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Reconstructing pre-European forests of south-western WA – The contribution of 1750 vegetation mapping

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ABSTRACT: Previous workers had stressed the significance of the climate, landforms and soils in determining the distribution of plant communities in this area. Our recent vegetation-mapping project in 4.25 million hectares of the Southwest Forest Region is a synthesis of regional patterns in vegetation in relationship to underlying landforms, soils and climate.

The predictive capacity of the resulting vegetation maps at both 1:250,000 (vegetation complexes, Mattiske and Havel 1998) and 1:500,000 (ecological vegetation systems, Havel and Mattiske 1998) enabled the vegetation patterns prior to European settlement to be determined through extrapolation at a regional scale. The maps are more detailed than the earlier forest mapping by Bradshaw *et al.* (1997). There is now a range of maps scales from detailed and localised mapping at 1:10,000 (site-vegetation types), through 1:250,000 (vegetation complexes, based on 1:50,000 mapping) to 1:500,000 (ecological vegetation systems and landscape conservation units), Havel (1968, 1975a), Mattiske and Havel (1998), Havel and Mattiske (1998), Havel (2000) and Mattiske Consulting Pty Ltd and Havel Land Consultants (2003). The more detailed mapping is useful to local managers and the broader mapping is more useful for regional planning. The fact that the smaller precision categories are nested within the increasingly broader categories facilitates their application at all levels of planning, operational activities and management. This continuity has been achieved by upward agglomeration.

Whilst there appears to be a global decline in the use of vegetation maps for managing forest systems in Western Australia vegetation maps have been used for a range of management purposes. These purposed have included assessing the adequacy of the reserve systems, investigating the potential spread and intensification of fungal diseases, reviewing impacts of selective land uses such as mining and dam building and planning fire management programs at a regional and subregional scale. The maps, with the implied underlying relationships between vegetation and environmental factors provide many opportunities for future research and management. The potential applications are immense and the work as presented provides a critical baseline for understanding and managing the forests in the southwest region.

1 HISTORICAL CONTEXT FOR VEGETATION MAPPING IN SOUTHWEST FOREST REGIONS

The relationships between the vegetation and the underlying geology, landforms, soils and climate was observed and recorded by people from the early days of European settlement. Many of the early European settlers selected sites best suited for agriculture (seasonally moist, fertile soils) on the basis of correlation between vegetation and soils. York gum (*Eucalyptus loxophleba*) was used as an indicator of fertile loams and Banksias (*Banksia menziesii* and *Banksia attenuata*) as indicators of infertile soils. In recent decades, the scientists have confirmed many of these relationships in different areas of the southwest forest region; although only in a few instances have the spatial relationships between vegetation and underlying causative factors been mapped.

2 EARLY ATTEMPTS AT ECOLOGICAL CLASSIFICATION AND MAPPING

Gentilli (1979a and 1979b) summarized and reviewed the early floristic maps. The first floristic map was produced by C.Woodhouse in the Surveyor-General's Office in 1880. This map (at a scale of 1:1,170,000) covered the forest areas within the State and was the first attempt to define forests in the area from Moore River to Pallinup River. This map distinguished the six dominant tree species - jarrah *(Eucalyptus marginata*), karri (*Eucalyptus diversicolor*), 'white gum' or wandoo (*Eucalyptus wandoo*), 'tooart' or tuart (*Eucalyptus gomphocephala*), York Gum (*Eucalyptus loxophleba*) and 'red gum' or marri (*Corymbia* (formerly *Eucalyptus*) *calophylla*). This early work illustrated the distribution of the dominant tree species in the southwest forest region of Western Australia.

This early work was followed by a series of successive floristic maps, which illustrated the broader floristic regions within the State (Drude 1884, Sievers 1895). This earlier tradition of floristic maps of dominant forest species was continued by Moore (Ednie-Brown 1896, 1899), Lane-Poole (1920) and latter by Hall *et al*. (1970), Chippendale (1973) and Brooker and Kleinig (1990). In recent years substantial taxonomic studies have led to revisions of many of the species which dominate the South West Forest Region (Brooker and Hopper 1991, Brooker and Hopper 1993).

Another early attempt at vegetation mapping was that of Schimper (1898) who described the sclerophyllous woodlands in the southwest region of the State. . Although the botanical collections and descriptions in southwestern Australia date back to the early days of colonization in 1830 (Drummond), the first major scientific attempt to classify and map the vegetation on a structural basis was that of Diels (1906) in his classic Die Pflanzenwelt von West Australien sudlich des Wendeskreises - The Plant World of Western Australia South of the Tropic.

The work of Diels was ambitious as it was undertaken at a time when transport was limiting. It was perceptive in that it defined relationships between the vegetation and the underlying environmental factors, especially climate and soils. The key perception was that the vegetation of the south west has no counterpart in Mediterranean regions elsewhere in the world, in particular the presence of tall trees with vertical leaves, the strong development of hard-leaved shrubby understorey and the replacement of the grasses and annuals by perennial herbs of the families Cyperaceae and Restionaceae. He also identified the great floristic richness of the vegetation in spite of, or perhaps because of, the extreme infertility of the sandy and gravelly soils. Apart from the main forest formations, Diels also described swamp and granitic rock formations, giving a brief enumeration of species for each.

As a plant geographer, Diels was interested in endemism, which has considerable bearing on the detection of plant indicators. He considered the jarrah forest to be relatively poor in endemics amongst its 875 species, with the endemism at a maximum near its northern limit, where the climatic gradient is steepest. For the South-West province as a whole, he listed *Lyginia, Anarthria, Dasypogon, Kingia, Phlebocarya, Conostylis, Synaphea* and *Nuytsia* as first-class endemics, that is without any relations outside, and *Desmocladus, Diplolaena, Platytheca, Tremandra, Hypocalymma, Calothamnus* and *Andersonia* as second-class endemics, that is with some relations outside but markedly different from them. Diels subdivided the southwest province into seven botanical districts.

These early observations are significant as they highlighted the relationships that underpinned the development of the concepts tested in more recent studies in the southwest forest region.

Several authors contributed to the vegetation mapping in the period from 1906 to 1940, although these studies were relatively minor for interpretations in the southwest region. Hardy (1911) in Gentilli (1979b) defined the forest areas as "winter rain forest" which recognised the potential role of climatic conditions in determining forest boundaries.

Gardner's (1923a, 1923b) description was little more than a brief summary of Diels' work in English. It was followed by a vegetation map in Gardner (1928). Geisler (1930) included the dominant floristic element in each plant formation and his accuracy on the dominant species appears to reflect a certain degree of regional knowledge of the State. The overall description of the vegetation of Western Australia by Gardner (1944) elaborated on the work of Diels, and added to the knowledge of areas not visited by him, but the scheme of classification was essentially that of Diels. The jarrah forest was mentioned only briefly, with no additional information.

Prescott's (1931) vegetation map is well known, although it did not differ substantially from the earlier map of Gardner (1928). Wood (1950) published a map, which included a more realistic appraisal of the characteristics of the Australian vegetation. These three latter authors all recognised the significance of climate in determining forest types, although some differences were noted in their interpretations on "wet sclerophyll forest", "dry sclerophyll forest" and "temperate Eucalyptus rain forest" and "mesophytic forest".

3 FORESTS DEPARTMENT - AERIAL PHOTOGRAPHIC INTERPRETATIONS

Following the Second World War, the Forests Department utilized the technology developed for aerial reconnaissance to map the areas under its control from black and white photography. The outcome of this photo-interpretation work was mapped at a scale of 1:63,360 and by 1970 covered the entire forest region to the stage where it could be used by Smith (1972, 1973, 1974), Beard (1979a, 1979b and 1979c) and Heddle *et al.* (1980a), in association with their own vegetation mapping work. The Aerial Photographic Interpretation (API) maps chiefly described and mapped the structural features of the vegetation, such as height, class and crown cover. Only some of the species with characteristic structural features can be identified on the aerial photographs, for example karri (*Eucalyptus diversicolor*), rock sheoak (*Allocasuarina huegeliana*) and the swamp paperbark (*Melaleuca preissiana*).

This work provided a foundation for more detailed maps of forest types and vegetation maps in the intervening years and formed a key planning tool for managing forest products after the second world war. The efforts of the earlier tree markers and foresters must not be underestimated in this context as they provided ground checks on the photo interpretations through extensive foot traverses.

4 POST SECOND WORLD WAR STUDIES IN THE FOREST

In the years after the second World War there were major steps taken in developing our ecological understanding of the ecosystems in the southwest forest regions and a major shift was seen from a floristic approach to a systems approach.

Examples of this work included the studies by Williams in 1932 and 1945 who carried out two small scaled, but detailed, studies in the northern jarrah forest (within the Cohen Brook and Darkin River catchments. Holland (1953) recognised the eroded valleys as migration routes with the distribution of species potentially resulting from past expansions and contractions. In recent fauna debates similar concepts have been used to raise the significance of streamzones. Through the delineation of informal reserves along watercourses in the southwest forest regions.

Williams (1955) followed on from the earlier work of Wood (1950) and relied on structural characteristics. Sochava and Korchagin (1970), utilising William's 1955 map, defined twenty-three types of vegetation.

Speck in 1958 developed the earlier work of Diels (1906) by carrying out detailed field investigations and by illustrating the structure of plant communities by profile diagrams.

5 CLIMATE STUDIES

There have been many attempts at defining those features of the climate of southwestern Australia which determine the vegetation patterns. There is generally a reference to climate in every mapping or classification scheme, as well as stand-alone discussions on the climate-vegetation interactions.

The relationships of tree species with underlying climatic conditions was highlighted by Lange (1960) in his studies on the relationships between the distribution of tree species in the Narrogin district with underlying climatic and edaphic factors. He attributed the disjunct occurrence of the western species to an arid period in the late Quaternary, as postulated by Crocker (1959). Churchill (1961, 1968) expanded on the influence of past climatic conditions through the palynological investigations with *Eucalyptus marginata, Corymbia calophylla* and *Eucalyptus diversicolor.* Churchill concluded that a drier climate would favour an increase in *Corymbia calophylla* at the expense of *Eucalyptus diversicolor.* He recognised the strong north-south and east-west patterns in the distributions of the individual species.

Havel (1975b) studied the effect of climate on vegetation in a series of field surveys set of subcatchments spanning the climatic range in the northern Jarrah forest from 600 to 1300mm of annual rainfall. Beard (1981a, 1981b and 1990) analysed the climatic patterns for the region as a whole in relation to the vegetation and noted the striking difference between coastal and inland localities. He gave considerable consideration to past climates, chiefly drawing on the studies by Churchill (1961 and 1968). The differences in temperature regimes between coastal and inland areas was also noted by Churchward *et al.* (1988). Temperature gradients were also noted by Inions (1990a, 1990b). The current climatic patterns are considered to have persisted over the past 5000 years, but it is recognised that a major climatic shift is in progress now.

Gentilli (1989) has refined the classification of climate in the southwest region by introducing the concept of summer stress, to take into account the strong summer drought lasting 4 to 7 months, which is characteristic of southwestern Australia. According to Gentilli (1989) not only the magnitude of the rainfall is significant, but also it's timing. The dry and hot summers have also been considered in the recent studies by Havel (2000), although this was balanced by consideration of the waterlogging in winter for some of the ecosystems.

6 GEOMORPHOLOGICAL STUDIES

A range of geomorphological studies within the southwest region increased our understanding of the systems within the southwest forest region. The earliest geomorphological studies commenced in the 1920's and 1930's (Clarke 1926, Jutson 1934) however the main studies in the forested areas commenced in the 1970's (Mulcahy and Kingston 1961, Mulcahy *et al.* 1972, Finkl 1976). These studies were later extended by McArthur *et al.* (1977), Churchward and McArthur (1980), Churchward *et al.* (1988) to entire forested region, though some gaps remained.

Parallel to the work being undertaken by the CSIRO Division of Land Resources by Mulcahy, McArthur and Churchward, the Department of Agriculture commenced the Land Resources Series, which filled in the gaps in the geomorphological mapping. These studies included the work of Wells (1989) in the Mandurah and Murray shires, King and Wells (1990) to the east of Perth, Lantzke and Fulton (1992) in the Northam region, Tille (1996) in the Wellington and Blackwood areas, Tille and Lantzke (1990) in the Busselton – Margaret River and Augusta areas and Churchward (1992) in the Manjimup area, Smolinski (in press) covered the southern Blackwood Plateau and areas south of the Blackwood River and east of Manjimup as part of the regional forest agreement geomorphology studies.

From the earliest stages of this work the geomorphologists interacted with the forest ecologist and plant ecologists (McArthur and Clifton 1975, Churchward and Batini 1975, McArthur *et al.* 1977, Havel 1975a and 1975b, Churchward and McArthur 1980 and Heddle *et al.* 1980a). On occasions the ecologists drew attention to new landforms and on other occasions the geopmorphologists drew attention to new vegetation types. This interaction led to a greater insight into the relationships between the underlying geomorphology and the vegetation and was utilised by Mattiske and Havel (1998).

7 DEVELOPMENT OF ECOLOGICAL STUDIES SINCE THE 1970'S IN THE SOUTHWEST FOREST REGION

Within a similar time frame a range of broad, as well as very specific and localized floristic and vegetation studies were undertaken in the southwest region by a range of authors. These included the broadscale account of the climate, landform and vegetation by McArthur and Clifton (1975) in the Pemberton district as an aid to landuse planning. This work enabled the development of linkages between vegetational features and the soil associations in sections of the southwest forest region.

More detailed ecological studies were also undertaken by:

- Loneragan (1978) in the Jarrah (*Eucalyptus marginata*) forests and the Wandoo (*Eucalyptus wandoo*) woodlands,
- McCutcheon (1978 and 1980) in the northern half of the Blackwood Plateau,
- Bettenay *et al*. (1980) in the Collie area,
- Heddle (1979), Heddle *et al*. (1980a) and Heddle and Marchant (1983) in the northern and central sections of the southwest forest region,
- Havel (1975a and 1975b) in the northern forest regions,
- Christensen (1980) in the Perup forest areas in association with vertebrate fauna studies,
- Trudgen (1984) in the Westdale-Dobaderry group of reserve on the north-eastern section of the southwest forest region,
- Semeniuk (1987, 1988, 1997) and Semeniuk *et al*. (1990) in the wetland systems in the Darling and southwestern areas of Western Australia.
- Strelein (1988) on the Darling Plateau south of the Blackwood River and on the adjacent Southern Coastal Plain,
- Inions *et al.* (1990a and 1990b) in the karri forests in the southern sections of the southwest forest region,
- Wardell-Johnson *et al.* (1989, 1995) in the southern sections of the southwest forest region,
- Mattiske and Burbidge (1991) in the northern forest region near the Darling Scarp,
- Griffin (1992 and 1995) in the northern fringes of the southwest forest region and in the southern Wheatbelt areas respectively.
- Smith (1994) in his targeted studies on the Blackwood Plateau and near Margaret River.
- Ecologia Environmental Consultants (1994) in the wandoo areas east of Perth.
- Gibson *et al.* (1994) in the studies on the southern Swan Coastal Plain on the fringes of the forested areas of the southwest forest region.
- Grein (1995) in the studies on the Blackwood River.
- Mattiske Consulting (1996) in the studies on the Scott Coastal Plain.
- Markey (1997) in the studies in the northern Darling Range.
- Hopkins and Beard (1999) in the re-classification and mapping of Beard's earlier work in the southwest forest region.
- Lyon *et al.* (2000) in the studies on the flora in the Warren bioregion.

In addition, a significant amount of work has been undertaken for industry groups in targeted areas from Scott Coastal Plain in the south to vast areas of the northern Jarrah forest. During the regional mapping process the authors had access to many of these industry-based data sets for interpretation of regional patterns in vegetation and relationships with underlying geomorphology and soils.

8 DEVELOPMENT OF METHODOLOGY FOR RECONSTRUCTING PRE-EUROPEAN (1750) FORESTS OF SOUTH-WESTERN WA

The previous sections place the vegetation-mapping project undertaken by Mattiske and Havel (1998) into a wider context. The concept that the vegetation which existed before 1750 could be reconstructed from underlying patterns in geomorphology, landforms, soils and climate was not a new idea at the time of the studies, however no one had attempted a detailed approach mapping on a regional scale. Previous authors had developed and or tested some of these determining relationships either conceptually or in a local context. There is no doubt that some of the patterns were clearly identified by the early settlers on the basis of careful observations of the landscapes and the resulting dominant species. It is only in later years that we have been able to test and analyse some of these patterns.

The vegetation mapping approach taken during the regional forest agreement process attempted to define and maps these relationships on a regional scale utilizing the information and data of many previous authors and researchers and the additional information collected by the authors of the vegetation mapping project (Mattiske and Havel 1998).

The matching of vegetation to landform and climate was carried out by means of toposequences, that is gradients of topography, soils and vegetation within individual landform and climate categories. The process represents a progression from localised objective quantitative studies of simple systems (Havel 1975b) to the more subjective synthesis of the region as a whole.

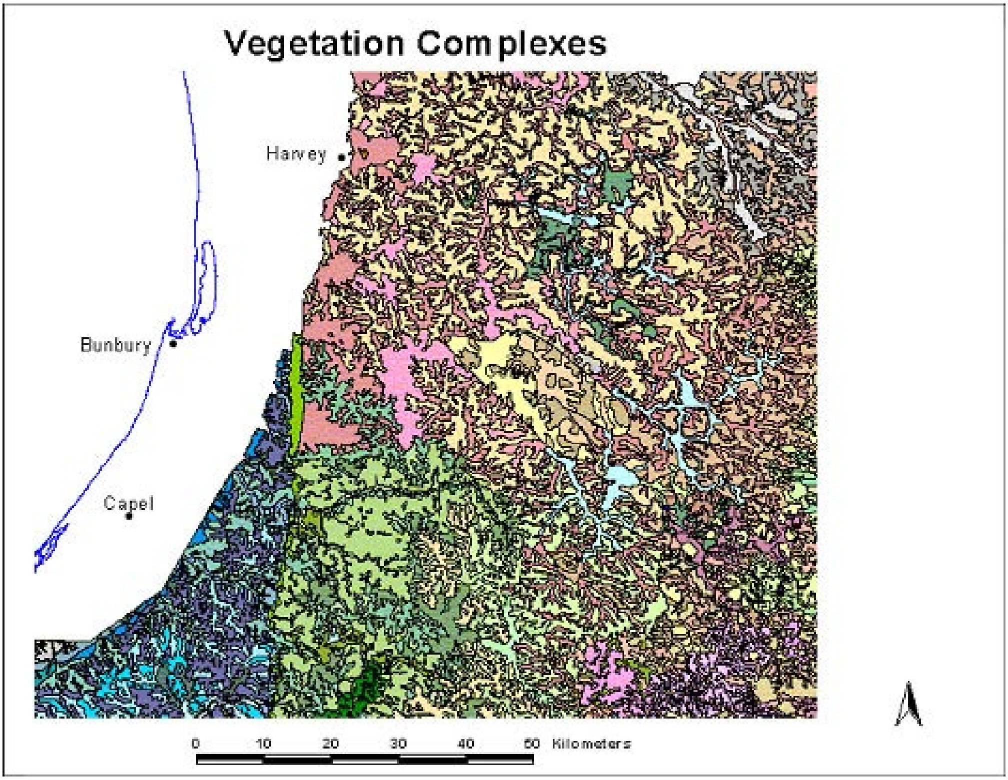


Figure 1. Section of the Vegetation Complexes in Southwest Forest Region, Western Australia (Mattiske and Havel 1998).

The vegetation complexes were defined using data points from more than 18,000 sites which were available from previous authors and researchers, detailed and local studies by Mattiske (nee Heddle) and from additional data collected during the regional forest agreement vegetation-mapping program.

The current series of maps is envisaged as bridging the gap between Beard's (1981a) 1:1 000 000 series, Hopkins and Beard (1999) and Beard's (1979a, 1979b, 1979c, 1979d) and Smith's (1972, 1974) 1: 250 000 series of Vegetation Survey of Western Australia, which are primarily based on vegetation structure and dominant species. The vegetation mapping at the vegetation complex level is an extension of the Heddle *et al.* (1980a) maps, which covered the System 6 area (which included the Swan Coastal Plain and the central and northern Jarrah forests). In this latter mapping, the structure and floristic of the vegetation was combined with environmental factors, in particular geomorphology and climate, to the remainder of the forested region of southwestern Australia. An extract of the vegetation complex maps is provided in Figure 1.

Because the bulk of the vegetation in the two regions consist of either forest or woodland of primarily jarrah (*Eucalyptus marginata* subsp. *marginata* and *Eucalyptus marginata* subsp. *thalassica*), mapping on structure or dominance has severe limitation. The bulk of variation in the vegetation resides in the shrub and herb storey, which includes over 3000 vascular plant species. Some 3244 native vascular plant taxa were defined for the regional forest agreement area, which encompasses the majority of the southwest forest region (Commonwealth of Australia and the State of Western Australia 1999, Western Australian Herbarium 2004). Past quantitative studies have demonstrated the feasibility of subdividing the structurally uniform vegetation of the region on the basis of floristics. However, direct mapping of floristically homogeneous communities (or site-vegetation types) can only be done at the scale of 1:10,000 to 1:25,000. It requires intensive fieldwork and is costly and slow.

In this project the geomorphologic maps covering the two bioregions were converted into maps of vegetation complexes by using climatic data and outputs of localized quantitative vegetation studies, including detailed data from more than 18,000 site specific data points, a range of site specific studies undertaken by different authors and researchers and the detailed research findings from studies undertaken in the southwestern area of Western Australia (as indicated in above). Detailed analyses were undertaken on specific targeted and representative areas and then findings were extrapolated to regional patterns utilizing the underlying geomorphological maps, information on landforms, soils and vegetation within the various climate zones. The relationships were summarized in the text, a series of maps and profile diagrams to illustrate the relationships between the various factors used to define the vegetation complexes (Mattiske and Havel 1998).

The pictorial component of the format follows the pattern already previously utilized by Speck (1958), Havel (1968, 1975b) and Beard (1981a, 1981b) to illustrate the ecological relationships, that is the configuration of the land and the structure and composition of the vegetation (Figure 2). This is augmented by a brief description of climate and soils in terms of criteria most relevant to plant ecology, in particular the water balance, and by description of the composition of the dominant stratum, of the second story and of the shrub and herb story.

This format makes it possible to get a rapid overview of similarities between the various vegetation/climate/landform combinations. For the sake of brevity these records of vegetation/climate/landform combinations in the form of diagrams and the associated text were referred to as toposequences (ecological profiles). Such an approach enabled a rapid assessment and comparison of detailed observations with the site specific data collected through the region over the mapping base.

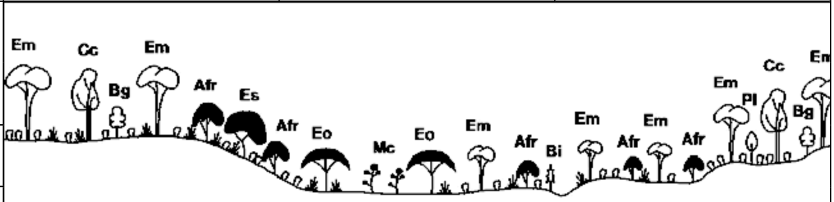
Geographic Region	Humid south		NE of Denmark
Geomorphologic Catena – VC (EVS)	TR2 – Trent (Jg6)	Bu – Boulongup (Yv4)	MI – Mitchell (Jg6)
Landform and Vegetation profile			
100m			
80m			
60m			
40m			
20m			
Land form description	Flat topped hills in sedimentary terrain	Broad, shallow depressions in sedimentary terrain with rises and lunettes	Broadly undulating uplands in sedimentary terrain
Soil structure, texture and fertility	Gravelly yellow duplex soils with laterite on crests, leached sands with iron pans on flanks, infertile	Sandy podzols on rises and lunettes; yellow solonetzic soils in depressions, infertile	Gravelly yellow duplex soils and laterite on rises, leached sands in depressions, infertile
Soil hydrology	Neither shedding nor gaining, good infiltration and water storage capacity	Mostly water gaining (via subsoil) seasonally water-logged with poor internal drainage	Mildly water shedding (via subsoil) good infiltration and water storage capacity
Over storey (canopy or emergents)	Open Forest of *Eucalyptus marginata* subsp. *marginata* (Em) and *Corymbia calophylla* (Cc) on crests, Woodland of *Eucalyptus marginata* subsp. *marginata* (Em) *Eucalyptus staeri* (Es) on sandy slopes	Low Forest of *Eucalyptus occidentalis* (Eo) with some *Melaleuca cuticularis* (Mc) in depression, Woodland of *Eucalyptus marginata* subsp. *marginata* (Em) *Allocasuarina fraseriana* (Afr) and *Banksia ilicifolia* (Bi) on rises	Open Forest of *Eucalyptus marginata* subsp. *marginata* (Em) and *Corymbia calophylla* (Cc) on crests, Woodland of *Eucalyptus marginata* subsp. *marginata* (Em) and *Allocasuarina fraseriana* (Afr) in sandy depressions
Second storey	Weakly developed, *Banksia grandis* (Bg) second storey under forest,not in woodland	Not developed	Sparse *Banksia grandis* (Bg) and *Persoonia longifolia* (Pl) under forest,not in woodland
Shrub and herb storey	*Leucopogon verticillatus* *Xanthosia rotundifolia* *Bossiaea linophylla* on creek, *Agonis parviceps* Adenanthos cuneatus Pultenaea reticulata *Andersonia caerulea* on flanks	*Adenanthos cuneatus* *Adenanthos obovatus, Kunzea recurva, Dasypogon bromeliifolius* on rises; *Calothamnus lateralis* *Hypocalymma angustifolium* *Baeckea astarteoides* in depressions	*Bossiaea linophylla, Hakea amplexicaulis, Hibbertia hypericoides, Acacia pulchella* under forest; *Adenanthos cuneatus, Pultenaea reticulata* *Beaufortia decussata* *Xanthosia rotundifolia* under woodland

Figure 2. Relationships between Vegetation Complexes and other Site Parameters

The annual median rainfall discounted by summer (December to February) evaporation was used as the key broad scale determinant of vegetation patterns. This was based on the climatic studies of Gentilli 1989. Within the climatic zones developed the moisture balance was considered to be further modified by landforms, ranging from steep slopes with shallow soils, which have no capacity to store winter rainfall toward summer transpiration, to depressions with prolonged water accretion or to deep soils capable of storing the bulk of the incoming rainfall. Landforms were also considered to be the determinants of fertility, the extremes of the range being loamy soils freshly developed over basic crystalline rock and highly leached sands that have been through more than one cycle of soil formation. The maps were initially prepared at a scale of 1:50,000 and then reduced to a scale of 1:250,000 (vegetation complexes – Mattiske and Havel 1998) and then combined into a single map of ecological vegetation systems at the scale of 1:500,000 (Havel and Mattiske 1998, Havel 2000).

The systems were defined as segments of the vegetation continuum associated with a particular combination of climate and landform. These relationships were illustrated by the use of colour to delineate regional patterns. This approach was adapted from the earlier climatic interpretations by Gentilli (1979a). The degree of dissection and hence the fertility of the site is reflected in the intensity of the colour. Steep slopes with fresh fertile soil are indicated by darker shades of colour. Mild slopes with reworked siliceous soils are indicated by pale shades. Intermediate slopes with gravelly lateritic soils are indicated by medium shades. The colour scheme used primarily reflects the water balance of the site and the composition and structure of the vegetation it supports. The woodlands of xeric sites of the arid – perarid zone are coloured yellows and orange. The tall open forest of hyperhumid sites is coloured mauve or blue. Intermediate sites are coloured yellow-green and green. Extreme sites are coloured red (eg. the main granite outcrops).

The resultant products included a comprehensive report summarizing the historical context, the series of vegetation complex maps for the Perth, Pinjarra, Collie, Pemberton, Busselton-Augusta and Mt Barker areas as well a detailed series of appendices and supporting documents (Mattiske and Havel 1998). Havel developed this synthesis further in his Ph.D. Thesis (Havel 2000) focussed on the ecological patterns in the southwest forest region

9 APPLICATION OF PRE-EUROPEAN 1750 VEGETATION MAPPING TO FOREST MANAGEMENT

As indicated earlier the early reliance of the foresters on the aerial photographic interpretations (API's) was rapidly followed by the ecologists recognizing the value of these early interpretation of not only defining the key forest production areas but also the delineation of non-forest areas. The pre-European vegetation mapping highlighted the relevance of this information as it was utilized in the 1980 mapping work by Heddle *et al*. (1980a) which was a pre-cursor to the more extensive mapping by Mattiske and Havel (1998).

The early recognition of the need to set aside areas for conservation within the southwest forest regions was undertaken by the foresters in response to scientific opinions at the time. This resulted in the gazetting of a flora and fauna reserve west of Bannister in 1894. The foresters (Ednie Brown, Lane Poole) aimed at perceiving forest against alienation and agricultural clearings for the North Dandalup reserve was the brainchild of the Association for the Advancement of Science led by Woodward. Both processes started concurrently in 1894, under Forrest's government. The timber industry succeeded in having the flora and fauna reserve reclassified to timber requirements. To reflect the impact of community pressures, within four years there was support for the area to be used for timber production. In 1911, the area was incorporated into State Forest (Ride 1975). Interestingly part of the area has now been included in the conservation estate as a result of the efforts by foresters and forest ecologists (Heddle *et al.* 1980b; Department of Conservation and Environment 1983, Department of Conservation and Land Management 1987a, 1987b, 1987c, 1994, McKenzie *et al.* 1996 and Conservation Commission 2002).

The latter example, forms only part of the history of the renewed efforts to reserve representative portions of the State forest. A brief re-collection of the events is summarized below:

- 1962 - Australian Academy of Science, WA Subcommittee carried out a review of reserves, but its action did not have a great impact.
- In late sixties, there was informal reservation of virgin jarrah forest about to be logged.
- In early 1970s, closure of Wundowie as last major area of unlogged jarrah-wandoo in the northeastern section of the southwest forests. This was an internal Forest Department initiative. Also protection of last major areas of prime unlogged jarrah forest between Dwellingup and Collie.
- A public debate then arose over the southern karri forests. This led to a polarization in the community.
- In 1976, major changes occurred in forest policy 'Focus on Forest Policy' and the 1977 General Work Plan – through the delineation of Management Priority Areas (Heddle et al 1980b).
- In 1980 the Environmental Protection Authority's "Conservation through Reserves Committee" focussed on System 6 – of which the maps (Heddle, Loneragan and Havel 1980) were part of the scientific basis for the Committee and community's deliberations on reserve design.

Vegetation mapping and classification systems have also been used in the interpretation of disease spread and intensification (Havel 1979, Shearer *et al.* 1987, Shearer and Tippett 1989). In addition, vegetation maps have been used on a range of occasions for management and political purposes. Trudgen's 1984 report for Westdale-Dobaderry group of reserves on the north-eastern fringes of the southwest forest region, along with the earlier ecological studies by Havel (1975a and 1975b), were used by the Campaign for Native Forests (Cahill 1984) to put forward a proposal for a Wandoo reserve.

Havel (1981, 1989a and 1989b) highlighted the relevance of vegetation classifications in reviewing planning options for various land uses including conservation and other multiple land use activities. Havel (1989b) assessed the adequacy of conservation of the various vegetation complexes and concluded the proportions protected by reservation ranged from 0% to 56.8%, being least for those impacted by agriculture because of more fertile soils. A second major wave of vegetation mapping and reserve delineation was initiated by the Regional Forest Agreement between the Commonwealth of Australia and the State of Western Australia. The entire forested region was covered by maps of forest types by Bradshaw *et al* (1997) and by more detailed vegetation maps of Mattiske and Havel (1998). The mapping of systems were integrated through a peer review process and a series of forest ecosystems were defined (Bradshaw and Mattiske 1997). These ecosystems (which included non-forest ecosystems) were used in the application of the "JANIS" criteria during the regional forest agreement process. Consideration was also given to the complexity of the pattern of vegetation complexes in informing the selection process for conservation reserves during the regional forest agreement process (Commonwealth of Australia and the State of Western Australia 1999) and subsequently through the development of conservation areas in the Forest Management Plan (Conservation Commission 2002).

The regional vegetation maps developed by Heddle *et al.* (1980a), Mattiske and Havel (1998) and Havel and Mattiske (1998), Havel (2000) have also been used by ecologists and researchers to place their research into regional context, in selecting research sites, in defining risk from disease and pests and in facilitating searches for rare and endangered flora and fauna.

Subsequently, Mattiske Consulting Pty Ltd and Havel Land Consultants (2003) have defined and mapped a series of landscape conservation units as a means of assisting the fire management branch with the Department of Conservation and Land Management test fire behaviour in different landscapes. These landscape conservation units (LCU's) were developed through an agglomeration of the 315 vegetation complexes into 26 landscape conservation units. The LCUs are used as the fire management units of the southwest forests and form the basis for fire management planning, whilst still addressing biodiversity conservation albeit with lower degree of precision. The trade-off between fecundity and precision can be seen by comparing Figures 1 and 3.

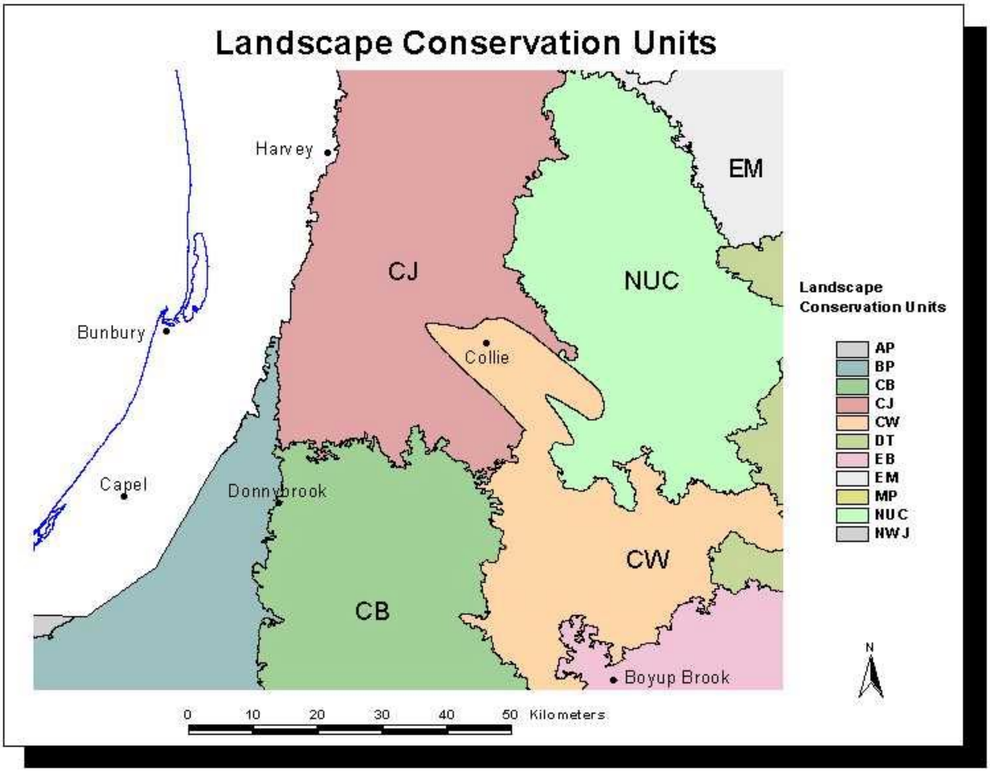


Figure 3. Landscape Conservation Unit classification (Mattiske Consulting Pty Ltd and Havel Land Consultants 2003)

The linkages between the different scales of information on species, communities and ecosystems with underlying site parameters may be available for local site specific and targeted survey areas, but generally lacking on a regional basis.The work by Mattiske and Havel (1998) provides another milestone for the next generation of ecologists, forester and scientists to test their hypotheses on the inter-relations between different management and operational activities and the very biodiversity values that exist in these systems. Christensen (unpublished) has also been integrating the vegetation complexes as developed by Mattiske and Havel (1998) into the Fauna Distribution Information System (FDIS) being managed and implemented by the Department of Conservation and Land Management.

10 CONCLUSIONS

Land management is recognized as a complex business and the more tools that the community and land managers have before them, the greater the ability to manage the assets in the southwest forest regions and to monitor the management.Whenever the maps are used, they are tested, adapted and refined.

It is well recognized that our understanding of the systems in the southwest forest regions is still limited by the resources allocated for scientific research. The vegetation mapping, which attempted to define patterns that would have occurred in the vegetation irrespective of the clearing activities since European settlement, have assisted the land managers and community groups in defining what values still persist but also underpins the future testing a range of critical management options in the south west region.The wider community has a major role in facilitating the support of the scientific and operational staff in the southwest region so that the very values that have been defined can be managed not just for conservation but for sustainable operational activities.

The vegetation mapping as developed by Mattiske and Havel (1998) for the southwest forest region not only provides a key summary of relationships between the underlying geomorphology, landforms, soils and vegetation, but also provides a tool for researchers and land managers

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