Section II: Supplementary methods

Quick Start (Vol. I) describes the four basic monitoring methods relevant to most monitoring programs. This section describes supplementary methods that address more specific objectives. They are generally used in addition to the basic measurements described in the Quick Start. This section also includes alternative Line-point intercept methods.

Supplementary Methods (in Section II)

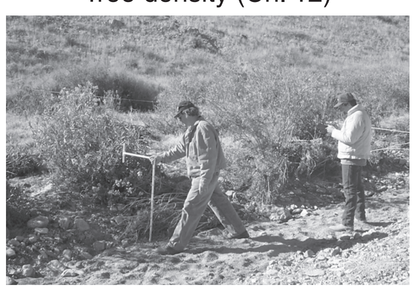
Compaction test (Ch. 7)

Vegetation structure (Ch. 11)

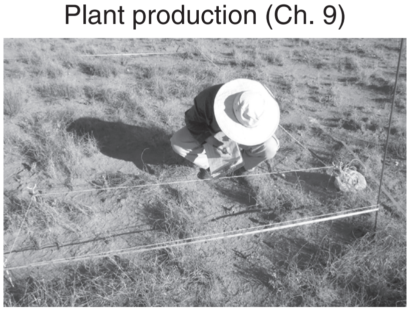
Infiltration test (Ch. 8)

Tree density (Ch. 12)

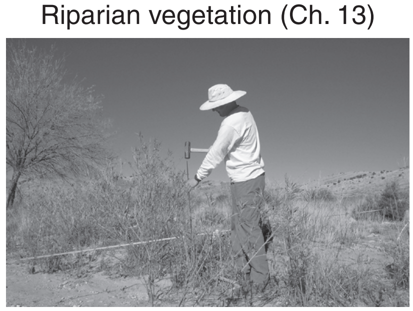
Plant production (Ch. 9)



Riparian vegetation (Ch. 13)



Species richness (Ch. 10)



Channel/gully profiles (Ch. 14)

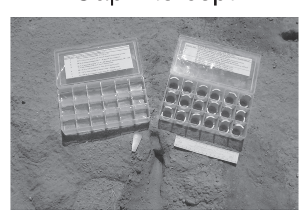
Core Methods

(Quick Start)

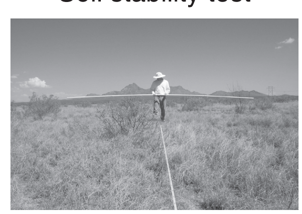
Photo points

Line-point intercept
(also in Vol. II, Ch. 15)

Gap intercept



Soil stability test



Belt transect

Chapter 7

Compaction test

The impact penetrometer is used to monitor changes in soil compaction that can limit water infiltration, root growth and microorganism activity. Because penetrometer measurements are very sensitive to soil moisture, measurements can be compared among years only if soil moisture content is the same during each sampling period. Use Table 7.1 to decide whether or not to include this measurement.

Table 7.1. Checklist for impact penetrometer use. If all items are checked, consider including the penetrometer.

Cobbles or stones (>7.6 cm or 3 in diam.), uncommon*	___________
Compaction present, or compaction risk exists (e.g., off-road vehicle use)	___________
Compaction is affecting, or is likely to affect, water infiltration and/or plant growth	___________

* The impact penetrometer can be used in soils with a higher gravel content than a traditional strain gauge penetrometer, but should not be used in soils with large (>10 cm [4 in]) rocks near the surface.

The penetrometer can help determine whether or not a soil is currently compacted, if reference data for similar soils with the same moisture content are available. However, qualitative methods (e.g., Pellant et al. 2005) are generally more reliable for determining whether soil is compacted. For example, platy soil structure and abrupt changes in root growth patterns not related to a texture change are good indicators of compaction.

Caution!

- Never use this instrument near buried power or pipelines.
- Wearing earplugs and heavy leather gloves is highly recommended.
- Always keep hands away from the strike plate when operating the penetrometer.

Figure 7.1. Impact penetrometer with sliding hammer elevated.

Materials

- The same transect(s) used for Line-point and Gap intercept
- Impact penetrometer (see Appendix A for specifications)
- Thick leather gloves
- Clipboard, Soil Compaction - Impact Penetrometer Data Forms and pencil(s)

Standard methods (rule set)

1. **Define hammer drop height and record at the top of the form.**

Rules

1.1 Standard drop height is 40 cm. Drop height can be increased for compacted soils and decreased for loose (low bulk density) soils.

2. **Define maximum depth.**

Rules

2.1 Maximum depth should be at least 10 cm and include qualitatively identified compaction zones (e.g., lateral root growth).

3. Randomly select the sample locations you plan to measure.

Rules

3.1 Use randomly selected points along the transects used for Line-point and Gap intercept measurements.

3.2 Record sampling locations (positions) on the data form in the "Position on line" column.

3.3 Make measurements at least 1 m (3 ft) from the transect to avoid affecting vegetation measurements.

3.4 Penetrometer resistance cannot be measured on plant bases or surface rocks. If you encounter a rock or plant base, move measurement 1 m (1 yd) down the transect. The sample points have to be at least 1 m from each other.

3.5 In areas with duff or embedded litter (e.g., under coniferous trees), clearly define a standard depth to which litter will be removed, based on soil and litter characteristics (e.g., depth at which there is 80 percent mineral soil by volume), *OR* leave litter in place, *OR* exclude these areas. Exclude sample points where a stick is embedded in the soil.

3.6 Clearly record which of the three options listed in Rule 3.5 was applied.

4. Determine soil moisture.

Rules

4.1 Check at least three different locations on the plot for soil moisture by digging a small pit or using an auger and assessing soil moisture by touch.

4.2 Record soil moisture for each depth by circling the appropriate category on the Soil Compaction - Impact Penetrometer Data Form.

4.3 If possible, determine soil moisture quantitatively by measuring wet and oven-dry weights of at least three soil samples. Percent soil moisture is: wet weight minus oven-dry weight divided by oven-dry weight and multiplied by 100% or

$$\frac{\text{(wet wt)} - \text{(oven-dry wt)}}{\text{(oven-dry wt)}} \times 100\%$$

5. Record the dominant vegetation cover class in the "Veg class" column of the Soil Compaction - Impact Penetrometer Data Form.

Rules

5.1 The area to be classified is a circle with the same diameter as the top of the penetrometer cone (see Appendix A).

5.2 Use one of the following cover classes:

NC = no perennial grass, shrub or tree canopy cover
G = perennial grass canopy and grass/shrub canopy mixture
F = perennial forb
Sh = shrub canopy
T = tree canopy

6. Check hammer drop height.

Rules

6.1 Measure the distance from the bottom of the hammer to the stop collar (Fig. 7.2).

6.2 Be sure that the distance is identical to the height recorded at the top of the data form.

6.3 Adjust stop collar if necessary.

6.4 There should be an average of at least three strikes per depth increment. Lower drop heights (more strikes) increase sensitivity. Higher heights increase efficiency by reducing the number of strikes per depth increment.

Figure 7.2. Hammer height is the distance from the hammer to the strike plate.

7. Determine the cumulative number of strikes required for each 5 cm (2 in) depth increment.

Rules

7.1 Wearing thick leather gloves and ear protection is highly recommended. Always keep hands away from strike plate when operating the penetrometer.

7.2 Press the cone into the soil so the top of the cone is flush with the soil surface (Fig. 7.3).

Figure 7.3. The top of the cone is flush with the soil surface.

7.3 Keep the penetrometer vertical at all times. On slopes, this means that the penetrometer will be at less than a 90^{o} angle to the soil surface.

7.4 Raise the hammer to the stop collar and release (Fig. 7.1). Do not exert any downward pressure on the hammer while releasing it.

7.5 Repeat until the penetrometer rod is inserted 5 cm (2 in) into the soil (Fig. 7.4), the first increment.

7.6 Record the number of strikes to 5 cm on the Soil Compaction - Impact Penetrometer Data Form.

7.7 If a strike pushes past a 5 cm (2 in) mark, record it as a half strike (e.g., 9.5 strikes instead of 10).

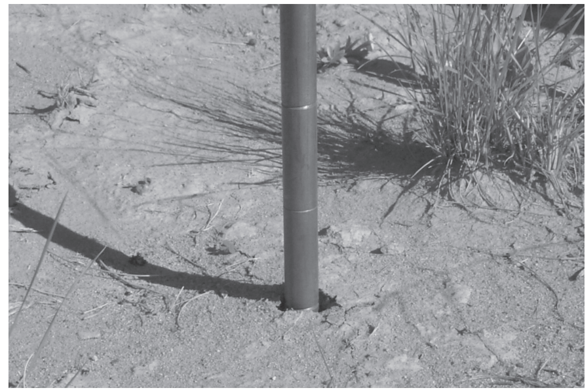


Figure 7.4. Record the number of strikes required to reach each 5 cm (2 in) increment (marked by the scribed marks on the rod).

7.8 Repeat for the next increment and record the cumulative (total) number of strikes.

7.9 A change in tone, together with sudden increased resistance in stony soils, indicates a stone or other hard object has been intercepted. Stop hammering and record "rock" for that depth on the Soil Compaction - Impact Penetrometer Data Form.

8. Remove the penetrometer.

Rules

8.1 Pull straight up on the penetrometer.

8.2 If this doesn't work, try tapping the penetrometer at the soil surface with a rubber mallet, or rotating it in an increasing radius circle (Fig. 7.5), being careful not to bend it. Then pull straight up.

8.3 At least one of the manufacturers (Synergy) will include a second sliding hammer below the strike plate to assist with removal.

9. Tighten cone if necessary.

Rules

9.1 If cone loosens from rod, apply Loctite™ or a similar material to the cone threads and tighten.

9.2 Because the cone has been hardened, it is more brittle than the rod. It can break at the threads if it becomes loose.

10. Repeat steps 2 through 9 for all sample positions.

Figure 7.5. Gently rotating or tapping the penetrometer at the soil surface can help remove it.

Compaction test indicator calculations

These instructions are used to calculate the average number of strikes, which are linearly related to resistance. For example, twice as many strikes are the same as twice the resistance. For equations to convert the number of strikes to resistance, see Herrick and Jones (2002), Minasny and McBratney (2005) and Herrick (2005). To make this conversion, you will need the drop height and the mass (weight) of the hammer.

1. **Calculate the average number of strikes for each depth (Average No. of Strikes, All).**

Rules

1.1 Add all values in each column and record the total in the “Sum no. of Strikes, All” row of the Soil Compaction - Impact Penetrometer Data Form.

1.2 Count the number of values in each column and record that number in “Measurement no., All” row.

1.3 For each column, divide “Sum no. of Strikes, All” in rule 1.1 by “Measurement No., All” in rule 1.2, and record in “Average no. of Strikes, All” row.

2. **Calculate the average number of strikes for each depth, using measurements with no vegetation cover (NC).**

Rules

2.1 Add all values with no vegetation cover in each column and record the total in the “Sum no. of Strikes, NC only” row of the Impact Penetrometer Data Form (Veg class = NC).

2.2 Count the number of values in each column and record that number in “Measurement no., NC only” row.

2.3 For each column, divide “Sum no. of Strikes, NC only” in rule 2.1 by “Measurement No., NC only” in rule 2.2, and record in “Average no. of Strikes, NC only” row.

3. **Calculate the average number of strikes for each depth, using measurements under vegetation cover (G, F, Sh, T).**

Rules

3.1 Add all values with vegetation cover in each column and record the total in the “Sum no. of Strikes, Veg only” row of the Impact Penetrometer Data Form (Veg class = G, F, Sh or T).

3.2 Count the number of values in each column and record that number in “Measurement no., Veg only” row.

3.3 For each column, divide “Sum no. of Strikes, Veg only” in rule 3.1 by “Measurement No., Veg only” in rule 3.2, and record in “Average no. of Strikes, Veg only” row.

4. **Calculate the ratio of the number of strikes in areas without and with vegetation (ratio of interspaces: under-plant canopies), and record in the last row.**

Rules

4.1 For each depth, divide the average number of strikes for samples with no cover by the average number of strikes for samples with cover.

4.2 Using data from the example data form, 5 cm depth, we divide 5.3 by 4.8 to get a Ratio of NC / Veg of 1.1.

Example

Soil Compaction - Impact Penetrometer Data Form

Monitoring plot: 5 **Date:** 4 June 2003

Observer: Jane Smith **Recorder:** Dave Miller **Hammer height:** 20 (cm or in?) circle one

Veg Class:

NC = No perennial canopy
G = Perennial grass or grass/shrub mix
F = Perennial forb
Sh = Shrub
T = Tree

Soil moisture (circle one for each depth):

Surface	Dry	Moist	Wet
0-5 cm	Dry	Moist	Wet
5-10 cm	Dry	Moist	Wet
10-15 cm	Dry	Moist	Wet
15-20 cm	Dry	Moist	Wet
____________	Dry	Moist	Wet

Line	Position on line	Veg class	Number (no.) of cumulative strikes (lower depths optional)									
			5cm	10cm	15cm	20cm						
1	5.5	NC	5	9.5	23	30						
1	15.5	G	4	8	Rock	Rock						
1	25.5	NC	6.5	11	26	32						
1	35.5	Sh	5	10	15.5	21						
1	45.5	G	5.5	10.5	16	Rock						
1	49.5	NC	4.5	9	22	27						
Sum no. of strikes, All			30.5	58.0	102.5	110.0						
Measurement no., All			6	6	5	4						
Avg. no. of strikes, All (Avg. All)			5.1	9.7	20.5	27.5						
Sum no. strikes, NC only			16.0	29.5	71.0	89.0						
Measurement no., NC only			3	3	3	3						
Avg. no. strikes, NC only (Avg. NC)			5.3	9.8	23.7	29.7						
Sum no. strikes, Veg only			14.5	28.5	31.5	21.0						
Measurement no., Veg only			3	3	2	1						
Avg. no. strikes, Veg only (Avg. Veg)			4.8	9.5	15.8	21.0						
Ratio of NC / Veg (= Avg. NC ÷ Avg. Veg)			5.3/4.8= 1.1	1.0	1.5	1.4						

Soil Compaction - Impact Penetrometer Data Form

Monitoring plot: ________________________ **Date:** ________________

Observer: ________________ **Recorder:** __________________ **Hammer height:** _______**(cm or in?)** circle one

Veg Class:

NC = No perennial canopy
G = Perennial grass or grass/shrub mix
F = Perennial forb
Sh = Shrub
T = Tree

Soil moisture (circle one for each depth):

Surface	**Dry**	**Moist**	**Wet**
0-5 cm	**Dry**	**Moist**	**Wet**
5-10 cm	**Dry**	**Moist**	**Wet**
10-15 cm	**Dry**	**Moist**	**Wet**
15-20 cm	**Dry**	**Moist**	**Wet**
___________	**Dry**	**Moist**	**Wet**

Line	Position on line	Veg class	Number (no.) of cumulative strikes (lower depths optional)								
			5cm	10cm	15cm	20cm					
Sum no. of strikes, All											
Measurement no., All											
Avg. no. of strikes, All (Avg. All)											
Sum no. strikes, NC only											
Measurement no., NC only											
Avg. no. strikes, NC only (Avg. NC)											
Sum no. strikes, Veg only											
Measurement no., Veg only											
Avg. no. strikes, Veg only (Avg. Veg)											
Ratio of NC / Veg (= Avg. NC ÷ Avg. Veg)											

Chapter 8

Single-ring infiltrometer (for water infiltration)

Infiltration rate is a measure of how fast water enters the soil. Water entering too slowly may lead to ponding on level areas or to erosion from surface runoff on sloped areas. A Single-ring infiltrometer provides a *relative* indication of infiltration capacity under saturated conditions.

Infiltration cannot be measured with this method on very rocky/gravelly sites, steep slopes or areas with dense root mats at the surface.

Materials

- The same transect(s) used for Line-point and Gap intercept
- Six infiltrometer rings (see Appendix A, diameter = 12.5 cm)
- Six 25 x 50 cm (10 x 20 in) terrycloth towels
- Two 370 ml (12.5 oz) cups*
- Two 30 x 30 cm (12 x 12 in) sheets of plastic (e.g., grocery bags)
- Five gallons of water
- One 15 cm (6 in) ruler
- Stopwatch
- Six infiltration bottles full of water (diameter = 8.7 cm) (see Appendix A for construction instructions)
- Clipboard, Single-ring Infiltrometer Data Forms and pencil(s)

*Based on volume required for 3 cm depth in a 12.5 cm diameter ring. For other ring diameters, volume = 9.4 x r^2, where radius equals one-half the diameter ($r = \frac{1}{2} d$).

Standard methods (rule set)

1. Determine locations for the tests.

Rules

1.1 Randomly select points along the transects used for Line-point and Gap intercept (Fig. 8.1).

1.2 Record sampling locations (positions) on the data form in the "Position on line" column.

1.3 If you are also making vegetation measurements, move the infiltration measurements at least 1 m (1 yd) from the transect, and move the infiltration measurement at least 1 m from any penetrometer measurement(s).

2. Record the vegetation class for the sample point in the "Veg class" column of the Single-ring Infiltrometer Data Form.

Rules

2.1 Lay down the infiltrometer ring on the sample point and record the dominant cover class for the sample area:

- **NC** = no perennial grass, forb, shrub or tree canopy cover
- **G** = perennial grass canopy and grass/shrub canopy mixture
- **F** = perennial forb canopy
- **Sh** = shrub canopy
- **T** = tree canopy

2.2 If the soil surface is protected by a rock or embedded litter that prevents ring insertion, select another sample point 1 m (1 yd) down the transect and note the move.

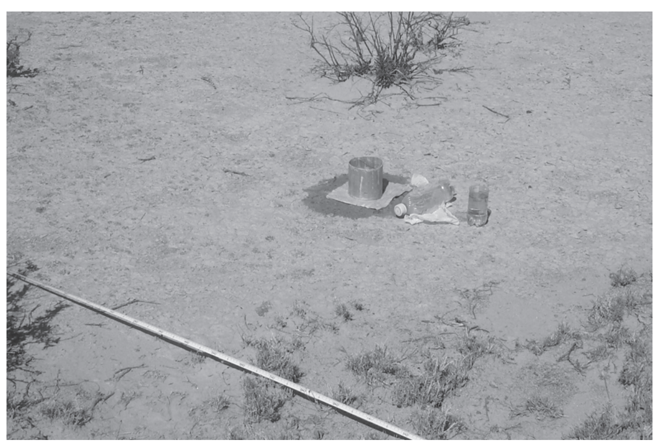


Figure 8.1. Infiltrometer supplies and sample location.

3. Remove the aboveground vegetation (Fig. 8.2).

Rules

3.1 If the sample point is located on a plant, carefully remove aboveground vegetation to within 1 cm of ground level, using a serrated knife and cutting with a sawing motion.

3.2 Do not disturb the soil crust in or around the plant.

3.3 Gently remove loose (not embedded) litter obstructing the edge of the ring.

3.4 In areas with duff (e.g., under coniferous trees), clearly define a standard depth to which litter will be removed, based on soil and litter characteristics (e.g., depth at which there is 80 percent mineral soil by volume), *OR* leave litter in place and insert ring to standard depth in the mineral soil, *OR* exclude these areas. If pieces of litter create a visible hole in the soil when the ring is inserted, select another sample point at least 1 m (1 yd) down the transect and note the move. This is necessary because the ring will not seal.

3.5 Clearly record which of the three options in rule 3.4 was applied.

Figure 8.2. Remove aboveground vegetation.

4. Pre-wet the soil to a depth of at least 4 cm (1.5 in) (Fig. 8.3).

Rules

4.1 Fold a moistened towel in half and lay over the sample area.

4.2 Using the 370 ml cup, pour water slowly on the towel in a series of applications.

4.3 Wait several minutes between applications.

4.4 Minimize water runoff from under the towel.

4.5 Continue adding water until soil is wet to 4 cm (1.5 in). The required volume varies with soil texture and structure, but should be approximately 740 ml (25 oz), or two cupfuls.

Figure 8.3. Pre-wet the soil to a 4 cm depth.

5. Insert the infiltration ring to a depth of 3 cm ($1^3/_{16}$ in) (Fig. 8.4).

Rules

5.1 Distribute pressure evenly on as much of the ring as possible. If necessary, twist the ring very slightly while pushing.

5.2 Test if the ring is set securely in the soil by gently wiggling the sides. If there is any movement, push the ring into the ground an additional 0.5 cm ($^3/_{16}$ in).

Figure 8.4. Insert infiltration ring to 3 cm.

6. **Add water to the ring without disturbing the soil surface (Fig. 8.5).**

Rules

6.1 Line the bottom and sides of the ring with the plastic sheet.

6.2 Pour sufficient water onto the sheet to bring the water depth to approximately 3 cm (1.25 in) and gently pull out the plastic sheet (Fig. 8.5). For a 12.5 cm ring, this is 370 ml water.

Figure 8.5. Add 370 ml water, using plastic sheet.

7. **Watch for leaks (Fig. 8.6).**

Rules

7.1 Observe the ring, watching for obvious leaks. Wetting at the soil surface around the ring is normal and does not constitute a leak.

7.2 Water should not pond on the soil surface or glisten around the outside edge of the ring (Fig. 8.6). If either of these occurs, the ring is leaking.

7.3 If a leak occurs, gently push the ring in 0.5 cm ($^3/_{16}$ in) more and see if the leak stops.

7.4 If the leak persists, remove the ring and relocate the sample at least 1 m (1 yd) away in the same vegetation class (up or down the transect line). Note the move.

8. **Place bottle in ring (Fig. 8.7).**

Rules

8.1 Push the infiltration pipette almost all the way into the bottle.

8.2 Open the cap on the bottle so that water will come out when it is upside down, but the cap will not fall off. The cap should be very loose.

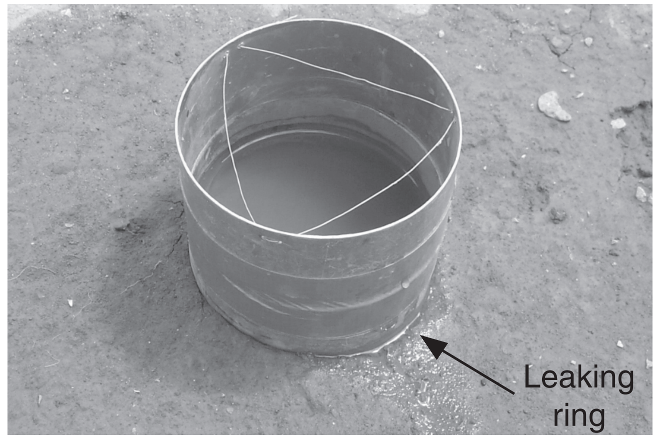


Figure 8.6. Water leaking from the ring.

Figure 8.7. Suspend bottle inside the ring.

8.3 Gently place the infiltration bottle in the ring so the silicone beads on the bottle catch on the ring suspension wires.

8.4 The bottle should be suspended in the ring with the cap end completely submerged *but not touching the soil surface*.

9. **Adjust the pipette to maintain the water in the ring at 3 cm (1.25 in) depth (Fig. 8.8).**

Rules

9.1 It is crucial to keep the water level inside the ring at 3 cm ($1^3/_{16}$ in) or a similar standard depth, such as 5 cm (2 in). For 3 cm, a range of 2.5 to 3.5 cm is allowed. The bottle will do this automatically after the pipette is adjusted. *To increase depth* follow rules 9.2 through 9.6. *To reduce depth* follow rules 9.7 through 9.11.

9.2 *To increase the depth*, raise the pipette. Supporting the bottle carefully with one hand, gently twist and pull the pipette upwards with the other hand until air bubbles come from the lower end of the pipette.
9.3 At this point, stop pulling up on the pipette and start pushing down a tiny distance, until the bubbles stop. This often amounts to less than 1 mm of movement.
9.4 Wait several seconds for the bubbles to start again. Bubbles should emerge at a constant rate within 10 seconds to one minute.
9.5 If no bubbles appear within one minute, slowly pull the pipette upwards and readjust its level (i.e., repeat 9.2 through 9.4).
9.6 Measure water depth. If too shallow, repeat 9.2 through 9.6. If too deep, follow 9.7 through 9.10.
9.7 *To reduce water depth*, push the pipette down. Supporting the bottle carefully with one hand, gently twist and push the pipette downwards. ***Caution: Grasp the side of the pipette only. Do not place your palm on top of the pipette.***
9.8 Wait until bubbles appear. This often takes several minutes, because water must drain from the ring into the soil.
9.9 If no bubbles appear within several minutes, measure the water depth. If the desired depth has been reached, pull the pipette upwards and follow steps 9.2 through 9.6.
9.10 When bubbles appear, measure water depth. If too shallow, repeat steps 9.2 through 9.6. If too deep, follow steps 9.7 through 9.10.

Figure 8.8. Adjust the pipette.

10. Move the rubber band to mark the water level and record the start time (Hours:Minutes:Seconds) in the "Start Time" column.

Rules

10.1 The top of the rubber band should mark the bottom of the meniscus where it intersects the vertical line of the bottle.
10.2 The "meniscus" is the bottom of the curved line formed by the surface of the water inside the bottle.
10.3 Record the start time.
10.4 Check for leaks during the run (defined in 7.2 above).
10.5 If a leak occurs, you must start over.

11. Wait for the water level in the bottle to drop at least 50 mm (2 in).

Rules

11.1 Make sure the water level inside the ring stays at a 3 cm ($1^3/_{16}$ in) depth (± 0.5 cm or $^3/_{16}$ in).
11.2 If water inside the ring drops below the allowable level, carefully pour water into the ring and adjust the pipette if necessary.

12. Record the infiltration end time and measure the distance the water level has dropped.

Rules

12.1 Simultaneously record the infiltration end time and the distance.
12.2 Record infiltration end time as Hours:Minutes:Seconds.
12.3 Record infiltration distance as the distance between the top of the rubber band and the meniscus (in mm or 16^{th}s of an inch).
12.4 Measure infiltration distance along the straight portion of the bottle only. Use the vertical line on the infiltration bottle as a guide.
12.5 You can safely make measurements as far down the bottle as you like, as long as the final measurement is greater than 50 mm (2 in) and the water level inside the bottle does not go past the curve in the bottle.

Bottleless Infiltration Method (Semi-quantitative Alternative)

Pre-wet sample point, insert ring, and pour water into the plastic bag just as with the standard Single-ring infiltration test (Steps 1-6). Carefully remove bag and record start time. Allow water to infiltrate. When 95% of the soil surface inside the ring is not shining, quickly insert the plastic bag and add another cup of water. Record the start time when the bag is removed. Record the end time when 50% of the soil surface is not shining. The difference between the start and end time is the time required for 3 cm (1.25 in) to infiltrate the soil.

Single-ring infiltrometer indicator calculations

If you use the ring and bottle sizes specified in Appendix A, your correction factor is 0.48 and you may skip to step 4. Otherwise please begin at step 1.

1. Calculate the cross-sectional area of the bottle.

Rules

1.1 The formula for area is: Area = π x $r^2 \approx$ 3.14 x r^2

Area $\approx$ 3.14 x (d ÷ 2) x (d ÷ 2)

r = radius = $^1/_2$ d

d = diameter (width)

1.2 If you don't know the bottle diameter, you can calculate if from the circumference, C.

d $\approx$ C ÷ 3.14

1.3 Record on the Single-ring Infiltrometer Data Form.

2. Calculate the cross-sectional area of the ring (see Step 1).

Rules

2.1 The formula for ring area is: Ring area = 3.14 x r^2

or = 3.14 x r x r

or = 3.14 x (d ÷ 2) x (d ÷ 2)

2.2 Bottle area = 3.14 x r^2

2.3 Record on the Single-ring Infiltrometer Data Form.

3. Calculate the correction factor for the difference between the area of the bottle and the area of the ring.

Rules

3.1 Correction factor = bottle area ÷ ring area.

3.2 Record on the Single-ring Infiltrometer Data Form.

4. Calculate the infiltration time in hours.

Rules

4.1 Subtract the end time from the start time.

4.2 Record in "Total time (min)."

4.3 Convert to hours by dividing by 60.

4.4 Record in "Total time (hr)."

4.5 Example: Start time = 12:55:01, End time = 1:04:31. Time elapsed (min) = 1:04:31 – 12:55:01 = 9.5 min. Time elapsed (hr) = (9.5 min) ÷ (60 min/hr) = 0.1583 hr.

5. Calculate the bottle infiltration rate in mm/hr.

Rules

5.1 Infiltration rate = distance the water dropped (in mm) divided by the amount of time it took to drop (in hours).

5.2 Record the bottle infiltration rate in "Bottle rate" column of data form.

5.3 Example:

Distance traveled was 5.1 cm.

Convert 5.1 cm to mm:

(5.1 cm) x (10 mm/cm) = 51 mm.

Divide distance traveled by time:

51 mm ÷ 0.1583 hr = 322.17 mm/hr.

6. Calculate the soil infiltration rate (corrected for the difference in area between the ring and the bottle).

Rules

6.1 Multiply the infiltration rate (from step 5) by the correction factor (from step 3).

322 mm/hr x 0.42 = 135 mm/hr.

6.2 Record in "Infil rate (mm/hr)" column of data form.

Single-ring vs. double ring infiltrometers

While double ring infiltrometers are sometimes recommended, it has been clearly shown (both theoretically and experimentally) that they provide little advantage over single-ring infiltrometers (Bouwer 1986), and the measurements take much longer. The best way to improve the accuracy of ponded infiltration measurements is to increase ring diameter, provided that this does not increase the risk of leaks (e.g., in soils with gravel or woody litter).

Example

Infiltration Data Form

Monitoring plot: *East Pasture 1*

Date: *15 September 2003*

Observer: *Tara North*

Recorder: *Tim White*

Veg Class:

NC = No perennial canopy
G = Perennial grass or grass/shrub mix
F = Perennial forb
Sh = Shrub
T = Tree

Soil moisture (circle one for each depth):

Surface	Dry	Moist	Wet
0-5 cm	Dry	Moist	Wet
5-10 cm	Dry	Moist	Wet
10-15 cm	Dry	Moist	Wet
15-20 cm	Dry	Moist	Wet
20-25 cm	Dry	Moist	Wet

Ring diameter: *12.5*

Bottle diameter: *8.7*

Correction factor (CF): *0.48*
CF = Bottle area ÷ ring area

Ring area: *122.7*

Bottle area: *59.4*

Ring insertion depth (cm): *3*

Record time to the nearest second.

Line	Position on line	Veg class	Begin time	End time	Distance (mm)	Total time (min)	Total time (hr)	Bottle rate(1)	Infil rate(2) (mm/hr)
1	2.5	G	12:55:01	13:04:31	52	9.5	0.16	328	158
1	12.5	NC	12:58:05	13:12:02	48	13.9	0.23	206	99
1	22.5	NC	13:01:29	13:16:59	55	15.5	0.26	213	102
1	32.5	G	13:04:53	13:11:33	60	6.7	0.11	540	259
1	42.5	T	13:08:24	13:19:30	58	11.1	0.19	314	150
1	49.5	NC	13:11:05	13:25:05	50	14	0.23	222	107

Average infiltration rate (sum all numbers in column ÷ number of measurements): *146*

(1) Bottle rate = Distance (mm) ÷ Total time (hours)
(2) Infil rate = Bottle rate x Correction factor

Notes:

Infiltration Data Form

Monitoring plot: ______________________ **Date:** ____________________

Observer: __________________________ **Recorder:** _________________________

Veg Class:

NC = No perennial canopy
G = Perennial grass or grass/shrub mix
F = Perennial forb
Sh = Shrub
T = Tree

Soil moisture (circle one for each depth):

Surface	Dry	Moist	Wet
0-5 cm	Dry	Moist	Wet
5-10 cm	Dry	Moist	Wet
10-15 cm	Dry	Moist	Wet
15-20 cm	Dry	Moist	Wet
20-25 cm	Dry	Moist	Wet

Ring diameter: [ ] Bottle diameter: [ ] **Correction factor (CF):** [ ]
CF = Bottle area ÷ ring area

Ring area: [ ] Bottle area: [ ] Ring insertion depth (cm): [ ]

Record time to the nearest second.

Line	Position on line	Veg class	Begin time	End time	Distance (mm)	Total time (min)	Total time (hr)	Bottle rate(1)	Infil rate(2) (mm/hr)

Average infiltration rate (sum all numbers in column ÷ number of measurements): [ ]

(1) Bottle rate = Distance (mm) ÷ Total time (hours)
(2) Infil rate = Bottle rate x Correction factor

Notes:

Chapter 9

Plant production

Total annual production, which includes woody material, is an expression of all aboveground plant production during a single growing year, regardless of accessibility or palatability to grazing animals.

Total annual forage production is the amount of total annual production composed of forage species, or species likely to be used by grazing animals.

Annual production can be divided into many different classes, such as herbage production for herbaceous species (grasses, sedges, rushes and forbs) or woody plant production for woody species (trees and shrubs). For woody plant production (trees, shrubs and half-shrubs), annual growth includes only leaders, leaves and fruit, or seed production for the current growing season, not the entire plant.

Annual production is an attribute of rangeland vegetation that is very difficult to quantify, but is important for management. There can be tremendous variation in annual production within a single pasture or management unit. As plants grow at different times of the year, determining when to quantify annual production and how to adjust for material that has not yet been produced or has been removed can be very difficult. In addition, total aboveground production can vary tremendously from year to year due to climatic variations (especially seasonal differences in precipitation), irrespective of management actions. Because of these challenges, and the time involved in data collection, most monitoring programs do not include annual or forage production methods.

When estimates of annual production are needed or desired, there are three basic methods for collecting data: (1) estimating (by weight units); (2) double sampling (an approach that includes estimating and harvesting to correct estimates); and (3) harvesting, an approach that uses clipping of plots and air drying harvested material to obtain a measure of dry matter production. Double sampling is recommended because it combines the efficiency of estimation with the accuracy of harvesting. All three methods are detailed in the NRCS *National Range and Pasture Handbook*, Chapter 4, Inventory and Monitoring Grazing Land Resources, pages 4-3 through 4-13 (USDA-NRCS 1997). The double sampling method is described below.

Figure 9.1. Weighing a clipped sample.

The methods described here:

- Follow standard USDA-NRCS national protocols.
- Are based on English units, in order to maintain consistency with USDA-NRCS protocols. For metric conversions, please see Appendix B.
- Allow the inclusion of correction factors for material that has not yet been produced or has been removed.
- Generate production estimates for a single, user-determined (usually calendar) year.

Materials

- The same transect(s) used for other measurements
- 1 pair grass clippers
- 1 pair pruning shears for woody vegetation
- Quadrat frames (1.92, 4.8 or 9.6 ft^2)
- Paper bags for weighing samples
- Gram spring scales: 0-60 g; 0-100 g x 1 g, 0-300 g x 2 g; 0-600 g x 5 g
- Plant identification guides
- Ecological Site Descriptions
- Clipboard, Plant Production Data Forms and pencil(s)

Standard Methods (Rule Set)

1. Establish subplots. (For this example we chose 10 – any number is possible.)

Rules

1.1 Randomly locate 10 sample locations. These can be located on the transect(s) used for other measurements.

1.2 The number of subplots commonly recommended is 10. The formulas in Appendix C can be used to calculate the optimum number of subplots. Additional guidance will be posted on the Internet when available (http://usda-ars.nmsu.edu).

1.3 Separate sample locations by at least 10 m (33 ft).

1.4 Record the sample location for each subplot on the data form under "Subplot position."

1.5 Place subplots with the edge of the sampling frame adjacent to the transect.

1.6 Locate subplots on the side of the transect not walked along for other vegetation measurements.

1.7 Determine production of herbaceous and half shrub species using 1.9, 4.8 or 9.6 ft^2 subplots. In most arid and semi-arid areas, 9.6 ft^2 is the best size. As production and plant density increases, smaller frame sizes are appropriate. For example, the 9.6 ft^2 is more appropriate in the desert, while the 1.9 ft^2 or 4.8 ft^2 would be more appropriate in tallgrass prairie and pasture ecosystems.

1.8 Where total production and/or woody production is of interest, expand a subset of subplots to 0.01 acre to measure tree and shrub production. The 0.01 acre expanded subplot is usually a circle with an 11 ft 10 in radius (3.6 m radius). However, you can also use a 21 by 21 ft square (6.4 m sides).

1.9 Woody production is more variable than herbaceous production. Where woody production is of interest, include a minimum of two expanded plots.

2. Record all species in a subplot.

Rules

2.1 At least 50 percent of the plant base must be located within a subplot to be recorded.

2.2 Record each species within a subplot once.

2.3 Record the species in the "Species code" column of the Plant Production Data Form, using one of the following: the PLANTS database species code (http://plants.usda.gov); a four-letter code based on the first two letters each of the genus and species; or the common name.

2.4 Record the subplot size for each species (see 1.6 and 1.7 for options).

3. Determine the weight unit for each species (for the first subplot) or determine the weight unit for each species not previously recorded (for the remaining subplots).

Rules

3.1 Within a species, a weight unit can consist of a plant part, an entire plant or a group of plants.

3.2 Grams are the unit of measure for herbaceous and half shrub species.

3.3 Pounds are the unit of measure for tree species. Grams or pounds may be used for shrubs.

3.4 Determine a weight unit appropriate for each species. Select a weight unit that is easy to identify, count and remember. Be careful not to select a weight unit that is too small, nor too large.

3.5 Select the equivalent of the weight unit and harvest it.

3.6 Determine the actual weight of the weight unit.

3.7 Repeat steps 3.4 through 3.6 until the weight unit can be accurately estimated.

3.8 Record the weight unit weight in the "Wt unit wt" column of the Plant Production Data Form.

3.9 Enter the unit of measure (grams or pounds) in the "Wt unit g or lb" column.

4. Estimate the number of weight units by species.

Rules

4.1 Enter the number of weight units located in each subplot for each species in the appropriate column of the form.

4.2 If only a trace amount of a species is detected, record "T" for that subplot.

4.3 At least 50 percent of the plant base must be located within a subplot to be recorded.

5. Repeat for all subplots and expanded plots.

Rules

5.1 Repeat steps 2 through 4 for all herbaceous subplots.

5.2 Repeat steps 2 through 4 for all woody expanded plots.

6. Clip species to allow for later calculation of the double sampling correction factor.

Rules

6.1 Select at least two of the ten subplots in which to clip and weigh each species. These subplots should include all or most of the species found in all the subplots.

6.2 Circle the subplots on the data form.

6.3 Record the clipped weight for each species in the “Clip wt” column.

6.4 Record a clipped weight for any species not found in your selected subplot(s) using a sample from another subplot. Make sure to note where the sample was collected.

6.5 Enter the appropriate values under “Clipped subplots Est wt” and “Clipped subplots Clip wt.”

7. Record the subplot size conversion factor.

Rules

7.1 Record subplot size conversion factor in the “Plot Size CF” column for each species.

7.2 Convert the sampled weight to pounds per acre using the appropriate conversion factor:

CF = 50 where subplot size is 1.92 ft^2 with grams as the unit of measure

CF = 20 where subplot size is 4.8 ft^2 with grams as the unit of measure

CF = 10 where subplot size is 9.6 ft^2 with grams as the unit of measure

CF = 0.22 where subplot size is 0.01 acre with grams as the unit of measure

CF = 100 where subplot size is 0.01 acre with pounds as the unit of measure.

8. Enter the air-dry weight adjustment for each species.

Rules

8.1 Enter the appropriate air-dry weight (ADW) proportion in decimal form in the “ADW adj” column.

8.2 If available, use established charts and tables that convert green weight to dry weight based on various stages of growth. If local charts or tables are not available, vegetation can be air dried.

8.3 Repeat for each species.

9. Enter the utilization adjustment for each species where livestock and/or wildlife grazing has occurred.

Rules

9.1 Enter the proportion of the plant remaining after utilization, in decimal form, in the “Util adj” column.

9.2 Utilization can vary among subplots, so make sure to use the average utilization for the entire plot.

9.3 Example: if a plant averages 40 percent utilization, then 60 percent remains and you enter 0.60 in the “Util adj” column.

10. Enter the growth adjustment for each plant species.

Rules

10.1 Enter the cumulative proportion of growth (in decimal form) that has occurred during the current year in the “Gwth adj” column.

10.2 This proportion is relative to the total production expected *for that year*, regardless of climatic variation. The growth adjustment corrects for how much the plant has grown for that year, against its potential for the year (100 percent). For example, if growth adjustment on July 1 is 60 percent during a dry year, it is also 60 percent on July 1 during a wet year, even though the total amount of growth on July 1 of a dry year may be much less than that of a wet year.

10.3 Growth curves are available for most major rangeland species in the United States. These growth curves show the typical cumulative proportion of growth by calendar date. These curves are approximate, as they do not account for annual variability in rainfall distribution. Contact your local NRCS office or Extension office for further assistance.

11. Enter the weather (climate) adjustment for each plant species.

Rules

11.1 Enter the weather (climate) adjustment in decimal form in the "Wthr adj" column.

11.2 The weather adjustment is used to describe the kind of growing conditions that have occurred or are expected. This includes precipitation amount, intensity and timing, as well as temperature, and their relationships to one another.

11.3 Enter a value between 0.1 and 2.0.

11.4 This adjustment can be different for different species, depending on the moisture and temperature requirements of the plants.

11.5 Example: An adjustment of 1.0 would indicate that the growing conditions were normal for the site that growing year. An entry of 1.2 would indicate that the growing conditions exceeded normal by an amount sufficient to increase species productions by 20 percent. An adjustment of 0.75 would indicate that the growing conditions were only sufficient to support 75 percent of normal species productions.

Plant production calculations

1. Add the total weight units for each species.

Rules

1.1 Add the weight units in each subplot by species and enter this in the "Total wt units" column.

1.2 Record weight units to the nearest decimal.

1.3 Ignore trace amounts, or "T's."

2. Calculate the double-sampling correction factor.

Rules

2.1 For the clipped subplots only, enter the total estimated weight for each species in the "Clipped subplots Est wt" column.

2.2 Total estimated weight = total weight units (Total wt units) in the clipped subplot, multiplied by the weight unit weight (Wt unit wt).

2.3 Enter total clipped weight for each plant species for the clipped subplots in the "Clipped subplots Clip wt" column.

2.4 Calculate the double sampling correction factor by dividing the "Clipped subplots Clip wt" by the "Clipped subplots Est wt."

2.5 Enter the double sampling correction factor in the "Clip/Est CF" column.

3. Calculate pounds per acre for each plant species.

Rules

3.1 Use the following equation to calculate air-dry reconstructed weight in pounds per acre, where s = the number of subplots:

$$\text{lb/ac} = \frac{(\text{Total wt units} \times \text{Wt unit wt} \times 1/s \times \text{Plot size CF} \times \text{ADW adj} \times \text{Clip/Est CF})}{(\text{Util adj} \times \text{Gwth adj} \times \text{Wthr adj})}$$

3.2 Enter this value in the "Total wt (lb/ac)" column.

Example

Plant Production Data Form

Monitoring plot: North Pasture 1 **Observer:** Renee Smith **Recorder:** Ken Fields **Page** 1 **of** 1

Line: 2 **Date:** 9 October 2003

Species code	Subplot position (meter marks on tape): record wt. units for each species in the appropriate column															Total wt units	Wt unit wt	Wt unit g or lb*	Clip wt	Clip unit g or lb*	Subplot size ft^2 or ac*	Plot Size CF	ADW adj	Util adj	Gwth adj	Wthr adj	Clipped sub-plots		Clip/ Est CF	Total wt lb/ac*
	Transect 1					Transect 2					Transect 3																			
	10	20	30	40	50	5	15	25	35	45																	Est wt	Clip wt		
PAVA2	5.5	0	0	0	0	0.1	0	0.75	0	0						6.35	34	g	138	g	9.6 ft^2	10	0.6	1	1	1	212.5	138	0.65	84.12
ERAR5	8	2	1	1	2	0	0	1	0	0						15	3	g	40	g	9.6 ft^2	10	0.6	1	1	1	27	40	1.48	40
CHAL7	6	0	0	0	12	0	0	10	0	0						28	1	g	15	g	9.6 ft^2	10	0.7	1	1	1	16	15	0.94	18
BOAR	2	0	9	7	0	0	0	4	0	0						22	4	g	22	g	9.6 ft^2	10	0.8	1	1	1	24	22	0.92	65
AMFI	1	0	0	0	0	0	0	0	0	0						1	1	g	2.5	g	9.6 ft^2	10	0.7	1	1	1	1	2.5	2.50	2
HOGL2	0	0	0	0	0	0	0	3	0	0						3	1	g	5	g	9.6 ft^2	10	0.6	1	1	1	3	5	1.67	3
CYDA	2	0	0	0	0	0	8	16	0	0						26	2	g	30	g	9.6 ft^2	10	0.8	1	1	1	36	30	0.83	35
MACM2	0	0	0	0	0	0	0	1	0	0						1	2	g	3	g	9.6 ft^2	10	0.9	1	1	1	2	3	1.50	3
OPEN3	0.5	0	0	0	0	0	0	0	0	0						0.5	0.25	lb	0.3	lb	0.01 ac	100	1	1	1	1	0.125	0.15	1.20	2
LYEX	1.2	0	1	0	0	0	0.3	0.6	0.6	0.6						4.3	0.2	lb	0.25	lb	0.01 ac	100	1	1	1	1	0.36	0.25	0.69	6
PRVE	1	0	0	0	0	1	1.5	0	1.5	0.5						5.5	0.3	lb	0.25	lb	0.01 ac	100	1	1	1	1	0.3	0.25	0.83	14
GUSA2	2	0	2	0	0	0.5	1	1	0	0						6.5	0.08	lb	0.25	lb	0.01 ac	100	1	1	1	1	0.24	0.25	1.04	5
LATR2	0	0	0	0	0	0	0	1	0	0						1	0.09	lb	0.1	lb	0.01 ac	100	1	1	1	1	0.09	0.1	1.11	1
ACCO2	1	0	0	9	2	0	1	8	0	0						21	0.1	lb	1	lb	0.01 ac	100	1	1	1	1	0.9	1	1.11	23
OPVE	2	0	0	0	0	0	0	0	0	0						2	0.15	lb	0.25	lb	0.01 ac	100	1	1	1	1	0.3	0.25	0.83	3

* For calculations to work, you must use g and ft^2 <u>or</u> lb and ac.

Total production (lb/ac): 302.62

Plant Production Data Form

Monitoring plot: ____________________ **Observer:** ______________________ **Recorder:** ______________________ **Page**_____**of**_____

Line: _______________ **Date:** ______________________

Species code	Subplot position (meter marks on tape): record wt. units for each species in the appropriate column															Total wt units	Wt unit wt	Wt unit g or lb*	Clip wt	Clip unit g or lb*	Subplot size ft^2 or ac*	Plot Size CF	ADW adj	Util adj	Gwth adj	Wthr adj	Clipped sub-plots		Clip/ Est CF	Total wt lb/ac*
	Transect 1					Transect 2					Transect 3																Est wt	Clip wt		

* For calculations to work, you must use g and ft^2 or lb and ac.

Total production (lb/ac): ______

Chapter 10

Plant species richness (modified Whittaker approach)

"Plant species richness" is the total number of species in an area. It is one indicator of biodiversity. This Plant species richness method is based on Stohlgren et al. (1995) and Bull et al. (1998). The Plant species richness method is very time intensive. The number of measurements may be reduced, depending on information requirements and time availability. A minimum estimate of species richness can be calculated from Line-point intercept data. The Line-point intercept estimate of species richness can be supplemented by a thorough search for exotics and other species of interest throughout the plot area.
Note: precise unit conversions are used in this chapter to facilitate calculations.

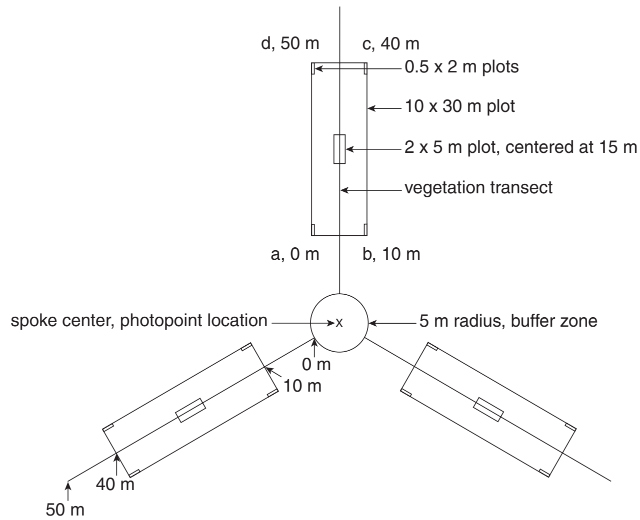


Figure 10.1. Species richness plots and their layout with respect to a monitoring plot. Drawn to scale.

Figure 10.2. Pulling out tape to set up the species richness plot.

Materials

- The same transect(s) used for Line-point and Gap intercept
- 100 m (328 ft) tape
- Metal stakes and hammer for marking plot corners
- At least 120 m (400 ft) of twine to mark plot borders
- Clipboard, Plant Species Richness Data Forms, pencil(s)

Standard methods (rule set)

1. Set up plots.

Rules

1.1 Lay out the 10 by 30 m plot.

1.2 Anchor 100 m (328 ft) tape at point "a" on the plot, 5 m (15 ft 5 in) and 90° away from the "0" end of the transect (Fig 10.1).

1.3 Pull the tape out, crossing the "0" end of the transect, to 10 m (32 ft 10 in) (point "b") and wrap it around another stake (Fig. 10.2).

1.4 Continue pulling the tape out, parallel to the transect. At 30 m (98 ft 5 in), insert another stake (point "c"). The tape will read 40 m (131 ft 3 in) at this stake. Continue to point "d."

1.5 Finish by pulling the tape back to point "a."

1.6 The tape should read 80 m (262 ft 6 in) once you are done.

1.7 Pull in the tape, but leave all the stakes in place.

1.8 Anchor twine at one of the stakes and string it out where the tape was.

1.9 Continue laying out the smaller plots, using twine, as in Figure 10.1.

1.10 Center the 2 x 5 m (6 ft 7 in x 16 ft 5 in) plot at the 15 m (49 ft 3 in) position on the vegetation transect.
1.11 Place four 0.5 x 2 m (1 ft 7 in x 6 ft 7 in) plots in the corners of the large (10 x 30 m or 32 ft 10 in x 98 ft 5 in) plot.
1.12 Repeat steps 1.1 through 1.11 for the two remaining vegetation transects, if desired. Due to the high sampling costs, it is generally more cost-effective to sample fewer transects (one can be sufficient) at more locations.

2. Record number of species in each plot.

Rules

2.1 Make all observations on all species richness plots on one transect at a time. Complete observations on all transects within a plot. Then move to the next transect.
2.2 Use one data form for each transect.
2.3 Start with the smallest (0.5 x 2 m or 1 ft 7 in x 6 ft 7 in) plots.
2.4 Record all species that occur in a small plot under the appropriate column on the data form (Fig. 10.3).
2.5 At least half of a plant base must be inside the plot boundary to be recorded. Plants with less than half their bases in the plot are not recorded.
2.6 Record the species in the "Species code" column of the Plant Species Richness Data Form, using one of the following: the PLANTS database species code (http://plants.usda.gov); a four-letter code based on the first two letters each of the genus and species; or the common name.

Figure 10.3. Record each plant species within each of the four small (0.5 x 2.0 m or 1 ft 7 in x 6 ft 7 in) plots.

(Relatively) rapid alternatives

The simplest alternative is to use the minimum estimate provided by the Line-point intercept. However, this will miss most species. Another alternative is to search the 10 x 30 m plot without subplots. This is appropriate if the species-area curve is not required.

2.7 Move to the next small plot and record all species in that plot in the next column.
2.8 Repeat 2.1 through 2.7 until all four small plots are sampled.
2.9 Search the 2 x 5 m (6 ft 7 in x 16 ft 5 in) plot and record all species detected.
2.10 Search the 10 x 30 m (32 ft 10 in x 98 ft 5 in) plot and record all species detected.
2.11 Make sure to include all species already found in the smaller plots in the list for the 10 x 30 m (32 ft 10 in x 98 ft 5 in) plot.

Plant species richness calculations

1. Measure species richness.

Rules

1.1 Count all species encountered in all the plots.
1.2 Each species is counted only once, no matter how many plots it occurs in.

2. Estimate species richness (not included on data form).

Rules

2.1 This should only be calculated by someone with an understanding of linear regression. It is based on the assumption that there is a linear relationship between the number of species and the log of the area for uniform areas.
2.2 Graph the number of species found in each plot against the log of the area of each plot (0, 1 and 2.5 for the 1, 10 and 300 m^2 plots).
2.3 The equation below can be used to predict species richness in a larger area *provided that the area is relatively uniform and that the plot is representative of the area.*

Species richness = intercept + (constant) x (log [area])

2.4 For monitoring, it is strongly recommended that only measured species richness be used.

Example

Plant Species Richness Data Form

Page 1 of 1

Shaded cells for calculations

Monitoring Plot: 8 Line: 2

Observer: James Smith Recorder: Nancy Brown Date: 29 September 2002

First 0.5 x 2 m plot	Second 0.5 x 2 m plot	Third 0.5 x 2 m plot	Fourth 0.5 x 2 m plot	2 x 5 m plot		10 x 30 m plot		
PHHE	POPR	KOMA	PF04	BOHI2	SCSC	AMCA6	ANHA	SCSC
CAEL2	ERSP		LYJU	ANHA	CALO	ROAR3	SCSC	CALO
AMPS	PAVI2		SPCR	SCSC		PHHE	PASM	
BOGR2				PASM		CAEL2	PG01	
DIOLS				PG01		AMPS	SOMI2	
CALO				SOMI2		BOGR2	HEPAP2	
				HEPAP2		DIOLS	OPFR	
				OPFR		CALO	PASE5	
				PASE5		POPR	PF02	
				PF02		ERSP	LIPU	
				LIPU		PAVI2	OPPO	
				OPPO		KOMA	HECOC8	
				HECOC8		PF04	ASER3	
				ASER3		LYJU	PSTE5	
				PSTE5		SPCR	ANNE	
				ANNE		BOHI2		
Total:	Total:	Total:	Total:	Total:		Total:		
6	3	1	3	18		33		

Total number of plant species encountered in all plots: 33

Plant Species Richness Data Form

Page__________ of ____________

Shaded cells for calculations

Monitoring Plot: _______________ Line: ______________

Observer: ______________________ Recorder: ______________________ Date: _____________________

First 0.5 x 2 m plot	Second 0.5 x 2 m plot	Third 0.5 x 2 m plot	Fourth 0.5 x 2 m plot	2 x 5 m plot		10 x 30 m plot		
Total:	Total:	Total:	Total:	Total:		Total:		

Total number of plant species encountered in all plots:

Chapter 11

Vegetation structure

The Vegetation structure method provides information on visual obstruction and habitat structure (and thus suitability) for various wildlife species. Visual obstruction methods have also been used to estimate plant biomass. A large amount of literature exists related to various uses of this method and associated indicators (e.g., Flather et al. 1992, Interagency Technical Reference 1996, MacArthur and MacArthur 1961, Robel et al. 1970, Nudds 1977).

There are many ways to measure vegetation structure based on visual obstruction. There is no standard method, nor is there a standard set of indicators. The Vegetation structure method described here is similar to methods that have been used historically for research and monitoring, such as a Robel pole, cover board, vegetation profile board or density board.

The dimensions of the cover pole can be easily modified to address different objectives.

Materials

- The same transect(s) used for Line-point and Gap intercept
- Cover pole (see Appendix A for construction)
- 1 m (3 ft) PVC sighting pole
- Clipboard, Vegetation Structure Data Forms, pencil(s)

Standard methods (rule set)

Before beginning the measurements, record the length of each segment on your cover pole at the top of the data form. The four segments are numbered from the top to the bottom of the pole. Each segment is subdivided into five equal bands. A typical segment length is 0.5 m (1 ft 8 in) on a 2 m (6 ft 8 in) pole. Each band is then 10 cm (4 in).

1. Randomly select five positions along each transect.

Rules

1.1 Record the transect or line number under "Line" on the data form.

1.2 Record each position under "Position" on the data form.

Figure 11.1. Observer stands 5 m (15 ft) from the cover pole, along the transect.

1.3 Positions must be at least 7 m (22 ft) apart.

2. Place the cover pole at the first position.

Rules

2.1 The recorder places the cover pole at the sample position.

3. Collect Vegetation structure data.

Rules

3.1 The observer stands 5 m (15 ft) from the cover pole, along the transect.

3.2 Using the "sighting pole" to maintain a constant observation height, the observer records whether or not each band is covered by vegetation.

3.3 A band is considered covered by vegetation if at least 25 percent of the band is visually obstructed by vegetation.

3.4 Record "1" on the data form if the band is visually obstructed. Record "0" if the band is not obstructed.

3.5 The observer repeats steps 3.1 through 3.4, standing 5 m (15 ft) from the cover pole in the opposite direction, along the transect.

4. Repeat steps 1 through 3 for all sample positions along a transect and for all transects.

Vegetation structure indicator calculations

1. **Calculate the average percent of visual obstruction.**

Rules

1.1 Add the number of bands within each segment obstructed by vegetation.

1.2 Percent visual obstruction = 100% x (number of bands obstructed ÷ total number of bands)

1.3 Calculate the plot average for each segment. Add up all percent visual obstructions (Vis. obst.). Then divide this total by the number of Vis. obst.

2. **OPTIONAL. Calculate the foliage height diversity (FHD, the vertical structural diversity).** ***Note: This indicator requires a calculator or computer, so it is not included on the field data form.***

Rules

2.1 The formula for foliage height diversity is:
$FHD = -\Sigma p_i \ln p_i$

2.2 For each segment at each observation, add the number of bands obstructed by vegetation.

2.3 Sum the number of bands in each segment for the entire plot.

2.4 Calculate the proportion of total hits found in each segment:
p_i = proportion of hits in the i^{th} segment, where $i = 1$ to 5.

2.5 Multiply the proportion of hits in each segment (from rule 2.4) by its natural log
$p_i * \ln p_i$

2.6 Add up all $p_i * \ln p_i$.

2.7 Multiply the sum obtained in Rule 2.6 by -1.

Figure 11.2. Example of a cover pole with some visual obstruction.

Example

Vegetation Structure Data Form

Monitoring plot: 12 **Date:** 12 September 2003 **Observer:** Michelle Evans **Recorder:** Jennifer Clark

Segment 1: 0 -0.5 m or ft? **Segment 3:** 1.0-1.5 m or ft? **Obs A = 5 m or 15 ft before Position, along the transect**

Segment 2: 0.5-1.0 m or ft? **Segment 4:** 1.5-2.0 m or ft? **Obs B = 5 m or 15 ft after Position, along the transect**

Record a "1" if >25% of the band is covered/obstructed by vegetation. Record a "0" if <25% of the band is covered/obstructed.

Line: 1		Position: 5		Position: 15		Position: 25		Position: 35		Position: 45	
Segment	**Band**	**Obs A**	**Obs B**	**Obs A**	**Obs B**	**Obs A**	**Obs B**	**Obs A**	**Obs B**	**Obs A**	**Obs B**
1	1	1	0	1	1	0	0	1	1	0	1
1	2	0	0	0	1	0	0	1	0	0	0
1	3	1	1	0	1	0	0	1	0	0	1
1	4	0	0	0	0	0	0	0	0	1	1
1	5	0	0	0	0	0	0	0	0	1	1
Total no. of bands		2	1	1	3	0	0	3	1	2	4
2	6	0	0	1	1	0	1	1	1	1	0
2	7	0	0	1	0	0	0	0	1	0	0
2	8	0	0	1	0	0	1	0	0	1	0
2	9	0	0	1	0	0	1	0	0	0	0
2	10	0	0	0	0	1	1	0	0	0	0
Total no. of bands		0	0	4	1	1	4	1	2	2	0
3	11	0	1	1	0	1	1	0	0	0	1
3	12	0	0	0	0	0	1	0	0	0	0
3	13	0	1	1	1	0	0	0	0	1	0
3	14	1	0	0	0	0	0	0	0	1	0
3	15	1	1	0	0	0	0	0	0	0	0
Total no. of bands		2	3	2	1	1	2	0	0	2	1
4	16	1	1	0	1	1	1	1	0	0	0
4	17	0	1	0	0	1	0	0	0	0	0
4	18	0	1	0	1	1	1	1	1	0	0
4	19	0	0	1	1	1	1	0	0	0	0
4	20	0	0	1	1	0	1	0	0	0	0
Total no. of bands		1	3	2	4	4	4	2	1	0	0

$$\text{Visual obstruction} = 100\% \times \frac{\text{Segment total}}{\text{No. of obs.}}$$

Segment total	No. of observations	Vis. obst.
17	50	34%
15	50	30%
14	50	28%
21	50	42%

Notes:

Average visual obstruction: 34%

Vegetation Structure Data Form

Monitoring plot: ____________________ **Date:** _________________ **Observer:** _______________________ **Recorder:** _____________________

Segment 1: _________**m or ft?** **Segment 3:** _________**m or ft?** **Obs A = 5 m or 15 ft before Position, along the transect**

Segment 2: _________**m or ft?** **Segment 4:** _________**m or ft?** **Obs B = 5 m or 15 ft after Position, along the transect**

Record a "1" if >25% of the band is covered/obstructed by vegetation. Record a "0" if <25% of the band is covered/obstructed.

$$\text{Visual obstruction} = 100\% \times \frac{\text{Segment total}}{\text{No. of obs.}}$$

Line:_______		**Position:** ______		**Position:** ______		**Position:** ______		**Position:** ______		**Position:** ______				
Segment	**Band**	**Obs A**	**Obs B**	**Obs A**	**Obs B**	**Obs A**	**Obs B**	**Obs A**	**Obs B**	**Obs A**	**Obs B**			
1														
1														
1														
1													**Segment total**	**No. of observations**	**Vis. obst.**
1														
Total no. of bands														
2														
2														
2														
2												**Segment total**	**No. of observations**	**Vis. obst.**
2														
Total no. of bands														
3														
3														
3														
3												**Segment total**	**No. of observations**	**Vis. obst.**
3														
Total no. of bands														
4														
4														
4														
4												**Segment total**	**No. of observations**	**Vis. obst.**
4														
Total no. of bands														

Notes:

Average visual obstruction: ☐

Chapter 12

Tree density

It is important to quantify the density and size of trees in savannas and grazed woodlands in order to understand the structural diversity of the plant community. Structural diversity at a site can provide protection from elements and cover for wildlife. Increased density of trees in savannas and grazed woodlands could indicate a trend toward an important community change.

The method described here is extracted from the *USFS Forest Inventory and Analysis (FIA) National Core Field Guide Volume I: Field Data Collection Procedure for Phase 2 Plots,* Version 1.7 (USDA Forest Service 2003). The FIA protocol includes a large number of additional requirements (e.g., assigning a unique record number to each tree) and indicators not needed for our monitoring objectives. For more information on the FIA protocol, please see http://www.srs.fs.usda.gov/fia/data_acquisition/field_guide/p2manual.htm.

Materials

- The same transect(s) used for Line-point and Gap intercept
- Extending range pole
- Steel pins for anchoring tape
- Additional tape (for defining subplots)
- Diameter or DBH tape
- Clipboard, Tree Density and Size Data Forms and pencil(s)

Standard methods (rule set)

1. **Define measurement area for trees and saplings (>2.5 cm [1 in] in DBH [Diameter at Breast Height] or DRC [Diameter at Root Collar]).**

Rules

1.1 Establish four subplots, one with its center located at the center of the spoke and the remaining three located at 36.6 m (120 ft) on each of the three transects (Fig. 12.1).

1.2 Subplots should have a 7.3 m (24 ft) radius (see subplots in Fig 12.1).

1.3 Other subplot sizes may also be used. If using a different subplot size be sure to record the size and adjust indicator calculations accordingly.

2. **Determine for which species DRC will be used instead of DBH.**

Rules

2.1 DRC is normally used on multi-stemmed species.

2.2 A list of species that the USFS classifies as multi-stemmed can be found in Appendix 4 of the FIA protocol (USDA Forest Service 2003).

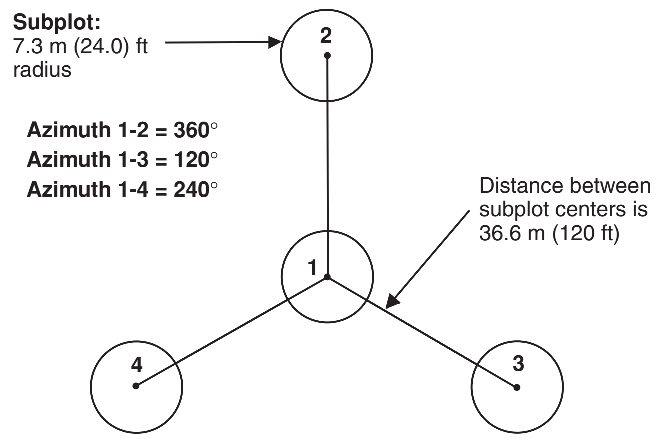


Figure 12.1. USFS Forest Inventory and Analysis plot diagram (modified from USDA Forest Service 2003).

3. **Record the species or common name for each tree that falls within each subplot.**

Rules

3.1 Include only those individuals with at least 50 percent of the plant base inside the plot.

3.2 Use the same codes or names used for the Line-point intercept method.

3.3 Record the species code in the "Species" column of the Tree Density and Size Data Form.

Figure 12.2. Savanna/woodland ecosystem showing relatively low tree density.

4. Record the DBH or DRC in the appropriate column.

Rules

4.1 Measure DBH at 1.4 m (4.5 ft) using a diameter tape (Fig. 12.3).

4.2 If a diameter tape is not available, measure with a standard tape measure and convert to diameter with the following formula ($\pi \approx 3.14$):

$$\text{diameter} = \text{circumference} \div \pi$$

4.3 Measure DRC as illustrated in Fig. 12.4. For multi-stemmed individuals,

DRC for the tree = SQRT (SUM [DRC^2]).

Figure 12.3. Measuring DBH.

5. Record each tree's height.

Rules

5.1 Measure the maximum height of the tree as the distance from the bottom of the trunk to the highest point of the canopy.

5.2 If the tree is too tall to measure with a meter/yard stick, use an extendable range pole (Fig. 12.5), visually estimate the height, or use a clinometer and trigonometry.

5.3. Record tree height in the "Height" column on the data form.

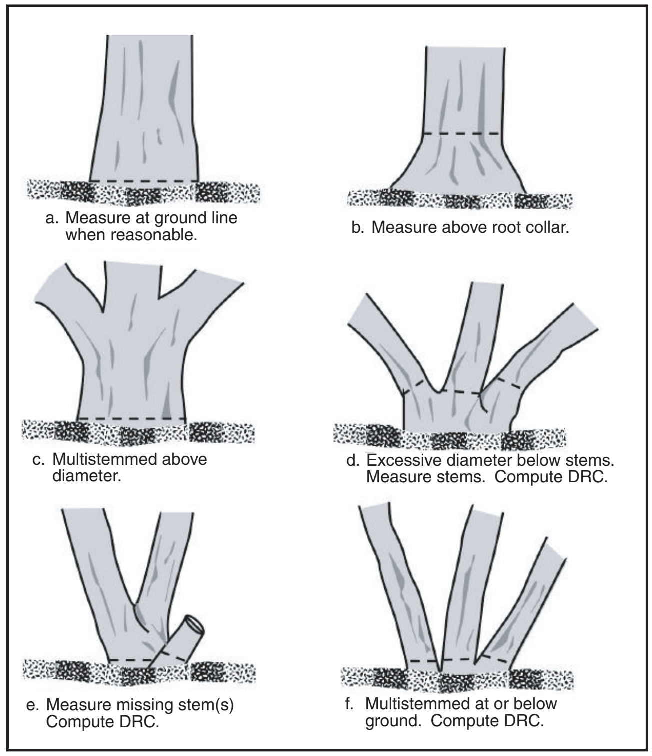


Figure 12.4. How to measure DRC (modified from USDA Forest Service 2003).

Figure 12.5. Measuring tree height with an extendable range pole.

Tree density calculations

1. Calculate the plot area in acres.

Rules

1.1 Plot area = (4 x π x plot radius x plot radius) ÷ conversion factor (π ≈3.14).

1.2 The metric conversion factor is 10,000 (converts square meters to hectares).

1.3 The English conversion factor is 107,639 (converts square feet to hectares).

2. Sum the number of trees and saplings.

Rules

2.1 Count all trees detected on all four subplots (trees have a DBH or DRC ⩾12.7 cm or 5 in).

2.2 Count all saplings detected on all four subplots (saplings have a DBH or DRC ⩾2.5 cm or 1 in and ⩽12.7 cm or 5 in).

3. Calculate densities.

Rules

3.1 Tree density = (total no. of trees) ÷ (plot area).

3.2 Sapling density = (total no. of saplings) ÷ (plot area).

Example

Tree Density and Size Data Form

Monitoring plot: 3 **Date:** 22 July 2003 **Line length:** 36.6 **(m or ft?)** circle one

Observer: Mark Second **Recorder:** Tara Third

Subplot radius 7.3 **(m or ft?)** circle one **Diameter units: (cm or in?)** circle one **Height units: (m or ft?)** circle one

Subplot 1 (plot center)				Subplot 2 (Line 1)				Subplot 3 (Line 2)				Subplot 4 (Line 3)			
Species	DBH	DRC	Ht.	Species	DBH	DRC	Ht.	Species	DBH	DRC	Ht.	Species	DBH	DRC	Ht.
POFR	40		6.5					POFR	52		11.5	POFR	4		3
												FRVE	35		10

Total plot area (all subplots) = (4 x 3.14 x [7.3] m x [7.3] m) ÷ 10,000 = [0.07] hectares
(plot radius, plot radius)

Total plot area (all subplots) = (4 x 3.14 x [ ] ft x [ ] ft) ÷ 107,639 = [ ] hectares
(plot radius, plot radius)

[3] = Total number of TREES (DBH ≥ 12.7 cm [5 in])

[1] = Total number of SAPLINGS (2.5 cm [1 in] < DBH < 12.7 cm [5 in])

$$\text{Tree density} = \frac{\text{No. of trees}}{\text{Plot area}} = \frac{3}{0.07} = 42.9$$

$$\text{Sapling density} = \frac{\text{No. of saplings}}{\text{Plot area}} = \frac{1}{0.07} = 14.3$$

Tree Density and Size Data Form

Monitoring plot: ____________ **Date:** ____________________ **Line length:** __________ **(m or ft?)** circle one

Observer: __________________________ **Recorder:** ___________________________

Subplot radius _________ **(m or ft?)** circle one **Diameter units: (cm or in?)** circle one **Height units: (m or ft?)** circle one

Subplot 1 (plot center)				Subplot 2 (Line 1)				Subplot 3 (Line 2)				Subplot 4 (Line 3)			
Species	DBH	DRC	Ht.	Species	DBH	DRC	Ht.	Species	DBH	DRC	Ht.	Species	DBH	DRC	Ht.

Total plot area (all subplots) = (4 x 3.14 x [ ] m x [ ] m) ÷ 10,000 = [ ] hectares
plot radius plot radius

Total plot area (all subplots) = (4 x 3.14 x [ ] ft x [ ] ft) ÷ 107,639 = [ ] hectares
plot radius plot radius

[ ] = Total number of TREES (DBH ≥ 12.7 cm [5 in])

[ ] = Total number of SAPLINGS (2.5 cm [1 in] < DBH < 12.7 cm [5 in])

Tree density = $\frac{\text{No. of trees}}{\text{Plot area}} = \frac{[\ ]}{[\ ]} = [\ ]$

Sapling density = $\frac{\text{No. of saplings}}{\text{Plot area}} = \frac{[\ ]}{[\ ]} = [\ ]$

Chapter 13

Riparian channel vegetation survey

The Riparian channel vegetation survey provides a general assessment of plant cover and composition along both sides of the channel. It is appropriate for systems and reaches with the potential to support a continuous band of riparian vegetation on the banks.

This approach is based on the "greenline" method developed by Alma Winward (2000), except that Winward's greenline method is based on identifying the plant community at each point along the channel. Winward's method is superior to the method presented here and is recommended if the expertise is available to identify plant communities.

Winward's definition of the greenline is critical: "the first line of perennial vegetation that forms a lineal grouping of community types on or near the water's edge." Winward adds, "Most often the greenline is located at or near the bank-full stage (Fig. 13.1). Or, as flows recede and the vegetation continues to develop summer growth, it may be located part way out on a gravel or sandbar (Fig. 13.2). At times when banks are freshly eroding or when a stream has become entrenched, the greenline may be located several feet above bank-full stage (Fig. 13.3). In these situations, the vegetation is seldom represented by hydrophilic species and, in fact, may be composed of non-riparian species…" (Winward 2000).

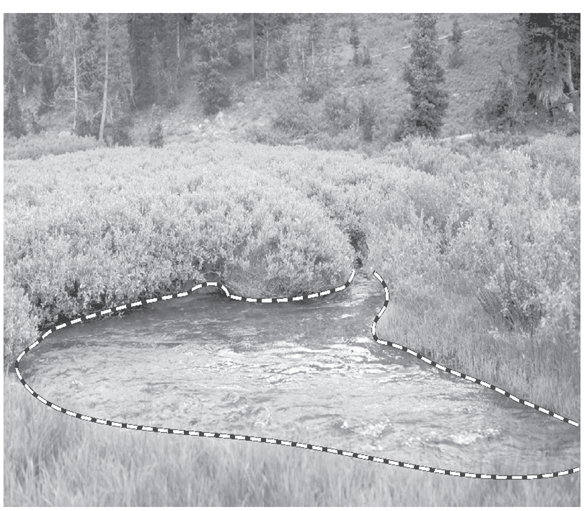


Figure 13.1. Location of the greenline at or near bank-full stage (Winward 2000).

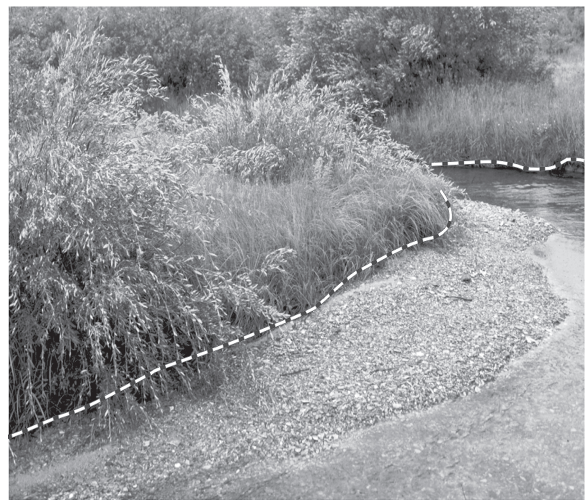


Figure 13.2. Location of the greenline (Winward 2000).

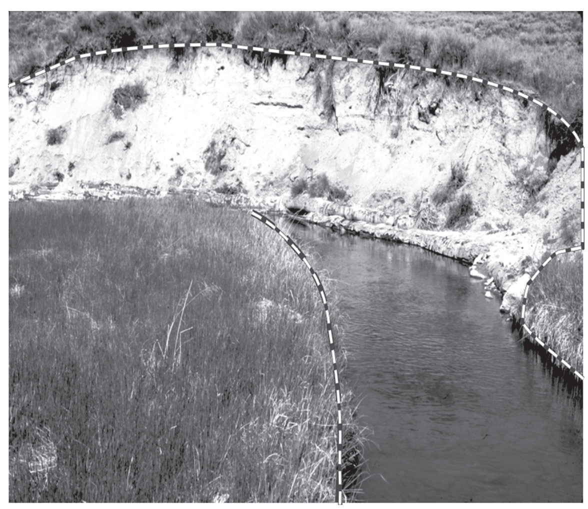


Figure 13.3. Location of the greenline on an eroded bank. Following the definition of greenline, "the first line of perennial vegetation that forms a lineal grouping of community types on or near the water's edge," the eroded non-riparian portion of the stream bank serves as the current greenline (Winward 2000).

Materials

- "L" tool or dual-ended laser pointer (see Appendix A for construction and suppliers)
- 50 or 100 m tape (150 or 300 ft)
- Meter (or yard) stick
- Extending range pole
- Clipboard, Riparian Channel Vegetation Survey Data Forms and pencil(s)

Standard Methods (rule set)

Note: Due to the difficulty in defining the greenline, and the physical impossibility of defining a permanent transect, on-site trainings are particularly important for this method. Where possible, this method should be repeated by the same person each time it is completed.

1. Determine pace length.

Rules

1.1 In order to increase the repeatability of this method, observers should try to calibrate their pace 1 m or 3 ft.

1.2 Determine pace length by repeatedly walking along a measuring tape and counting the number of paces required for a particular distance (e.g., 100 m or 100 yd) (Fig. 13.4).

1.3 Divide distance by pace number to determine pace length (e.g., 100 m ÷ 125 paces = 0.8 m [80 cm] per pace).

2. Measure the channel vegetation.

Rules

2.1 Begin in the channel at the point the Line-point or Gap intercept tape crosses the channel.

2.2 Indicate the direction of the "walk" (upstream or downstream) and record the side of the channel (e.g., NE, NW, SE or SW) in the blank next to "Stream side" on the Riparian Channel Vegetation Survey Data Form.

2.3 Select a stream side and direction and begin the survey, keeping in mind the standard pace length. Place the "L" tool at the first pace ("Pt." on the data form) along the edge of the greenline with the "scope" end pointing away from the center of the channel (Fig. 13.5).

2.4 For the point defined by the center of the L-tool scope, record the uppermost top layer species intercept under "Top layer" on the data form.

2.5 Look up and down the scope, if necessary, to ensure that all species are recorded. Record additional species intercepts in the appropriate "Lower layers" column.

2.6 Record the appropriate soil surface code in the last column of the data form.

2.7 If desired, record the height of the tallest plant intercepted in the "Ht." column.

Figure 13.4. Checking pace length.

Figure 13.5. Conducting the Riparian channel vegetation survey.

3. **Repeat the measurement for all four sides of the channel.**

Rules

3.1 Return to the start point for each of the four "walks," two upstream and two downstream on each side of the channel, and repeat steps 2.2 through 2.7.

3.2 The stopping points on one bank may not coincide with those on the other bank due to differences in the lengths of meanders on each side of the channel.

Riparian channel vegetation survey indicator calculations

See the Line-point intercept section in Quick Start for foliar cover, basal cover and bare ground. Instructions are provided here for calculating three additional indicators.

Site-specific indicators based on functional groups can be extremely valuable in riparian areas. Winward (2000) includes specific suggestions for developing indicators of greenline successional status and greenline bank stability, based on community types that have been defined for the U.S. Intermountain Region.

1. **Calculate percent stabilizing species cover.**

Rules

1.1. Acquire or develop a list of bank stabilizing species. Winward (2000) includes lists for the U.S. Intermountain region.

1.2. Count the total number of sample points at which a stabilizing species was recorded.

1.3. Multiply the number of stabilizing species sample points (from rule 1.2) by 2* and record your "% stabilizing spp. cover" in the blank provided on the data form.

2. **Calculate stabilizing species as a percent of total species cover**.**

Rules

2.1 Acquire or develop a list of bank stabilizing species (see Winward 2000).

2.2 Count the total number of times that a stabilizing species was intercepted ("Top layer" and "Lower layers" columns). Where more than one stabilizing species is intercepted at a point, all are counted. Record this on the data form as the numerator or "Total no. of stabilizing spp intercepts."

2.3 Count the total number of plant intercepts, to include species and litter intercepts ("Top layer" and "Lower layers" columns). Record this on the data form as the denominator or "Total no. of plant intercepts."

2.4 Divide the total number of stabilizing species intercepts by the total number of plant intercepts. Multiply this value by 100 and record in the blank provided.

3. **Calculate percent woody species cover.**

Rules

3.1 Acquire or develop a list of woody species.

3.2 Count the total number of sample points at which a woody species was recorded and record in the blank provided on the data form.

3.3 Multiply the number of samples points with woody species (from 3.2) by 2* and record your "% woody spp cover" on the data form.

---

*For 50 points per line. Multiply by 1 for 100 points per line. Multiply by 4 for 25 points per line.

**Note that this is total *species* cover, not total cover. Total cover would require that multiple plant intercepts of the same species be recorded.

Example

Riparian Channel Vegetation Survey Data Form

Page 1 of 1

Date: 15 September 2002

Shaded cells for calculations

Plot: North

X Upstream or ____ Downstream

Stream side: NE

Observer: Cathy Berger

Recorder: Tom Marshall

Pace length: 100 (cm or in?) circle one

Pt.	Top layer	Ht.	Lower layers Code 1	Code 2	Code 3	Soil surface	Pt.	Top layer	Ht.	Lower layers Code 1	Code 2	Code 3	Soil surface
1	FEID	40				FEID	26	ARTRT	85	L			S
2	NONE					S	27	ARTRT	155	L			ARTRT
3	NONE					R	28	ARTRT	200				S
4	NONE					R	29	COSE	105				S
5	NONE					R	30	COSE	190	ARTRT	L		S
6	POPR	10				S	31	ARTRT	170				S
7	NONE					S	32	COSE	145	FEID			S
8	NONE					R	33	ROWO	90				ROWO
9	ARTRT	180				S	34	FEID	10				S
10	NONE					R	35	FEID	5	L			S
11	ARTRT	155	L			S	36	FEID	5	L			S
12	ARTRT	220	L			ARTRT	37	COSE	120	FEID			S
13	NONE					R	38	COSE	130				S
14	NONE					R	39	NONE					S
15	NONE					R	40	COSE	210				S
16	NONE					R	41	COSE	190				COSE
17	ARTRT	205				S	42	ARTRT	160	L			S
18	NONE					R	43	ARTRT	180	L			S
19	NONE					R	44	COSE	220				S
20	ARTRT	220				S	45	ROWO	100				S
21	ARTRT	190	L			S	46	ARTRT	200				ARTRT
22	ARTRT	160	L			S	47	ARTRT	90				S
23	ARTRT	210	FEID			ARTRT	48	ARTRT	150				S
24	ARTRT	240	FEID	L		S	49	POFR	700	ARTRT	L		S
25	ARTRT	220	FEID			ARTRT	50	POFR	550	ARTRT			S

Top layer codes: Species code, common name, or NONE (no cover)

Lower layers: Species code, common name, L (herbaceous litter), WL (woody litter, >5mm [1/4 in] diameter)

% foliar cover = 36 top layer pts (1st col) x 2 = 72 %

% bare ground* = 3 pts (w/ NONE over S) x 2 = 6 %

% basal cover = 8 plant base pts (last col) x 2 = 16 %

Unknown species codes:
AF# = annual forb
PF# = perennial forb
AG# = annual grass
PG# = perennial grass
SH# = shrub
TR# = tree

Soil surface codes (do not use litter):
Species code (for basal intercept)
R = rock fragment (>5mm [1/4 in] diameter)
BR = bedrock
M = moss
LC = visible biotic crust on soil
S = soil, without any other soil surface code
EL = embedded litter
D = duff

% stabilizing spp cover = 8 pts with stabilizing spp x 2 = 16 %

$$\frac{\text{Total no. of stabilizing spp intercepts}}{\text{Total no. of intercepts}} \times 100\% = \frac{8}{44} \times 100 = 18.2\ \%$$

% woody spp cover = 31 pts with woody spp x 2 = 62 %

*Bare ground occurs ONLY when Top layer= NONE, Lower layers are empty (no L), and Soil surface = S

Riparian Channel Vegetation Survey Data Form

Page ____ of ____ Date: ________________ **Shaded cells for calculations**

Plot: ______________ ____ Upstream or ____ Downstream Stream side: ______________

Observer: __________________ Recorder: __________________ Pace length: ________ (cm or in?) circle one

Pt.	Top layer	Ht.	Lower layers Code 1	Code 2	Code 3	Soil surface	Pt.	Top layer	Ht.	Lower layers Code 1	Code 2	Code 3	Soil surface
1							26						
2							27						
3							28						
4							29						
5							30						
6							31						
7							32						
8							33						
9							34						
10							35						
11							36						
12							37						
13							38						
14							39						
15							40						
16							41						
17							42						
18							43						
19							44						
20							45						
21							46						
22							47						
23							48						
24							49						
25							50						

Top layer codes: Species code, common name, or NONE (no cover)

Lower layers: Species code, common name, L (herbaceous litter), WL (woody litter, >5mm [$^1/_4$ in] diameter)

% foliar cover = ____ top layer pts (1st col) x 2 = ____%

% bare ground* = ____ pts (w/ NONE over S) x 2 = ____%

% basal cover = ____ plant base pts (last col) x 2 = ____%

Unknown species codes:

- AF# = annual forb
- PF# = perennial forb
- AG# = annual grass
- PG# = perennial grass
- SH# = shrub
- TR# = tree

Soil surface codes (do not use litter):

- Species code (for basal intercept)
- R = rock fragment (>5mm [$^1/_4$ in] diameter)
- BR = bedrock
- M = moss
- LC = visible biotic crust on soil
- S = soil, without any other soil surface code
- EL = embedded litter
- D = duff

% stabilizing spp cover = _____ pts with stabilizing spp x 2 = ______%

$$\frac{\text{Total no. of stabilizing spp intercepts}}{\text{Total no. of intercepts}} \times 100\% = \frac{\boxed{}}{\boxed{}} \times 100 = \_\_\_\_\_\_\%$$

% woody spp cover = _____ pts with woody spp x 2 = ______%

*Bare ground occurs ONLY when Top layer= NONE, Lower layers are empty (no L), and Soil surface = S

Chapter 14

Riparian channel and gully profile

The Riparian channel and gully profile provides a description of channel shape. This method can also be used to record the shape of the soil surface (e.g., covered by rills and gullies) in uplands.

Caution!

- Stream currents can be dangerous.
- Use this method only when and where it can be safely applied.

Materials

- Two 1.5 m (5 ft) rebar stakes
- 100 m (300 ft) roll of nylon string
- Hacksaw
- Hand sledge
- String line level
- Meter stick
- 100 m (300 ft) tape
- Clipboard, Riparian Channel Profile Data Forms and pencil(s)

Standard Methods (rule set)

1. Determine the location for the profile.

Rules

1.1 Measure the profile where the Line-point or Gap intercept crosses the channel.

1.2 Determine where the edge of the greenline is on each side of the channel.

2. Erect rebar, string and tape.

Rules

2.1 Using the hacksaw, make a notch on both pieces of rebar about 3 cm from the end.

2.2 Pound one rebar in on one side of the channel at least 2 m (6 ft 7 in) in from the edge of the greenline, leaving 25-50 cm (10-20 in) exposed (Fig. 14.1). Install with the notch end up.

2.3 Tie the nylon string at the notch and pull it tight across the channel.

2.4 Determine how high the other rebar should be in order for the line to be level on the opposite side of the channel, and then pound in the other rebar.

2.5 Pull the string tight and tie off at the notch on the second rebar.

2.6 Install the line level and fine-tune the depth of either rebar until the line is perfectly level (Fig. 14.2).

2.7 Stretch the tape between the pieces of rebar with the 0 end on the left as you are looking upstream.

Figure 14.1. Installing rebar 2 m from edge of greenline.

Figure 14.2. Level the string across the channel.

3. Record the channel profile.

Rules

3.1 Beginning at the rebar at the 0 m end of the measuring tape, measure the distance from the soil surface to the string, using a meter stick (Fig. 14.3).

3.2 Record the position along the tape under "Tape distance" and the channel depth measurement under "Channel depth" on the data form.

3.3 Repeat these measurements at 50 cm (1 or 2 ft) intervals.

3.4 Make the final measurement at the rebar on the opposite end of the channel.

3.5 For riparian systems only (not gullies), record the location of the greenline (bank-full) on each side of the channel.

Figure 14.3. Record the channel depth every 50 cm (1 to 2 ft) for the length of the tape crossing the channel.

Riparian channel profile and soil surface contour indicator calculations

Note: Due to the difficulty in defining channel width, the same person should calculate these indicators each time. Save the raw data so the indicators can be recalculated in the future. These indicators can be used to monitor relative changes. Interpretation requires a trained professional who is familiar with the area. Please see Chapter 17 for more information.

1. Graph the channel profile.

Rules

1.1 Mark a line at the top of the graph to represent the string. Make sure it is parallel to the "x" (horizontal) axis, and set it to "0".

1.2 Graph heights relative to the "y" (vertical) axis, creating a graph that looks like the shape of the channel.

1.3 Always draw the graph as if you are looking at the profile from downstream of it.

1.4 Graph each measurement as a negative number against the distance along the measuring tape.

1.5 If measurements are not evenly spaced or a measurement is missing and you are using a computer, be sure that the "x" axis is correct. In Microsoft® Excel, you must use the "scatter" (not the "line") graph option.

2. Calculate the bank angle.

Rules

2.1 On the graph, mark the base and top of the bank on the side of the channel marked by the 0 end of the tape.

2.2 Measure the horizontal distance between these two points.

2.3 Measure the vertical distance between these two points.

2.4 Divide the vertical distance by the horizontal distance.

2.5 To express the angle in percent, multiply the result of Rule 2.4 by 100.

2.6 To express the angle in degrees, use a calculator to calculate the arctangent of the result of Rule 2.4. Excel and some calculators report the result in radians. To convert from radians to degrees, multiply by 57.3. In Excel, the formula is:

=DEGREES(ATAN(result of Rule 2.4)).

2.7 Record this as the "bank angle (0-end)" in the blank provided on the data form. Include appropriate units (percent or degrees).

2.8 Repeat 2.1 through 2.7 for the other bank on the non-zero end of the tape and record as the "bank angle (non-0 end)." Ensure you subtract the base from the top at the non-0 end.

3. Calculate the width:depth ratio.

Rules

3.1 The *width* is the horizontal (parallel to the "x" axis) distance between the points used for the bank angle at the top of each bank.

3.2 The *depth* is the greatest vertical distance from a straight line drawn between these two points to the bottom of the channel. The straight line between the two points will not necessarily be horizontal.

3.3 Divide the width by the depth and record as the "width:depth ratio" in the blank provided on the data form.

Sinuosity

The level of sinuosity is an excellent indicator of stream status, particularly in relatively low gradient systems. Sinuosity is most easily quantified using aerial photography. A simple index of sinuosity is the ratio of distance along the streambed to the straight-line distance between two points.

Example

Riparian Channel Profile Data Form

Date: 5 October 2002

Shaded cells are for calculations

Monitoring plot: North **Line:** 1

Observer: Ken Fields **Recorder:** Ken Fields

Side of channel where line starts (N, S, E, W): E

Tape distance always starts at "0" with a reading from where the string is tied to the rebar.
The last reading should be where the string is tied to the rebar on the opposite side of the channel.

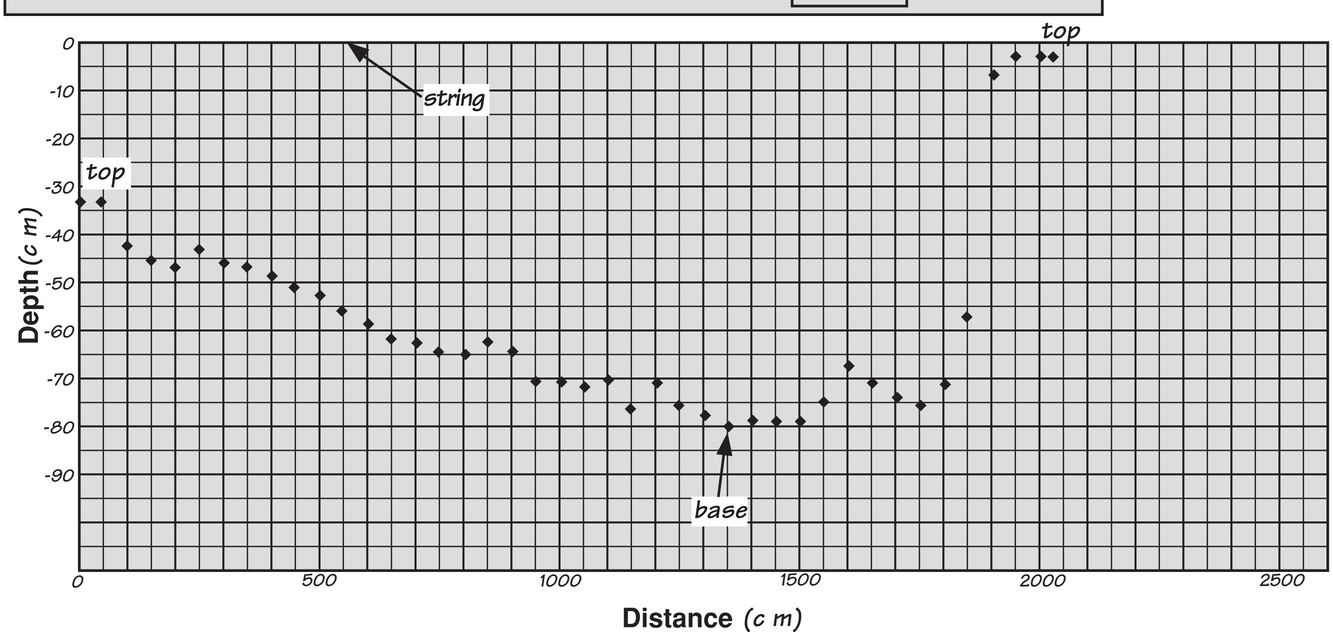
Tape distance	Channel depth (cm)	Tape distance	Channel depth (cm)	Tape distance	Channel depth (cm)	Tape distance	Channel depth (cm)
0	33.0	600	58.5	1200	71.5	1800	71.0
50	33.0	650	62.0	1250	75.5	1850	57.5
100	42.5	700	62.5	1300	77.5	1900	7.0
150	45.5	750	64.5	1350	80.0	1950	3.5
200	46.5	800	65.0	1400	78.5	2000	3.0
250	43.5	850	62.5	1450	79.0	2022	3.0
300	46.0	900	64.5	1500	78.5		
350	47.0	950	70.5	1550	75.0		
400	48.5	1000	70.5	1600	67.5		
450	51.0	1050	72.0	1650	71.0		
500	52.5	1100	70.0	1700	74.0		
550	56.0	1150	76.5	1750	75.5		

Bank angle (0 end) = $\frac{\text{vertical distance}}{\text{horizontal distance}}$ x 100% = $\frac{47}{1300}$ x 100% = 3.6 %

Bank angle (non-0 end) = $\frac{\text{vertical distance}}{\text{horizontal distance}}$ x 100% = $\frac{77}{650}$ x 100% = 11.8 %

Remember for this end: 2000 - 1350 = 650

Width:depth ratio = $\frac{\text{width}}{\text{depth}}$ = $\frac{1950}{77}$ = 25.3



Riparian Channel Profile Data Form

Date: ______________________________ **Shaded cells are for calculations**

Monitoring plot: ____________________ **Line:** _______

Observer: _________________________ **Recorder:** _________________________

Side of channel where line starts (N, S, E, W): ______________

Tape distance always starts at "0" with a reading from where the string is tied to the rebar.
The last reading should be where the string is tied to the rebar on the opposite side of the channel.

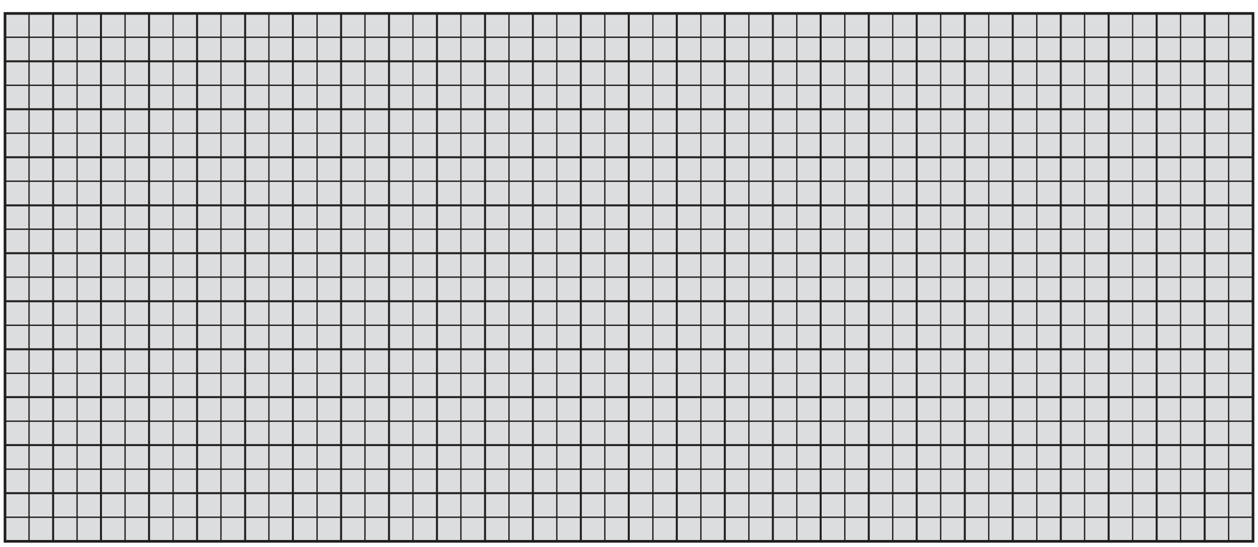
Tape distance	Channel depth (cm)	Tape distance	Channel depth (cm)	Tape distance	Channel depth (cm)	Tape distance	Channel depth (cm)

$$\text{Bank angle (0 end)} = \frac{\text{vertical distance}}{\text{horizontal distance}} \times 100\% = \frac{\boxed{}}{\boxed{}} \times 100\% = \underline{}\ \%$$

$$\text{Bank angle (non-0 end)} = \frac{\text{vertical distance}}{\text{horizontal distance}} \times 100\% = \frac{\boxed{}}{\boxed{}} \times 100\% = \underline{}\ \%$$

$$\text{Width:depth ratio} = \frac{\text{width}}{\text{depth}} = \frac{\boxed{}}{\boxed{}} = \underline{}$$

Depth



Distance

Chapter 15

Density, frequency and Line-point intercept alternative methods

This chapter includes a brief discussion of density and frequency methods, and alternative Line-point intercept methods. Density and frequency are generally used for individual species of interest, although it is possible to use them for all species encountered in an area. For more information on density and frequency, see Elzinga et al. 2001.

Density

Plant density is simply the number of individuals per unit area. It is particularly useful for monitoring vegetation where cover varies widely during the season (e.g., annuals). It is not appropriate where individuals are difficult to distinguish (e.g., many rhizomatous grasses).

Method. Count the number of individuals of the species of interest that have at least 50 percent of their base in a subplot (quadrat) or other plot of defined size. The subplots should be large enough so that most of them include more than one individual of each species that is being monitored. Multiple noncontiguous subplots are randomly or systematically located in the plot.

Calculations. Add the number of individuals found in each subplot. Divide this sum by the area of subplots to generate the average density (number per square meter or square feet). To convert to the number per hectare, multiply the density by 10,000 (if working with square meters). To convert the density in number per square feet to the number per hectare, multiply by 107,639.

Frequency

Plant frequency is the proportion of subplots out of all subplots of a specified size that contain a particular species. It is a rapid and useful indicator of the spatial distribution of different species, and is appropriate for the same types of species as density (above). Two methods for collecting frequency data are the rapid method and the intensive method. The rapid method generates data for just one species. The intensive method produces data for many species. Data collected with the intensive method (below) can generate information about fine-scale associations among species.

Rapid method. Define and use only one subplot size. The subplot should be small enough to ensure that the species of interest does not occur in all subplots. This is because if the species occurs in all subplots, frequency will always be 1.0. Randomly or systematically locate and establish subplots. Count the number of subplots in which at least one individual of the target species is located. A species must have at least 50 percent of its base in a subplot to be considered present.

Intensive method. Define and use only one subplot size. Subplot size should be selected based on the species of greatest interest. Randomly or systematically establish subplots. Make a comprehensive species list. For each subplot, record whether or not each species occurs in that subplot. A species is recorded for a subplot if at least 50 percent of at least one plant base falls within the subplot.

To increase speed, use a species list with tally marks or dot boxes. A dot box consists of four dots in a square connected by four lines with an “X” in the middle. Each dot and each line represents a plot in which the species occurs, for a total of 10 individuals per complete dot box.

Calculations. Divide the number of subplots in which the species occurs by the number of subplots searched. This is frequency.

Alternative vegetation methods

Line-point intercept alternatives

Line-point intercept can be used to generate more indicators than virtually any other monitoring method. Adding height measurements (Option B in Table 15.1) generates additional information on vegetation structure. The height of first (top layer) intercept is recorded under 'Ht'. If litter or woody litter is the tallest element (i.e., taller than the plant at that point), record this in the notes. An alternative method (used by the USDA National Resources Inventory) is to record the tallest element within a 15 cm radius of the point. If species information is required, the species of this element (or WL for woody litter) should be recorded in a separate column. Options D through H take less time, but generate fewer indicators.

Figure 15.1. Line-point intercept with height alternative.

Typical applications. Line-point intercept (Table 15.1: A-E) should be used where precise, repeatable measurements are required. Options D and E can reduce time where changes in species composition (e.g., grass to shrub, or annuals to perennials) are not important. Option D is ideal where the primary objective is to document changes in erosion resistance.

Step-point intercept methods (Table 15.1: F-H) require less time because no tape is required. They can be relatively accurate *provided that a pin is used in place of the toe of your boot.* Using the toe can significantly overestimate cover because plants are pushed over by the foot, which artificially increases measured cover data.

Quadrat-point intercept. Where quadrats (or subplots) are being used along a line (e.g., to monitor frequency or density), points on the four corners of the frame can sometimes be used to replace four points along the line, provided that the points are sufficiently far apart. The minimum distance varies with plant community. To determine whether or not this method is appropriate, randomly select six transects and compare means and variability for both methods. For example, a 50 m transect with 100 points with a point every 50 cm would be compared with a 50 m transect with 25 frames (four points each), one frame located every 2 m.

Table 15.1. Alternative Line-point intercept methods comparison. See also quadrat-point intercept below.

		Modifications from Standard (Alternative A = Quick Start)				------Indicators------			
	Alternative	**Method**	**Form**	**Time**	**Accuracy & Repeatability**	**Foliar/ Basal**	**Comp- osition**	**Structure**	**Ht.**
				-----Line-point intercept-----					
A	Standard (Quick-Start)	None	None	Mod. to High	High	Yes/Yes	Yes	Yes	No
B	Standard + height	Add height of highest intercept at least every 10th point	Add height column	High	High	Yes/Yes	Yes	Yes	Yes
C	Standard + dead	Only record each species once, but if you intercept a dead plant part for a given species, place a check in the "Dead" column	Change "Height" in Option B to "Dead"	Mod. to High	High	Yes/Yes	Yes	Yes	No
D	Total, foliar, basal cover only	Record first intercept + any plant basal hits	Delete lower layers	Mod. to Low	High	Yes/Yes	No	No	No
E	Total cover only	Record only first intercept (foliar, litter, rock, etc...)	Delete lower layers and soil surface	Low	High	Yes/No	No	No	No
				-----Step-point Intercept with Pin-----					
F	Standard (Quick-Start "Semi-quantitative alternative"	Pace transect, drop pin 15 cm (6 in) in front of toe	None	Mod.	Mod. to Low	Yes/Yes	Yes	Yes	No
G	Total, foliar, basal cover (species not recorded)	See D and F	See D	Low	Mod. to Low	Yes/Yes	No	No	No
H	Total cover (species not recorded)	See E and F	See E	Very Low	Mod. to Low	Yes/No	No	No	No

Line-point Intercept with Height Data Form

Page ____ of ____

Shaded cells for calculations

Plot: ______________ Line No.: __________ Observer: __________________ Recorder: ___________________

Direction: _________ Date: ______________ Intercept (point) spacing interval = _____ cm (_____ in)

Pt.	Top layer	Ht.	Lower layers Code 1	Code 2	Code 3	Soil surface	Pt.	Top layer	Ht.	Lower layers Code 1	Code 2	Code 3	Soil surface
1							26						
2							27						
3							28						
4							29						
5							30						
6							31						
7							32						
8							33						
9							34						
10							35						
11							36						
12							37						
13							38						
14							39						
15							40						
16							41						
17							42						
18							43						
19							44						
20							45						
21							46						
22							47						
23							48						
24							49						
25							50						

% foliar cover = ____ top layer pts (1st col) x 2 = ____%

% bare ground* = ____ pts (w/ NONE over S) x 2 = ____%

% basal cover = ____ plant base pts (last col) x 2 = ____%

Top layer codes: Species code, common name, or NONE (no cover)

Lower layers: Species code, common name,
L (herbaceous litter), WL (woody litter, >5mm [1/4 in] diameter)

Unknown species codes:

- AF# = annual forb
- PF# = perennial forb
- AG# = annual grass
- PG# = perennial grass
- SH# = shrub
- TR# = tree

Soil surface codes (do not use litter):

- Species code (for basal intercept)
- R = rock fragment (>5mm [1/4 in] diameter)
- BR = bedrock
- M = moss
- LC = visible biotic crust on soil
- S = soil, without any other soil surface code
- EL = embedded litter
- D = duff

*Bare ground occurs ONLY when Top layer = NONE, Lower layers are empty (no L), and Soil surface = S