Evaluation of Land Suitable for Maritime Pine within 200 km north and east of Perth

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SUMMARY

The land base available for Maritime Pine (*Pinus pinaster)* within 200 km north and east of Perth was estimated on the basis of:

- total cleared farmland excluding native bushland in reserves or on farms and urban areas
(1.28 million ha)
- soils suitable for Pinus pinaster (non-saline, adequate depth, non-waterlogged) (0.42 million ha)
- that the trees will be either dispersed across 20% of the farms or planted in particular niches (0.08 million ha).

This is a conservative area estimate, based on an arbitrary 20% planted on suitable soils and only represents 6% of the total cleared farmland. The proportion planted on suitable soils could thus be increased.

LAND DEGRADATION AND BENEFITS OF TREE PLANTING

Land degradation problems in the 400-600 mm rainfall zone are summarized in various reports (Robertson 1988; Select Committee into Land Conservation 1990). Major issues include salinity, wind and water erosion, water-logging, acidification, soil structural decline and water repellency (Harper 1994).

Salinity has the potential not only to destroy large areas of agricultural land, but also adjacent nature reserves (State Salinity Strategy 1996). Recent Agriculture WA estimates (Ferdowsian *et al.* 1996) suggest that 1.8 million ha (9% of cleared land) is currently saline, with this area eventually increasing to 6.1 million ha (32%), unless remedial action is taken. Much of this land is in areas with rainfall <600 mm. Salinity is caused by a hydrological imbalance induced by replacing deep rooted native vegetation with shallow rooted agricultural plants.

In contrast to salinity, most damage from wind erosion follows a combination of poor seasonal conditions and very strong winds. These conditions recur every few years and can cause spectacular damage to farm infrastructure, remnant vegetation and soils (Harper and Gilkes 1995).

Trees have a role not only in restoring the water balance and providing protection against wind erosion, but also in providing shelter for crops, pastures and livestock (Shea and Bartle 1988). Similarly, they are a viable land-use option for soils, such as deep sands, which are poorly productive to shallow-rooted agricultural crops and pastures.

NATURAL ENVIRONMENT OF THE TARGET AREA

1.1 Location

The target area is located on the west coast of Western Australia, extending in a 200 km arc, north to east of Perth.

1.2 Land use history

In areas alienated for agriculture native vegetation has now been mostly cleared and replaced with farming systems, based on rotations of cereal and legume cropping and annual pastures.

European settlement of the study area began in the mid-19th century. Land development, primarily for grazing, progressed along rivers and its tributaries on the floodplain of the Moore River. About 60% of the area has been cleared. Large reserves of natural vegetation remain within conservation reserves, Crown land and State forest.

The study area has long been recognised as a pastoral district. Sheep grazing is still the major land use with some cropping of coarse-grained cereals and fodder crops. Irrigated horticulture is also practised, mainly confined to the soils of the Dandaragan Plateau. This is expanding within the coastal plain.

Limestone and sand are mined in coastal areas area. Mineral sands are mined near Cataby and Eneabba, from deposits which lie adjacent to the Gingin Scarp.

1.3 Climate

The area has a Mediterranean-type climate with hot dry summers and cool wet winters. Many climatic factors show a south-west to north-east variation due to the slight change in latitude and coastal influences. The Dandaragan Plateau also imposes a topographical effect.

1.3.1 Rainfall

Table 1 Mean monthly and annual rainfall (mm) for selected stations in the target area (n is years of record)

Station	n	J	F	M	A	M	J	J	A	S	O	N	D	Total
Moora		11	15	18	26	61	92	89	63	38	25	13	9	460
State Forest 65 (N)	21	7	16	14	48	96	138	129	92	57	44	15	4	660
Lancelin	12	6	11	13	35	83	135	158	90	52	40	16	5	644
Cowalla	60	8	11	15	37	99	155	147	106	58	43	15	8	702
Gingin	77	8	11	18	33	106	156	160	122	71	54	18	12	769

Rainfall records for the target area were obtained from the Bureau of Meteorology for the Moora station. These had been recorded for periods ranging from 1897 to the present. The mean annual rainfall varies from just over 750 mm near Gingin to 460 mm near Moora (Table 1). The break of season is usually mid-April and the agricultural growing season lasts five to seven months.

The distribution of rainfall through the year is also of importance. Table 2 indicates the proportion of the rainfall which falls between April and November, and May and October.

Table 2 Proportion of total rainfall received between April and November and May and October at selected stations in the target area

Station	Annual Rainfall	Proportion of total (%)	
	(mm)	Apr—Nov	May—Oct
Moora	462	88	80
State Forest 65	660	94	84
Lancelin	644	95	87
Cowalla	702	94	87
Gingin	769	94	87

Summer rainfall is much more variable (i.e. less reliable) than the winter rainfall, and must be considered a bonus rather than as an assured part of the annual rainfall.

1.3.2 Evaporation

Annual pan evaporation is 1,700mm near the coastline within the study area and 2,250mm at Moora (Table 3). The best estimates of evaporation are made with a U.S. Class A evaporation pan. Evaporation increases with distance from the coast, as the maritime influence decreases, compounding the effect of decreasing water availability with reduced rainfall.

Table 3 Mean monthly and annual evaporation (mm) for Moora

Station	J	F	M	A	M	J	J	A	S	O	N	D	Total
Moora	337	299	276	140	76	58	57	72	106	185	252	316	2249

1.3.3 Temperature

Table 4 Mean monthly temperatures for Moora [2]

Temperature (°C)	J	F	M	A	M	J	J	A	S	O	N	D
Minimum	32.2	30.9	27.0	22.5	19.3	16.5	15.4	16.7	17.9	21.7	23.7	28.9
Maximum	37.4	37.8	34.1	29.4	24.8	20.3	18.5	19.2	22.3	28.1	30.5	35.5

Temperature data for Moora are presented in Table 4. The mean maximum temperature of the hottest months ranges from 35 to 38°C. Between 30 and 40 days can occur in summer with temperatures above 32°C with ten days exceeding 40°C. The mean minimum temperatures in winter are between 15.4 and 16.7°C. Due to a maritime influence areas close to the coast will have less extreme fluctuations in temperature. Mean winter temperatures will be higher near the coast, whereas summer temperatures will be lower than inland areas.

1.3.4 Frost

Climatic data on frost frequency are not available within the study area; the closest station being Pearce. Inference from this station indicates that frost is rare. No frost occurs from November to March, while in winter no more than two frost days can be expected in any month.

1.4 Geology

The underlying geology of the target area is described in detail by several authors (Johnstone *et al.* 1973; Wilde and Low 1980; Carter and Lipple 1982). In simple terms sedimentary rocks in the Perth Basin are separated from the Archaean granites of the Yilgarn Craton or Darling Plateau by the Darling Fault. This bisects the area in a north-south direction, near Perth forming the Darling Scarp.

1.5 Geomorphology

The Perth Basin is comprised of two major geomorphic features:

- *The Swan Coastal Plain*
  This has a series of coastal dune systems and alluvia associated with river systems

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[2] From 1989 WA Year Book

emerging from the Yilgarn Craton. This is further described in several publications (Bettenay *et al.* 1960; McArthur and Bettenay 1960)

- *The Dandaragan Plateau*
  This is comprised of uplifted sedimentary rocks, bounded on the east by the Darling Fault and to the west by the wave-cut Gingin scarp (Churchward 1970). These rocks were deeply weathered (lateritised) in the Tertiary period, forming a deep mantle of clayey materials, surficial ferricrete gravels and sands. This mantle has subsequently been modified. Down–cutting by several rivers, which run in a westerly direction to the coast, has exposed a variety of parent materials in the river valleys.

The Yilgarn Craton is predominantly granitic, and this has also been deeply weathered to depths of up to 100 m (Gilkes *et al.* 1973). This lateritic mantle has also been removed to various depths by the local river systems (Mulcahy 1967). In the target area there are thus broad patterns:

- broad interfluves with soil profiles, which are effectively many metres deep, formed on deep weathering profiles. Deep sand sheets are often associated with these deep weathering profiles, and these often occur in lower areas of the landscape.
- Valleys, where the weathering profile has been removed and basement rocks have been exposed (e.g. Bindoon)

1.6 Soils

1.6.1 Introduction

Both the soil pattern and the chemical and physical properties of the soils can be related to previous deep weathering and subsequent patterns of stripping. As a consequence of pre-weathering, the soils formed on lateritic profiles have a clay fraction dominated by kaolinite and secondary iron and aluminium minerals, with a low base status, and small amounts of nutrients compared to those formed on fresh rocks (Turton *et al.* 1962; Robson and Gilkes 1981). Smectites may occur where soils are derived from mafic rocks.

Upland areas where the deep weathering profile has not been truncated, or only partially so, have soils dominated by ferricrete gravels with a matrix of sand or sandy loam (Mulcahy 1973). In some areas it is thought that the prior lateritic profile was truncated to the mottled zone, with gravelly soils forming from the mottled zone. Ferricretes may occur as massive duricrusts, with ferricrete gravels becoming finer down-slope. These are underlain by mottled yellow substrates up to 3 m thick. Where the deep weathering profile has been stripped, the soils formed depend on the degree of truncation and the lateritic horizon (mottled zone, pallid zone) which has been exposed. Solodic and podzolic soils dominate, with non-calcic brown soils on mafic dykes. Deposits of varying depth occur on slopes, with the soils often sandy or gravelly

(Mulcahy 1960) and these have been described as sandy yellow earths, earthy sands and sands overlying ferricrete gravels (Churchward 1970).

Soils of the target area are described in some detail in a number of reports, summarized in Table 5.

Table 5: Summary of major soil reports for the target area

Geomorphic Zone	Soil reports
Swan Coastal Plain	(McArthur *et al.* 1959; Bettenay *et al.* 1960; McArthur and Bettenay 1960; McArthur 1991; Schoknecht and Bessell-Browne 1994; Smolinski and Scholz 1997)
Dandaragan Plateau	(Hosking and Greaves 1935; Churchward 1970; McArthur 1991)
Darling Plateau	(Mulcahy 1967; Mulcahy *et al.* 1972; Dimmock *et al.* 1974; Churchward and McArthur 1980; Churchward and Dimmock 1989; King and Wells 1990; McArthur 1991; Lantzke 1993a; Lantzke 1993b)

1.6.2 Major properties of soils

The general form of most of the soils is of a sandy textured surface horizon overlying ferricrete gravel and sandy clay. The depth of the clay varies markedly across the landscape, as is expected to be deepest in areas of deep weathering.

The soils are perhaps better understood if they are regarded in terms of individual layers, each of which have particular properties which will affect tree growth.

1.6.2.1 Sand layer

The major features of the sand horizons are:-

- It is composed predominantly of fine grained quartz sand, with small amounts of clay (<5%).
- An accumulation of organic matter in the surface horizon that has caused dark staining.
- Small amounts of nutrients such as phosphorus, nitrogen and various trace elements occur near the soil surface. The present content of these nutrients reflects past fertiliser applications and management.
- The sand is of variable depth, depending on the location of the soil, ranging from a few centimetres to several metres deep on some sand dunes.
- The sand is usually white or grey in colour. Sands which are bright yellow at depth are generally regarded as being more fertile, usually due to slightly larger contents of clay and potassium.

1.6.2.2 Ferricrete gravels

Horizons composed of ferricrete gravels ("laterite") are a common feature of the soils. These can comprise >50% of the horizon, with a sandy matrix. The horizon is of variable depth, tending to be deeper on old laterite surfaces.

The occurrence and extent of cemented horizons, which would impede root growth, such as seen in the Darling Range is not known, but these can be ameliorated by ripping.

1.6.2.3 Clayey horizons

Clayey horizons underlie the gravel and sandy horizons throughout the landscape, at variable depths.

- Clay horizons range in texture from sandy clay loams to medium clays.
- From limited analysis, the subsoil clays appear to be chemically more fertile than the sands, with accumulations of calcium, potassium and magnesium.
- Salinity often increases with depth.
- The depth of the clay horizons, above un–weathered rock are highly variable.

1.6.3 Soil water relations

Superimposed on the above sequence of materials, are the water relations of the soil, which are determined by local drainage conditions. Tree growth will be affected both by an excess (waterlogging), or deficiency, of water (Havel 1968). The site survey recommendations (Table 9) have been designed to avoid these sites.

The location of soils in the landscape is important. Deep sandy soils for example can be well drained or poorly so; deep sand on a hill crest will provide different conditions for tree growth to deep sand found within a swamp.

- **Waterlogging**
  During the winter, when rainfall is high and evaporation low, water can accumulate above the poorly permeable clayey B horizons.
- **Soil water storage**
  The water storage of the soil is related to such soil attributes as texture, structure and depth of the soil available to roots. Factors affecting root penetration, and thereby effective soil depth, include, waterlogging, compaction and cementation, unfavourable chemical conditions such as salinity and extremes of pH and a shallow depth to underlying rock.

1.7 Native vegetation

The vegetation of the study area was mapped at a scale of 1:250,000 by Beard (1979). These studies identified the major communities and indicated the structural formation and dominant species of each strata. Various studies have recognised that the structural and floristic composition of the vegetation is influenced by the general south-north trend of increasing aridity. Conspicuous examples are the absence of *Eucalyptus marginata* (jarrah) and *Allocasuarina fraseriana* (sheoak) in the study area. *Hakea obliqua*, a species more common north of the study area, is present on the Bassendean Dunes.

Major vegetation associations of the target area are described by Smolinski and Scholz (1997):

Banksia ilicifolia **(holly-leaf banksia)** ***Low Woodland***

This occurs on pale and bleached siliceous sands and is also encountered with *B. attenuata* and *B. menziesii* on lower slope positions.

Banksia prionotes **(acorn banksia)** ***Low Woodland***

This is associated with siliceous sediments of post-Pleistocene age. Soils are commonly pale, fine to medium-grained sands associated with aeolian or alluvial landform elements.

Eucalyptus gomphocephala **(tuart)** ***Tall Woodland***

A prominent stand of remnant tuart woodland occurs between Beermullah West Road and Lake Bidaminna. It is found on the Spearwood Dune System on crest and mid-slope positions, near outcropping limestone. Isolated stands also occur along the Moore River and Gingin Brook over limestone.

Eucalyptus decipiens **(redheart)** ***Low Woodland***

This formation has limited distribution, often in isolated clumps in association with aeolianite, travertine or marl. It is found on the Spearwood Dune System. On the Beermullah Plain it occurs where it may be associated with rare *Eucalyptus foecunda* (coastal dune mallee).

Corymbia calophylla **(marri)** ***Woodland***

Marri is the most common tall tree species of the study area. It does not tolerate dry sites and therefore can be a reliable indicator of good pasture land. On the Spearwood Dune System it forms a tall woodland and may be associated with tuart. Within the sandplains it forms a dense stand on the periphery of incipient drainage lines and lakes. Marri occurs sporadically on the alluvial soils of the river systems and the Beermullah Plain. It can be associated with *Eucalyptus decipiens* in an open woodland formation or as an emergent species in *Melaleuca*, *Allocasuarina* or *Acacia* shrubland.

On the footslopes of the Gingin Scarp it forms a woodland especially where the brown sands have clayey sand to sandy loam subsoil textures within 1m.

Eucalyptus wandoo **(wandoo)** ***Woodland***

Two remnant stands of wandoo occur on a brown duplex soil and on red to brown acid duplex soils.

Casuarina obesa **(swamp sheoak)** ***Woodland and Low Forest***

Swamp sheoak is found on fine textured alluvium in poorly drained areas and is a good indicator of salinity.

Eucalyptus rudis **(flooded gum)** ***Open Woodland***

This commonly occurs in association with *Melaleuca rhaphiophylla* (paperbark) along Gingin Brook and Moore River. It is also found within the Bassendean Dune System near lakes and drainage lines.

Melaleuca viminea **(tea-tree)** ***Shrubland***

This is the most common tea-tree of the alluvial plains. It forms a shrubland on the poorly drained fine-textured soils associated with *Melaleuca lateritia* (robin redbreast bush), *M. teretifolia* (banbar), *M. uncinata* (broombush), *M. cuticularis* (saltwater paperbark), *M. incana* (grey honeymyrtle), *Viminaria juncea* (swishbush), *Hakea varia* (variable-leaved hakea), *H. trifurcata* (two-leaf hakea), *H. prostrata* (harsh hakea), *Acacia saligna* (black wattle) and *Actinostrobus pyramidalis* (swamp cypress).

ESTIMATION OF LAND AVAILABLE FOR MARITIME PINE SCHEME

1.8 Methods

1.8.1 Soil-landform data sets

The soil landform data used in this analysis was from the Atlas of Australian Soils (Northcote *et al.* 1967). Although this 1:2 000 000 scale mapping is not ideal, it is the only data set which provides consistent coverage across the target area. More detailed maps at scales of 1:50 000 and 1:100 000 scale are available for some parts of the target area (Table 5), however a regional compilation at this scale is not available.

1.8.2 GIS analysis

All analysis and plotting were undertaken using ARC-INFO. The digital soil-landform map was interrogated and a listing made of polygons and their area (Appendix 1).

1.8.3 Calculation of land suitable for Maritime Pine

The area of suitable land was calculated by a series of steps:

1. Removal of "woody" and urban land cover. "Woody cover" encompassed native bushland in State Forests, National Parks, nature reserves and remnants on farmland. It also included vineyards, orchards and existing plantations. Urban areas were removed using Metropolitan Regional Planning Scheme Boundaries. This remaining area is cleared farmland and is termed "**Available land**".

2. Soil suitability. Descriptions and soil classifications for each of the listed polygons were examined and given a weighting between 0 and 1 for the following factors:

- salinity and waterlogging
- soil depth
- other factors such as excessive slopes (>15%), exposure (i.e. coastal dunes) and miscellaneous factors (beaches, lakes, rivers).

These ratings were combined as a "multiplication factor", with a resultant value between 0 (unplantable) and 1 (no limitations). The area of each unit was multiplied by this factor to provide an estimate of the "**Plantable land**".

3. Proportion of farmland planted. As the target area for *Pinus pinaster* is farm-land it was assumed that afforestation would proceed by planting 20% of all suitable. This is termed "**Nett area**."

4. Rainfall. Rainfall isohyets (mean annual rainfall) from Commonwealth Bureau of Meteorology were used.

5. Distance from Kewdale. A series of radial distance zones (50, 100,150 and 200 km) from Kewdale were developed.

1.9 Results

1.9.1 Map legend.

Fig. 1 shows the Atlas of Australian Soils Mapping (Northcote *et al.* 1967) reinterpreted in terms of four soil suitability classes, derived from the soil suitability calculation described in §1.8.3. These portray the proportion of that mapping unit considered likely to be suitable in four classes (0-25, 26-50, 51-75 and >76%). Each unit contains an array of soils.

1.9.2 Area estimates

Tables 6-8 show estimates of land available for planting, using the procedures outlined in §1.8.3. Total cleared farmland, excluding native bushland in reserves or on farms and urban areas totals 1.28 million ha (Table 6). Of this land after removal of non-suitable soils (saline, shallow and waterlogged) 0.42 million ha is considered plantable (Table 7). Approximately 80,000 ha can be planted if trees are planted as strips or belts across 20% of the farms or in particular niches (Table 8).

1.10 Discussion

1.10.1 Soil constraints

Several aspects of the soils could potentially limit the establishment of trees and subsequent growth and these were considered to be:

- shallow soils such as occur on valley sides, with rock outcrop (e.g. Bindoon, Toodyay)
- salinity either due to natural salinity (salt lakes) or induced by agriculture

Table 6: Area of "available land": cleared agricultural land in the target area, by rainfall zone and distance from Perth

Distance (km)	Rainfall (mm)		Total
	400-600	>600	
	(ha)		
<50	0	10,696	10,696
51-100	151,751	224,814	376,565
101-150	333,920	170,090	504,010
151-200	362,894	33,059	395,953
Total	848,565	438,659	1,287,224

Table 7: Area of "plantable land": cleared agricultural land with limiting soils removed in the target area, by rainfall zone and distance from Perth

Distance (km)	Rainfall (mm)		Total
	400-600	>600	
	(ha)		
<50	0	3,221	3,221
51-100	85,511	61,530	147,041
101-150	116,257	35,414	151,671
151-200	109,545	6,447	115,992
Total	311,312	106,612	417,924

Table 8: "Nett" area of land (ha) available in the target area, by rainfall zone and distance from Perth, calculated by assuming 20% of the "plantable land" will be afforested

Distance (km)	Rainfall (mm)		Total
	400-600	>600	
	(ha)		
<50	0	644	644
51-100	17,102	12,306	29,408
101-150	23,251	7,083	30,334
151-200	21,909	1,289	23,198
Total	62,262	21,322	83,585

- heavy textured valley floor soils such as gilgai flats and with heavy textured, alkaline sub-soils such as near Moora.

1.10.2 Soil conditions for success

Soils considered most favourable were mostly those formed on deeply weathered lateritic profiles, lateritic sandplain and aeolian dunes. These were considered to have the best water storage.

The soil factors most likely to affect *Pinus pinaster* survival and growth are related to soil water storage and salinity. Successful planting of the trees in this lower rainfall environment will need:

- non-saline conditions, either current, or likely to develop during the rotation.
- adequate soil depth (at least 2-3 m) or access to moisture under the adjacent crop or pasture
- fresh water additions from run-on, seepage or groundwater (George 1991).

1.10.3 Manageable soil properties

For this analysis, the following soil properties were assumed to be non-limiting to tree performance, and if present could be overcome by appropriate site management:

- ferricrete hard pans (laterite, duricrusts) which were either limited in extent, or could be ripped. Other types of hardpans (silcrete and calcrete) were of limited extent in the soils considered suitable.
- non-saline waterlogged areas which could be drained and mounded.
- duplex ("sand over clay") soils
- water repellency and soil acidity
- soil fertility
- water repellency, which prevents the wetting of the soil at the start of the growing season. Water repellency may be used to advantage with modification of establishment techniques to divert water to trees.

The combination of fine sand grains and low clay contents predisposes many of the soils to wind erosion. The amount of surface cover provided by plants can modify the erosion risk; as plant productivity is related to soil depth, deeper sands often have less cover and are more susceptible to wind erosion. Wind erosion will only be a problem at establishment, with the trees increasing soil stability as they grow.

1.10.4 Limitations of analysis

This analysis has the following limitations:

- The 20% tree planting is an arbitrary figure – if followed this will only represent 6% tree planting on cleared agricultural areas. There is scope to substantially increase the area of trees planted by increasing the proportion of certain soils planted.
- The soil-landscape mapping units often comprise several soils, with no indication of the actual proportion of different soils in each unit. These had to be inferred.

- Depth and nature of soil sampling - much of the soil-landscape analysis was undertaken for agricultural purposes, with shallow examinations (<1 m). Tree growth in this area will require soil depths of ~2-3 m. The regional pattern of deep weathering profiles affected by variable degrees of stripping however is very strong and the depth of weathering can be confidently inferred from the existing mapping.
- Soil data are mostly descriptive, hence likely limiting factors such as salinity or waterlogging were inferred. Profile hydrology is uncertain, as is the distribution of deep profile salinity and its affect on tree growth. These issues are currently being researched.

1.11 Detailed site investigation needed for plantation establishment

The scale of the mapping presented in this report is such that the soils should be regarded as general for each unit. Similarly, mapping from the regional soil compilation will when available be too generalized for farm planning.

It will be necessary to survey the soils of each site at a larger scale, such as 1: 10 000 as a prelude to tree establishment. Site selection guidelines for Maritime Pine, as currently used by CALM in the target area, are summarized in Table 9.

Table 9: Land Selection Criteria for Maritime Pine (*Pinus pinaster*)

Guideline 1:	Soils should have >2.5 m of root penetrable material. Soil inspection in backhoe pits is recommended so as to assess likely root penetration. Roots will be impeded by rock (limestone, granite, dolerite etc), continuous hardpans (ferricrete, coffee rock) and poorly structured sub-soils. Some effort should be made to assess the variability of depth across the site.
Guideline 2:	Poor tree growth is expected on sandy soils, >2 m deep, which are white (Munsell chromas <3) throughout the soil profile. These sites should be avoided. Sands with brighter colours within the profile (Munsell chromas >3) are acceptable.
Guideline 3:	Sites with waterlogging, within 1 m of the surface for more than 2 months a year should not be planted. Indications of waterlogging include landform, gleyed sub-soil clays and vegetation such as paperbark (*Melaleuca* spp) and rushes (*Juncus* spp).
Guideline 4:	The current expression of salinity should be assessed from surface indicators such as scalds, salt efflorescences and surface plant indicators such as barley grass and using an EM38 salinity meter. Sites with values >60 mS/m should not be planted.
Guideline 5:	The future risk of salinity developing via rising groundwater tables should be deduced from landscape position. Deep drilling will not occur. Likely quality of groundwaters should be determined from the Geological Survey of WA, WAWA and Agriculture WA data.
Guideline 6:	Soils with extreme alkalinity within the soil profile (pH >8.5) should be avoided. These sites are often associated with shallow limestone, or with incipient salinity.
Guideline 7:	Soil fertility should be assessed via analysis of surface (0-10 cm) soil samples. Phosphorus fertilizers may be required on sites with <10 ppm bic-P. Potassium fertilizer responses have not been reported for *Pinus pinaster* in WA; those sites with very low levels of bic-K. (<40 ppm) may have other limitations. Nitrogen fertilizer responses are unlikely irrespective of previous pasture condition.
Guideline 8:	All of the above limiting factors should be assessed using a soil survey as a framework.

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APPENDIX 1: AREA ESTIMATES DATA

Polygon	Distance (km)	Rainfall (mm)	Suitability Class	Available land	Plantable land (ha)	Nett area
4	<50	800	0-25%	6,834	854	171
3	<50	800	26-50%	713	267	53
2	<50	800	51-75%	21	13	3
1	<50	800	76-100%	1,371	1,199	240
7	<50	900	0-25%	91	11	2
6	<50	900	26-50%	664	249	50
5	<50	900	51-75%	1,003	627	125
10	51-100	500	0-25%	9,366	1,171	234
9	51-100	500	26-50%	10,080	3,780	756
8	51-100	500	76-100%	47,146	41,253	8,251
13	51-100	600	0-25%	27,916	3,490	698
12	51-100	600	26-50%	28,539	10,702	2,140
11	51-100	600	76-100%	28,703	25,115	5,023
17	51-100	700	0-25%	54,210	6,776	1,355
16	51-100	700	26-50%	9,548	3,581	716
15	51-100	700	51-75%	9,151	5,720	1,144
14	51-100	700	76-100%	12,427	10,874	2,175
21	51-100	800	0-25%	98,202	12,275	2,455
20	51-100	800	26-50%	18,450	6,919	1,384
19	51-100	800	51-75%	10,548	6,592	1,318
18	51-100	800	76-100%	9,169	8,023	1,605
24	51-100	900	0-25%	1,979	247	49
23	51-100	900	26-50%	732	274	55
22	51-100	900	51-75%	398	249	50
28	101-150	500	0-25%	42,374	5,297	1,059
27	101-150	500	26-50%	105,890	39,709	7,942
26	101-150	500	51-75%	7,102	4,439	888
25	101-150	500	76-100%	27,589	24,141	4,828
32	101-150	600	0-25%	84,363	10,545	2,109
31	101-150	600	26-50%	47,582	17,843	3,569
30	101-150	600	51-75%	9,439	5,899	1,180
29	101-150	600	76-100%	9,582	8,384	1,677
36	101-150	700	0-25%	124,299	15,537	3,107
35	101-150	700	26-50%	6,213	2,330	466
34	101-150	700	51-75%	20,596	12,873	2,575
33	101-150	700	76-100%	1,522	1,331	266
38	101-150	800	0-25%	12,818	1,602	320
37	101-150	800	26-50%	4,643	1,741	348
42	151-200	500	0-25%	55,611	6,951	1,390
41	151-200	500	26-50%	22,351	8,382	1,676
40	151-200	500	51-75%	30,350	18,969	3,794
39	151-200	500	76-100%	40,255	35,223	7,045
46	151-200	600	0-25%	169,871	21,234	4,247
45	151-200	600	26-50%	36,171	13,564	2,713
44	151-200	600	51-75%	8,110	5,069	1,014
43	151-200	600	76-100%	175	153	31
49	151-200	700	0-25%	25,294	3,162	632
48	151-200	700	26-50%	6,272	2,352	470
47	151-200	700	51-75%	1,494	933	187

LAND SUITABILITY FOR MARITIME PINE – NORTHERN CELL

Total	1,287,224	417,924	83,585