A visual guide to soil surface condition in Australia




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Photographs provided by:

(AB) Andrew Biggs

(BB) Bronwyn Bosomworth

(JB) Jon Burgess

(MC) Mark Crawford

(SED) Sue-Ellen Dear

(DH) David Hall

(DS) Dan Smith

(DPIRD) Department of Primary Industries and Regional Development, Western Australia

Soil *surface condition* is a term used to describe the nature of the soil surface, in either a natural or disturbed state. It is an important indicator of the way soils behave, particularly in relation to water entry and erosion. It is also a concept that is understood and used by farmers, agronomists, soil scientists and many others – even cricketers.

The terms used to describe soil surface condition in Australia have been outlined for many years in the *Australian Soil and Land Survey Field Handbook* (currently in its fourth editions). Despite the definitions in the Field Handbook, some aspects of surface condition remain difficult to teach or recognise. This booklet aims to visually describe surface condition in various soil types in Australia and can be used in conjunction with the Field Handbook.

Soil surface condition is defined in the Field Handbook as being recorded for the dry state of the soil, in order to achieve consistency in determination. From a land management perspective, this can lead to a knowledge gap, as the surface condition when moist/wet may sometimes be just as, or more important than the dry condition. In some landscapes, such as wetlands or high rainfall environments, it may be uncommon to see the soil surface when dry. The list of terms in the Field Handbook can in fact be used in any situation (wet to dry), but it is important to record the soil moisture condition at the time of observation. Some surface conditions (e.g. self-mulching) will not be visible when the soil is wet, which is why the Field Handbook opts for recording surface condition in a dry state.

Some soils are resilient to change and their surface condition remains the same under agricultural practices, while others are easily altered (and usually degraded) by practices such as tillage. Soil surface condition should be described as you see it (to the best of your ability in the prevailing conditions), but in the case of cultivated soils, it is worth noting the surface condition of representative undisturbed areas of the same soil type. It can be difficult to evaluate the soil surface condition if there is dense/thick pasture or extensive stone cover. These are field practice challenges that are not easily resolved, other than through expert knowledge and experience.

There are 16 soil surface condition terms described in the Field Handbook. While they have historically been listed in no particular order, they fall into three groups that describe different aspects of the soil surface. These are:

- Consistence related terms: loose, soft, firm, hardsetting
- Surface characteristic terms: surface flake, crusting, cracking, (weakly) self-mulching, snuffy, cryptogam, gravel pavement, saline
- Terms describing significantly altered surfaces: poached, trampled, cultivated

Consistence related terms have a direct connotation with soil strength and the soil consistence categories described on page 161 of the Field Handbook. Hardsetting sits in two groups, as it defines both a consistence (hard) and a characteristic suite of properties and processes (the right combination of particle sizes to pack densely, coupled with slaking and/or dispersion with an associated behaviour of increasing soil strength as the soil dries out). Surface characteristic terms relate to inherent features of the soil that are influenced by factors and processes such as mineralogy, particle size distribution, waterlogging and erosion. With the exception of hardsetting, the terms refer to characteristics other than the consistence of the soil material. Surfaces that have been significantly altered (invariably by human-related activities) are catered for by a specific set of terms.

The Field Handbook notes some terms are mutually exclusive, but does not provide any guidance on which terms specifically are, or are not, mutually exclusive. A matrix is provided at the end of this booklet (page 21) to assist in understanding this.

The Field Handbook does not indicate whether consistence related terms should always be recorded in conjunction with other terms – for example, the surface of a self-mulching cracking clay (Vertosol) is invariably loose when dry, but practitioners do not always record this term, as it is an inherent feature of a self-mulching surface. It is recommended to always record the consistence related terms in conjunction with other terms, with the exception of hardsetting, as discussed above. Terms for altered surfaces should also be used in conjunction with other terms e.g. a hardsetting, poached surface; a loose, trampled surface.

Water repellence is also covered in this text. While it is described via a field test and not specifically listed as a surface condition, it is an important characteristic of the surface of many soils, hence its inclusion here.

At a glance

Consistence related terms

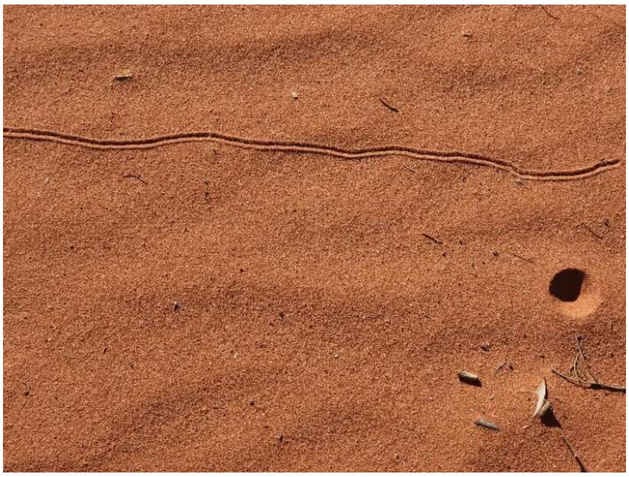
Four terms are used to describe the consistence/coherence/strength of the soil surface. These terms can be applied to any soil. Assessment relies on a number of obvious features, although it is in part subjective, as it relies on pressing a finger into the soil to gauge the category. This will obviously vary slightly from person to person and with soil moisture status (although the assessment should be done when the soil is dry).

Loose

The easiest of the terms to understand, this applies to incoherent soil material i.e. less than two thirds of the soil material is united. There is a general absence of cohesion of soil particles together, whether that be through particle packing, organic matter or cementation. While this state is most commonly observed in sand, it can also occur in well aggregated soils, such as self-mulching clays (Vertosols), particularly after cultivation. A finger can be pushed all the way into the soil with ease (right up to the knuckles of your hand). In the case of loose (and some soft) sandy soils, the soil can become more coherent when moisture content increases – compared with clay soils where coherence typically decreases with increasing moisture content.

A loose surface is normally associated with incoherent sands. (AB)

A finger may be pushed easily into a loose surface. (AB)



A loose soil surface is easily disturbed by insects. (AB)

A loose, self-mulching surface. (AB)

Soft

In a soft surface, the soil is coherent, but a finger is easily pushed into it. There is a recognisable but small degree of resistance felt, but you should be able to push your finger in easily to the first joint, and possibly up to the second joint. This surface condition can apply to soils across the full spectrum of textures (sand to clay). The small degree of cohesion in the soil is created by factors such as particle size distribution (particle packing), clay type, and iron, organic matter or silica bonding.

A finger can be pushed in to the first joint with relative ease in a soft soil surface. (AB)

A soft soil surface is indented by pressure – in this case an emu's foot, but there is a degree of resistance. (AB)

Firm

Like a soft surface, a firm soil surface is coherent, and the term can apply to a wide range of soils. A firm soil surface requires more effort to push a finger into it than a soft one, and there is sufficient resistance to prevent a finger being in. As a guide, you should be unable to get your finger in but your finger should create an indentation in the soil. Your finger may bend (and you may observe colour change in your skin) as a result of the pressure on your finger. Even very sandy soils can have a firm surface condition if they are cemented by iron or silica or their particles pack together very tightly. In clay soils, the amount and type of clay and amount of organic matter is a key influence. Crusty soil surfaces are often firm (see page 9). In agricultural settings, compaction is a common cause of a firm surface.

Moderate pressure is required to push a finger into a firm soil surface (SED)

Hardsetting

As the name implies, hardsetting soils are very hard when dry, but they are soft when wet. There has however been a variety of interpretations over the years in terms of what constitutes hardsetting. In general, the material is apedal (lacks structure), is hard below any surface crust or flake that may occur, and it is not disturbed or indented by pressure of a forefinger. From a strength perspective, the soil material is very firm to strong (see strength terms in the Field Handbook). Obviously a hardsetting characteristic extends to some depth into a soil, typically the A horizon(s) – but there is no minimum or maximum depth specified. Logically though, the nature of the material is a thickness greater than evident for crusts.

There are a number of mechanisms that can lead to a hardsetting soil surface. Chief amongst these is a process of disruption of particles as the soil wets, followed by bridging/packing of particles together as the soil dries. Factors and processes relevant to disruption can include slaking, dispersion, cracking and loss of organic matter related aggregation. The main mechanism of drawing particles together is drying of the soil, but other processes, including precipitation of soluble compounds, such as salts and silica, may also be important. Given most naturally hardsetting soils are non-dispersive, the process is regarded as primarily a physical one.

Many parts of Australia contain hardsetting soils and the condition can be found in a wide variety of soils. It is frequently associated with mid-range textures with a significant proportion of sand e.g. sandy loam to sandy clay loam field textures. A small number of Vertosols possess a hardsetting surface – in such cases there is usually a considerable sand and silt fraction in conjunction with clay (see picture to left).

Cultivation often leads to hardsetting characteristics in pre-disposed soils, due to loss of organic matter and destruction of aggregates.

A hardsetting surface in a Vertosol. In this case the hardsetting horizon is separated from the subsoil by a thin conspicuous bleach. The difference in physical properties affects the rate of drying and shrinkage, causing the upper and lower horizons to separate as the soil dries. (AB)

A fine sandy loam hardsetting surface on a texture contrast soil. (MC)

A soil that appears to have a hardsetting surface. It is however the exposed B horizon of a sheet eroded soil. This is not hardsetting, as it is high bulk density, structured clay, with a surface crust (DS)

Hardsetting soils (in this case a Kandosol) are often characterised by poor ground cover, particularly in semi-arid to arid landscapes. (AB)

Surface characteristic terms

Surface flake

A surface flake is a thin (<10 mm), massive surface layer, which is easily separated from the underlying soil material when dry. It is distinguished from a surface crust (see below) by a number of characteristics, in particular the tendency of a surface flake to curl as it dries. Flakes are typically thinner than crusts – often only as thick as a few sheets of paper. Surface flakes are comprised primarily of dispersed clay, unlike crusts, which often have a considerable sand fraction.

Surface flakes are a common feature of soils with a moderate to high clay content, particularly in areas of surface inundation. For example, the bed of dried out waterholes, lakes and dams, or in flooded areas after the water has receded. In such cases they are the result of deposition of fines that were suspended in the water. Surface flakes are also very common on the bare surface of cracking clays (Vertosols) after rainfall events.

Surface flake formed on a lakebed. (AB)

Surface flake on a drying saline soil. (AB)

Surface flakes often have a characteristic curling edge. (AB)

Small and large surface flakes on a recently waterlogged, cultivated Vertosol. (AB)

Surface crusting

A surface crust is a distinct, often laminated, surface layer ranging in thickness from a few millimetres to a few tens of millimetres. It is coherent and does not curl as it dries. Crusts are often stronger than surface flakes (typically firm). The Field Handbook indicates that surface crusts do not separate as easily from the underlying soil material as surface flakes do. While this is a useful diagnostic criteria, some care is required in its use. Some very coherent and recognisable surface crusts separate from the underlying soil relatively easily due to differences in aggregation and bulk density that develop (see image below right, of a crust in a Vertosol). When viewed very closely, a layer of the underlying soil usually remains bound to the crust. The crust appears to be separated by virtue of the soil material under the crust being strongly structured and loosely aggregated.

Surface crusts can form in a wide variety of soil types, particularly when they are bare. Raindrop impact re-organises the surface materials (sand, silt and clay), which naturally cement together to make a massive (unstructured) layer. Dispersion of clay is often instrumental in surface crust development, either naturally or as a result of application of sodium rich waters. Bonding by precipitated salts and carbonates can also lead to crust formation. Crusts can be formed by flood deposition of material, in which case they often have a characteristic laminated nature. Even a very thin surface crust can be a significant barrier to water entry and seedling emergence.

A surface crust on a bare Vertosol. Fine sand and silt has been puddled to the surface by raindrop impact. (AB)

A surface crust formed by raindrop impact on a bare Vertosol. The crust is 5-10 mm thick. (AB)

An easily disturbed surface crust on a clay soil. While this crust can be separated from the soil profile with ease, a layer of the underlying soil remains bound to the crust (AB)

A thick, firm surface crust formed by raindrop impact on a salinised bare Kandosol. The vesicular nature of the of the crust is evident. (AB)

A surface crust with entrapped air bubbles on a sandy soil. (AB)

A thin surface crust on a cracking clay soil. The inability to separate the crust from the underlying soil is clearly visible (AB)

Cracking

In order to be classified as *cracking*, a soil must possess cracks at least 5 mm wide that continue upward to the soil surface – this implies that the cracks extend for some depth into the profile, but no minimum depth is specified in the Field Handbook. Cracks occur in soils dominated by shrink-swell clays and develop as the soil dries out. Consequently, it can be difficult to observe cracks if the soil is moist/wet, has a hardsetting surface, or dense surface cover of vegetation or leaf litter. Cracking is generally associated with Vertosols but can occasionally be seen in some other soil types, such as vertic Dermosols or the subsoils of texture contrast soils.

Some soils develop very wide and/or very deep cracks, while others develop cracks that only appear to be narrow and/or shallow. Pushing a steel rod down apparently narrow cracks can be quite revealing – surface conditions can often hide extensive crack patterns in much the same way that snow can hide crevasse fields.

It is presumed that crack geometry and dimension is a function of the inherent shrink/swell properties of the soil, which is influenced by clay mineralogy, clay content and soil chemistry. Ground cover, shade, evaporation and soil water use by plants obviously influence soil water loss patterns vertically and horizontally, with subsequent effects on crack development. When intense rainfall events or 'dry floods' occur on dry, cracked soils, water rushes down the cracks and the subsoil is wet quickly. As water flows down cracks, it can carry organic matter and other materials, but it can also lead to crack widening through physical erosion and dispersion.

A cracking soil surface in a Vertosol (AB)

Cracks are readily visible when ground cover is absent (AB)

Narrow cracks in a partially dried saline mudflat. The cracks widen and extend deeper as the soil dries. (AB)

Wide cracks in a Vertosol. (JB)

Cracks often grade into holes. (JB)

This crack/hole is over 1 m deep. Secondary cracking is evident, resulting from slumping of soil around the hole. (AB)

Self-mulching

A *self-mulching* surface is only associated with cracking clay soils (Vertosols). Self-mulching is a type of behaviour associated with wetting and drying cycles of shrink/swell clays. The strongly aggregated soil surface breaks down when wet and re-aggregates as it dries out. A self-mulching surface is usually dominated by fine (<5 mm), granular peds. Self-mulching surfaces can be subplastic i.e. their field texture is lighter than suggested by their clay content. Self-mulching soils typically develop a surface flake after rainfall. This breaks down over time to reveal the aggregates.

A distinction is made between *weakly* and *strongly* self-mulching surfaces. A weakly self-mulching surface only re-aggregates slightly and its structure is less visible than in a strongly self-mulching surface. Weakly self-mulching surfaces correspond to an *epipedal* soil surface in the Australian Soil Classification. A strongly self-mulching surface will be looser and more obviously aggregated than a weakly self-mulching surface. Vertosols with strongly self-mulching surfaces generally have a lower sand content than those with weakly self-mulching surfaces. Strongly self-mulching Vertosols are typically associated with basalt, but can also be found on other lithologies, such as mudstone.

Weakly self-mulching surface. A surface flake is readily visible (AB)

The same soil (as to left) 48 hours after a small rainfall event showing loss of the surface structure. The soil has cracked through quickly because there was insufficient rain to wet the profile. (AB)

Weakly self-mulching surface. Aggregates are not visibly dominant (JB)

Fine, strongly self-mulching surface. (AB)

Strongly self-mulching surface with a thin surface flake that has started to break down. (AB)

Coarse, strongly self-mulching surface in which the surface aggregates are readily visible. (AB)

Snuffy surface

A snuffy surface is a relatively uncommon feature. It is usually only seen in iron rich, non-cracking clays such as Ferrosols. It is characteristically loose, powdery or pulverescent and water repellent, particularly when dry. It is comprised of very fine structure and frequently strongly acidic.

A snuffy Red Ferrosol. (SED)

Cryptogam surface

This is the only soil surface condition that specifically relates to biological features. It is formed by algae, liverworts, mosses and related plants that grow on the soil surface. Despite these species often being associated with wet conditions, cryptogam surfaces are frequently observed in semi-arid to arid areas, often on soils with very low permeability. The surface is flake- or crust-like when dry, can easily be peeled off and is typically water repellent.

A cryptogam surface (dark zone) on a texture contrast soil (erosion has exposed the pale B horizon). (AB)

A moist cryptogam surface on a crusting, cracking clay soil. (AB)

A thin, dry cryptogam surface (dark zone) on a red sand. (AB)

A sporadic cryptogam surface on a crusting, sandy surface. The polygonal cracks are due to drying of the crust – they do not qualify as a cracking soil surface. (AB)

Moss growing on a crusting Red Kandosol. Remnants of a dead cryptogam surface associated with a surface flake are evident on the right-hand side of the image. (AB)

Gravel pavement

These are soil surfaces dominated by gravels i.e. the surface cover of gravel exceeds 75%, although there may be sporadic patches with a lesser amount of gravel. The gravel may be of uniform size and nature or variable in size and shape. Gravel pavements are usually found in the arid zone and the gravels typically display 'desert varnish' – a characteristic sheen caused by alteration and wind abrasion of the surface of the stones.

Gravel pavements are usually associated with the arid zone and sparse vegetation. (AB)

Gravel pavements may be associated with microrelief, in this case, normal gilgai. (AB)

Saline surface

Saline soil surfaces are formed from the evaporation of soil water in situations with high salinity. They are typically bare and often develop as a firm crust with visible salt crystals. In sandy soils, it may be difficult to see the salt and testing of the soil salinity is useful. Saline clay soils frequently develop a characteristic 'talcum powder' or 'puffy' surface that can be confused with a self-mulching characteristic. It is however the result of salt crystals growing and breaking apart the soil structure. Such very fine surfaces are often prone to wind erosion.

A solid salt crust that has bound coarse organic matter to the soil. (AB)

A saline soil surface showing variations in soil surface condition related to moisture content and salinity. The darker zones are moister/puffy and the pale zone is drier/crusty. (AB)

A visible salt crust on the surface of a cultivated, crusting, cracking clay. Note the poor germination success and growth of the crop (AB)

A 'puffy' saline soil surface that has re-formed a thin surface flake after rainfall. The texture is fine sandy clay loam. The surface is easily disturbed by slight pressure. (AB)

Black alkali and white alkali are often characteristic features of saline soil surfaces, particularly in areas associated with the discharge of high alkalinity groundwater – for example Great Artesian Basin springs or bores. Both alkali forms are related to the presence of carbonates, but in black alkali there is also dissolved organic matter present.

Black and white alkali on a soil surface. (AB)

Black alkali on a sandy red soil, associated with use of alkaline artesian water for a garden. (AB)

Significantly altered surfaces

The following terms apply where the soil surface has been significantly altered by agricultural practices – either livestock or machinery related. These terms are not exclusive to other surface condition terms, as some soils become crusting, hardsetting or otherwise change their nature when subject to physical disturbance. The terms for altered surfaces should be used in conjunction with consistence-related terms.

Recently cultivated

This term is applied to any instance where the soil surface has been recently ploughed. In some cases, the inherent nature of the soil surface may not have changed and should still be recorded. For example, the soil may also be cracking and self-mulching. Typically, the surface would also be described as loose or soft.

A recently cultivated Vertosol, showing clods from compaction. (AB)

Blade ploughed pasture showing heavy disturbance of the soil surface. (AB)

Trampled

The congregation of animals (generally hoofed livestock) leads to a trampled soil surface. In contrast to a poached soil, the process occurs when the soil is dry soil i.e. the soil is pulverised. Any aggregates or forms of cementation present are broken down. A trampled soil surface is typically very fine/powdery and loose, resulting in it being more prone to wind or water erosion.

Cattle pads are a common cause of trampled soil. (BB)

Poached

When soils with sufficient clay content are trampled in wet conditions by animals, in particular hoofed animals, the surface develops a characteristic poached nature. The process occurs when the soil is wetter than the plastic limit and the soil is deformed/re-moulded. The surface usually dries to a hard state (crusting to hardsetting) and is very uneven, with many footprints evident. Any soil structure that existed in the soil surface is typically destroyed. The distinctive nature of the surface typically lasts until the soil is re-wet.

A lightly poached surface, caused by birds when the sandy loam soil was wet. (AB)

A strongly poached clay soil surface, caused by cattle when the soil was wet. (AB)

Water repellence

Water repellence is a behaviour that is often seen in the soil surface but it is not regarded as a surface condition. It is caused by hydrophobic coatings on soil particles (such as sand grains and aggregates) as well as organic matter (both living and dead). All soil textures, from sand to clay, can demonstrate this behaviour and it can occur with a variety of surface conditions e.g. loose, crusting, hardsetting, even self-mulching. In some soils it is a relatively permanent characteristic, while in others it is seasonal. Water repellence is a feature that has achieved more recognition in recent years due to its influence on infiltration in cropping soils. From a practical perspective it not only affects water entry into soils but also soil description activities such as field pH tests and texturing. Water repellence is evaluated using field tests with water and/or ethanol.

A water droplet on a hydrophobic sand. (DPIRD)

A strongly water repellent, sandy surface. (DH)

Further information

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The relationship between surface condition classes (dark cells cannot be recorded, green cells are unlikely to be recorded)

	Loose	Soft	Firm	Hardsetting	Surface flake	Surface crust	Snuffy	Cracking	Weakly self-mulching	Self-mulching	Cryptogam	Gravel pavement	Trampled	Poached	Saline	Cultivated
Loose																
Soft																
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