Soils of the Swan Coastal Plain

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Almost all the soils of the Swan coastal plain are formed by material deposited by rivers and wind. The Yilgarn Block, east and south of the Scarp bordering the Swan Coastal Plain (Fig. 1), rose about 40 to 50 million years ago. This caused erosion of the block by rivers and streams, and the eroded material was either deposited onto the Swan Coastal Plain or washed into the sea. The eroded material formed new soils on the Plain.

Broadly there are two major types of soils on the Coastal Plain. The first is a series of dune systems near the coast formed as a result of deposits from the sea, and including material originally derived from erosion of the Yilgarn block mixed with material from the sea. Once formed, the dunes can be eroded by strong winds. The sand is mostly eroded from the dunes nearest the coast, and is re-deposited on the dunes further inland. The second major soil types are a series of soils formed by deposits directly eroded from the Yilgarn block and which comprise soils of the Pinjarra plain, occurring between the dunes and the scarp. There is a third, very narrow strip of soil, called the ridge hill shelf, next to the scarp, formed from material eroded from the scarp. It is too small to be of any significance.

Dunes

The formation of the dunes is a continual process. At times the process is reversed as the sea erodes dunes. Subsequently the eroded material is re-deposited from the sea and new dunes are formed. The net trend has been for increased dune formation. As new dunes have been formed, so the older dunes occur further inland. The dunes change with age, and 3 types of dunes have been identified according to age.

The youngest dunes are the **Quindalup dunes** nearest the coast. Next come the **Spearwood dunes**, and farthest from the coast are the oldest **Bassendean dunes**. Limestone occurs as pipes (see later) in the profile of the Quindalup dunes and the western margin of the Spearwood dunes, and as limestone rock at the base of both the Quindalup and Spearwood dunes. There is no limestone under the Bassesdean dunes.

Between the dune systems, inlets, lakes and swamps occur. Inlets (e.g. the Leschenault inlet) occur between the Quindalup and Spearwood dunes. Lakes and swamps occur between all three dune systems. The soils under the swamps and lakes are rich in organic matter, so they are peat swamps, and have often been drained and used for vegetable production. In other places near cities (Perth, Mandurah, Bunbury) or towns (Waroona, Harvey, Pinjarra) the swamps have been used as rubbish tips, or filled in and used for sport and recreation, or as building sites.

All the dunes are composed largely of sand, with little structure, and are very infertile.

Quindalup dunes. The dunes are composed of unconsolidated sand (quartz grains) and shell fragments. Sometimes organic matter darkens the surface layers. The shell fragments are mostly calcium carbonate, so the sands are alkaline. As the shell fragments dissolve, calcium moves down the profile and is deposited as lime, initially around plant roots, to form pipes, which are exposed by wind erosion of sand from the surface of dunes at or near the coast (i.e. the Quindalup dunes), or on the western margin of the Spearwood dunes. Eventually, the lime is deposited as limestone at the bottom of the profile of the dunes. The lime at the base of the dunes is dissolved by water to form caves. Good quality water suitable for irrigation is stored in the caves, and is used to water gardens and parks on the Quindalup and Spearwood dunes, or to water vegetable crops grown on the Spearwood dunes (see later).

The Quindalup dunes are not used for agriculture or horticulture for the following reasons. The dunes hold very little water and are only wet when heavy rain is falling. The dunes are also extremely infertile and, when cleared of native vegetation, are very easily eroded by winds. In addition, unlike the native plant species, agricultural and horticultural species are not well adapted to surviving the strong winds and salt spray from the ocean.

Because of their proximity to the ocean, the Quindalup dunes are rapidly being urbanised.

Spearwood dunes. The Spearwood dunes are often higher than either the Quindalup or Bassendean dunes. The Spearwood dune system is believed to have been formed about 40,000 years ago, and comprise red/brown, yellow and pale yellow/grey sands. The sands are coated with both iron and aluminium oxides, with the amount of iron oxide coating the sands largely responsible for the colour of the sands. The greater the amount of iron coating the sand, the darker the colour. The amount of iron and aluminium coating the sand grains increases the capacity of the sands to retain phosphorus (P). The darkest coloured red/brown sands occur farthest to the west of the Spearwood dune system, nearest the Quindalup dunes. These darker coloured sands are closely associated with the limestone pipes or rock, and are exposed by wind erosion of the yellow sand that overlayed the darker sand and limestone.

The eroded sand was blown inland, to expose the darker coloured sand and the limestone. The red/brown sands have been called **Cottesloe sands**, or terra rosa soils. Most of the Spearwood sands are yellow, and are called **Karrakatta sands**. The sands become less coloured as they age because the iron (and aluminium) coating the sands is leached. The paler coloured Spearwood sands are farther inland. The red/brown sands are only found near the Quindalup dunes, and are originally deep in the profile, unless exposed by wind

erosion, and are coated with the most amount of iron (and aluminium). The yellow sands, the **yellow phase** of the **Karrakatta sands**, are to the west of the Spearwood dune system. The paler yellow/grey sands, the **grey phase** of the **Karrakatta sands**, occur to the east.

The multitude of names used for the sands of the Spearwood system has lead to great confusion. The Cottesloe and Karrakatta sands of the Spearwood dune system frequently have good quality water suitable for irrigation relatively close to the soil surface, consequently these sands have been used for vegetable production. Initially the Cottesloe and yellow phase of the Karrakatta dunes were preferred. However, both the Cottesloe and yellow phase Karrakatta sands are now being urbanised, because they are in popular areas near the coast, forcing vegetable growers onto the grey phase Karrakatta sands and onto the Bassendean dunes (see later).

Bassendean dunes. These are the oldest of the three dune systems, thought to be about 800,000 years old, and so are the most leached, infertile and acidic. The sands contain little silt or clay, and very low levels of nutrient elements, with any nutrient element content being associated with organic matter. The dunes are low lying hills with poorly drained areas between the hills The depth to ground-water varies from close to the surface to at most 10 m below the surface. The water is suitable for irrigation.

Three types of Bassendean sands have been identified. The **Jandakot sands** are well drained sands on the crests and upper slopes of the low hills or ridges. In their B horizon they have an iron podzol (contains iron oxide, which appears as a bright orange layer, that can include hardened concretions). The watertable is about 10 m below the surface of the Jandakot sands. **The Gavin sands** occur further down slope from the crest, where the watertable is about 2 m below the surface, and in the B horizon, an iron-humus podzol (a bright orange-brown layer which contains iron oxide and organic matter) occurs, which can be partly cemented (the constituents are compacted and so bound together). Finally, **the Joel sands**, often a sandy loam (loam texture due to organic matter), occurs in the lowest part of the dune system, where the watertable is very close to the surface, and seasonal waterlogging occurs at the wettest time of the year (typically June to mid-August). The B horizon is a humus (soil organic matter that has been changed physically and chemically by soil animals, fungi, bacteria, algae and protozoa to humus) podzol, comprising a strongly cemented dark brown organic B horizon.

Major agricultural and horticultural industries on the dunes

The Bassendean sands have been sown to pasture for the grazing industries. They require large inputs of fertiliser. Nitrogen, phosphorus, potassium and sulphur are leached from fertilised pastures both vertically (Jandakot and Gavin sands) and laterally (Joel sands) into the many natural and man-made drains in the area,

polluting the drains, swamps, lakes, streams, rivers and estuaries (collectively called waterbodies) in the area, and contributing to eutrophication. Until recently, the Bassendean sands were not used to grow vegetables because they were too infertile. The Cottesloe and yellow phase of the Karrakatta sands were preferred. But as the suburbs of cities and towns, and industrial areas have moved onto the Spearwood dunes, so vegetable growers are increasingly being forced onto the Bassendean sands.

Pinjarra Plain soils

The soils are complex, and comprise a successive layering of soils formed from erosion of material from the scarp and east of the scarp. Rivers and streams have mostly carried the eroded material, which is deposited from the water as fans of alluvium. Therefore, the plain, is made up of layers of soils of different ages. It occupies about one third of the Swan Coastal Plain, and most of it has been cleared and sown to pasture for the grazing industries, mostly dairy, with some beef. Only small remnants of the indigenous (native) vegetation remain.

The oldest soils on the Pinjarra Plain are believed to be the **Coolup soils**. The profile of the Coolup soils is similar to that of the laterite formed east of the scarp. This is probably because similar material that gave rise to the laterite soils east of the scarp were eroded and deposited on the plain and therefore produced a similar profile.

The profile is a sand over lateritic ironstone gravel over predominantly kaolinite clay, with a mottled zone in the clay layer just below the laterite. The mottles are iron leached from the ironstone gravel that is re-precipitated as spherical iron nodules or concretions.

The Coolup soils are highly leached and infertile, with low cation exchange capacities, with almost all nutrients coming from organic matter in the surface. The typical Coolup soil, in the top 30 cm, contains about 90 per cent sand, 6 per cent silt and 4 per cent clay. It is therefore classified as a sand. Below this, the soil comprises about 60 to 80 per cent sand, 5 per cent silt and from 15 to 31 per cent clay, with the percentage clay content increasing with depth, so the subsoil is a sandy loam to a sandy clay loam.

The Coolup soils are found on the eastern edge of the Plain, next to the ridge hill shelf of the scarp. The soils that formed **after** the Coolup soils were produced from alluvium fans deposited on top of the Coolup soils from rivers and streams, or from material deposited on the banks of the rivers and streams as they cut through the Coolup soils. Therefore, the soils formed after the Coolup soils are usually found to the west of the Coolup soils.

The **Wellesley soils** are believed to be the next oldest after the Coolup series. They are fine textured (high levels of silt and clay) alluvium. The Wellesley soils are dark brown/grey soils containing 45 to 55 per cent clay, predominantly kaolinite. The surface of the soil is self-mulching, and large cracks appear in the surface when the soil is dry. Usually kaolinite does not expand and contract as the soil moisture content changes. So reasons why the soils develop cracks when dry are not known. The cracks rapidly disappear as the soil wets up.

The soils occur in the lowest parts of the western margin the Plain, . They are wet and salty owing to water draining onto them from the area due east of the Wellesley soils where the newer soil described below are found.

The Bassendean sands are usually found to the west of the Wellesley soils. When newly cleared for agriculture, the Wellesley soils had a low pH in the surface, typically 4.5 ($CaCl_2$), increasing to near neutral pH with depth. The soils contain from 45 to 55 per cent clay, and are classified as medium clay. Silt varies from about 25 per cent near the surface (top 30 to 40 cm), to 10 per cent at depth, sand varies from about 25 to 40 per cent with depth.

Younger soils formed on the Plain derive from alluvium deposited on top of the Wellesley and Coolup soils. These younger soils usually occur to the east of the Wellesley soils and west of the Coolup soils.

The next soils formed after the Wellesley soils are thought to be the **Boyanup soils**. These are loams that are bright yellow-brown, so they are distinctive and easily identified. It is the major soil in the Harvey area. The soil has a high silt content, which decreases from about 20 to 10 per cent with depth, while the clay content increases from about 25 to 50 per cent with depth. The Boyanup soils often have gilgai areas, which are scattered mounds and hollows which have been attributed to the shrinkage and swelling of the Wellesley soil present in the subsoil as the water content of the subsoil changes. As stated above, when the Wellesley soils are at the surface, the surface of the soils are self-mulching, and, for unknown reasons, expands and contracts as the soil water content changes.

The **Blythwood soils** are believed to be the next soils formed. They occur alongside present-day rivers and streams, and were formed from alluvium deposited when the waterways cut through the old Coolup system. The Blythwood soils are red, and contain much sand (from about 80 per cent near the surface, to about 60 per cent at depth) throughout the soil profile. The soils are duplex soils, containing much less clay at the surface (top 30 cm) than at depth. The soils typically comprise about 80 per cent sand, 13 per cent silt and 7 per cent clay in the top 30 cm (loamy sand) compared with 10 per cent silt and 20 to 35 per cent clay below about 30 cm (loam to a clay loam).

The **Belhus soils** are thought to be the next soils formed. They are confined to terraces of the Swan Valley. While similar to the Blythwood soils, they contain more sand and therefore are better drained. They are ideal for viticulture.

The **Dardanup** soils are believed to be formed from the next deposits, and occur as a broad alluvial fan over the older systems of soils. They are found in the Dardanup, Harvey and Waroona area. They are dark reddish brown soils at the surface, becoming dark brown from about 30 cm and below. In the top 30 cm, the soils contain about 80 per cent sand, 15 per cent silt and 5 per cent clay (loamy sands). Below this they contain about 70 per cent sand, 15 per cent silt and 15 per cent clay (sandy loams).

The **Pyrton soils** are similar to the Dardanup soils, but occur as low river terraces rather than as alluvium fans. Also at depth, the Pyrton soils change abruptly from a dark brown sandy loam to a layer of fine white to pale yellow sand.

The final system of soils are the **Vasse soils**. These soils differ from all the above soils because they are formed from estuarine alluvia, and are at about sea level. They are found near the Vasse and Wonnerup Inlets, east of Busselton and north of Capel. They are very variable soils, comprising layers of clay, shells, marine algae and coarse calcareous sand. Because they contain much organic matter, these were the first soils cleared in the area and were used to grow vegetables. They are now mainly pastured and used for grazing.

Major agricultural industries on the Pinjarra Plain. Dairy and beef production on the Swan Coastal Plain are largely located on soils of the Pinjarra Plain. The Pinjarra Plain soils comprise about one third of the soils on the Swan Coastal Plain and are located between the Bassendean dunes to the west and soils of the Ridge Hill Self, next to the scarp, on the east

Ridge Hill Shelf

This is a very narrow strip of soil, at most 3 km wide, adjacent to the scarp. It is composed of coarse lateritic ironstone gravel, that makes up more than 50 per cent of the soil by weight, and coarse sand. The soil is very old, and has a very poor water-holding capacity, and is extremely infertile. The soil is located at the highest elevation of the Swan coastal plain soils. This, combined with the poor water-holding capacity of the soil, means water is rapidly drained from the soil and the soil rapidly dries out after rain. It is therefore frequently dry, even in the growing season. However, there is good quality water suitable for irrigation so these soils can be used for vegetable production.

Phosphorus status of uncleared soils of the Swan Coastal Plain

The indigenous (native) phosphorus was highest in the Dardanup soils when they were first cleared for agriculture or horticulture, followed by the Cottesloe and Wellesley soils, and then by the Boyanup and Blythwood soils (Table 3). The other soils, like most Western Australian soils, were acutely phosphorus deficient when first cleared. As previously stated, the Quindalup dunes are not used for agriculture or horticulture.

Table 3. Total phosphorus (P) [A] measured for soils collected from uncleared, previously unfertilised remnant native vegetation

Soil	Total P [A] (mg kg P per g soil)
Coastal dunes	
1. Quindalup dunes	290
2. Spearwood dunes	
(a) Cottesloe	190
(b) Karrakatta yellow phase	44
(c) Karrakatta grey phase	22
3. Bassendean Dunes	
(a) Jandakot	18
(b) Joel	30
Pinjarra Plain Soils	
1. Coolup	52
2. Wellesley	180
3. Boyanup	120
4. Blythwood	130
5. Dardanup	510

[A] Determined by digesting the soil in concentrated sulphuric acid and measuring the concentration of phosphorus in the digest.

Further Reading

McArthur, W.M. (1991). Reference soils of south-western Australia. Western Australian Department of Agriculture, South Perth, Western Australia.

Anon. (1988). Soils of south-western Australia. Ministry of Education, Western Australia.

Photo captions

1. Quindalup dunes (calcareous sand) at Redgate.
2. Spearwood dune at Gelorup (Cottesloe type).
3. Spearwood (yellow phase Karakatta dunes) at Boranup.
4. Cottesloe sand (Spearwood dunes) at Boranup.
5. Bassendean sands at Scott River.
6. Gavin sand (Bassendean sand). White sand over iron humus podzol.
7. Marybrook soil south of Busselton. Similar to Blythwood soil.