Estimating tractor power needs

This information paper provides guidance and calculation tools to enable you to determine the appropriate power (in kW or horsepower) that your field operations will require.

It will allow you to determine the size of the tractor that best suits your needs without being under- or over-powered. This is of critical importance, as a machine that's not well matched for the tasks it will perform is likely to operate inefficiently. This can lead to fuel waste or early breakdown.

Introduction

Tractors throughout Australia tend to be over-powered for the tasks they typically perform. This is likely because the most common approach farmers acquiring tractors have taken to date has been to opt for those with the highest 'horsepower-per-dollar' they can afford. This outdated tactic, however, may be a false economy, since smaller tractors may be as capable of handling the major tasks farmers require, and will save those who use them considerable amounts of fuel.

The following guidelines present a method by which you can determine the real power requirements of your farm's specific field operations. Nonetheless, it is imperative that you obtain additional advice from experts and local industry leaders so you can adapt the method to your specific needs and situation.

Step 1: Identify your 'priority critical field operation'

Complete a thorough review of your tractor's requirements in relation to its intended usage.

Begin by listing all the tasks you'll need the new machine to perform, such as: fertiliser/chemical application, tillage, loader work, PTO-driven operations, etc. Consider that an occasional high-horsepower task may not justify dragging extra tonnage around on a daily basis. It may be more cost-effective and fuel-efficient to subcontract out such tasks.

Review the list of tasks that the machine will perform and **identify the most critical operation that will require an implement with the highest draft force**.[1] You may wish to use Table 1 to help you estimate the draft force from various implements.

Step 2: Estimate the time you'll have available to complete this priority task

Determine the time period available (or the period expected) to complete your priority critical field operation.

As an illustration, your requirements may be for tillage work to be completed over the span of a week, working Monday through Friday, eight hours a day. This equates to having 40 hours available for the job.

Step 3: Find the work rate (hectares per hour)

Once you have determined the time available, you can calculate the required hectares-per-hour (ha/h) rate using your farm's dimensions. Continuing from our previous example, assume that the size of the field for tillage is 120 hectares. This means that the task must operate at the following rate:

$$\frac{120\ ha}{40\ h} = 3\ ha/h$$

Step 4: Determine the width of the implement required

The next step is to use the work rate of your operation (i.e. how many hectares you need to cover per hour) and the expected working speed of the job to determine the width of the implement required. This is given by the following equation:

$$\substack{required \\ implement\ width} = \frac{11.8 \times work\ rate\ (ha/h)}{working\ speed\ (km/h)}$$

The 'work factor' 11.8 is a dimensionless number that represents the number of hours required to cover an entire hectare when using a metre-wide implement, at 1 km/hr, assuming losses of 18 percent from overlapping, turning and other field inefficiencies[2]. Following from the previous example, let's establish that we'll be using an offset disc harrow to conduct primary tillage at 8 km/h. The required width of the offset disc plough can therefore be determined as follows:

$$\substack{required \\ implement\ width} = \frac{11.8 \times 3\ ha/h}{8\ km/h}$$

$$= 4.425\ m$$

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[1] Draft is a measure of the force imposed by the implement on the machine as it travels through the soil.

[2] You may calculate this factor yourself for differing efficiency values using the following equation:

$$\substack{work \\ factor} = \frac{1 + efficiency\ losses}{portion\ of\ hectare\ covered\ during\ an\ hour\ with\ 1\ m\ wide\ implement\ at\ 1\ km/h}$$

e.g.: For 18% field efficiency losses, $\substack{work \\ factor} = \frac{1+0.18}{0.1} = \frac{1.18}{0.1} = 11.8$

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Alternatively…

If you already know the size of the implement that will be used with your machine, you may wish to determine the work rate your equipment will allow for. You may do this using the following equation:

$$\underset{(ha/h)}{Work\ rate} = \frac{\underset{width\ (m)}{implement} \times \underset{(km/h)}{working\ speed}}{11.8}$$

If the resulting work rate is too low for your requirements, consider obtaining a wider implement

Step 5: Determine soil resistance

When conducting your priority field operation, identify the type of soil your field will have (i.e. clay, loamy or sandy). Use this information and Table 1 to find the resistance that will be offered by the soil per unit of width and depth (i.e. its draft force). Then calculate your total soil resistance by multiplying this measure by your expected working depth and the full length of the implement.

$$\underset{resistance}{Soil} = implement\ width \times working\ depth\ \times resistance\ per\ width$$

Expanding from our previous example, let's assume that the soil type is sandy, that our offset disc harrow is for primary tillage and that the working depth is 10 centimetres. Table 1 tells us that this particular implement for this soil type will present a draft force of 598 Newtons per metre of implement width, per centimetre of depth. Hence, for our total width of 4.425 metres and the 10-centimetre working depth, we have:

$$\underset{resistance}{Soil} = 4.425\ m\ \times 10\ cm\ \times 598\ Nm^{-1}cm^{-1}$$

$$\underset{resistance}{Soil} = 26{,}461.5\ N$$

Step 6: Determine power required at the drawbar

Our next step is to equate this pulling force into the power required at the drawbar from the machine. This is obtained by using the following equation:

$$\underset{drawbar\ power}{required} = \frac{\underset{resistance}{soil}\ (Newtons) \times \underset{speed}{working}\ (km/h)}{3{,}600}$$

The number 3,600 is a required conversion factor that must be used if the working speed is provided in km/hour. Alternatively, the equation can be simplified if the working speed is known in metres per second, as so:

$$\underset{drawbar\ power}{required} = \underset{resistance}{soil}\ (Newtons) \times \underset{speed}{working}\ (ms^{-1})$$

Following, once more, from our previous example, we determine that the drawbar power required is:

$$\underset{drawbar\ power}{required} = \frac{26{,}461.5\ N \times 8\ km/h}{3{,}600} = 58.803\ kW$$

Implement	Unit	speed km/h	Draft force for soil type (N/unit/cm depth)		
			Clay	Loamy	Sandy
Major tillage tools					
Subsoiler/manure injector					
Narrow point	tools	8	517	361	233
12-inch winged point	tools	8	669	468	301
Moldboard plough	metre	7	1,281	896	580
Chisel plough					
2-inch straight point	tools	8	201	172	131
3-inch shovel/14-inch sweep	tools	9	243	207	159
4-inch twisted shovel	tools	9	280	238	182
Sweep plough					
Primary tillage	metre	8	781	666	511
Secondary tillage	metre	8	517	437	333
Disk harrow, tandem					
Primary tillage	metre	9	672	592	529
Secondary tillage	metre	9	408	356	316
Disk harrow, offset					
Primary tillage	metre	8	770	672	598
Secondary tillage	metre	8	471	414	368
Disk gang, single					
Primary tillage	metre	9	224	195	172
Secondary tillage	metre	9	155	132	121
Coulters					
Smooth or ripple	tools	8	95	84	74
Bubble or flute	tools	8	114	100	89
Field cultivator					
Primary tillage	tools	8	88	75	58
Secondary tillage	tools	8	61	53	40
Row crop cultivator					
S-tine	rows	8	226	191	147
C-shank	rows	8	419	356	271
No-till	rows	8	730	620	475
Rod weeder	metre	7	362	310	236
Disk-bedder	rows	8	366	315	285
Minor tillage tools					
Rotary hoe	metre	11	305	305	305
Coil tine harrow	metre	8	115	115	115
Spike tooth harrow	metre	8	299	299	299
Spring tooth harrow	metre	8	1,046	1,046	1,046
Roller packer	metre	8	345	345	345
Roller harrow	metre	8	1,551	1,551	1,551
Land plane	metre	8	4,585	4,585	4,585
Seeding implements					
Row crop planter, prepared seedbed					
Mounted – seeding only	rows	8	242	242	242
Drawn – seeding only	rows	8	438	438	438
Drawn – seed, fertiliser, herbicides	rows	8	767	767	767
Row crop planter, no-till					
Seed, fertiliser, herbicides – 1 fluted coulter/row	rows	8	898	898	898
Row crop planter, zone-till					
Seed, fertiliser, herbicides – 3 fluted coulter/row	rows	8	1,809	1,809	1,809
Grain drill w/press wheels					
< 6.5 feet drill width	rows	8	198	198	198
6.5 to 10 feet drill width	rows	8	147	147	147
> 10 feet drill width	rows	8	54	54	54
Grain drill, no-till					
1 fluted coulter/row	rows	8	378	378	378
Hoe drill					
Primary tillage	metre	8	3,620	3,620	3,620
Secondary tillage	metre	8	1,724	1,724	1,724
Pneumatic drill	metre	10	2,155	2,155	2,155

Table 1: Draft and power requirements for tillage and seeding implements Adapted by NSW Farmers from (Williams, 2007).

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Step 7: Determine the PTO power required

The final step is to determine the power that your machine should have at the power-take-off point (PTO) so that it can achieve the required power at the drawbar. This is calculated using a rule-of-thumb multiplying factor, which takes into account the type of soil condition you will experience. These multiplying factors are shown in Table 2 (below).

Soil condition	Multiply drawbar kW by
Firm, untilled soil	1.5
Previously tilled soil	1.8
Soft or sandy soil	2.1

Table 2: PTO power multiplication factors for different soil conditions. From (Williams, 2007).

$$\begin{matrix} Required \\ PTO\ power \end{matrix} = \begin{matrix} required \\ drawbar\ power \end{matrix} \times multiplying\ factor$$

For our running example, we will assume that conditions are for untilled soil. This means that our final PTO power requirement is given by:

$$\begin{matrix} Required \\ PTO\ power \end{matrix} = 58.803\ kW \times 1.5 = \mathbf{88.205\ kW}\ (118.28\ hp)$$

Step 8: Adjust for further considerations

Before finalising your goal power, consider the following:

- The outcome produced by the previous steps is representative of the **minimum** power requirements for the set conditions that were inputted into the calculations. Different soil conditions, inefficiencies and various other set-up variables (hydraulics, driving methods, etc.) will play a role, and can substantially influence the real power that will be available and that will be required for a given task.
- To operate correctly, certain implements may require minimum PTO power and engine speeds. Consult your implement's specifications to identify such cases.
- Continuously using a machine that is underpowered for the tasks it undertakes will damage it and decrease its lifespan.
- When taking advice or considering power requirements, it's important to remember that most engines are at their most fuel-efficient when working at 80 percent of their rated 'max' power output. Operation at or around 80 percent of full power will provide both optimal fuel efficiency and the promotion of a long, productive service life. Likewise, running an engine at light loads (30–50% of rated capacity) may not be the most fuel-efficient method for completing the task. Consider using a lower-powered tractor where possible.

Given this, we recommend that you increase the goal power calculated in the previous steps by 10 to 15 percent.

However, as noted previously, experts say that tractors throughout Australia tend to be oversized for the tasks they perform. Moreover, running an engine at light loads (30–50% of rated capacity) may not be the most fuel-efficient method for completing a task. It is therefore crucial that you consider the realistic scenarios you expect to perform with your tractor, and use a lower-powered tractor wherever possible.

PTO versus engine power

Be careful with power metrics as they may be expressed differently for different machines! For 2WD and MFWD tractors, rated power is usually stated at the power take-off (PTO). For 4WD tractors, however, rated power is typically quoted at the engine (engine power). PTO power is approximately equal to 85 percent of engine power (Michelin North America, Inc., 2001).

Further information

Calculator tool

The NSW Farmers' Association tractor power calculation tool is available to assist you in following the guidelines instanced in this paper, and is available in an easy spreadsheet format. You may download it by visiting the following link:

http://www.aginnovators.org.au/sites/default/files/ AgInnovators - Tractor Power Calculator.xlsx

References

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