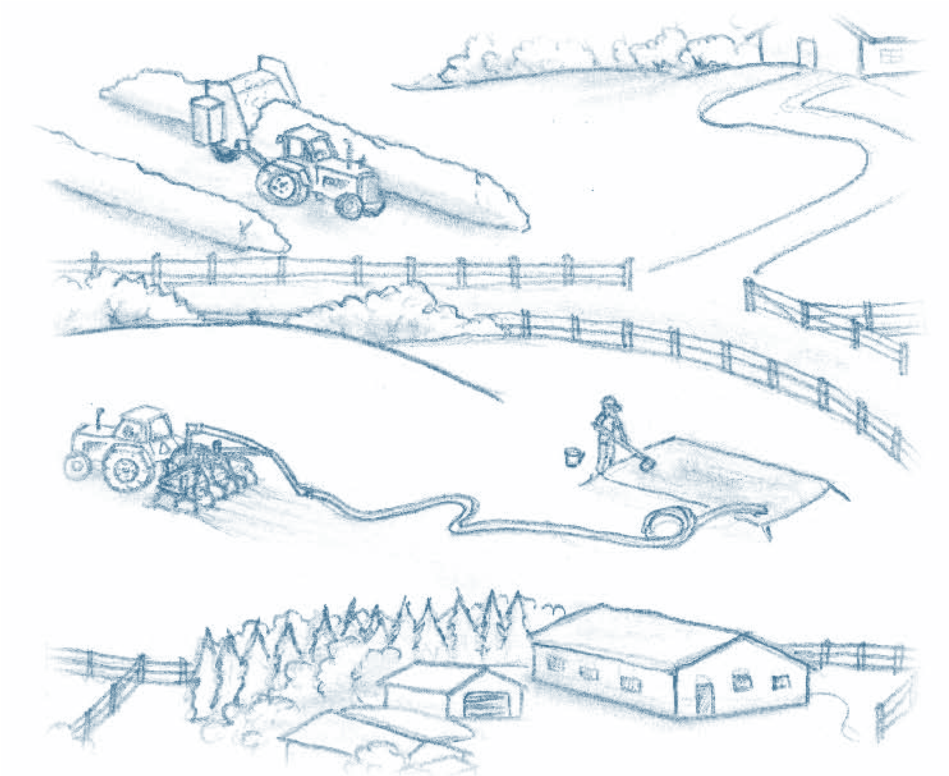
Chapter 4.6

Calibrating Manure Application Equipment



learning objectives

- Describe two methods for calibrating manure application systems and situations where each is preferred.
- Determine the appropriate spacing between spreader passes to obtain uniform coverage with the manure.
- Explain how to achieve a desired application rate using the information generated from a calibration.
- Explain why calibration curves are useful for application equipment with multiple settings.

tip

Water can be used as an alternative source to liquid manure for the initial calibration of manure applicators. This approach is cleaner and will provide a relatively accurate calibration. Some fine tuning of the equipment may be required when liquid manure is being applied.

Important Terms

Table 4.6.1 Key Terms and Definitions

Term	Definition
Calibration	To check, adjust, or determine by observation or testing the rate or volume of manure being applied by a piece of equipment.
Corrected Target Speed	The target application speed of a spreader, that has been corrected to account for differences in density between the manure to be applied versus the manure used during the equipment calibration.
Effective Spreader Width	This is the spreading width that an implement can apply manure at a uniform application rate. An application pass one 'effective spreader width' from the last should provide an ideal application overlap that will result in a relatively uniform application.
Gross Weight	The total weight without deduction for tare or waste.
Net Weight	The weight of actual goods (manure), excluding container, wrapper or tarp; also called actual.
'Reference' Application Rate	Used to determine an application speed for a targeted application rate based on material with a difference in bulk density.
'Struck Load'	Is the volume contained in the level-full box. The volumetric capacity of spreaders may be given as a typical "heaped" load condition or as a "struck" load condition.
Tare Weight	The empty or clean weight of a container, wrapper or tarp.

To be able to apply manure at desired rates it is important to know the performance capabilities of application equipment. While manufacturers provide some basic specifications about the equipment, such as dimensions or capacity, seldom is any information provided about application rates.

Calibrating application equipment provides important information about what rates are possible with a particular piece of equipment, and also the speed (and settings) that can be used to achieve target application rates. There are two calibration techniques:

- The load-area method involves estimating the weight or volume of manure in a loaded spreader and then determining the area required to spread an entire load (or several loads).
- The weight-area method involves weighing the manure spread over a known area to calculate the rate at which the manure was applied.

A calibration technique should be selected based on the application equipment being used and the type of manure being applied. If liquid manure is injected, use the load-area method since injected manure cannot be collected. Surface applications of liquid, solid or compost manure should be calibrated using the weight-area method.

Load-Area Calibration

The load-area calibration technique involves measuring the volume of manure in a typical load and the area required to spread the load at constant speed and applicator settings. Dividing volume in the load by the area used to spread the load will yield the application rate for that speed and setting. It may take several loads to cover a known area. In this case the total volume applied will need to be divided by the known area.

This technique requires a note pad, a calculator and flags or stakes to mark off the boundaries of the calibration test area. The distance between markers can be estimated by counting the number of paces between markers and multiplying this by the average distance traveled in a pace.

Follow the steps below to use the load-area technique to calibrate application equipment.

1. Determine the Capacity of the Manure Spreader
Manufacturer's specifications will usually include the capacity of the spreader. However, for solid spreaders the capacity reported is often for a level or 'struck' load. If using heaped loads or if capacity of the spreader is unavailable, the capacity of the spreader will need to be estimated (Figure 4.6.1).

The manufacturer's capacity specification may need to be converted into units that are compatible with those on the manure test report and used to express the recommended application rate (Table 4.3.3, Chapter 4.3). Record the capacity (specified or estimated) of the spreader.

Volume in cubic metres or feet can be converted into litres or gallons using the conversion factors in Table 4.6.2.

Tank Spreaders

Volume = L x D x D x 0.785   Volume = L x W x D x 0.785

L = length   D = diameter   W = width

Figure 4.6.1 Volume Calculations for Various Manure Application Equipment.

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To determine the average distance traveled in a single pace, measure the distance traveled in 10 normal paces and divide by 10.

Table 4.6.2 Factors to Convert Between Measures of Volume

Start Units:	Multiply start units by factors in the appropriate column to get:				
	ft^3	m^3	L	US gal	Imp gal
Cubic feet (ft^3)		0.0283	28.32	7.481	6.229
Cubic metres (m^3)	35.31		1000	264.2	220.0
Litres (L)	0.0353	0.001		0.2642	0.2200
US gallons (US gal)	0.1337	0.0038	3.785		0.8327
Imperial gallons (Imp gal)	0.1605	0.0045	4.546	1.201	

Calculating the Capacity of a Liquid Tank Spreader

A non-round tank spreader has a length of 8.5 m, a width of 3.75 m and diameter of 2.5 m. The volume of the spreader is:

Volume (m^3) = 8.5 m × 3.75 m × 2.5 m × 0.785

= 62.55 m^3 is the volume of the spreader

To convert this volume into litres:

Spreader Volume (L) = Spreader Volume (m^3) × 1000 L/m^3

= 62.55 m^3 × 1000 L/m^3

= 62,550 L is the volume of the spreader

2. Spread Manure on Calibration Test Area

While maintaining constant speed, spread the load (or loads) of manure on a calibration test area. To achieve uniform coverage with the manure, make passes with application equipment one-spreader width from the centre of adjacent passes.

3. Measure the Calibration Test Area

Use flags, stakes or some other reliable marker to mark out the boundaries of the calibration test area where the test loads of manure were spread. Measure the distances between the markers and calculate the area (in m^2 or ft^2). The area covered by the test load(s) of manure can be converted to hectares (or acres):

Calibration Test Area (ha) = Calibration Test Area (m^2) ÷ 10,000 m^2/ha

Calibration Test Area (ac) = Calibration Test Area (ft^2) ÷ 43,560 ft^2/ac

Measuring the Calibration Test Area

Three loads of manure were spread onto a rectangular test area with a width of 92 m and a length of 205 m. The estimated area covered by the three test loads of manure is:

Calibration Test Area (m^2) = 92 m × 205 m

= 18,860 m^2 is the estimated area covered by the test loads

To convert this to hectares:

Calibration Test Area (ha) = 18,860 m^2 ÷ 10,000 m^2/ha

= 1.89 ha is the calibration test area

4. Calculate Application Rate

To calculate the application rate, multiply the estimated volume of manure applied by the number of loads applied and then divide by the area covered by the test loads:

Application Rate = (Volume per Spreader Load × Number of Loads) ÷ Calibration Test Area

Calculating Application Rate

The volume of manure per spreader load is 62,550 L and the calibration test area covered by three loads of manure applied at a given speed was 1.89 ha. The application rate is calculated as:

Application Rate (L/ha) = (volume (L/load) × number of loads) ÷ calibration test area

= (62,550 L/load × 3 loads) ÷ 1.89 ha

= 187,650 L ÷ 1.89 ha

= 99,286 L/ha is the application rate

Calculating Application Rate for a Dragline System

Dragline application systems are slightly easier to calibrate since application rate can be determined using the flow rate, the width of application and ground speed of the applicator. The application rate in a dragline system is calculated as:

Application Rate (L/ha) =
[Flow rate (L/min) × 60 min/h × 10000 m^2/ha] ÷ [Speed (km/h) × 1000 m/km × Width of application (m)]

Or,

Application Rate (gal/ac) =
[Flow rate (gal/min) × 60 min/h × 43560 ft^2/ac] ÷ [Speed (mi/h) × 5280 ft/mi × Width of application (ft)]

The conversion factors in the top and bottom lines of each equation are necessary so that the units in the calculation are compatible. The desired application rate can be achieved through altering any of the factors in the equation. Note that this strategy also works for other liquid application systems where flow rate can be manipulated.

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If sheets or pans are used for several runs, the tare weight must be determined before each run to account for any residual manure remaining.

tip

Tarps are convenient for the purposes of collecting solid manure since they are easily secured to the ground, inexpensive, easy to clean, and typically come in standard dimensions. Long, shallow, plastic home organization boxes, though somewhat more costly, are equally convenient for liquid manure calibrations.

Achieving Target Application Rate in a Dragline System

The example below only shows the values for each of the known factors, since the units in this equation (particularly those of the conversion factors) can become confusing.

The target application rate for a field is approximately 13,000 L/ha. The field conditions dictate that ground speed should not exceed 6 km/h. The application width of the dragline system is approximately 4.9 m. The flow rate that would be required to achieve an application rate of 13,000 L/ha would be:

$$\text{Application Rate (L/ha)} = \frac{\text{Flow Rate (L/min)} \times 60 \text{ min/h} \times 10{,}000 \text{ m}^2\text{/ha}}{\text{Speed (km/h)} \times 1{,}000 \text{ m/km} \times \text{Width of application (m)}}$$

$$\textbf{Flow Rate (L/min)} = \frac{\text{Application Rate (L/min) x Speed (km/h) x 1,000 m/km x Width of application (m)}}{60 \text{ min/h x } 10{,}000 \text{ m}^2\text{/ha}}$$

$$= \frac{13{,}000 \text{ L/ha x 6 km/h x 1,000 m/km x 4.9 m}}{60 \text{ min/h x } 10{,}000 \text{ m}^2\text{/ha}}$$

$$= \frac{382{,}200{,}000}{600{,}000}$$

$$= 637 \text{ L/min is the flow rate}$$

Weight-Area Calibration

The weight-area calibration technique directly measures the weight of manure delivered to a known area at a given speed and setting. This is then used to determine the application rate in t/ha (or tn/ac).

This technique requires one or more plastic sheets, tarps or collection trays; means for securing these in place (e.g., pegs, weights); a suitable scale to weigh the manure collected; a tape measure; a notepad and a calculator. Weighing can be made easier by having a large plastic pail or garbage can on hand.

Follow the steps below to use the weight-area technique to calibrate application equipment.

1. Prepare the Collection Sheets or Pans

Use either a single large sheet, or several smaller sheets installed side by side, spanning the equivalent of twice the spreader width to collect solid manure. If using a single long sheet, divide the sheet evenly into sections using paint, tape or another suitable method. Ensure that the total area covered by the collection sheets or pans is at least 9 m^2 (100 ft^2). For liquid manure use a series of strategically placed shallow pans (Figure 4.6.2). For best results, use a minimum of 8 to 10 pans for the calibration.

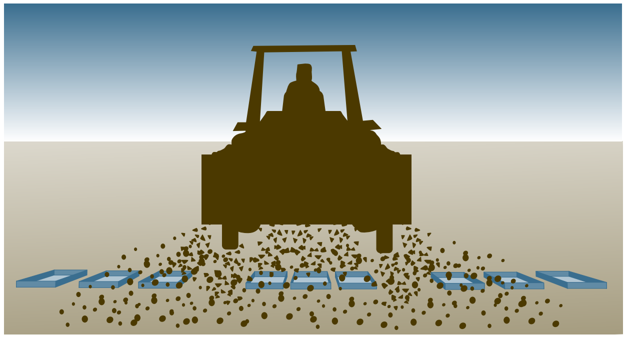

Figure 4.6.2 Sample Layout Pattern for Sheets or Pans

Determine the total collection area by multiplying length by width of each sheet or pans and then multiplying by the number of sheets or pans that will be used during the calibration. If the intention is to weigh manure directly on sheets or pans, pre-weigh the sheets or pans and record the empty or clean weight (i.e., tare weight) of each. Record the total collection area and the tare weight for each collection sheet or pan.

2. Secure Collection Sheets or Pans

Lay out collection sheets or pans in the desired pattern, across the equivalent of two spreader widths. If using several sheets, space them evenly or secure them side-by-side. Stretch sheets out to remove any wrinkles and secure to the ground using pegs or some other method. This will prevent them from being moved by wind or wheel pressure from the equipment passing over.

Since pans can be easily crushed by equipment, space the pans to allow space for equipment tires to pass in between. Marking out the spreader's path can help prevent collection pans from being crushed.

3. Make a First Pass with the Spreader

Perform a single pass with the spreader directly through the middle of the test area. Begin spreading prior to reaching the test area to ensure the spreader is fully functional while passing over the collection pans or sheets.

4. Weigh Manure Collected

Weigh the manure collected either by directly weighing the sheet or pan with manure or by transferring the manure to a container that is easier to handle. Containers, such as a large plastic garbage can for solid manure, or a pail for liquid manure can be used for this purpose. Remember to weigh and record the weight of the container prior to beginning to establish a tare weight that can be subtracted from the gross weight. If using a single collection sheet, weigh the manure collected in each marked off section.

Use a scale that is appropriate for the specific situation. If using small sheets or pans to collect solid or liquid manure, either a kitchen (for less than 2 kg or 5 lb) or bathroom scale (up to 25 kg or 50 lb) is suitable. If collecting solid manure on larger sheets, a spring-tension scale or milk scale (more than 25 kg or 50 lb) might be more appropriate.

Remember that the weight that registers on the scale is the total weight of the manure plus the container. Subtract the tare weight of the sheet, pan or container to get the net weight of manure collected. Record the net weight of manure collected.

5. Calculate Application Rate

To calculate application rate in kg/m^2 (or lb/ft^2), divide the total net weight of manure collected in kg (or lb) by the area of the sheet(s) or pans in m^2 (or ft^2). To convert this rate to t/ha (or tn/ac) use the conversions below:

Application rate (t/ha) = Application rate (kg/m^2) × 10
Application rate (tn/ac) = Application rate (lb/ft^2) × 21.78

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Take special care to avoid spilling manure as this can affect the calibration considerably.

Calculating Application Rate

A series of six evenly spaced, 1.5 m^2 tarps, collected a total of 16.2 kg of solid manure. The resulting application rate is:

Total Collection Area (m^2) = 1.5 m^2/tarp × 6 tarps

= 9 m^2

Application Rate (kg/m^2) = Weight of collected manure (kg) ÷ Total collection area (m^2)

= 16.2 kg ÷ 9 m^2

= 1.8 kg/m^2

Application Rate (t/ha) = Application rate (kg/m^2) × 10

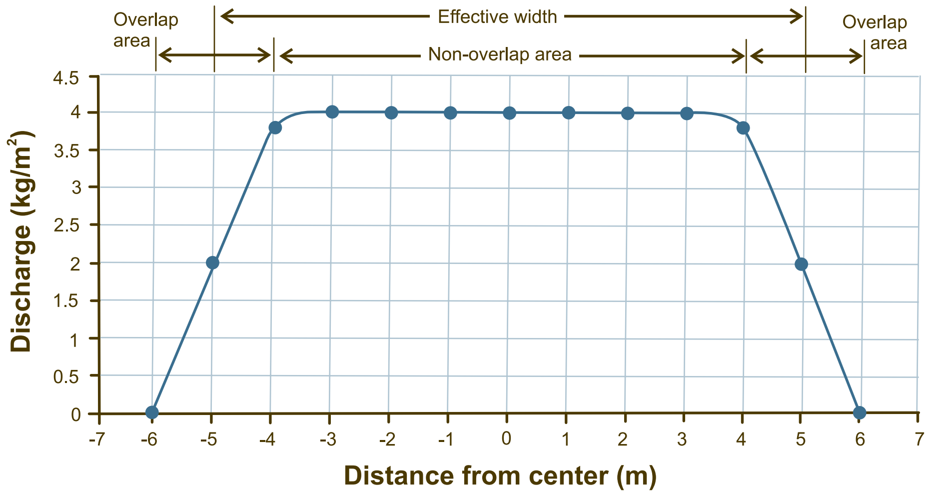
= 1.8 kg/m^2 × 10

= 18 t/ha

Determining Spacing Between Spreader Passes

When using surface application systems, a uniform application can be achieved by adjusting the spacing between adjacent passes with the spreader so that the passes overlap. The spacing between passes that will result in the most uniform application can be determined by graphing the outcome of the first spreader pass.

Using graph paper, plot application rates on a graph where application rate (or discharge) is on the vertical axis and distance of the center of the collection pan, sheet or sheet section from the center of the spreader path is on the horizontal axis (Figure 4.6.3). Connect the data points with a line to develop a uniformity curve.



Source: B.C. Ministry of Agriculture, Forestry and Lands, 2005

Figure 4.6.3 Sample Application Uniformity Curve Generated from the Results of a Uniformity Test

The ideal spacing between spreader passes is equal to the effective spreader width. Using the graph, identify the horizontal distances to the left and right of the center where the application rate fell to 50 percent of the maximum observed during the test. The distance between these two points on either side of center is the effective spreader width. Spacing the passes one effective spreader width from the last should provide an ideal application overlap that will result in a relatively uniform application.

Verifying Application Rate and Spreader Pass Spacing

Once again, spread manure at the same speed and setting over the test area where sheets or pans are laid out, only this time make three passes. Spread the first pass directly over the center of the collection area. Make the remaining two passes, one effective spreader width to the left and right of the center of the first pass.

Weigh the manure collected and calculate the application rate for each of the pans, sheets or sheet sections across the width of the test area. If the spacing between spreader passes is correct the application rate across the width of the test area should be relatively consistent. If application rates appear to be heavier in between spreader passes, this suggests that the spreader passes should be made further apart. Conversely, if application rates are noticeably lighter in between, spreader passes should be moved closer together.

Record the average application rate across the width of the test area, the speed and setting (if applicable) used during the calibration. If applying solid manure the density of the manure should be recorded as well. This information can be used to quickly recalculate applications speeds and setting if manure with a different density is to be applied with the same machine and is discussed in the following section.

Using Calibration Results to Plan Manure Applications

Calibrating will provide an application rate that was achieved when travelling at a constant speed and equipment settings. Altering the travel speed of the spreader according to the relationship below will change the application rate:

Desired Application Rate
= Calibration Test Speed × Calibration Application Rate
÷ Target Speed

This equation can be rearranged to yield the target speed to achieve the desired application rate:

Target Speed
= Calibration Test Speed × Calibration Application Rate
÷ Desired Application Rate

If applying solid manure, a correction must be made for differences in density between the manure to be applied versus the manure used during the calibration:

Corrected Target Speed
= (Calibration Test Speed × Calibration Application Rate
× Present Manure Density) ÷ (Desired Application Rate
× Calibration Manure Density)

Calculating Ground Speed to Achieve a Target Application Rate

A calibrated solid spreader was found to apply manure with a density of 923 kg/m^3, at a rate of 12.5 t/ha when traveling at a speed of 4 km/h. The target application rate for a field is 9 t/ha. The travel speed necessary to apply manure with a density of 794 kg/m^3 at a rate of 9 t/ha using the calibrated setting for this applicator is:

Corrected Target Speed (km/h)

= (4 km/h × 12.5 t/ha × 794 kg/m^3) ÷ (9 t/ha × 923 kg/m^3)

= (39,700) ÷ (8,307)

= 4.8 km/h is the approximate corrected target speed

Developing Calibration Graphs

Spreaders with multiple settings (e.g., PTO-driven) offer the advantage of being able to achieve multiple application rates through variable setting and ground speed combinations to accommodate field conditions. Considerable time can be saved in the future by developing calibration "curves" for each of the settings on the spreader. To do so, use the following procedure:

1. Use either the load-area or weight-area method to determine the application rate at a low and high speed for a specific setting (if applicable). Record the density of manure used during the calibration (for solid manure), the setting (e.g., PTO speed) and the travel speed of the spreader.
2. On a piece of graph paper, plot the application rate for the setting at low and high speeds on a graph with application rate on the vertical axis and speed on the horizontal axis (Figure 4.6.4).

3. Draw a straight line to connect the data points corresponding to the application rates at low and high speeds. This line is the calibration curve for that particular setting.
4. Repeat steps 1 through 3 for each available setting for the spreader.

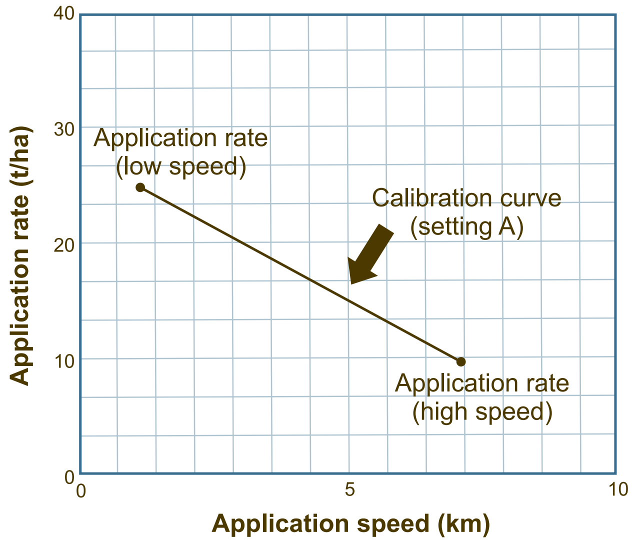


Figure 4.6.4 Sample Calibration Graph for a Manure Spreader

Once lines have been graphed for each of the settings, they can be referred to in the future when using this equipment. For each target application rate, identified along the vertical axis of the graph, a corresponding equipment setting and speed can be selected (Figure 4.6.5). Building a calibration graph is time consuming, but in the long run the overall benefit of the calibration graph is that it will save time. The calibration graph can be quickly referenced so that manure application rates, equipment settings and travel speeds can be adjusted to meet a variety of field conditions.

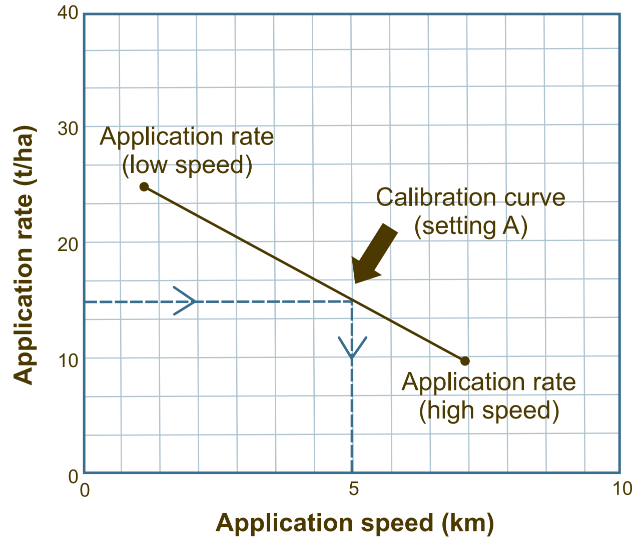


Figure 4.6.5 Identifying the Travel Speed from a Calibration Line.

Adjusting for Differences in Manure Density

Basically, if lower density manure is being applied, a higher travel speed is required to apply an equivalent amount of material that has a higher density. A calibration graph for a solid manure spreader, calibrated for a specific density of material can be used to determine the correct traveling speed for application of material with a different density.

If the density of the manure changes, the actual application rate can be derived from the vertical axis of the calibration graph by using the following equation.

'Reference' Application Rate
= Desired Application Rate (for the un-calibrated manure to be applied) x (Calibration Manure Density ÷ Density of Manure to be Applied)

tip

Completing this process can be very beneficial to custom manure applicators who are dealing with a variety of different types and densities of manure.

The equation will determine the manure 'reference' application rate that must be looked up, along the vertical axis of the calibration graph. A straight line can be drawn horizontally from this 'reference' application rate to the calibration line, for a given setting (Figure 4.6.6). From this identified point on the calibration line a vertical line can be drawn down identifying the travel speed, which will be required to achieve the desired application rate for the different density material.

For example, if the calibration curve was developed for manure with a density of 0.9 t/m^3 and the manure to be applied had a density of 0.45 t/m^3, the application rate of the new manure would have to be doubled in order to put on an equivalent amount of material. To double the application rate the application speed will have to be cut in half or settings adjusted. The calibration line can be used to determine the application speed needed to apply the desired rate of the lighter material.

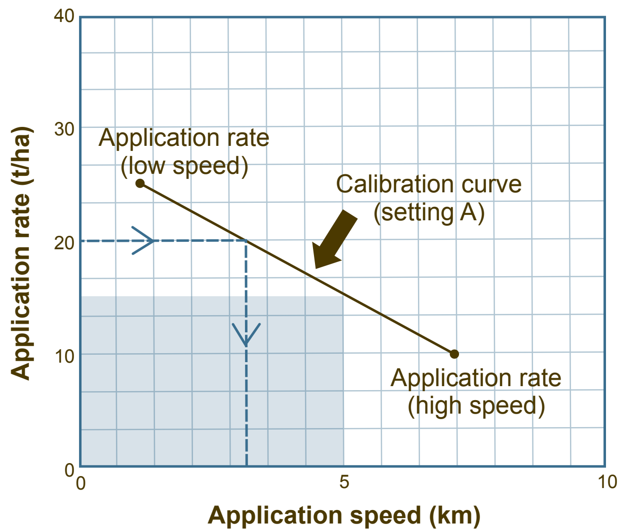


Figure 4.6.6 Using 'Reference' Application Rate to Determine Appropriate Application Speed.

Correcting Application Rate for New Manure Density in Order to Use an Existing Calibration Graph

A calibration graph for a solid manure spreader was based on cattle manure with a density of 0.72 t/m^3 (Figure 4.6.6). Sheep manure with a density of 0.56 t/m^3 is to be applied at a rate of 16 t/ha using the same spreader.

The 'reference' application rate needed to determine the appropriate speed using the existing calibration graph is calculated by:

'Reference' application rate (t/ha)

= 16 t/ha × (0.72 t/m^3 ÷ 0.56 t/m^3)

= 16 t/ha x (1.2857)

= 20.6 t/ha is the 'reference' application rate

The 'reference' application rate of 20.6 t/ha would be used on the vertical axis of the existing calibration graph to determine the appropriate speed for this particular applicator to apply the lighter sheep manure at a rate of 16 t/ha (Figure 4.6.6). This means that for this applicator to apply the lower density sheep manure, at a rate of 16 t/ha, this applicator would travel at the slower application speed needed as if it was applying 20.6 t/ha of the heavier cattle manure.

summary

- The load-area calibration is used for liquid manure injection systems and involves calculating the average area required to apply a single spreader load.
- The weight-area calibration involves weighing the amount of manure applied to a known area (usually plastic sheets, tarps or pans) and is used to calibrate surface application systems.
- Surface spreader passes should be approximately one effective spreader width apart to get relatively uniform coverage. Passes with injection equipment should be made immediately next to the previous.
- Altering the ground speed will change the application rate. If spreading solid manure, target ground speed must be corrected for differences in density between the manure to be applied and manure applied during the calibration.
- Calibration curves can be developed for spreaders with multiple settings by repeating the calibration for high and low speeds at each setting and graphing the results. This allows the selection of appropriate combinations of speed(s) and setting(s) to achieve a target application rate.