

# Meteorological methods: temperature; humidity; rainfall; wind speed

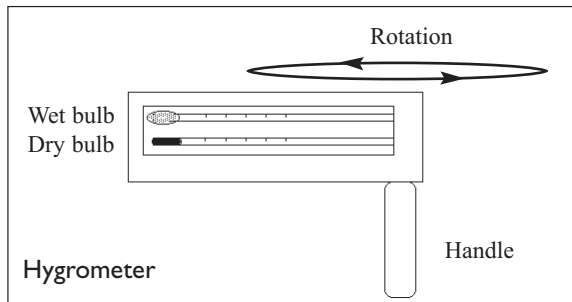
## DON'T FORGET

**EQUIPMENT:** Maximum/minimum thermometers or thermistors and data logger; whirling hygrometer or relative humidity probe; rain gauge (coffee can, funnel and graduated cylinder); cup anemometer or propeller and vane gear; compass; meter; logger; batteries for logger.

### AIR TEMPERATURE

#### Method

- Record maximum and minimum air temperatures regularly at all sites using a maximum/minimum thermometer. Protect bulbs from direct sunlight and wind damage. If monitoring for extended periods in any one area, take daily readings at the same time each day. Return indicator to level of mercury using a magnet after reading. Read temperature at least to the nearest 0.5 °C.
- Thermistors, thermocouples and data loggers also need protection from sunlight. A simple screen can be built from wood or grasses to house the temperature probe or max-min thermometer. Programme the data logger to provide average daily temperatures and other statistics (maximum/minimum, etc.) as required.

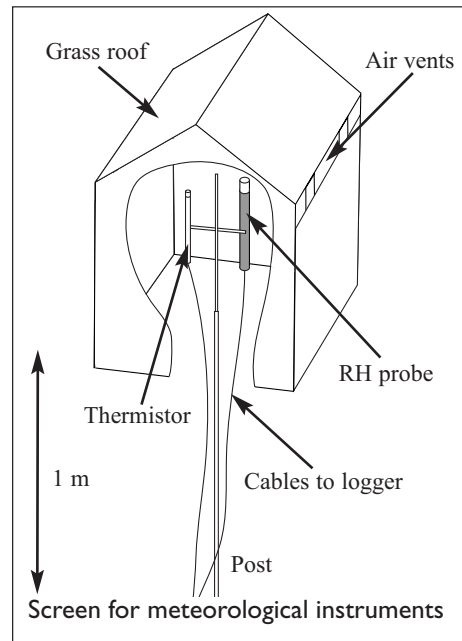


### RELATIVE HUMIDITY

#### Method

##### Whirling hygrometer

- Top up the wick reservoir with water and check the wet bulb is moist before whirling the hygrometer for 1 min (like a football rattle) above your head. Make a note of the temperatures of both thermometers and use the difference in temperatures to read off the percentage relative humidity from the table provided with the hygrometer. Take readings at fixed times daily and plot average(s) against time.
- Alternatively, meter readings from relative humidity probes can be stored in the meter or a data logger.



### RAINFALL

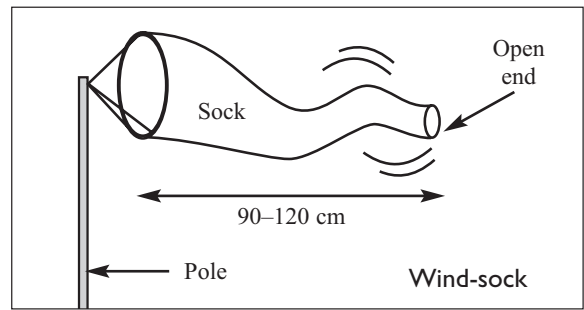
#### Method

- Find a suitable site to place the gauge – out of direct sunlight to reduce evaporation, and away from animals, drips and splashes.
- Place a straight-sided coffee can or pan at the site and record rainfall in millimetres after a fixed period. Evaporation can produce serious errors unless rain is collected directly after the event.
- Alternatively, use a funnel set into a pot or measuring cylinder. Check and empty daily, measuring the volume of rain in the graduated cylinder and relating this to the collecting area of the funnel and report in millimetres.
- Commercial gauges are already calibrated and millimetres of rain can be read off directly and plotted against time (histogram is conventional).

## WIND SPEED AND DIRECTION

### Wind-sock Method

- Suspend a wind-sock on a tall pole that is unobstructed from the wind by buildings, trees, etc. Note the direction of wind using a compass. Note that direction is measured in degrees so a wind from the east (easterly) is recorded as 90°, and from the south-east as 135°. Take readings in the morning and afternoon.

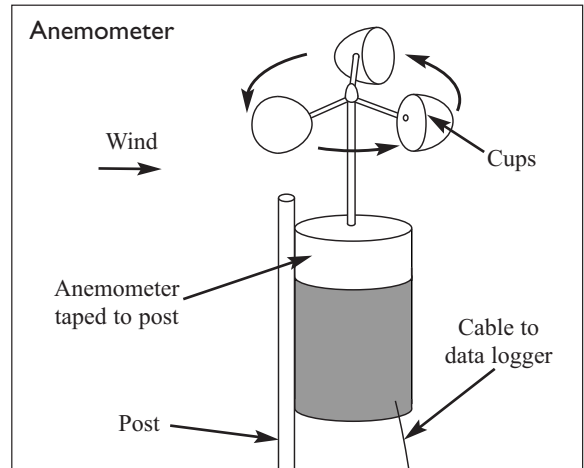


### Wind vane Method

- A more accurate way is to use a wind vane, on a 6–10 ft (1.8–3.0 m) pole, connected to a meter or data logger. Recordings can be averaged daily and plotted as a radial diagram (example Figure 1.16 in chapter 1).

### Anemometer Method

- Measure wind speed in an unobstructed area. Hold the anemometer or pitot gauge tube at arm's length and read off the wind speed in kilometres per hour.
- Some gauges will give a number against the pith ball path that is converted on a table to kilometres per hour.
- Daily statistics can be more easily obtained from an electronic anemometer wired to a meter/data logger.
- Repeat at the same time each day.



The Beaufort (Wind Force) Scale: approximate wind speed using visual cues

Beaufort Force	Wind type	Probable terrestrial features	Knots	Metres per second
0	Calm, no wind	Smoke rises vertically	0	0
1	Light air	Smoke drifts downwind; wind vane static	1–3	1–5
2	Light breeze	Wind felt on face; leaves rustle; wind vane moves	4–6	7–10
3	Gentle breeze	Leaves and twigs in constant motion; wind extends light flag	7–10	12–18
4	Moderate breeze	Dust and loose paper raised; small branches move	11–16	20–29
5	Fresh breeze	Small trees in leaf begin to sway; white crests form on inland water	17–21	31–38
6	Strong breeze	Large branches in motion; telephone lines whistle	22–27	40–49
7	Moderate gale	Whole trees in motion; walking against wind requires effort	28–33	51–60
8	Fresh gale	Twigs break off trees; progress on foot impeded	34–40	62–73
9	Severe gale	Slight structural damage to buildings (slates/tiles removed)	41–47	74–85
10	Whole gale	Trees uprooted; considerable structural damage to buildings	48–55	87–100
11	Storm	Rarely experienced; widespread destruction	57–65	104–116
12	Hurricane	Very rare and dangerous	68+	118+

# Physico-chemical measurements in water

## DON'T FORGET

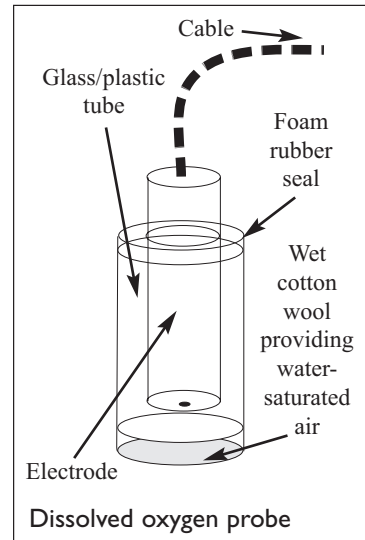
**EQUIPMENT:** Oxygen, pH and conductivity meters; distilled water; pH standards and papers; thermometer; spare battery; pencil; notebook.

The electrodes, especially pH, are easily damaged or broken. Carry spare membranes and electrolyte. Calibrate meters before going into the field.

### DISSOLVED OXYGEN

#### Method

- At the water's edge, re-check the calibration of the electrode and meter. Set the barometric pressure and water temperature (if not automatic). Switch the meter to percentage saturation and place the end of the electrode in a tube containing saturated (with water) cotton wool and leave for 30 s to equilibrate. The reading should be about 100%.
- Take a dissolved oxygen reading by waving the electrode slowly in the water for 30 s. Note the temperature, oxygen concentration in  $\text{mg O}_2 \text{ l}^{-1}$  and/or percentage saturation.
- Rinse the electrode and replace the electrode tip into distilled or clean water.
- Now note the time and light conditions, e.g. sunny, overcast, etc.
- Take two readings at each site. In standing water, take surface and depth readings at intervals of 0.5 m (limited by electrode cable length). Oxygen readings are at their highest about mid afternoon.



**Tip:** The solubility of oxygen in water varies with ambient temperature and pressure. Some oxygen meters compensate for this. The table below provides for the correction of oxygen at temperatures between 5 and 30 °C and enables the Winkler determinations to be corrected and also percentage saturation of water with oxygen to be calculated.

If the barometric pressure is known at the time of reading then a correction for pressure (negligible in terms of ecological work) can also be made:

$$\frac{\text{Solubility at pressure } x}{760} = \frac{\text{Solubility at 760 mm} \times \text{observed pressure}}{760}$$

Temperature (°C)	Oxygen solubility (mg/l)	Temperature (°C)	Oxygen solubility (mg/l)
5	12.77	18	9.46
6	12.45	19	9.27
7	12.13	20	9.08
8	11.84	21	8.91
9	11.55	22	8.74
10	11.28	23	8.57
11	11.02	24	8.42
12	10.77	25	8.26
13	10.53	26	8.12
14	10.29	27	7.97
15	10.07	28	7.84
16	9.86	29	7.70
17	9.65	30	7.57

### % Saturation of water with oxygen

If the measured oxygen concentration at 17 °C was 10.6 mg O<sub>2</sub> l<sup>-1</sup>, and using the table showing solubility of oxygen at 17 °C to be 9.65 mg l<sup>-1</sup> at 760 mm, then:

$$\% \text{ saturation} = 10.6/9.65 \times 100$$

= 110% saturation of water with oxygen.

### pH

#### Method

- Check the calibration of the pH meter again before use – the calibration knob can get moved during transportation. Remove the electrode from its protective housing, rinse with distilled water and place in pH buffer to check calibration, rinse again.
- Follow the same procedure for oxygen measurement (second bullet point) and note the temperature if not a compensating electrode.
- For pH papers, take a sample of water in a jar and immerse the end of the paper for 30 s; remove paper and compare after a further 30-s delay with the colour comparator provided.

### CONDUCTIVITY

#### Method

- The electrodes are more robust and calibration is usually unnecessary in the field.
- Follow the same procedure for oxygen measurement in water, and note the temperature if not a compensating electrode. Report as Siemens cm<sup>-1</sup> (or mhos cm<sup>-1</sup>).
- Rinse electrode and dry before storing.

### DEPTH

#### Method

- Measure depth with a pole in shallow water or with a rope, weighted at the end and knotted or marked at 0.5 m intervals, in deeper water. Suspend the rope from a boat and read the markers. If the water is moving, it may be difficult to suspend the rope vertically. Also, if waves are lapping the boat, take several readings and calculate the average.

### WATER TEMPERATURE

#### Method

- Water temperatures can be measured by glass thermometer, and most oxygen, pH and conductivity meters.

### OTHER CONSIDERATIONS

In slow flowing rivers and lakes, pH, oxygen and (to a lesser extent) conductivity, vary quite widely with the time of day and biological activity. Standardize the times of measurement if possible and always record time and weather conditions.

Always maintain the electrodes and meters as instructed by manufacturers – especially if they are stored for long periods.

A GPS is useful to record positions of measurements.

# Turbidity

## DON'T FORGET

**EQUIPMENT: SUSPENDED SOLIDS:** Bucket; plastic graduated cylinder; pre-weighed filter papers to fit Buchner; Buchner funnel; side-arm flask; hand vacuum pump (optional); portable balance; permanent marker pens.

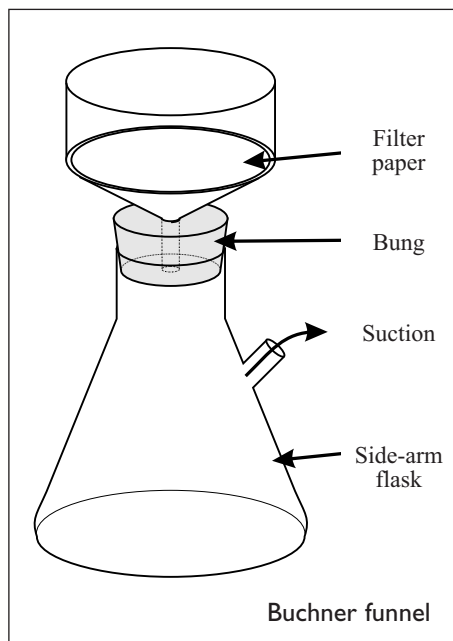
**UNDERWATER LIGHT/TURBIDITY:** Secchi disk and line.

### SUSPENDED SOLIDS

#### Method

- Take a sample of water in a bucket and quickly pour 500 ml–1 litre into a bottle or other clean container that can be sealed.
- Weigh a dry filter paper and put it in a Buchner or Hartley funnel attached to a side-arm flask. **Tip:** *Glass fibre papers are best because they do not absorb moisture and can be weighed before going to the field on a milligram balance; Whatman GF/C filter papers, 7 cm diameter are ideal.*
- If a hand or bench vacuum pump is available, pull a vacuum on the flask after pouring a shaken sample of known volume into the funnel. If the sample is very turbid, reduce the volume or it will take hours to filter through.
- Remove the filter paper when the surface no longer glistens and place on a drying rack in an oven (105 °C) for 1 h. Cool in a desiccator before weighing. If in the field, dry in direct sun to constant weight (repeat weighing until no significant change in weight).
- Calculate the concentration of suspended solids from the following:

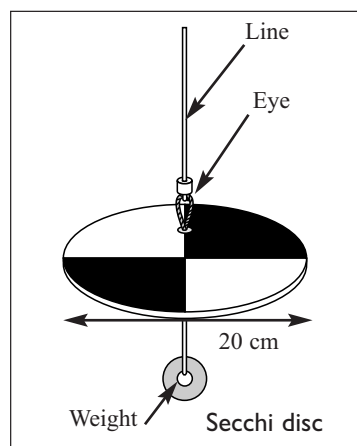
concentration of suspended solids in sample = weight of dried filter paper and solids less the weight of filter paper, divided by the volume of water poured through (in ml). Multiply by 1000 (ml) for ppm.



### UNDERWATER LIGHT/TURBIDITY

#### Method

- Clean Secchi disc with a wet rag and check the security of line before lowering it into the water. Let the disc sink slowly under its own weight until it just disappears from sight. Note this depth either by pinching the line at the water surface and hauling up to measure between the pinch and disc, or from knots tied in the line (e.g. at 0.25 m intervals from disc) that are counted while hauling up.
- Repeat the measurements several times to obtain and average extinction depth for each site.
- Dry the disk and line before stowage.



# Measurement of current

## DON'T FORGET

**EQUIPMENT:** Gessner tube; spare plastic bags and rubber bands; plastic measuring cylinder (250 ml) or flow meter; orange; two stakes (2 m length); hammer; 25 m tape measure.

Measurement of flow using a floating object is imprecise by comparison with the other methods.

### CURRENT SPEED BY FLOATING OBJECT

#### Method

- Place two stakes in the river and measure the distance between them. Throw in an orange or other heavy, floating object and time its unimpeded travel between the two points. Repeat 2–3 times to obtain an average surface flow rate in  $\text{m s}^{-1}$   
flow rate ( $\text{m s}^{-1}$ ) = distance travelled by float (m)/time to cover distance (s).
- Estimate river velocity (slower than surface velocity) by multiplying the average time by 0.8 before applying the equation above. This compensates for the drag caused by the river bed.

### CURRENT SPEED BY METER

#### Method

- Measure the depth of the water using a pole and then set the propeller depth on the shaft at a distance of one-third of the depth – measuring from the foot of the shaft. Point the propeller of a current meter upstream and record the number of turns logged after 30 s. Repeat several times, read off the current speed from the supplied calibration graph or a factor provided with the instrument, and average the result. Repeat at various depths if the river is deep enough to warrant a velocity profile.
- For estimating flow rate through a drift net, place the propeller at the mouth of the net. Take readings at the beginning and end of the drift sampling period, e.g. at time zero and 4 h. Calculate the average current through the net. (Custom-built meters that fit into the mouth of a drift net will integrate the variable flow through the net as the latter clogs up and impedes flow. This method is the preferred but expensive option.)

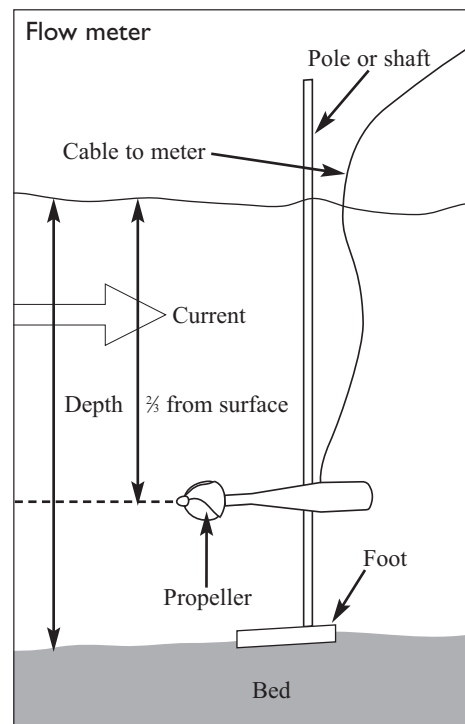
### CURRENT SPEED/VOLUME BY GESSNER TUBE

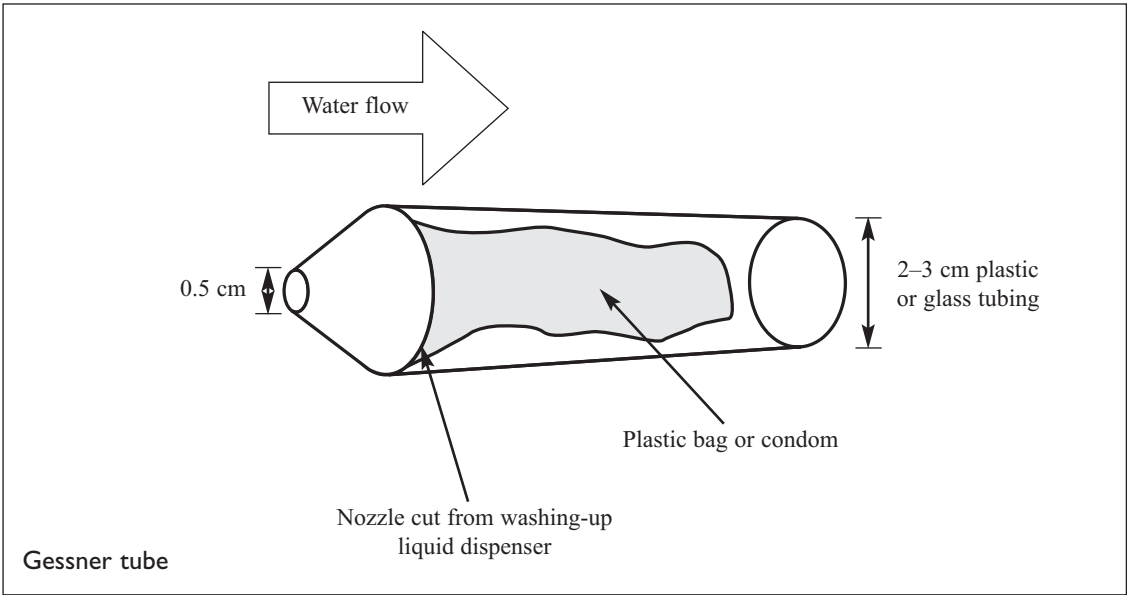
#### Method

- Close the funnel aperture with a finger and place the tube, funnel upstream, into the water. Remove finger for a few seconds to allow the water to flow into the tube before closing the aperture again. Remove the tube and measure the volume of water in the bag by pouring into a measuring cylinder. Repeat twice and at various depths if feasible. Calculate the flow rate from the formula:

flow ( $\text{cm}^2 \text{ s}^{-1}$ ) = volume of water trapped (ml)/time (s)  
x cross-sectional area of opening ( $\pi r^2$ )

flow volume ( $\text{cm}^3 \text{ cm}^{-2} \text{ s}^{-1}$ ) = (volume in ml/ $\pi$ ) x  
( $r^2$ )/time (s).





# Classification of aquatic substrates

## DON'T FORGET

**EQUIPMENT:** Cylinder sampler; scoop; set of sieves; bucket; spring balance; notebook; pencil.

The substrates of river and stream beds range from fine particles of clay to boulders. Substrate analysis can be rapid and crude or lengthy but more exacting depending on the goal. For the siting of sampling stations for monitoring work, a rapid analysis should suffice. This is normally done by eye in the first instance. The test of reasonably matched sites is to find reasonably matched biota.

### RAPID ANALYSIS

#### Method

- If the water is clear or very shallow, just note the main characteristics of the sampling station, e.g. percentage bedrock or pebble, gravel or sand, silt and clay.
- Water flowing over solid rock just needs noting: as very few invertebrates can inhabit this substrate – algae and vegetation are more successful – the medium does not lend itself to meaningful analyses of populations.

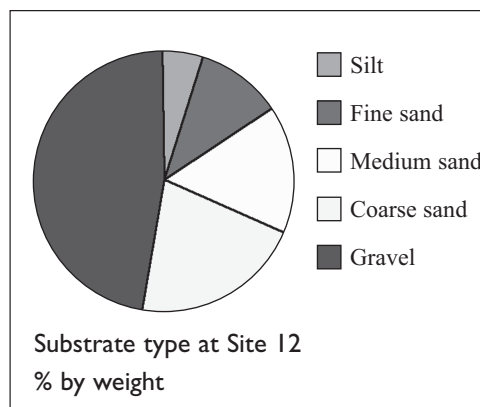
### PARTICLE SIZE ANALYSIS

#### Method

- Examine the substrate type in a delimited area – perhaps 1–5 m<sup>2</sup>. Estimate the size range and number of rocks.
- In substrates comprising smaller categories of material, use a cylinder sampler (see method sheet from chapter 9), turning the meshed opening away from the flow, lift the pebbles out and measure their lengths.
- Using a trowel or tin can, scoop up the underlying gravel, sand and sediment and place in a sieve series, shaking them in a bucket of water or nearby pool, to separate the particulate sizes.
- Let the materials drain for 5 min and weigh each sieve separately on a spring balance to estimate the material retained – subtracting the sieve weight.
- Repeat two more times in the same delimited area to characterize and then tabulate the result as, for example, lengths of largest parameter (stones/pebbles) or weights of materials from sieves.

#### Substrate categories

Name	Size range	Lengths/weight
Clay	<3.9 µm	Weight
Silt	3.9–63 µm	Weight
Fine sand	0.02–0.25 mm	Weight
Medium sand	0.25–0.5 mm	Weight
Coarse sand	0.5–1.0 mm	Weight
Gravel	2–16 mm	Weight
Pebble	16–64 mm	'Lengths'
Rocks	64–256 mm	'Lengths'
Boulder	>256 mm	



### OTHER CONSIDERATIONS

A sieve series with mesh apertures of 16 mm, 2 mm, 500 µm, 250 µm, and 100 µm should suffice. Narrower aperture sieves quickly clog and so silt/clay analyses are normally determined gravimetrically in a laboratory.

# Vegetative cover and shade

## DON'T FORGET

**EQUIPMENT:** Notebook; pencil; maps; keys to vegetation; light meter; GPS.

The survey team must have a good knowledge of vegetation types. Undertake an initial field visit to decide on number and location of sites and where estimates of cover will be made.

### Method

- Demarcate on a map the areas where pesticide interventions are to be made. Identify promising roads or tracks giving access to areas in sprayed and unsprayed terrain and ground-truth what appears on vegetation maps (if available) for accuracy, in terms of dominant species, e.g. *Julbernardia/Combretum* woodland, shrub savanna, grass steppe, etc.
- Members of the survey team should agree on the definitions and use of the ranks and scales for cover estimation (see suggestions in table).

Scales for estimating vegetative cover

Rank	Braun-Blanquet (% cover)
Bare ground	< 1
Rare	1–5
Occasional	6–25
Frequent	26–50
Abundant	51–75
Dominant	76–100

- Estimate the percentage cover in several areas of a potential sampling site using the Braun-Blanquet scale above. A site might be anything from 100 m<sup>2</sup> to 1 ha (100 x 100 m) depending upon cover, season and the techniques to be employed for the fauna (which may need to cover extensive ground as in bird or mammal monitoring).
- Survey to one side of the road (or vehicle) and then the other. Get a second surveyor to do the same and compare the results. Discuss any gross discrepancies and the means to ensure better objectivity in estimation.
- Make a sketch map of the area if it helps and record all the species identified and rankings made.
- Repeat the surveys at other potential sites (similar appearance) along the road or within the defined sprayed area. Mark the grid reference (or take a GPS waypoint) and number the sites in case you want to adopt them as monitoring stations.
- Repeat the whole operation in the unsprayed area until the recommended number of sites have been matched and identified.

### OTHER CONSIDERATIONS

It is possible to record over 100% cover in this method because there may be several layers of vegetation. For example, there may be algae, grasses, shrubs and trees occupying different layers. Visual observation on tree canopy height and under-canopy shade may also be useful descriptors. Bear in mind that it will not be possible to discriminate between very small percentages of cover if you create more classes of scale than those shown below. Make sure that the unsprayed area is at least 10–20 km from the sprayed area, to minimize the possibility of contamination from spray drift.

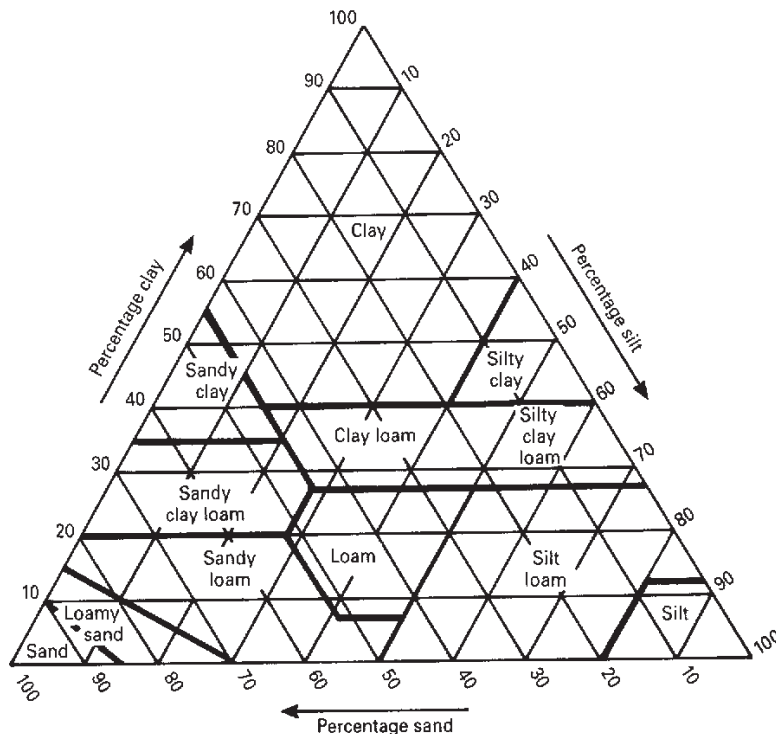
# Soil texture

## DON'T FORGET

**EQUIPMENT:** Wash bottle; trowel; hand lens; paper labels; notebook; pencil; plastic bags; permanent marker pen.

### Method

- Dig soil to a depth of 5–10 cm and collect a sample in a plastic bag containing a label (pencil on paper) in case a laboratory particle size analysis is later desired. Note how hard the soil was to dig: in the dry season, clay soil will be hard and of smooth appearance; sand grains will be noticeable on the surface of sandy soils. In the wet season, clay soils will be sticky, glistening, or plastic; sandy soils will be well drained, leaving grains on the surface that are visible to the naked eye (certainly with a hand lens).
- Take a handful of soil and wet it. Clay soils will absorb a lot of water compared with sandy ones. Wet almost to saturation point and then, using the thumb and forefinger, determine the amount of clay from its degree of stickiness and plasticity as follows.
  - Squeeze the soil by pressing it with a sideways/slightly forward motion of the thumb and try to form a long, thin ribbon or try to roll the soil into a thin, long ‘worm’ ( $\pm 10$  cm). If either is possible, then a clay soil is indicated. If the wet clay will take your fingerprint then a clay or silty clay is indicated. If sand grains are felt at the surface of the clay then a sandy clay is indicated
  - If a short ribbon or ‘worm’ can be produced (2–4 cm) or perhaps a longer one for a short period of time, then a clay loam is indicated.
- Determine the sand and silt content by rewetting the soil and see if the soil feels like flour when rubbed between the forefinger and thumb or whether sand grains can be felt. If the soil formed short ribbons or ‘worms’ and then felt floury, a silty clay loam is indicated, or if gritty, a sandy clay loam is probable. The latter soil will not allow the ‘worm’ to be bent into a ring. Equal amounts of flouriness and grittiness indicate a clay loam.
- A soapy feel without stickiness and an inability to bend ‘worms’ into a ring indicates a silt loam.
- Sandy loams and loamy sands will not form a ribbon or ‘worm’ but will just stay together if rolled into a ball.
- A sandy soil will not form a ribbon or a ball.



# Soil moisture, water-holding capacity, soil pH

## DON'T FORGET

**EQUIPMENT:** Plastic Petri dish; aluminium foil; portable balance; 10 cm filter papers; soil corer or tin can; distilled water; paper tissues; spatula; pH paper; pH sensitive electrode; pH meter.

Remember to calibrate the pH meter with buffers beforehand and set the slurry temperature if the meter does not automatically compensate for it.

### SOIL MOISTURE

#### Method

- Mix a few spade-fulls of freshly dug surface soil (0–20 cm) from a sampling site and place 1–2 kg immediately into thick polythene bags and label. Double bag if the polythene or plastic bags are too thin to prevent water loss during transportation and storage.
- Pass a small sample, e.g. 500 g, through a 2 mm sieve to remove vegetation/roots before placing small amounts of soil (25–50 g) on to shallow, weighed containers (Petri dishes, tin cans, or aluminium foil). Weigh wet soils and record weight.
- Spread soils out and, if sun-drying, protect from gusts of wind.
- Air-dry the soil samples in direct sunlight to constant weight, i.e. reweigh the containers of soil periodically until there is no discernible weight change.
- Subtract the weight of the soil container from the total weight to obtain wet and dry soil weights and then calculate the moisture content from the formula:

$$\% \text{ soil moisture} = \frac{\text{weight of wet soil} - \text{weight of dry soil}}{\text{weight of dry soil}} \times 100$$

- Keep the air-dried soil in plastic bags to oven-dry later.
- On return to the laboratory, check the dry weight of the soil by placing the air-dried sample in an oven at 105 °C overnight and re-weighing.

**WATER-HOLDING CAPACITY (1)** Use for soils prepared for nitrification estimates.

#### Method

- Fold three weighed filter papers and place each in a funnel. Put 25 g of soil (collected as described in soil moisture method) in each paper and saturate the soil with water. Cover the funnel with aluminium foil and allow the soils to drain by gravity for 1 h in the shade and then reweigh.
- Sun-dry the soil to constant weight (as at fourth bullet point above).
- To estimate the water-holding capacity in grams water, use the formula:

$$\text{field capacity (g water)} = \text{weight of gravity drained soil} - \text{weight of sun-dried soil}$$

or expressed as % water at field capacity =  $\frac{\text{weight of gravity drained soil} - \text{air-dried weight of soil}}{\text{air-dried weight of soil}} \times 100$

**WATER-HOLDING CAPACITY (2)** Use for comparison of field capacities between soils.

#### Method

- Take a soil core using a corer or tin can with one end removed and the other perforated with a few small nail holes. Weigh the corer or can, push into the soil and remove the core. **Note:** Use of a soil corer will minimize disturbance of the soil.
- Saturate the soil in the corer or can with water and let the water drain away under gravity for 1 h in the shade before re-weighing.
- Extract the soil from the corer/can and sun-dry to constant weight and apply the formulae from Water-Holding Capacity (1) at fifth bullet point to obtain an estimate of field capacity.

## SOIL pH BY PAPER

### Method

- Shake or stir equal volumes of soil (collected as described in 'Soil Moisture' method) and distilled water (e.g. 50 ml each) in a container and settle for 2–3 min until the supernatant clears.
- Momentarily dip a pH paper (range pH 4–8) into the water and compare the colour after it has developed (1 min) with the colour chart provided and read off the pH. **Tip:** *Narrow range paper (two pH units) can provide greater accuracy.*

## SOIL pH BY METER

### Method

- For more accuracy (preferable), suspend a pH-sensitive electrode and its reference electrode (often combined) in the soil mixture produced in the step above and swirl the soil into a slurry, reading the pH when it is stable (15 s).
- Rinse the electrode(s) with distilled water between measurement of further samples.

## OTHER CONSIDERATIONS

All these methods are adapted for use in the field and will not provide the accuracy or precision of laboratory standard methods.