Monitoring Manual

for Grassland, Shrubland and Savanna Ecosystems

Volume II: Design, supplementary methods and interpretation

by
Jeffrey E. Herrick, Justin W. Van Zee,
Kris M. Havstad, Laura M. Burkett and Walter G. Whitford

with contributions from
Brandon T. Bestelmeyer, Alicia Melgoza C., Mike Pellant,
David A. Pyke, Marta D. Remmenga, Patrick L. Shaver,
Amrita G. de Soyza, Arlene J. Tugel and Robert S. Unnasch

USDA - ARS Jornada Experimental Range
Las Cruces, New Mexico

Printed 2005

Publisher:
USDA-ARS Jornada Experimental Range
P.O. Box 30003, MSC 3JER, NMSU
Las Cruces, New Mexico 88003-8003
http://usda-ars.nmsu.edu

ISBN 0-9755552-0-0

Distributed by: The University of Arizona Press
Tucson, Arizona, USA
800-426-3797
www.uapress.arizona.edu

Cover: RB Design & Printing
Las Cruces, New Mexico 88001

Cover illustration:
Collecting Line-point intercept data
in a south-central New Mexico desert grassland.

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. 2000, *In Press*) 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.

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° 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 (*In Press*) and Herrick (*In Press*). 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	0.6	0.5					

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)											