs. For the vehicle traverses, however, where the line of traverse was evident on the photograph, the scale and other errors were corrected as follows. Sections of the traverse were scaled off on the photograph between features that had been recorded in the field, these sections being approximately 1000 m in length. However, shorter sections were selected between the top and bottom of slopes to allow the better correction and localization of errors due to wheel slip, which became considerable especially when traversing upslope. A continuously varying correction factor, calculated by using a computer to compare the cumulative recorded distances with the cumulative scaled distances at successive stations, was applied to correct the recorded distance within each section.

Fine-pointed screwed dividers, calibrated at least once daily to the equivalent of 4000 m on an accurately divided grid, were used for the scaling on photographs. Distances could be measured to the nearest 10 m (at 3 x magnification), and it was estimated that plotting was accurate to never more than 40 m from true position. This degree of accuracy was necessary if changes of pattern on the photographs were to be related to the recorded characteristics of the soils and vegetation.

## Interpretation of photographs

The characteristics of the image on the aerial photographs that were used to identify the different site types were: relief and smoothness of the ground surface; density of the tree canopy; tone and texture of the lower vegetation; and evidence of human activities.

In his mapping from aerial photographs of sites potentially suitable for pine plantations on the Swan Coastal Plain, Havel (1968) used structure, texture and tonal features as interpretation guides. The large-scale photographs that he used (1:15 840) allowed him to identify the structural forms (woodland, low open woodland and shrub heath) that were related to the different edaphic conditions in the region. He found that in the woodland formation, tonal differences indicated some edaphically controlled differences in species distribution, whilst in the shrub heath formation both tone and texture indicated the various site types, although more intense ground control was needed.

However, on upland soils of adequate depth, the Western Australian jarrah forest formation is almost uniform over all sites in its structure and its species composition. Except on very moist sites, only two species of eucalypt (E.marginata and E.calophylla) occur together; they occur in varying proportions but cannot be distinguished from each other on monochrome photographs of the scale used for the survey (1:40 000).

Differences of tone, usually in conjunction with other features, were used in interpretation of the aerial photographs in the Sunkland survey. A dark tone along creeks is generally due to the denser canopy and understorey in these zones. A dark tone associated with no large trees and with fine texture is indicative of dense heath vegetation, typical of leached sands. Dark tone but rough texture in an elevated situation is likely to indicate a low laterite ridge; careful inspection of the photograph may confirm this by revealing a slight variation in topography. The darker tone on these sites is believed to be due to the greater density of shadow thrown by the healthier crowns of jarrah.

A coarse texture, observed mainly on

valley floors but also extending up valley sides and over plateaux, is due to wide spacing of large crowns and is indicative of a loamy soil.

Lighter tone is evident on sites carrying no heavy vegetation, either in the tree canopy or in the shrub layer. Where the vegetation and soil have been mechanically disturbed, the reflection of light is very high, so that logging tracks, log dump areas and excavations for gravel appear white. The latter two can usually be distinguished from each other on the basis of situation and micro-topography; furthermore, the log dumps are often identifiable by the allied radial snig tracks. Hence, a patch of disturbed ground close to a made road and without surrounding snig tracks is an indication of the presence of gravel.

Logging tracks usually skirt around block laterite and so frequently serve to indicate occurrences of this. They also often avoid wet areas.

As mentioned in the Introduction, there tend to be characteristic topographic situations and surface shapes for the different soil types. These differences are not sufficiently reliable to be diagnostic for all types, but they have been used successfully in conjunction with other indications to identify soil types. For example, a feature of block laterite sites is an irregular micro-topography which can sometimes be detected on photographs. Large-scale surface relief is, however, the clearest indicator of the laterite soils: the ridges usually stand out clearly, and are the first areas to be identified in interpretation of aerial photographs. However, laterite soils (especially those of the gravelly phase) sometimes occur without topographic differentiation, and it is therefore possible for such an area to remain undetected.

Another geomorphic feature that may be used in interpretation is the form of a stream course. Where the stream meanders along a flat valley bottom it is most likely traversing an alluvial soil. Where the stream course shows abrupt changes of direction with intervening relatively straight sections, typical of rocky valleys in other landscapes, the presence of laterite adjoining the stream is likely, especially if the side slopes are steep for the region. Where the stream course is straight or only slightly sinuous, the adjoining soil type is likely to be sandy.

Since interpretation of the photographs proceeds by extrapolation from the soil types and boundaries recorded along traverses in the field, it is advantageous if the interpreter also compiled the field record. Similarly, experience in interpreting photographs is of great help to the field observer in ensuring that he records all potentially useful information (for example, those features which will be recognizable aids to location on photographs). However, for most of the Sunkland project, data were collected by a technical officer and assistants who did not carry out the interpretation.

## DISCUSSION

In mapping the forest soils on the gentle topography of the Sunkland, if ground traversing is to be the only surveying method used it must be of high intensity to provide a sufficiently accurate map. This is because cells of the different soil types are neither predictable enough in their location nor extensive enough to be necessarily intersected by a pattern of widely spaced traverses (more than 200 m apart). Furthermore, the vegetation obscures contours which could in some cases indicate to the surveyor the likely trend of soil boundaries, a difficulty which is not so great on more varied terrain. Indeed, in the two intensive surveys that preceded the broadscale mapping, widespread roving inspection was carried out to map soil boundaries between the traverses so that the unplantable areas of massive laterite and gravel soil could be located.

In view of the limitations of ground traverses, an approach that makes use of the overview provided by aerial photographs is likely to be more satisfactory. If the mapping units are clearly identifiable, then the map will also be reliable. This type of survey is most effective for a region where the distribution of soils is controlled by geologic or topographic factors such that each land unit is clearly recognizable on aerial photographs, as in the surveys reported by Duffy (1969) and by Finkl (1971 b).

In the Donnybrook Sunkland, decisions concerning a large area of land had to be made within a fairly short time; a rapid reconnaissance based on the interpretation of aerial photographs and supported by ground surveys was therefore specified. The use of photographs, coupled with the other techniques developed, resulted in a much more speedy reconnaissance survey than would be possible if traversing on foot were the only method used for inspection of soils.

During the project a comparison was made between the method developed for the survey and conventional soil mapping methods. Taking the time spent on the latter as 100%, the figure for reconnaissance using aerial photographs was 11%. As the survey progressed, increasing use was made of track traversing along logging tracks visible on more recent photographs than had earlier been available; the time saved due to this would be considerable, but has not been assessed. Track traversing is also likely to be more accurate than compass-and-chain traversing when plotting is being done on aerial photographs rather than on maps, and would be a valuable adjunct even on an intensive survey.

Given the uniformity of landscape and forest in the Sunkland region, it was suspected that interpretation of photographs might not be reliable in areas remote from ground control. Eleven traverses (a total of 384 sampling sites) starting at randomly selected points were therefore run over the first areas mapped with the object of checking the accuracy of the mapping. The mean success rate of predictions of soil types was 72%, with a range (95% confidence limits) of 39 to 97% (treated as cluster sampling with arc sine transformation of percentages). Plantation base maps prepared from aerial photographs taken after clearing provide a measure of the accuracy achieved in mapping the lateritic soil type early in the project. In addition to the 33% of that soil type originally mapped, field traversing indicated a further 13% of the total area to be lateritic soil unsuitable for planting; however, this included some areas that had been mapped as a shallow sand type overlying laterite and that were hence already classed as of doubtful plantability.

For the areas covered by both these accuracy checks the intensity of ground control was lower than that adopted later. However, it is probably still true to say that whilst the delineation of mapping unit boundaries using aerial photographs is more reliable than that based on widely spaced ground traverses, the identification of the units is less so.

Considering the comparative uniformity of topography, soil fertility and climate in the Sunkland region, the lower accuracy of identification achieved by interpreting photographs in comparison with that achievable by ground surveying is not of great importance. Once it is accepted that the addition of artificial fertilizer will be necessary and that physical amendment of some sites may be necessary, the selection of land for pine plantations is simplified. Physically unsuitable land must be avoided, and within a plantation cell the areas that might require costly site preparation to give satisfactory establishment and growth rates may need to be minimized. Mapping based on the method reported in this paper has led to the location of large areas of land that have a low proportion of soils known to be physically and nutritionally unsuitable for Pinus radiata and that are therefore suitable for planting.

The maps have also facilitated planning of the plantation road network, since soil conditions are of critical importance in the location of roads. The optimum road location is just off the edge of block laterite, either on gravel or on well drained sand, which does not require a deep gravel base to be laid for a road.

In addition, the maps have been used in the planning of fire control strategies because they indicate the most suitable locations for buffer zones between plantation cells. Since they are compiled partly on the basis of vegetation, they also provide a good indication of sites and areas suitable for the preservation of certain vegetation types and wildlife habitats.

When growth measurements of the pines on the trial plots become available for correlation with site characteristics, the maps may also be of use in determining the best establishment and silvicultural practices for pines.

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APPENDIX 1

Key to Sunkland soil types
(Forests Department 1974)

| | | Soil type no. |
|---|---|---|
| A. | Gravel percentage within 50 cm of surface is more than 20% | |
| B. | Texture "sand" or "loamy sand" | |
| C. | Gravel more than 20% is within 20 cm of surface | |
| D. | Gravel within 20 cm of surface is more than 60%; massive laterite present | 1b |
| D. | Gravel within 20 cm of surface is less than 60%; not massive laterite | 1g |
| C. | Gravel more than 20% is deeper than 20 cm from surface | |
| D. | Colour range grey or greyish-brown | |
| E. | Basement is moderate to heavy gravel | 2Gg |
| E. | Basement is massive laterite | 2Gb |
| D. | Colour range yellowish-brown or brownish-yellow | |
| E. | Basement is moderate to heavy gravel | 2Yg |
| E. | Basement is massive laterite | 2Yb |
| B. | Texture "sandy loam" or heavier | |
| C. | Gravel more than 20% is within 20 cm of surface | 1F |
| C. | Gravel more than 20% is deeper than 20 cm from surface | |
| D. | Colour range grey, greyish brown, yellowish brown | |
| E. | Basement is moderate to heavy gravel | |
| F. | Texture between gravel not heavier than "clay loam" | 5g (shallow phase) |
| F. | Texture between gravel "sandy clay" and maybe "clay" at surface; colour pale and mottling a feature | 6 (shallow phase) |
| E. | Basement is massive laterite | 5b |

| | | | | | | Soil type no. |
|---|---|---|---|---|---|---|
| | | | D. | | Colour range brownish yellow, strong brown, reddish; usually associated with drainage lines | 7 (shallow phase) |
| A. | | | | | Gravel percentage within 50 cm of surface is less than 20% | |
| | B. | | | | Texture "sand" or "loamy sand" | |
| | | C. | | | Colour range light yellowish brown to brownish yellow | 3 |
| | | C. | | | Colour range light grey to dark greyish brown | |
| | | | D. | | Profile dry; texture "sand"; colour very light grey | 4A |
| | | | D. | | Profile moist but well drained; texture "loamy sand" | 4C |
| | | | D. | | Profile moist to poorly drained; texture "loamy sand"; organic "coffee-rock" present | 4D |
| | | C. | | | Colour strong brown or reddish and associated with drainage line | 7 |
| | B. | | | | Texture "sandy loam" or heavier | |
| | | C. | | | Colour range, greys, greyish brown, yellowish brown | |
| | | | D. | | Profile shows change of two texture classes between $A_2$ and B horizons | 5D |
| | | | D. | | Texture change down profile is gradual | |
| | | | | E. | Gravel forms base to profile, with matrix of "sandy clay", which texture may occur at surface; profile colour pale and mottling a feature | 6 |
| | | | | E. | If gravel base, matrix texture not heavier than "clay loam" | 5G |
| | | C. | | | Colour strong brown or reddish; usually associated with a drainage line | 7 |

NOTE: Characterizing texture (level B in the key) is normally determined at 60 cm depth, unless it is obvious from the profile description that a lesser depth applies. In this case the depth of description will be that immediately above some limiting feature.

Moisture status of greyish sands may be partly inferred from colour (amount and depth of black humus incorporation) and from texture.