High levels of soil sodicity can severely reduce cane yield

Field Guide

Diagnosis of sodicity and related problems of soil and irrigation water in the sugar industry

This booklet is part of a Field Kit, the other components of which are shown below. The Field Kit is for diagnosis of sodicity, salinity and related problems of soil and water in the field. Consequences and management options are discussed in the Sodic Soils Manual and gypsum recommendations can be made with the help of the computer program 'Gypsy'.

Field kit components

1 Soil corer (or auger if corer not available)
2 Electrical conductivity (EC) meter with calibration solution and spare batteries
3 pH meter with calibration solutions (buffers) and spare batteries
4 Sodium (Na) meter with calibration solution and spare batteries
5 pH kit
6 Disposable pipettes
7 Bottle of hydrochloric acid (1M HCl)
8 Distilled or deionised water (5 L bottle and wash bottle)
9 Containers for making soil extracts and measuring dispersion
10 Plastic bags and marker pen for taking samples
11 Sample map sheets (and clipboard)
12 Paper towel and tissues
13 Teaspoons
14 Notebook
15 Tape measure
16 Cheese grater and stiring rod

Optional

17 EM38 salinity meter

BSES Advancing Sugar — Cooperative Research Centre for Sustainable Sugar Production — CSIRO Land and Water

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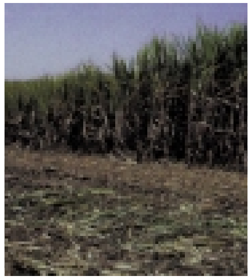


Variations in cane height can indicate the presence of sodicity

Site assessment and soil sampling

What is the approximate slope, where is the site situated in relation to water tables, saline areas and soil types? Examine soil maps and reports. Problems of sodicity and salinity are frequently worse in particularly wet or dry years. Has the year been particularly wet or dry?

INDICATORS OF SODICITY

Original vegetation and weeds

- Poorer vegetation than normal in district, few or stunted trees.
- Presence of beefwood (*Grevillia striata*) in the Burdekin, gum-topped box (*Eucalyptus moluccana*) in the Bundaberg district.
- Couch grass (*Cynodon* species) or Rhodes grass (*Chloris* species).
- Wetter areas, often dominated by *Melaleuca* species, are often wetter due to poor drainage associated with sodicity.

Crop properties and irrigation problems

- Variations in the height of cane across a block, or yield variations noted at harvest.
- Symptoms of water stress not long after irrigation.
- Poor penetration of irrigation water.

Location and soil properties

- Soil map unit described as sodic (especially in BRIA and MDIA, where soils are mapped at a scale of 1:25,000).
- Soil profile with hard-setting fine sandy loam topsoil, bleached at its base, with an abrupt change to a dense clay subsoil, which may have a domed surface.
- Coarse structure (> 20 mm), prismatic or columnar structure in the subsoil.
- Surface crusting.
- Dense, hard subsoil (could be any colour).
- Soapy feel when wetting and working up for texture.

- pH > 8.5.
- Cloudy water in puddles.
- Shallow rooting depth.
- Subsoil exposed or brought closer to the surface during levelling.
- Lime nodules in subsoil.

INDICATORS OF SALINITY

- Original vegetation and weeds, especially couch grass (*Cynodon* species).
- Crop properties: symptoms of water stress when soil is wet.

Soil properties

- Fluffy surface.
- Whitish salt crusts on tops of mounds or aggregates.

PRESENCE OF WATER TABLE

The presence of a shallow water table (< 1.5 m below the surface) is an important factor in managing sodicity and salinity. Groundwater depth may be seen in bores or drains. It may be necessary to dig a backhoe pit or bore hole. Where shallow groundwater is present it should be tested for salinity.

SOIL SAMPLING

Delineate the area of interest based on the indicators above, and then take several samples from within each area, bulking them if necessary. If a problem area is being analysed, also sample outside the problem area so that comparisons can be made. The more samples you take, the more meaningful the results. Sample at least the 0-250 mm and 250-500 mm depth layers. Sampling down to 750 mm is worthwhile. For each sample, analyse several replicates. Mark sampling site locations on a farm map, or record GPS coordinates. An example of a sampling mapping sheet is included at the end of this guide.

Cores are preferable to auger samples because the soil is not disturbed. Therefore, it is possible to see structure and mottles in core samples, and a dispersion test can be performed on undisturbed aggregates removed from the core. ▲

A strongly sodic subsoil (note the cloudy water)

Soil tests

Laboratory tests are the most reliable indicator of sodicity and related problems. However, the following field tests are complementary to lab tests: they can be performed within minutes to a day of sampling, at very little cost. Texture, pH, salinity and dispersion tests should be carried out as a matter of course where sodicity is suspected.

STRUCTURE, CONSISTENCY & COLOUR

All measurements of structure depend on water content and previous cultivation. However, while sampling it is possible to see and feel whether the soil is hard and dense, or soft and loose.

Light colours indicate leached layers and dark colours near the surface suggest high organic matter contents. Reddish colours indicate good drainage, yellow colours moderate drainage and greyish colours poor drainage. Mottles indicate intermittent waterlogging. Shiny surfaces on large aggregates indicate a high content of shrink-swelling clays.

TEXTURE

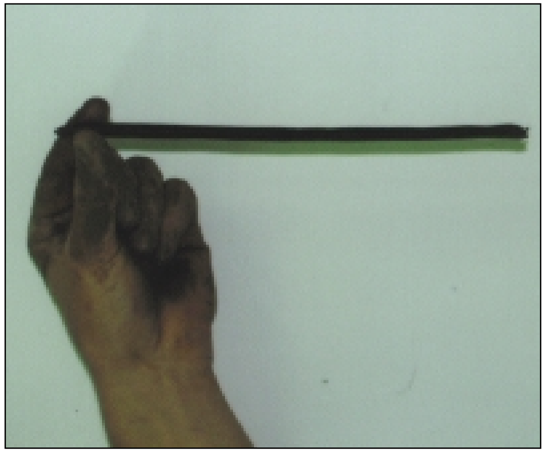
(from McDonald et al, 1984)

Field texture is a subjective but reproducible measurement that provides a useful assessment of the way in which soil behaves in the field.

If the soil contains gravel (particles with diameter greater than 2 mm diameter) and is dry enough, sieve soil through a 2 mm sieve. Fill the palm of the hand with soil and moisten it with water, a little at a time, kneading it until the ball of soil just fails to stick to the fingers. Add more soil or water to attain this condition, known as the sticky point. This approximates field moisture capacity for that soil. Continue kneading and moistening until there is no apparent change in the soil ball, usually a working time of one to two minutes. The soil ball, or bolus, is now ready for shearing manipulation, but the behaviour of the soil during bolus formation is also indicative of its field texture. The behaviour of the bolus and of the ribbon produced by shearing (pressing out) between thumb and forefinger characterises the field texture (Table 1).

After mixing soil with water and kneading for one to two minutes, a soil ball or bolus is formed

Shearing the soil bolus between thumb and fore-finger determines the soil's texture (see Table 1)



Medium and heavy clays can be moulded into rods of 3 mm diameter without fracturing

TABLE 1: **Field texture grades and the approximate percentage of clay (particles less than 0.002 mm in diameter) and silt (particles between 0.002 and 0.02 mm in diameter) according to the behaviour of a soil bolus**

Field texture	***Behaviour of moist bolus***	***Approx. clay content***
Sand	Coherence nil to very slight, cannot be moulded; single sand grains stick to fingers.	<10%,usually <5%
Loamy sand	Slight coherence; ribbon of about 5 mm.	5% to 10%
Clayey sand	Slight coherence; sticky when wet, many sand grains stick to fingers; ribbon of 5-15 mm.	5% to 10%
Sandy loam	Bolus just coherent but very sandy; ribbon of 15-25 mm.	10% to 15%
Light sandy-clay loam	Bolus strongly coherent but very sandy; ribbon of 20-25 mm.	15% to 20%
Loam	Bolus coherent and rather spongy; smooth feel when manipulated but with no obvious sandiness or 'silkiness'; may be greasy to the touch if organic matter present; ribbon of about 25 mm.	about 25%
Silt loam	Coherent bolus; very smooth to silky when manipulated; ribbon of about 25 mm	about 25%, with silt >25%
Sandy clay loam	Strongly coherent bolus, very sandy to touch; ribbon of 25-40 mm.	20% to 30%
Clay loam	Coherent plastic bolus, smooth to manipulate; ribbon of 40-50 mm.	30% to 35%
Silty clay loam	As above, silky to the touch.	30% to 35%, with silt >25%
Sandy clay	Plastic bolus, very sandy, ribbon of 50-75 mm.	35% to 40%
Silty clay	Plastic bolus, smooth and silky to manipulate; ribbon of 50-75 mm.	35% to 40%, with silt >25%
Light clay	Smooth plastic bolus; slight resistance to shearing; ribbon of 50-75 mm.	35% to 45%
Medium clay	Smooth plastic bolus; handles like plasticine and can be moulded into rods of 3 mm diameter without fracture; some resistance to shear; ribbon of 75 mm or more.	45% to 55%
Heavy clay	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; firm resistance to shear; ribbon of 75 mm or more.	50% or more

There are some factors other than sand, silt and clay content that influence field texture.

Type of clay mineral

The type of clay mineral influences behaviour of the bolus. Montmorillonite clays tend to make the bolus feel more clayey and kaolinite clays tend to make it feel less clayey.

Organic matter

Organic matter tends to make light textured soils feel heavier and clays feel lighter.

Oxides in red volcanic soils, when present in large amounts, make the bolus feel less clayey than it is. Longer manipulation makes these soils feel heavier.

Cation composition

In general, calcium-dominant clays accept water readily and are easy to knead and smooth to field texture. When dry, sodium- and magnesium-dominant clays are often difficult to wet and knead, producing a slimy, tough bolus, resistant to shearing.

Strong, fine-structural aggregation will tend to cause an underestimate of clay content, due to incomplete breakdown of the small aggregates. Longer and more vigorous kneading is necessary to produce a homogeneous bolus.

A highly sodic duplex soil

pH (ACIDITY OR ALKALINITY)

Field kit pH (indicator dye)

This is a very simple and useful test. Use the kit according to instructions. Values less than 5.5 indicate that a liming program may be necessary to prevent excessive acidification of the soil.

Calcium deficiency may occur at low pH. If Ca deficiency is suspected the soil should be tested for Ca in a laboratory in order to determine the liming requirement. Values of pH greater than 8.5 indicate sodicity (see below under 'Sodicity').

1-to-5 extract pH

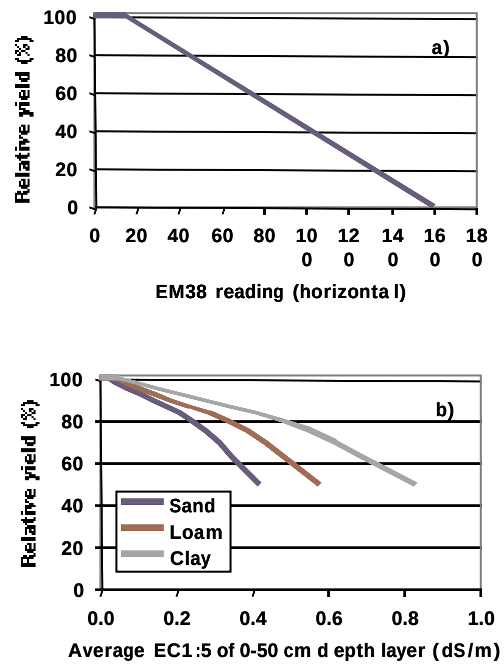
This is a more accurate test — described under 'Sodicity'.

SALINITY

Electromagnetic induction meters (EM38 and EM31)

Electromagnetic induction meters are valuable instruments for spot checks of salinity, or for surveying the extent and severity of its occurrence. Two types of instruments are available. The EM31 measures the amount of salt stored to 3 or 6m depth, and is thus useful for detecting the stores of salt that have the potential to move to the surface if management changes. The EM38 is more useful from an agronomic point of view, measuring soil salinity to approximately 0.75 or 1.5m depth. It may not pick up high concentrations of salt at very shallow depths.

FIGURE 1: **a) Relative crop yield versus EM38 reading, based on data from the Burdekin (Nelson and Ham, 2000), and b) Relative crop yield versus electrical conductivity of 1:5 soil:water extracts (EC1:5), based on Calcino (1994)**



Use these graphs as a general guide only, as the relationship depends on many factors. If soil from the 0-25 cm depth layer is used to measure EC1:5, relative yield will be less than indicated by the graphs

A survey consists of a series of transects across the area of interest. The distance between measuring points depends on how much detail is needed. Large distances between measuring points speed up the survey, but small site-specific problem areas can be overlooked.

For problem blocks, a measurement grid of 50 m is suggested. If large variations in measurement values occur, additional readings may help to interpret problems.

A GPS instrument is useful to record positions quickly and accurately. Alternatively, positions should be marked on a farm map. The grid point coordinates and EM readings are used to create a contour map of apparent conductivity.

The EM operating instructions are described in detail in the manuals, the main points to remember are:

• Remove any metal objects from the operator.

• Stay a few metres away from cables, pipes, fences, power lines and vehicles.

• Do a battery test.

• Set the instrument to zero. For the EM38 this involves holding the instrument at a height of 1.5 m, adjusting the mode switch (if necessary) until the vertical reading equals two times the horizontal reading. Calibration checks should be made frequently.

• Readings can now be taken by placing the meter on the ground, vertically for the 1.5 m depth reading, horizontally for the 0.75 m depth reading, or horizontally at knee height for readings at approximately 0.5 m depth.

• EM31 readings are less likely to be influenced by external interference, although an equipment functional check should be made before the survey begins (this is described in the manual). The instrument is held at hip level, the mode switch is turned to the operating position, and the range switch is then set on 100. If readings are greater than 100 the range switch is set to 1000. The instrument is normally held in the vertical position, to take readings in the horizontal position, the instrument is simply rotated by 90 degrees.

The EM38 can take spot readings of salinity at 0.75 and 1.5 metre depths

1-to-5 extract EC

Electrical conductivity (EC) is used to measure salinity of particular samples or layers. The procedure is given below under sodicity. Texture is also required to interpret salinity (see Figure 1b).

DISPERSION TEST

((Emerson dispersion test, from Loveday and Pyle, 1973)

This test needs no special equipment and is very simple. It is a good indicator of permeability problems and sodicity, as described in the section on sodicity.

• Collect representative undisturbed pea-sized aggregates from core or spade sample. If the aggregates are not dry, allow them to become air dry.

• Place each aggregate in about 50 mL of distilled water (or demineralised or rainwater) in a flat-bottomed clear container (at least three replicates per soil sample). The containers should not be disturbed.

• At two and 20 hours after immersing the aggregates, a visual judgement is made of the degree of dispersion, and at each time a score of 0, 1, 2, 3 or 4 is given.

• Most air-dry aggregates will crumble or slake when immersed in water. Slaking should not be confused with dispersion, which is the movement of clay out of the aggregate.

• For samples that disperse, the two and 20 hour scores are added together and then added to the number eight to give the dispersion index. The range of possible values is 9 to 16. For samples that do not disperse, the sample may be wetted up, remoulded, and new 'aggregates' formed and rated for dispersion in the same way as the natural air-dry aggregates. Their two and 20 hour scores are added together to give the dispersion index, with the range of possible values being 0 to 8. Sodic soils usually disperse without remoulding (dispersion index > 8).

Dispersion ratings can also be made using the appropriate irrigation water, because salts in the irrigation water influence dispersion. However, sodicity should only be estimated using the dispersion index determined using distilled water.

If the aggregates are wet, or have been disturbed during sampling, the test may still be carried out, but it is not as reliable. Disturbed or wet aggregates tend to disperse more easily than dry, undisturbed aggregates.

Dispersion test scores

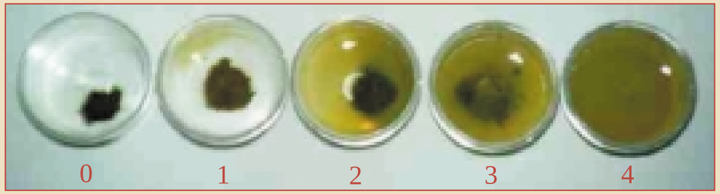
0 No dispersion.

1 Slight dispersion, recognised by a slight milkiness of the water adjacent to the aggregate and some times a narrow edging of dispersed clay to part of the aggregate.

2 Moderate dispersion with obvious milkiness.

3 Strong dispersion with considerable milkiness and about half of the original volume dispersed out wards.

4 Complete dispersion leaving only sand grains in a cloud of clay.



High levels of sodicity has caused com-plete crop loss in a section of this field

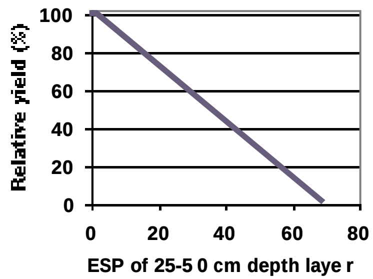
SODICITY

Sodicity can be estimated using the most appropriate methods from Table 2.

TABLE 2: **Summary of the disadvantages and advantages of four methods for estimating soil sodicity in the field**

Method	Disadvantages
Salinity (EM38)	• Not applicable in all districts. • Not all sodic soils are saline. • EM38 meters are expensive.
Field pH	• Hard to distinguish between colours. • Soils with pH <8.5 may or may not be sodic. • Not applicable in all districts.
Dispersion	• Water content influences result. • Sample should be undisturbed. • Takes overnight.
1-to-5 extract test	• Meters must be maintained and calibrated. • Measures sodicity only — doesn't measure other possible causes of dispersion such as exchangeable Mg.
Method	**Advantages**
Salinity (EM38)	• Quick and simple, involves no digging. • Accurate in some districts.
Field pH	• Quick and simple. • Accurate in some districts.
Dispersion	• Very simple. • Measures actual problem.
1-to-5 extract test	• Relatively rapid. • Applicable in all districts and soil types.

FIGURE 2: **Relative crop yield versus exchangeable sodium percentage (ESP) of the 25-50 cm depth layer, based on data from Spalding (1983) and Nelson and Ham (2000)**

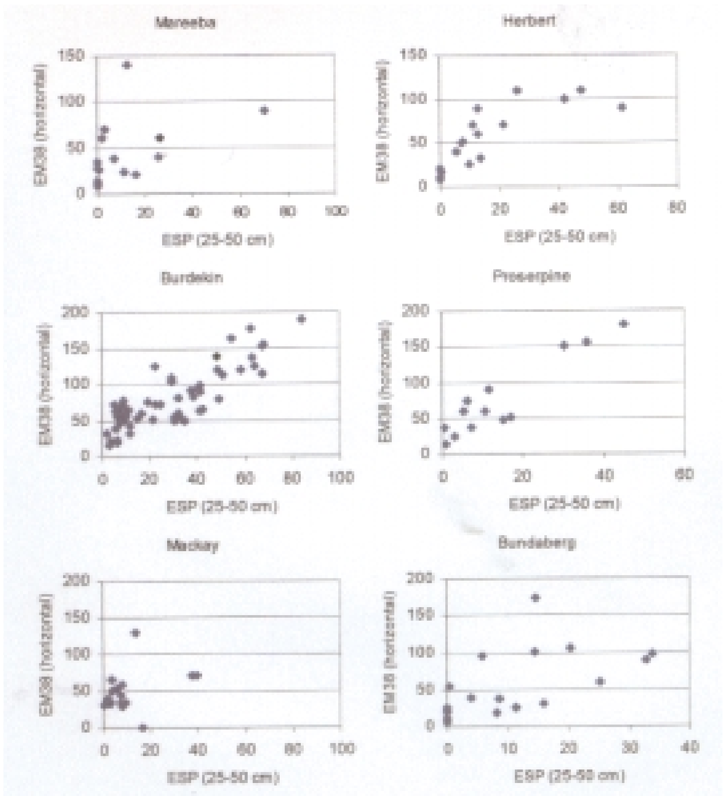


Use as a general guide only, because the relationship depends on many things

From salinity using EM38

Profile salinity, measured using the EM38 meter, is correlated with sodicity in some districts. Use Figure 3 to estimate ESP from the EM38 reading. The figure shows the range of values for a set of samples from each district. Reading across from your EM38 reading, the ESP of the soil is most likely to be near the centre of the cloud of points. In Mareeba, Mackay and Bundaberg, Figure 3 shows that ESP cannot be reliably estimated from EM38 reading.

FIGURE 3: **Relationship between sodicity and EM38 reading**

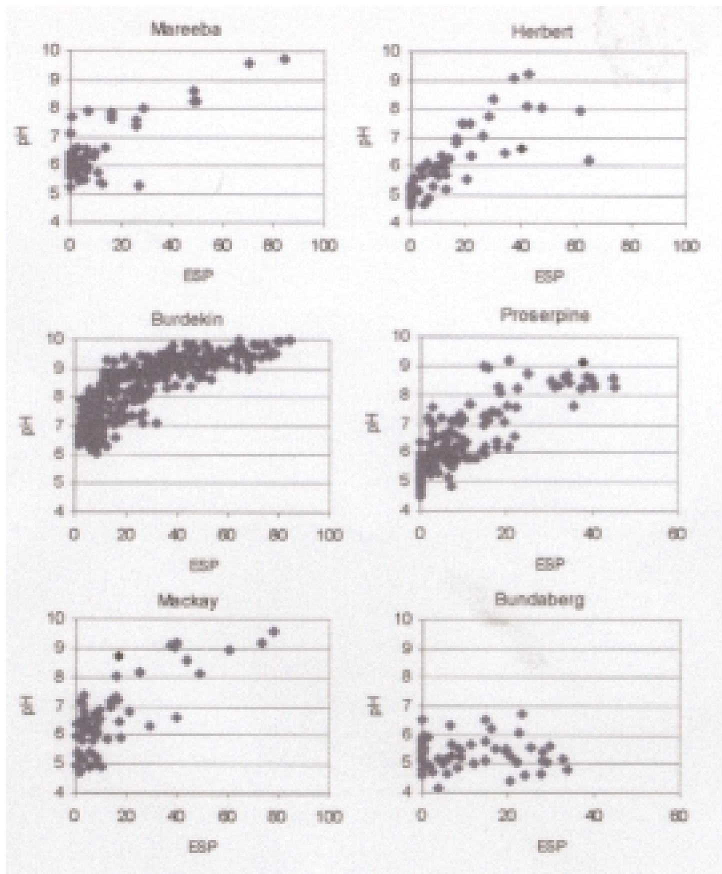


From field pH

This is a quick way to estimate sodicity in all districts except Bundaberg (Figure 4). Soils with pH > 8.5 are sodic, whereas those with pH < 8.5 may or may not be sodic.

Use Figure 4 to estimate ESP from pH.

FIGURE 4: **Relationship between sodicity and pH**

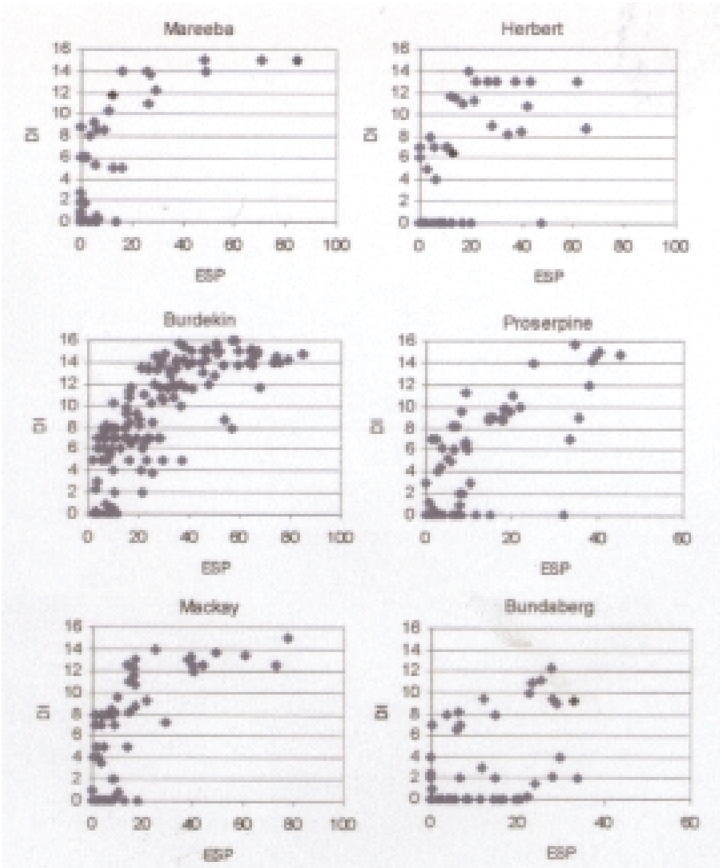


From dispersion test

A dispersion test is a simple technique for estimating sodicity reasonably accurately in most districts (Figure 5). If aggregates disperse within a 30 minute period, they are likely to be highly sodic.

Use Figure 4 to estimate ESP from dispersion index (DI). The figure shows the range of values for a set of samples from each district. Reading across from your DI value (for any depth), the ESP of the sample is most likely to be near the centre of the cloud of points. Figure 5 shows that DI is not a reliable indicator of ESP in Bundaberg.

FIGURE 5: **Relationship between sodicity and dispersion index (DI)**



1-to-5 extract

This method is a reasonably accurate way of estimating sodicity, salinity and pH in most districts. It is most accurate if the soil is dried, ground and weighed out (20 g soil plus 100 mL water). But the test can also be performed in the field, as set out below. It is most convenient to analyse several soil samples at the same time.

Calibration

All three meters in the field kit should be calibrated before analysing each batch of samples and used strictly according to their instructions. Without calibration the results are

Rhodes grass is a good indicator of sodic soils

meaningless. Ensure you have sufficient calibration solution, as the portion you use for calibration should be discarded after use. Calibration solutions for the EC and pH meters can be obtained from agricultural or laboratory supply stores.

The calibration solution for the sodium meter can be made up with lab grade, dry, sodium chloride (NaCl), distilled water and accurate scales and volumetric measuring containers. The 20 x 100 ppm standard is made by adding 5.08 g of laboratory grade sodium chloride (NaCl) to a container, and making the volume up to 1 L with distilled water. Smaller quantities may be made.

The 15 x 10 ppm standard is made by taking 75 mL of the 20 x 100 ppm standard, and making it up to 1 L with distilled water. The volumes can be measured using the set of scales, by assuming that 1 g of water equals 1 mL.

The sodium meters are very sensitive and adjustments during calibration should be made very gradually. The meter is calibrated using the wheel on the top of the instrument for the 20 x 100 ppm solution and the small screw under the flap for the 15 x 10 ppm solution.

Check both readings before adjusting the calibration. If the calibration is out, adjust each standard in turn, moving the value towards the correct value a little each time. After doing this several times, and if the readings are within 1 of the specified value, the meter is calibrated and ready for use.

Replacement of meters

The pH meters should be replaced approximately once every six months if used regularly, as the sensor degrades with use. A variety of pH meters are available from agricultural or lab supply stores. The EC meters will remain accurate much longer.

The sensor in the sodium meters should be replaced about once a year if used regularly. The current supplier of Horiba Na meter sensors is Australian Scientific, Newcastle, phone (02) 4956 2299, fax (02) 4956 2525.

Procedure

• Add distilled, deionised or rainwater up to the bottom mark (175 mL) of an extract bottle. Then add soil, crushed as fine as possible, until the level reaches the top mark (190 mL, equivalent to approximately 35 g soil).

• Depending on the soil texture and its moisture, the soil may be hard or moist (especially in clay soils) thus making it difficult to break down, if this is the case then use a cheese grater to break the soil down before adding to the distilled water. Alternatively use a stirring rod to crush soil in the distilled water.

• Shake the extract bottle vertically and vigorously for about two minutes, this will generally break up lumps.

• Measure pH, electrical conductivity (EC) and Na concentration. The pH and EC meters are dipped into the suspension. For Na, take a sample of the suspension with a pipette, and place on the sensor.

• Estimate exchangeable sodium percentage (ESP) of the soil from the tables in Figure 7, by reading between the values. The values read off the table are an approximate estimate only, and may differ from laboratory tests.

Measurement units

EC is expressed in dS/m (decisiemens per metre). Most EC meters read in µS/cm (microsiemens per centimetre, often labelled as µS on the meter) or mS/cm (millisiemens per centimetre, often labelled as mS on the meter). One dS/m equals one mS/cm, which equals 1000 µS/cm.

On the sodium meters, concentration is expressed in ppm (parts per million). One ppm equals one mg/L.

pH is expressed in pH units.

ESTIMATING CATION EXCHANGE CAPACITY (CEC)

Recommending gypsum rates requires an estimate of CEC. CEC is related to the amount and type of clay and organic matter content. A rough estimate can be made from field texture, as shown in the following figures.

Sodicity has significantly reduced the height and yield of this crop

It is important to estimate CEC, because the effects of sodicity are less in soils with low CEC than soils with moderate to high CEC.

There is a wide range of CEC values from each texture category, because CEC depends not only on clay content, but also on clay type and organic matter content. Soils with kaolinite clay or low organic matter content have lower values of CEC, whereas soils with montmorillonite clay have high values of CEC.

Familiarity with laboratory tests of soils from the area will help estimation.

TABLE 3: **Approximate CEC as related to soil texture for Queensland's sugar soils**

Field texture	Approximate CEC (meq/100g)
Sand, clayey sand, sandy loam, light sandy clay loam	0-5
Loam, sandy clay loam, clay loam	1-10*
Sandy clay, light clay	2-15*
Light medium clay, medium clay	5-30*
Heavy clay	10-40*

**Higher in the Burdekin, lower in other districts*

LIME OR CARBONATE

Alkaline sodic soils in low rainfall areas may contain calcium carbonate (lime) or calcium/magnesium carbonate (dolomite), usually in the subsoil. The carbonate may be visible as small white patches.

The correct concentration of HCl (1M) can be made up by carefully adding 500 mL of distilled water to 50 mL of concentrated HCl (available from laboratory supply shops).

Note: It is important to add the distilled water to the concentrated HCl due to the chemical reaction involved. Battery acid can be used as a substitute as it will also cause carbonate to fizz. ▲

Tables for estimating exchangeable sodium percentage (ESP) from 1-to-5 extract EC, pH and Na concentration

Look up the appropriate values of meter readings and read estimated ESP from the body of the table. Where necessary, estimate ESP by interpolation between the table values

Mareeba

Na (mg/L) \ pH	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
1	0	0	2	5	8	11	14	17	19	22	25
10	0	3	6	9	12	15	18	21	23	26	29
20	5	8	10	13	16	19	22	25	28	31	34
30	9	12	15	18	21	24	26	29	32	35	38
40	14	16	19	22	25	28	31	34	37	40	43
50	18	21	24	27	30	32	35	38	41	44	47
60	22	25	28	31	34	37	40	43	46	49	51
70	27	30	33	36	38	41	44	47	50	53	56
80	31	34	37	40	43	46	49	52	54	57	60
90	36	39	42	44	47	50	53	56	59	62	65
100	40	43	46	49	52	55	58	60	63	66	69
110	45	48	50	53	56	59	62	65	68	71	74
120	49	52	55	58	61	64	66	69	72	75	78
130	53	56	59	62	65	68	71	74	77	80	82
140	58	61	64	67	70	72	75	78	81	84	87
150	62	65	68	71	74	77	80	83	86	88	91

Herbert

pH 4.5-5.5

Na (mg/L) \ EC (dS/m)	0.01	0.1	0.2	0.3	0.4	0.5	0.6	0.7
1	6	0	0	0	0	0	0	0
10	>10	6	0	0	0	0	0	0
20	>20	23	6	0	0	0	0	0
30	>30	40	14	6	1	0	0	0
40	>40	57	23	11	6	2	0	0
50	>50	75	32	17	10	6	3	1
60	>60	92	40	23	14	9	6	3
70	-	>95	49	29	19	12	8	6
80	-	>95	57	34	23	16	11	8

pH 5.5-6.5

Na (mg/L) \ EC (dS/m)	0.01	0.1	0.2	0.3	0.4	0.5	0.6	0.7
1	12	0	0	0	0	0	0	0
10	>10	12	4	1	0	0	0	0
20	>20	29	12	6	4	2	1	0
30	>30	47	21	12	8	5	4	2
40	>40	64	29	18	12	9	6	5
50	>50	81	38	24	16	12	9	7
60	>60	99	47	29	21	16	12	10
70	-	>99	55	35	25	19	15	12
80	-	>99	64	41	29	23	18	15
90	-	>99	73	47	34	26	21	17

pH 6.5-7.5

Na (mg/L) \ EC (dS/m)	0.01	0.1	0.2	0.3	0.4	0.5	0.6	0.7
1	19	3	2	2	2	2	2	2
10	>10	19	10	7	6	5	4	4
20	>20	36	19	13	10	8	7	6
30	>30	53	27	19	14	12	10	9
40	>40	71	36	25	19	15	13	11
50	>50	88	45	30	23	19	16	14
60	-	>90	53	36	27	22	19	16
70	-	>90	62	42	32	26	22	19
80	-	>90	71	48	36	29	25	21
90	-	>90	79	53	40	33	27	24

pH 7.5-8.5

Na (mg/L) \ EC (dS/m)	0.01	0.1	0.2	0.3	0.4	0.5	0.6	0.7
1	25	10	9	9	9	9	8	8
10	>10	26	17	14	12	12	11	11
20	>20	43	25	20	17	15	14	13
30	>30	60	34	25	21	19	17	16
40	>40	77	43	31	25	22	20	18
50	>50	95	51	37	30	25	23	21
60	-	>95	60	43	34	29	25	23
70	-	>95	69	49	38	32	28	25
80	-	>95	77	54	43	36	31	28
90	-	>95	86	60	47	39	34	30
100	-	>95	95	66	51	43	37	33
110	-	-	>95	72	56	46	40	35

pH 8.5-9.5

Na (mg/L) \ EC (dS/m)	0.01	0.1	0.2	0.3	0.4	0.5	0.6	0.7
1	32	17	16	15	15	15	15	15
10	>15	32	23	21	19	18	18	17
20	>20	49	32	26	23	22	21	20
30	>30	67	41	32	28	25	23	22
40	>40	84	49	38	32	29	26	25
50	-	>90	58	44	36	32	29	27
60	-	>90	67	49	41	36	32	30
70	-	>90	75	55	45	39	35	32
80	-	>90	84	61	49	43	38	35
90	-	>90	93	67	54	46	41	37
100	-	-	>95	73	58	49	44	40
110	-	-	>95	78	62	53	47	42

Tables for estimating exchangeable sodium percentage (ESP) from 1-to-5 extract EC, pH and Na concentration

Look up the appropriate values of meter readings and read estimated ESP from the body of the table. Where necessary, estimate ESP by interpolation between the table values

Burdekin

pH 6-7

Na (mg/L) \ EC (dS/m)	0.01	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6
1	0	0	1	4	7	10	13	16	19
20	>1							24	29
40	>1							32	36
60	-							39	44
80	-							46	52
100	-	-	>10	19	29	37	45	52	58
120	-	-	-	>20	30	40	49	57	64
140	-	-	-	-	>30	42	52	61	70
160	-	-	-	-	-	>50	54	65	74
180	-	-	-	-	-	>50	55	67	78
200	-	-	-	-	-	-	>60	69	81

pH 7-8

Na (mg/L) \ EC (dS/m)	0.01	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6
1	4	7	10	13	16	19	22	25	28
20	>5	9	14	18	22	26	29	33	37
40	-	>10	17	22	27	32	37	41	45
60	-	-	18	25	32	38	43	48	53
80	-	-	>20	27	35	42	49	55	60
100	-	-	-	>30	38	46	54	61	67
120	-	-	-	-	39	48	58	66	73
140	-	-	-	-	>40	51	61	70	79
160	-	-	-	-	-	>50	63	74	83
180	-	-	-	-	-	>50	64	76	87
200	-	-	-	-	-	>50	64	78	90

pH 8-9

Na (mg/L) \ EC (dS/m)	0.01	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6
1	13	16	19	22	25	28	31	34	37
20	>20	18	23	27	31	35	38	42	46
40	-	>30	25	31	36	41	45	50	54
60	-	>30	27	34	41	46	52	57	62
80	-	-	>30	36	44	51	58	64	69
100	-	-	-	>40	47	56	63	69	76
120	-	-	-	>40	48	58	67	75	82
140	-	-	-	-	>50	60	70	79	86
160	-	-	-	-	-	>60	72	83	92
180	-	-	-	-	-	>60	73	85	96
200	-	-	-	-	-	-	73	87	99

pH 9-10

Na (mg/L) \ EC (dS/m)	0.01	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6
1	22	25	28	31	34	37	40	43	46
20	>30	27	32	36	40	43	47	51	55
40	>30	27	34	40	45	50	54	59	63
60	-	>30	38	43	50	55	61	66	71
80	-	-	>40	45	53	60	66	72	78
100	-	-	-	>50	56	64	71	78	85
120	-	-	-	>50	57	67	76	84	91
140	-	-	-	-	>60	68	79	88	96
160	-	-	-	-	>60	69	81	92	101
180	-	-	-	-	-	>70	82	94	105
200	-	-	-	-	-	-	>80	96	108

Proserpine

pH 4.5-5.5

Na (mg/L) \ EC (dS/m)	0.01	0.2	0.4	0.6	0.8	1.0
1	0	0	0	0	0	0
20	>1	0	1	2	3	4
40	>1	0	4	7	9	11
60	-	>5	6	10	14	17
80	-	-	>10	12	18	22
100	-	-	>10	13	20	26
120	-	-	-	>15	21	29
140	-	-	-	-	>25	31

pH 5.5-6.5

Na (mg/L) \ EC (dS/m)	0.01	0.2	0.4	0.6	0.8	1.0
1	2	3	3	3	3	3
10	>5	5	7	8	9	10
20	-	5	10	13	15	16
30	-	>10	11	16	19	22
40	-	-	>15	18	23	27
50	-	-	>15	18	26	31
60	-	-	-	>20	27	34
70	-	-	-	-	>30	36

pH 6.5-7.5

Na (mg/L) \ EC (dS/m)	0.01	0.2	0.4	0.6	0.8	1.0
1	8	8	8	8	8	8
20	>10	11	12	13	14	15
40	-	>15	15	18	20	22
60	-	>15	17	21	25	28
80	-	-	>20	23	29	33
100	-	-	>20	24	31	37
120	-	-	-	>25	32	40
140	-	-	-	>25	32	42

pH 7.5-8.5

Na (mg/L) \ EC (dS/m)	0.01	0.2	0.4	0.6	0.8	1.0
1	13	14	14	14	14	14
20	>15	16	18	19	20	21
40	>15	16	21	24	26	27
60	-	>20	22	27	30	33
80	-	-	>25	29	34	38
100	-	-	>25	29	37	42
120	-	-	-	>30	38	45
140	-	-	-	-	>40	47

pH 8.5-9.5

Na (mg/L) \ EC (dS/m)	0.01	0.2	0.4	0.6	0.8	1.0
1	19	19	19	19	19	19
20	>20	22	23	24	25	26
40	-	>25	26	29	31	33
60	-	>25	28	32	36	39
80	-	-	>30	34	40	44
100	-	-	>30	35	42	48
120	-	-	-	>35	43	51
140	-	-	-	>35	43	53

Tables for estimating exchangeable sodium percentage (ESP) from 1-to-5 extract EC, pH and Na concentration

Look up the appropriate values of meter readings and read estimated ESP from the body of the table. Where necessary, estimate ESP by interpolation between the table values

Mackay

Mackay

pH 4.5-5.5

Na (mg/L)	EC (dS/m) 0.01	0.2	0.4	0.6	0.8	1.0
0	0	0	0	0	0	0
20	>1	0	1	1	2	3
40	>1	0	3	5	6	7
60	-	>1	4	7	9	11
80	-	-	>5	8	12	15
100	-	-	>5	8	14	18
120	-	-	-	>10	14	20
140	-	-	-	>10	14	21
160	-	-	-	-	>15	21

pH 5.5-6.5

Na (mg/L)	EC (dS/m) 0.01	0.2	0.4	0.6	0.8	1.0
0	4	4	4	4	4	4
20	>5	5	7	7	8	9
40	>5	5	9	10	12	13
60	-	>5	9	13	15	17
80	-	-	>10	14	18	21
100	-	-	>10	14	20	23
120	-	-	-	>15	20	26
140	-	-	-	>15	20	27
160	-	-	-	-	>20	27

pH 6.5-7.5

Na (mg/L)	EC (dS/m) 0.01	0.2	0.4	0.6	0.8	1.0
0	9	9	9	9	9	9
20	>10	11	12	13	14	15
40	>10	11	14	16	18	19
60	-	>15	15	19	21	23
80	-	-	>15	20	24	27
100	-	-	>15	20	25	29
120	-	-	-	>20	26	31
140	-	-	-	>20	26	33
160	-	-	-	-	>30	33

pH 7.5-8.5

Na (mg/L)	EC (dS/m) 0.01	0.2	0.4	0.6	0.8	1.0
0	15	15	15	15	15	15
20	>15	17	18	19	20	20
40	>15	17	20	22	24	25
60	-	>20	21	25	27	29
80	-	-	>25	26	30	32
100	-	-	>25	26	31	35
120	-	-	-	>30	32	37
140	-	-	-	>30	32	38
160	-	-	-	-	>35	39

pH 8.5-9.5

Na (mg/L)	EC (dS/m) 0.01	0.2	0.4	0.6	0.8	1.0
0	21	21	21	21	21	21
20	>25	23	24	25	26	26
40	>25	23	26	28	30	31
60	-	>25	27	30	33	35
80	-	-	>30	32	35	38
100	-	-	>30	32	37	41
120	-	-	-	>35	38	43
140	-	-	-	-	>40	44
160	-	-	-	-	>40	45

Bundaberg

Na (mg/L)	EC (dS/m) 0.01	0.10	0.20	0.30	0.40	0.50	0.60
1	2	0	0	5	9	13	18
10	>5	6	5	8	12	16	20
20	>5	17	11	12	15	18	22
30	-	>20	16	16	18	21	24
40	-	>20	22	19	21	23	26
50	-	-	>25	23	23	25	28
60	-	-	>25	26	26	28	30
70	-	-	-	>30	29	30	32
80	-	-	-	>30	31	32	34
90	-	-	-	>30	33	34	36
100	-	-	-	-	>35	36	38

Irrigation water tests

SALINITY HAZARD (ELECTRICAL CONDUCTIVITY OR EC)

Salinity is measured by dipping an EC meter into the water. Calibration and care of the EC meter is described in the soil sodicity section ('1-to-5 extract'). The salinity hazard, and conversion to older EC units can be read off Figure 6.

FIGURE 6: **Salinity hazard of irrigation water**

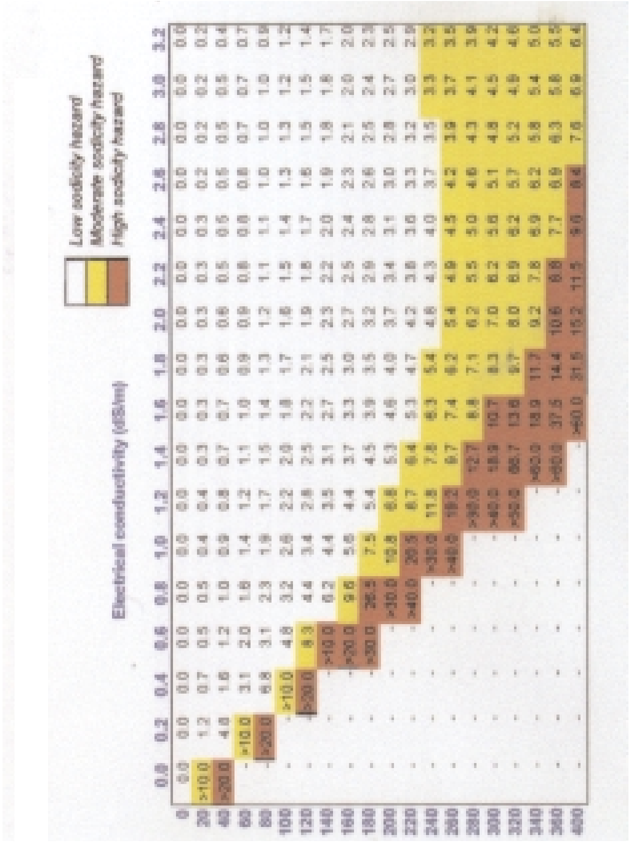
Salinity Hazard	EC dS/m	TDS mg/L	TDS grains/gallon
V. Low	0.00	0	0
	0.05	30	2
	0.10	60	4
	0.15	90	6
	0.20	120	8
	0.25	150	10
	0.30	180	13
Low	0.35	210	15
	0.40	240	17
	0.45	270	19
	0.50	300	21
	0.55	330	23
Moderate	0.60	360	25
	0.70	420	29
	0.80	480	34
	0.90	540	38
	1.00	600	42
	1.10	660	46
	1.20	720	50
	1.30	780	55
	1.40	840	59
High	1.50	900	63
	1.60	960	67
	1.70	1020	71
	1.80	1080	76
	1.90	1140	80
	2.00	1200	84
V. High	2.20	1320	92
	2.40	1440	101
	2.60	1560	109
	2.80	1680	117
	3.00	1800	126
Extreme	3.20	1920	134
	3.60	2100	147
	4.00	2400	168
	4.50	2700	189
	5.00	3000	210

EC = electrical conductivity
TDS = total dissolved salts

SODICITY HAZARD (SODIUM ADSORPTION RATIO OR SAR)

Sodicity hazard is measured by the sodium adsorption ratio (SAR). The SAR can be estimated from the EC and sodium concentration from the sodium meter. With these two measurements, read the estimated SAR off Figure 7. Irrigation water with a high sodicity hazard will tend to make a soil sodic. The ESP of the soil will eventually reach a value approximately equal to the SAR of the irrigation water. Calibration and care of the EC and sodium meters is described in the soil sodicity section ('1-to-5 extract').

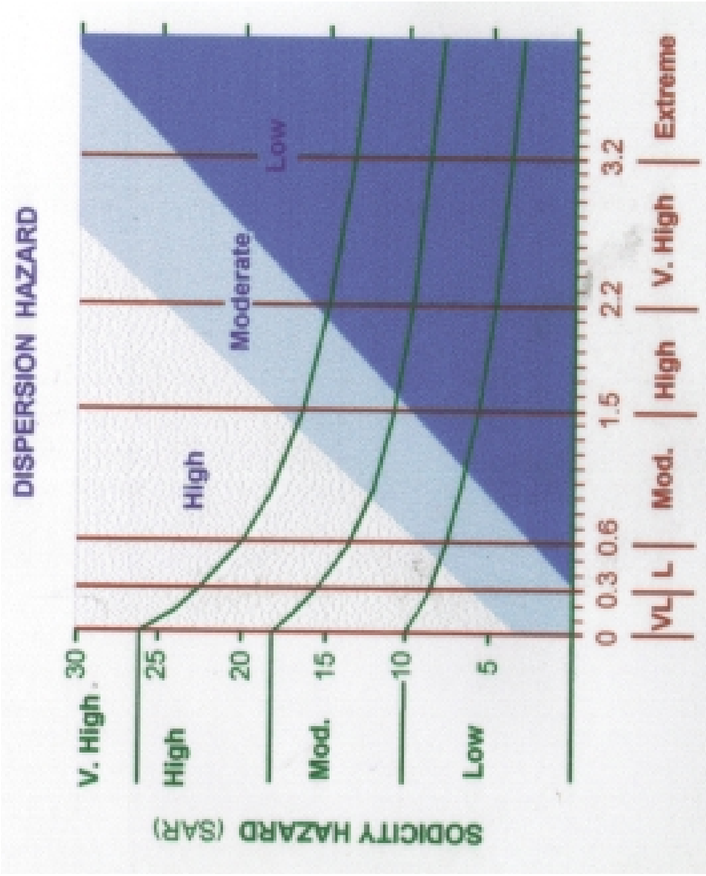
FIGURE 7: **Sodicity hazard (sodium adsorption ratio, SAR) of irrigation water, as estimated from electrical conductivity (EC) and sodium concentration**



DISPERSION HAZARD

The tendency of irrigation water to cause soil to disperse and seal up, or to remain permeable, is determined by its EC and SAR. The lower the EC and the higher the SAR, the greater the dispersion hazard. Dispersion hazard can be read off Figure 8.

FIGURE 6: **Dispersion hazard of irrigation water as determined from EC and SAR**



pH

Alkalinity or pH can be measured with a pH meter. If pH and SAR are both high, then residual alkalinity is also high. ▲

Record keeping

Records of all soil and water tests should be kept by the grower and adviser so that changes over time can be detected. Examples of record sheets for soil analyses are given at the end of this booklet. Similar tables should be kept for measurements of EM38 readings, dispersion index and so on.

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