Adaptive driving – the skill factor in fuel efficiency

Driver skill is a central element in achieving farm fuel efficiency. Modern diesel-engine tractors typically maximise their efficiency when operated within 60 to 80 percent of their rated power output. Maintaining this range requires skill and attention from the operator. Key factors in achieving efficient driving practices on farm are: driver skill, awareness and motivation; feedback systems provided by the machinery; and logging and analysing fuel consumption regularly. Fuel savings greater than 20 percent can be achieved in some situations.

What is adaptive driving?

'Adaptive driving' is a term used to describe a driving style characterised by awareness of and responsiveness to the machine and the operating environment.

If you habitually use higher powered gear and RPM combinations than are needed for the task at hand, you are likely to be using more fuel than necessary. A key technique in this regard is operating machines at higher gears in light load operations using the 'gear up, throttle down' (GUTD) method (detailed below).

Studies have shown that failing to drive 'adaptively' can increase fuel consumption by more than 20 percent (Intelligent Energy Europe, 2012). For most broadacre farmers, that could amount to wastage of tens of thousands of dollars per year.

Some tractors and harvesters operate almost completely autonomously, requiring little input from the operator. Nonetheless, it is important that even these machines be operated appropriately. In the case of non-automated machines, an operator's driving skill is of extreme importance.

The main factors in implementing adaptive driving practices are:

- driver skill , awareness and motivation;
- feedback systems provided by the machinery; and
- identifying good operators and driving practices by routinely logging and analysing fuel consumption.

Skill, awareness and motivation

Most farm owners have an intimate knowledge of their machinery and how to operate it efficiently. Farm staff, however, are likely to have varying skills and motivation when it comes to adaptive driving. The following management checklist may be helpful:

- Make it clear to staff that fuel efficiency is a priority and that you are monitoring their fuel consumption.
- Ensure that staff understand and use the feedback systems provided by the machines they operate.
- Praise and reward skilled operators.
- Ensure your staff understand and apply the 'gear up and throttle down' principle, when required.

Quick tips

- **Know your tractor.** Make sure you are aware of your tractor's performance and fuel consumption characteristics.
- **Bells and whistles!** Use the performance monitoring equipment fitted to the tractor.
- **Gather/use fuel-use data to compare against benchmarks and different driving styles.** Use your tractor's available data logging and telemetry electronics to observe what happens when you make changes in driving methods or swap operators.
- **Provide training.** Train your staff yourself, or investigate driving courses they can attend.
- **Operate at the '80 percent' point.** Where possible, operate engines within 80 percent of maximum capacity. This provides the engine with an additional torque region for spike loadings and ensures good overall fuel consumption.
- **Use the gear up and throttle down (GUTD) method when required.** GUTD is particularly useful in reducing fuel use when employing large tractors for low-load tasks.
- **Set up the tractor right from the word go.** Add/remove ballast when required and adjust tyre pressures to improve traction. Keep an eye on wheel slip to ensure your set-up is optimised properly. And ensure that any implements are correctly hitched and providing an even-level pull.
- **Consult manufacturers.** Dealers and manufactures can offer valuable advice and tips specific to your machines.
- **Discourage operators from 'tuning out'.** Listening to music and other distractions may prevent them from receiving feedback on engine performance.

Training staff

The most efficient way to teach adaptive driving is through demonstration, using the particular machines and tasks.

Driving skill is not the only factor contributing to fuel efficiency. In newer machines, technology plays a key role in providing operators with the feedback they need to practice adaptive driving. Training, therefore, must include skills in interpreting and reacting to the feedback provided by tractor instrumentation.

If you are not able to conduct such training yourself, consider providing external training or hiring staff who already have appropriate training in adaptive driving.

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All equipment suppliers should provide after-sale support in learning to operate their machinery. In addition, some manufacturers run workshops on efficient or 'eco' driving.

The Department of Primary Industries and other organisations offer tractor operation courses. The competency unit you should look for in this regard is **RIIMPO315D – Conduct tractor operations** (see *Further information*, below).

Figure 1: Adaptive driving considerations vary based on the task at hand.

Driver awareness

The level of awareness and continuous attention required to implement adaptive driving varies widely across tasks and operating environments. Part of operator training is demonstrating the appropriate level of focus, and where and when it is OK and not OK to relax.

Make it clear that operators must pay an acceptable level of attention to the task, and demonstrate specific parts of your operations – for example, handling turns and slopes – that require higher levels of attention.

Provide encouragement

A final key factor is motivation. Provide feedback and support to your operators. If you have collected fuel consumption information, think about sharing and commenting on any trends you have observed. Ask operators about previous experience in driving the machines they'll be using and identify whether there's room for improvement. If there is, think about how you can incentivise operators to perform even better (cash rewards are not always the best solution, but are an option you could explore).

Feedback systems

Adaptive driving depends on the operator (and his or her manager) receiving accurate feedback on both engine performance and driver performance. Depending on the age and capabilities of the tractor, the key sources of data are:

- in-cab, real-time monitoring of engine performance,
- listening to and feeling the engine, and
- learning the specific signals that tell you the limits of RPM reduction possible for given gearing and loads (although engine sound can be misleading – see *Engine load curve*, below).

It is important that your staff know the conditions that require them to react to equipment feedback. They must understand and have a plan on how to respond to various conditions, and to the signals given by the machine and/or its systems.

Fuel records and benchmarking

Logging fuel use by machine, task, date and operator is a key fuel-efficiency tool. It will help identify efficient driving conditions and styles, as well as keeping track of your fuel use for general farm energy planning.

Some modern tractors can automate the collection of this data via their telemetry and transport management systems (TMS). Make sure you know how to operate these systems correctly, and that the infrastructure needed to support them is available on your paddock (some TMS utilise cellular networks or wi-fi to communicate and upload data).

If automated systems are not available, a table such as the one below can be helpful for recording fuel use information.

Date	Time		Elapsed time	Description (plot, operation, implements used, operating conditions, working depth)	Area	Diesel consumption		
	From	Until	(h)		(ha)	(L)	(L/h)	(L/ha)
14 Nov 2013	09.30	15.45	6.25	Hill paddock, cutting, front-rear combination, first cut, 6 cm	16	82	13.12	5.125

Table 1: Data collection table. Adapted from (Handler, et al., 2012).

Remember: the real measure of fuel efficiency is **litres per hectare**, not litres per hour. Using less fuel per hour but taking more time to complete a task may mean fuel savings are not being achieved.

Once you've obtained information regarding average fuel use from your tractors and other vehicles, a first point of analysis should be to compare this fuel use against available benchmarks. Table 2 shows measured diesel consumption per hectare from various Australian farm operations. Comparing your recorded fuel use information with these typical consumption rates may help you to identify where there is room for improvement.

Figure 2: Adaptive driving may not necessarily be a key factor for harvesters or for tractors operating in predominantly power take-off mode, since the dominant power use here is not related to driving style.

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Working process/machinery	Use	Working process/machinery	Use
Soil cultivation		Rotary mower for cultivating	5 L/ha
Ploughing – light soil	15 L/ha	Rotary mower + mowing conditioner	6 L/ha
Ploughing – average soil	23 L/ha	Automatic mower + mowing conditioner	6 L/ha
Ploughing –heavy soil	40 L/ha	Rotary tedder	3 L/ha
Deep tilling (soil loosening)	21 L/ha	Rotary hay rake	4 L/ha
Stubble processing with grubber	9 L/ha	Loader for lifting of air-dried hay	7 L/ha
Deep grubbing	15 L/ha	Loader for lifting of wilted silage	9 L/ha
Spring tine harrow (fine grubbing)	7 L/ha	Exact forage harvester	12 L/ha
Harrow with seedbed combination	6 L/ha	Pressing of silage round bales	0.70 L/ha
Disc harrow	7 L/ha	Swathing of bales	0.40 L/ha
Rotary tiller	10 L/ha	**Fodder harvesting – silage maize**	
Milling	12 L/ha	Exact forage harvester	34 L/ha
Sowing		**Harvesting**	
Single grain seed	5 L/ha	Cereals, sunflowers, rape, field beans	22 L/ha
Mulch-single grain seed-maize	11 L/ha	Peas	27 L/ha
Drilling seed	5 L/ha	Corn (maize)	25 l/ha
Comb. rotary harrow + sower	15 L/ha	**Pressing of droughty goods (straw/hay)**	
Comb. milling + sower		High-pressure compressor (13 kg/bale)	0.02 L/ha
Comb. dovetailing rotor + sower		Round bale (250 kg/bale)	0.5 L/ha
Direct sowing	9 L/ha	Cuboid bale (200 kg/bale)	0.4 L/ha
Planting potatoes, semi-automatic	20 L/ha	Potato harvester	52 L/ha
Planting potatoes, fully automatic	15 L/ha	Potato harvester – self-propelling	51 L/ha
Fertilisation		Potato-clearing loader	32 L/ha
Tractor-mounted rotating spreader	1.5 L/ha	Potato-clearing loader – self-propelling	39 L/ha
Mounted pneumatic spreader	2.5 L/ha	Sugar beet harvester	49 L/ha
Sowing of calcium	2.5 L/ha	Sugar beet harvester – self-propelling	53 L/ha
Chemical plant protection		**Pomiculture**	
Agricultural sprayer	2 L/ha	Mulching – flail mower	10 L/ha
Mechanical plant protection		Flail mower for winter cut	26 L/ha
Harrowing	3.5 L/ha	Plant protection – tractor sprayer	7 L/ha
Cultivating maize (hoe machine)	4 L/ha	Chemical fertilisation – distributor	7.5 L/ha
Cultivating maize (cultivator)	5 L/ha	**Viniculture (fruits)**	
Cultivating and harrowing	5.5 L/ha	Milling small lanes	11 L/ha
Cultivating beets	5 L/ha	Cutting leaves	8 L/ha
Accumulating potatoes	5 L/ha	Mulching – flail mower	12 L/ha
Flame treatment	4 L/ha	Plant protection – tractor sprayer	5 L/ha
Maintenance		Earthing up / ploughing of vineyards	20 L/ha
Towing	4 L/ha	Clearing vineyards	18 L/ha
Rolling	3.5 L/ha	Subsoiling (rotary plough)	20 L/ha
Output of farm fertiliser		Vintage with vine harvester	20 L/ha
Spreading manure	14 L/ha	Cultivating	11 L/ha
Vacuum tank lorry	6 L/ha	Sowing of plants and grass	3 L/ha
Pump vat – towing pipe	7 L/ha	Cutting of vines	7 L/ha
Fodder harvesting – meadow land		Rolling	4 L/ha
Cutterbar mower cultivation	3 L/ha		

Table 2: Fuel consumption for different agricultural works (Austrian Council for Agricultural Engineering and Rural Development (ÖKL), 2008).

Gear up and throttle down

The key technique to master in adaptive driving is known as 'gear up and throttle down' (GUTD). In practice, this means using the highest gear and lowest revs that the load permits. One should avoid using small implements with large tractors; however, the GUTD method may improve fuel efficiency in cases where this is unavoidable.

Comparative field studies using dynamometers fitted to tractors have found that in lighter load situations, lowering the engine speed by shifting to a higher gear can save 10 to 15 percent of fuel (Intelligent Energy Europe, 2012). This finding is reinforced by studies conducted by the University of Nebraska, as detailed in Table 3 below.

Tractor model	Drive style	% fuel saved (75%–55% load)
245	Front-wheel assist	10–20
435	Front-wheel assist	11–14
655	4WD	11–14
8220	Front-wheel assist	15–18
9330	4WD	9–11

Table 3: Fuel savings achievable from correct gearing (University of Nebraska-Lincoln, n.d.).

A number of field operations, such as light tillage, planting, cultivating, spraying and hay raking, do not require full tractor power and therefore can be undertaken at lower RPM. GUTD can be used for these light load operations and for other activities that require less than 75 percent of full engine power (Virginia Polytechnic Institute and State University, 2011).

PTO operations

The GUTD method will not suit all tractor operations.

Certain PTO implements require high engine speeds and are incompatible with the GUTD method. When evaluating options for new purchases, make a point of clarifying how energy efficiency is optimised for PTO applications and how the PTO impacts general engine efficiency.

Don't overload the engine!

The most basic efficiency measure is to avoid overloading the engine by using a gear that is too high for the task. We hope you won't have to explain to operators that they should change to a lower gear if any of the following occurs:

- thick/black smoke starts coming from the exhaust,
- increasing the throttle does not result in a responsive increase in speed, or
- the engine begins to make lugging noises.

The engine load curve

For maximum operating efficiency, an engine should be operated at close to its rated capacity. This means using gearing to maintain an optimal engine speed for the desired ground speed. Modern diesel engine tractors typically maximise their efficiency when operated within 60 and 80 percent of both their rated power output and their engine speed. Relying on engine noise for feedback may result in working at higher engine speeds than are necessary.

It is also vitally important to ensure that the engine's working speed is maintained at the required torque/power for the task, and that the correct transmission ratio is matched so as to maintain work speed and the quality of the operation.

Maximising efficiency is not always simple, since every tractor will have its unique power and fuel consumption profile. We recommend that you obtain this profile from the manufacturer.

Figure 3 depicts a typical full load profile of a tractor, and illustrates that efficient performance is achieved at around 80 percent of the maximum engine speed.

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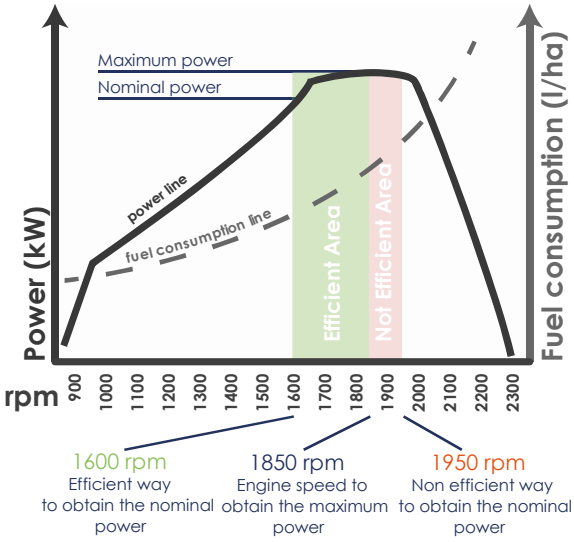

Figure 3: Full Load Curve – the relation between power and engine RPM to fuel consumption. Adapted *from (Handler, et al., 2012). This example shows that lowering the engine speed from 1,850 RPM to 1,600 RPM will achieve a near-identical power output but result in a substantial drop in fuel use per hectare.*

Comparing the manufacturer's load curve data to what you are hearing will help you optimise performance and give you confidence to operate at lower RPM.

Certain technologies, such as continually variable transmissions, will improve fuel efficiencies in most cases. If you are in the market for a tractor, consider buying one that has this type of technology.

Safety

It is essential to refer to your tractor's operator's manual and consult with your dealer or tractor's manufacturer before implementing any driving strategy. Always take appropriate safety precautions when changing the way you operate any machinery.

Acknowledgements

NSW Farmers thanks Mark Francis, Business Manager at New Holland Agriculture, for his input to this paper.

Further information

DPI course on safe tractor operation and maintenance
www.dpi.nsw.gov.au/agriculture/profarm/courses/safe-tractor-operation

List of organisations approved to deliver the 'RIIMPO315D - Conduct tractor operations' course
training.gov.au/Search/SearchOrganisation?nrtCodeTitle=RIIMPO315D&scopeItem=Unit&tabIndex=1&ImplicitNrtScope=True&orgSearchByScopeSubmit=Search

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