BULK DENSITY—ON FARM USE

Key points
- Bulk density is the weight of soil in a given volume.
- Sandy soils are more prone to high bulk density.
- Bulk density can be used to calculate soil properties per unit area.
- Soils with large amounts of gravel will have higher bulk densities.
- Accounting for the gravel fraction after soil analysis “dilutes” your soil test results.

Background
The soil bulk density (BD), also known as dry bulk density, is the weight of dry soil divided by the total soil volume. The total soil volume is the combined volume of solids and pores which may contain air or water, or both (figure 1). The average values of air, water and solid in soil are easily measured and are a useful indication of a soil’s physical condition.

Bulk density is most commonly used in agriculture when investigating compaction layers which occur between 10–40 cm as a result of machinery and stock impacts. This simple measurement can also be used to determine various nutrient levels and other soil quality indicators on an area basis, by converting weight measurements (e.g. mg/kg) to area measurements (e.g. kg/ha).

Measurement
Bulk density is relatively simple to measure and is best done when the soil is wet. Manually pre-wetting the soil will not affect the bulk density. For a full description on the sampling process for bulk density refer to the Bulk Density—Measurement fact sheet.

Management issues
Soils with low bulk density are generally more suitable for agriculture, since the high pore space has a greater potential to store water and allow roots to grow more readily. Bulk density increases with compaction and tends to increase with depth. Fine textured soils (high in silt and clay) tend to be less dense than sands, particularly if the size distribution of the sands is such that the gaps between larger particles are filled with smaller particles (Marshall and Holmes, 1992). As bulk density increases, resistance to roots increases and the amount of water available to crops decreases (see Subsurface Compaction fact sheet). Permeability of the soil also decreases and crops are more susceptible to waterlogging (see Waterlogging fact sheet).

Despite the practical significance, bulk density is not often measured during soil sampling. Estimation of bulk density is particularly difficult as it has little correlation with general soil types, particularly where management practices have led to increases across many soil types (NLWRA, 2001).

Using topsoil bulk density with your soil test results
Soil test results are most often presented either as a percentage of soil (e.g. % organic carbon) or as a weight per unit of soil (e.g. nitrogen, mg/kg). As bulk density is a measure of soil weight in a given volume, it provides a useful conversion from these units to an area basis unit (e.g. t/ha). The resulting number gives an easily understandable idea of the carbon storage or nutritional status of the soil on an area basis.
Soil analysis values can be converted to a meaningful volume for a paddock. For example:

Your soil 
(0–10 cm) 
1.5 g/cm³ 
20 mg/kg 
30 kg/ha

Bulk density 
Mineral nitrogen 
Mineral nitrogen

i.e. 10,000 m² in one hectare x 0.1 m soil depth 
× 1.5 g/cm³ bulk density = 1,500 t/ha of soil. 
20 × 1,500,000 kg = 30,000,000 mg-N/ha 
= 30 kg-N/ha

Tables 1 and 2 give an indication of the multiplication factors when converting soil quality indicators from units in percentage (table 1) and milligrams per kilogram (mg/kg, table 2). After determining the bulk density and approximate gravel content of your soil, you can convert your raw analysis data by multiplying with the appropriate factor in table 1 or 2.

**Table 1: Multiplication factors for converting percentage (e.g. total organic carbon) to tonnes per hectare (t/ha) for a 10 cm soil layer.**

<table>
<thead>
<tr>
<th>Gravel (%)</th>
<th>Bulk density (g/cm³)</th>
<th>1.2</th>
<th>1.4</th>
<th>1.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12.0</td>
<td>14.0</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10.8</td>
<td>12.6</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>9.6</td>
<td>11.2</td>
<td>12.8</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>8.4</td>
<td>9.8</td>
<td>11.2</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2: Multiplication factors for converting milligrams per kilogram (mg/kg, e.g. mineral nitrogen) of soil to kilograms per hectare (kg/ha) for a 10 cm soil layer.**

<table>
<thead>
<tr>
<th>Gravel (%)</th>
<th>Bulk density (g/cm³)</th>
<th>1.2</th>
<th>1.4</th>
<th>1.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.20</td>
<td>1.40</td>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.08</td>
<td>1.26</td>
<td>1.40</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.96</td>
<td>1.12</td>
<td>1.28</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.84</td>
<td>0.98</td>
<td>1.12</td>
<td></td>
</tr>
</tbody>
</table>

**Further reading and references**


Hunt N and Gilkes R (1992) Farm Monitoring Handbook. The University of Western Australia: Nedlands, WA.


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