     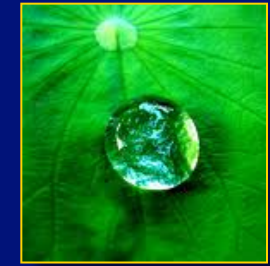

Understanding water analyses

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Consultation, research and training for agriculture

Parameters of water analysis

Conversions

Discussing parameters individually



Growing passion

Parameters of water analysis

Parameter analysed	Full name	Unit of analysis
pH		No unit
EC	Electrical conductivity	$mS.m^{-1}$ or $mS.cm^{-1}$
SAR	Sodium Adsorption ratio	No unit
USDA Classification		S and C Classification
TDS	Total dissolved solids	$mg.\ell^{-1}$
Cations	Calcium (Ca^{2+})	$mg.\ell^{-1}$ or $me.\ell^{-1}$
	Magnesium (Mg^{2+})	
	Potassium (K^{+})	
	Sodium (Na^{+})	
	Ammonium (NH_4^{+})	
Anions	Sulphate (SO_4^{2-})	$mg.\ell^{-1}$ or $me.\ell^{-1}$
	Nitrate (NO_3^{-})	
	Chloride (Cl^{-})	
Alkalinity (and anions)	Bicarbonate (HCO_3^{-})	
	Carbonate (CO_3^{2-})	
Hardness	Calcium Carbonate ($CaCO_3$)	
Micronutrients	Iron (Fe)	$\mu g.\ell^{-1}$
	Boron (B)	
	Manganese (Mn)	
	Fluoride (F)	

Elemental information for conversions

	Element	Symbol	Valency	Atomic weight	Equivalent weight
Cations	Calcium	Ca^{2+}	2	40	20
	Magnesium	Mg^{2+}	2	24	12
	Potassium	K^{+}	1	39	39
	Sodium	Na^{+}	1	23	23
	Ammonium	NH_4^{+}	1	18	18
Anions	Sulphate	SO_4^{2-}	2	69	48
	Carbonate	CO_3^{2-}	2	60	30
	Bicarbonate	HCO_3^{-}	1	61	61
	Nitrate	NO_3^{-}	1	62	62
	Chloride	Cl^{-}	1	35.5	35.5

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Unit conversions

- $1 \text{ dS.m}^{-1} = 100 \text{ mS.m}^{-1} = 100 \text{ mmho.m}^{-1} = 1000 \ \mu\text{mho.cm}^{-1}$
- $1 \text{ mg.}\ell^{-1} = 1 \text{ ppm}$
- Conversions
  - Equivalent weight

    $$\text{Equivalent weight} = \frac{\text{atomic weight}}{\text{valancy}}$$

  - $\text{mg.}\ \ell^{-1}$ to $\text{me.}\ \ell^{-1}$

    $$\text{me.}\ell^{-1} = \frac{\text{mg.}\ell^{-1}}{\text{equivalent weight}}$$

  - $\text{me.}\ \ell^{-1} = \text{mmol.}^{-1}$

    $$\text{mmol.}\ell^{-1} = \frac{\text{me.}\ell^{-1}}{\text{valency}}$$

  - TDS

    $\text{TDS} = \text{EC (mS.m}^{-1}) \times 6.4$

    if $\text{EC} < 500 \text{ mS.m}^{-1}$

  - REMEMBER

    $\sum \text{Cations} = \sum \text{Anions}$

    if in $\text{me.}\ell^{-1}$

Growing passion

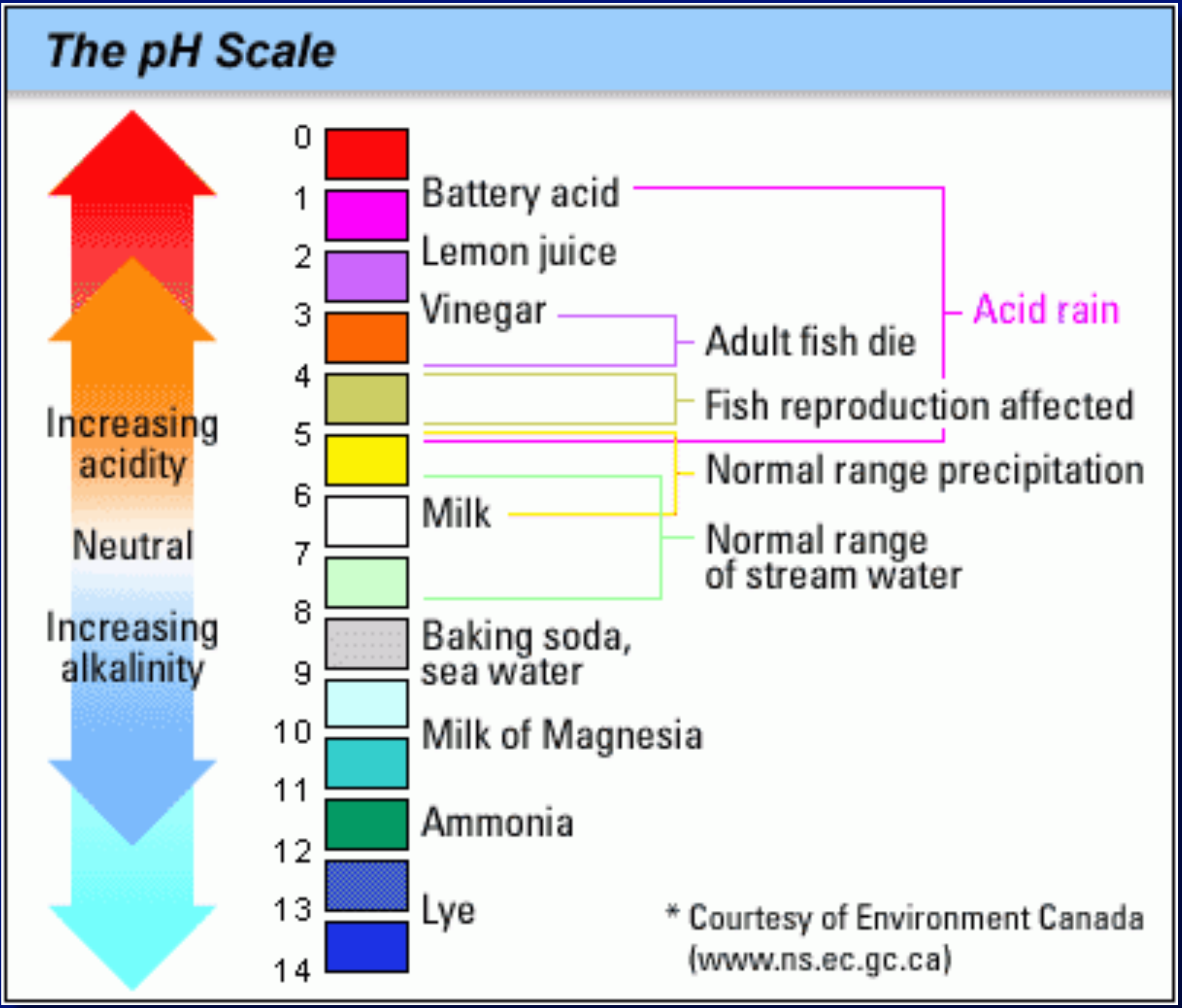
EC: Electrical Conductivity

- Electrical Conductivity
  - Amount of dissolved salts or nutrients or concentration of ions in the water
  - NOT a measure of what nutrients are in the water

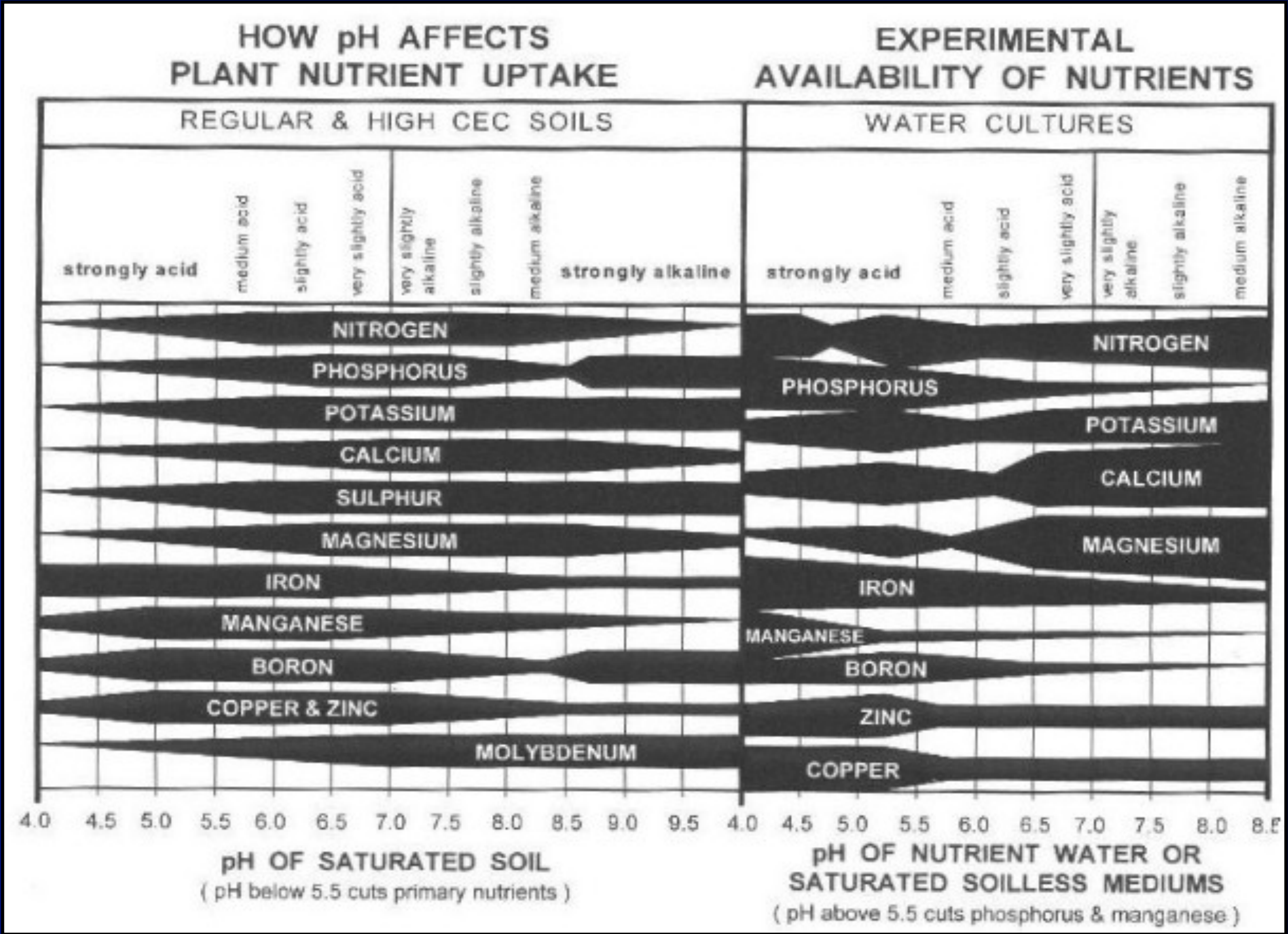
EC: Electrical conductivity

Use for water	Optimal range mS.m^{-1}	Remarks
Irrigation of open fields	< 25	No chances of sodification
	25 – 100	Low danger of sodification
	101 – 125	Chances of sodification
	106 – 175	Specialist management necessary
	> 176	Serious danger of sodification
Hydroponics	< 50	Ideal
	10 – 100	Usable but crop dependent
	> 101	Specialist management necessary
Human consumption	< 300	Usable but dependent on salts in water
Animals (Chickens)	< 75	Ideal
Animals (Sheep/cattle)	< 300	Dependant on salts present

pH scale


The pH Scale
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Increasing acidity
Neutral
Increasing alkalinity
Battery acid
Lemon juice
Vinegar
Milk
Baking soda, sea water
Milk of Magnesia
Ammonia
Lye
Acid rain
Adult fish die
Fish reproduction affected
Normal range precipitation
Normal range of stream water
* Courtesy of Environment Canada (www.ns.ec.gc.ca)

pH = Nutrient availability



Shattering the myth….

Adding acid to reduce pH of water?

Perseus and Medusa

So, I am not really reducing the pH?

- Acid do not reduce the pH of water but it neutralizes bicarbonate and carbonate concentration
  - If pH is below 8.3

$Ca(HCO_3)_2$ + H_2O → Ca^{2+} ion + HCO^{3-} ion + OH^- ion

Calcium Bicarbonate + Water → calcium + bicarbonate + hydroxide

$Mg(HCO_3)_2$ + H_2O → Mg^{2+} ion + HCO^{3-} ion + OH^- ion

Magnesium Bicarbonate + Water → magnesium + bicarbonate + hydroxide

So, I am not really reducing the pH?

- Acid do not reduce the pH of water but it neutralizes bicarbonate and carbonate concentration
  - If pH is above 8.3

$$CaCO_3 + H_2O \longrightarrow Ca^{2+} \text{ ion} + CO^{3-} \text{ ion} + OH^{-} \text{ ion}$$

Calcium Carbonate + Water → calcium + carbonate + hydroxide

$$MgCO_3 + H_2O \longrightarrow Mg^{2+} \text{ ion} + CO^{3-} \text{ ion} + OH^{-} \text{ ion}$$

Magnesium Carbonate + Water → magnesium + carbonate + hydroxide

So, what am I doing?

$Ca(HCO_3)_2$ and/or $Mg(HCO_3)_2$

and/or

$CaCO_3$ and/or $MgCO_3$ (only if pH > 8)

- When acid is added to water the acid or H^+ ion neutralize bicarbonate and carbonates
  - If Bicarbonate: H^+ (from acid) + HCO_3^- $\rightleftharpoons$ CO_2 (g) + H_2O (ℓ)
  - If Carbonates: H^+ (from acid) + CO_3^{2-} $\rightleftharpoons$ HCO_3^-

    H^+ (from acid) + HCO_3^- $\rightleftharpoons$ CO_2 (g) + H_2O (ℓ)

Water is now UNBUFFERED

So, what am I doing?

Unbuffered: a solution with an unstable hydrogen ion concentration

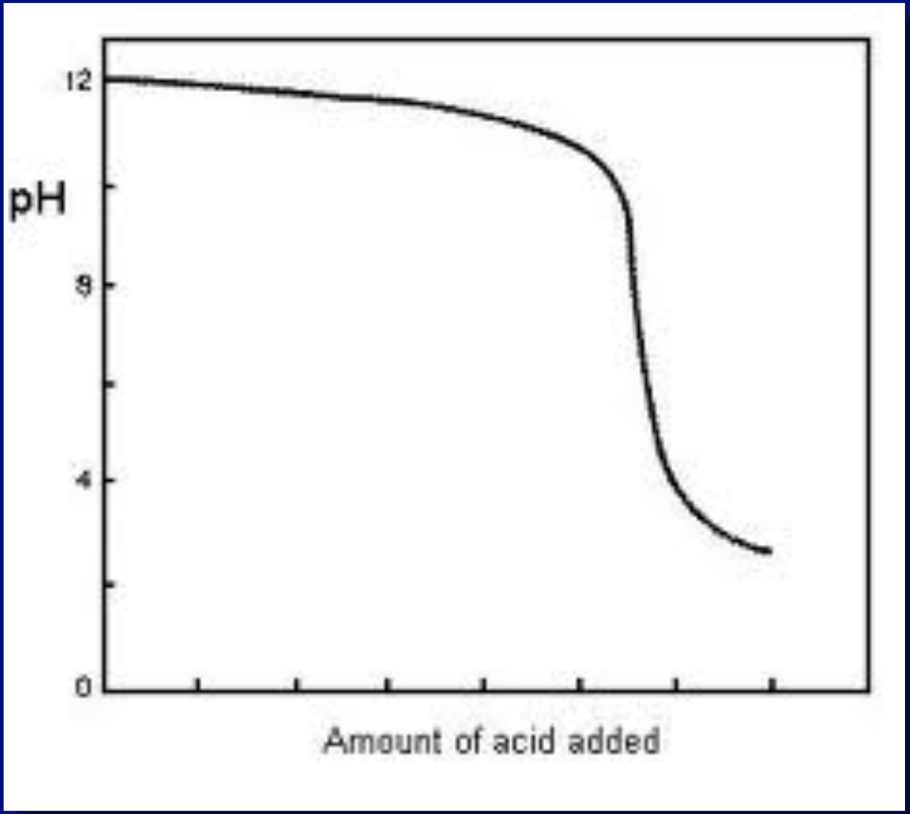
therefore

what ever you add to the water will stabilise the hydrogen ion concentration and thus establish the pH

TIME & VOLUME

I keep adding and adding and nothing happens!

pH = - log [H^+] not linier



TDS: Total dissolved solids



- TDS
  - Indicates quantity of salts dissolved in the water
  - Close relationship between TDS and EC
  - 1 $mS.m^{-1}$ (EC) = 5 – 7 $mg.\ell^{-1}$ TDS

TDS ($mg.\ell^{-1}$)	EC ($mS.m^{-1}$)	Water quality
0 - 175	0 – 25	Excellent
175 – 500	26 - 75	Good
500 - 1500	76 - 225	Moderate
1500 – 2500	226 - 400	Serious
> 2500	>401	Unsuitable

SAR: Sodium Adsorption Ratio

- SAR
  - Indicates the relationship between elements calcium, magnesium and sodium

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

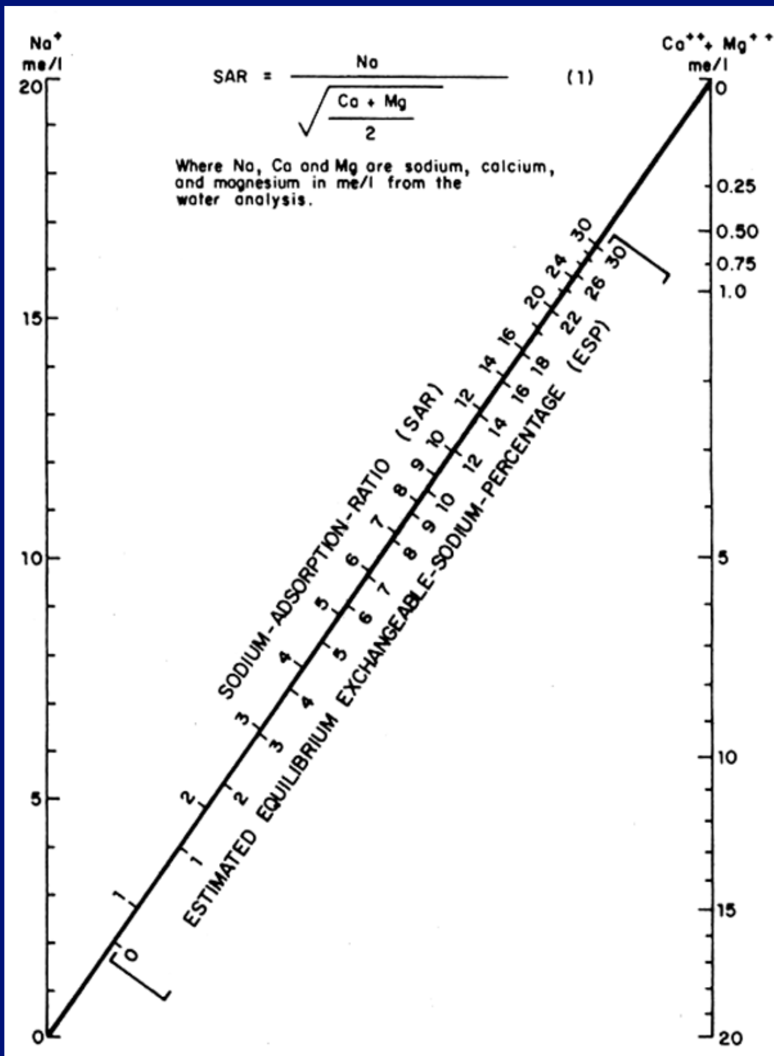
$me.\ell^{-1}$

SAR	
< 1.00	No problem expected
1.00 – 3.00	Special attention need to be given to water infiltration into the soil and possible crust formation on the soil
> 3.00	Specialist soil and irrigation management is imperative

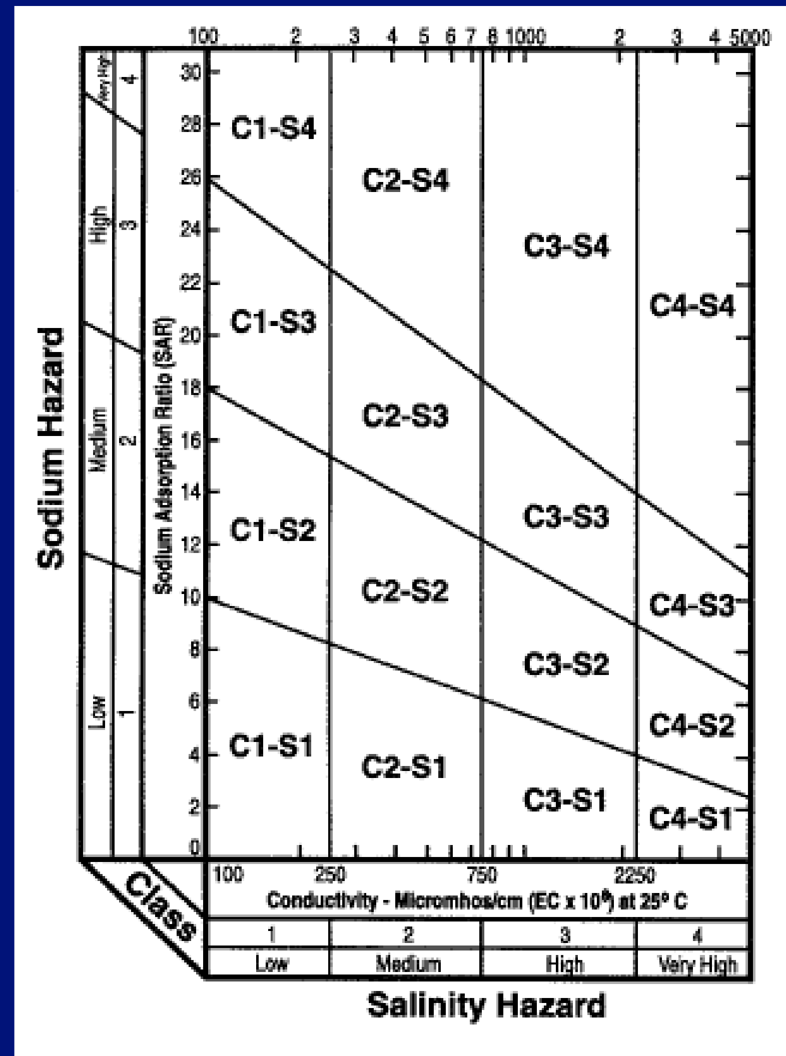
  - Close relationship between USDA classification

SAR & USDA classification

SAR



USDA classification



USDA C-classification

Salt concentration		
C1	0 – 0.25 $mS.cm^{-1}$ Low salt concentration	Water may be used for any application No additional drainage necessary
C2	0.25 – 0.75 $mS.cm^{-1}$ Medium salt concentration	Water may be used for any application Small percentage of drainage necessary
C3	0.75 – 2.25 $mS.cm^{-1}$ High salt concentration	Should not be used in soils with limited drainage Should only be used of very well drained soil
C4	2.25 – 4.00 $mS.cm^{-1}$ Very high salt concentration	Not suited for irrigation under normal conditions Additional management required
C5	> 4.00 $mS.cm^{-1}$ Exceptionally high salt concentration	Not suited for irrigation

USDA S-classification

Sodium concentration		
S1	SAR 0 – 10 Low sodium concentration	Water may be used for any application No sodification hazard
S2	SAR 10 – 18 Medium sodium concentration	Water has limited application Permeability of water into fine textured soils might be problematic
S3	SAR 18 – 25 High sodium concentration	Water has limited application Adversity to be expected on most soils Drainage of great importance
S4	SAR 26 Very high sodium concentration	Not suited for irrigation

C and S classification

- C2S1
  - 0.25 – 0.75 $mS.cm^{-1}$
  - Medium salt concentration
  - Water may be used for any application
  - Small percentage of drainage necessary
  - SAR 0 – 10
  - Low sodium concentration may be used for any application
  - No sodification hazard



Optimal nutrient concentrations

Cations	Calcium (Ca)	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Ammonium (NH_4)
Acceptable ($mg.\ell^{-1}$)	< 80	< 45	< 1	< 80	< 5

Anions	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Carbonate (CO_3)	Bicarbonate (HCO_3)
Acceptable ($mg.\ell^{-1}$)	< 40	< 70	< 5	< 80 (pH)	< 122

Water contains nutrients – contributes to crop nutrition

- Example:
  - Water contains 10 g/1000 ℓ Mg (100 ppm or $mg.\ell^{-1}$)
  - Irrigate 400 0000 ℓ water
  - Equivalent to 40 kg of Mg = 400 kg $MgSO_4$

Chlorides

Guideline	Example crops	Allowable concentration (mg.ℓ^{-1})
Chloride free	Oven dried tobacco	< 25
Chloride sensitive	Lettuce	< 53
Non-specific to chloride	Air dried tobacco	< 106
Chloride tolerant	Lucerne, Beetroot	< 175
Foliar feeds	Any	< 106
Hydroponics & potted plants	Any	< 106
Overhead irrigation	Tree crops	< 175
Any irrigation	Grapes, potatoes, tomatoes	< 355
Any irrigation	Barley, maize	< 532
Flood irrigation	Any	< 142
Sprinklers	Any	< 106

Boron

Boron (B) ($\mu g.\ell^{-1}$)			
Class	Sensitive crop	Moderate crop	Tolerant crop
Very good	< 0.33	< 0.67	< 1
Good	0.33 – 0.67	0.67 – 1.33	1.0 – 2.0
Fairly high	0.67 – 1.00	1.33 – 2.00	2.0 – 3.0
High	1.00 – 1.25	2.00 – 2.50	3.0 – 3.7
Unusable	>1.25	> 2.5	> 3.7
Crops	Pecan nuts, Prunes, Pears, Apples, Table grapes, Peaches, Citrus, Avocado	Sunflowers, Potatoes, Cotton, Tomatoes, Olives, Wheat, Maize, Pumpkins	Asparagus, Dates, Beetroot, Onions, Cabbage, Salad, Carrots

Alkalinity – hardness of water

Clarification	Alkalinity Calcium Carbonate ($CaCO_3$) ($mg.\ell^{-1}$)
Soft	0 – 50
Marginally soft	51 - 100
Slightly hard	101 - 150
Hard	151 - 300
Very hard	301 - 500