Controlled Traffic

Common Sense or Nonsense

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Introduction

If there is any one unit that characterises modern extensive agriculture, it is the large tractor. The tractor and the traction process are central to our mechanisation systems, so a great deal of time has been invested in the study of traction, tractive efficiency and the economic performance of tractors.

In working on tractor performance, its easy to miss the point of the whole exercise - to achieve optimal crop performance at minimum cost. This was missed in some of our early tractor performance/reliability surveys in the late 1970s, at least until performance was defined in terms of the minimum cost to plant a given crop area.

The defining moment in this work occurred when a grower pointed out that his new 15 tonne 4WD helped him avoid soil compaction by allowing him to start work later after rain. The idea of using a bigger tractor to beat soil compaction is not nonsense, but it helps concentrate the mind!

We took our first tentative steps in controlled traffic at about that time, aware of some of the original work on cotton in the USA, and potatoes in Scotland. When it was publicised, however, growers soon let us know that they thought; and a small number phoned to say they had been bed farming for some time. A much larger number pointed out all the reasons why it couldn't work!

In this paper I will describe what happens under a tractor tyre or track, then use result from our tractor survey to illustrate the magnitude of the costs of uncontrolled, 'random' traffic. A brief consideration of the options leads to the unsurprising conclusion that we must control tractor traffic, and discussion of the other 'system' benefits that follow from controlled traffic.

Traction, Compaction and Energy

Traction, or the development of thrust from wheels or tracks operating on yielding surfaces, is inherently inefficient. Tractive efficiency of 4WD tractors ranges from approximately 70% on tilled soil, to 85% on firm soil. For most practical purposes, in operations such as planting, we can expect tractive efficiency to be between 75% and 80%. Typically, about 10% of power is lost in slip, and about 15% of power is used to keep the tractor itself moving (i.e. lost in rolling resistance).

When we look at what is actually going on underneath the tyre or track, simple observation of rut depths and soil horizontal movement shows that trafficed soil is moved about 30-50 mm downward and the about the same distance backwards. It is this deformation within the soil that absorbs most of the wasted power.

Soil is highly non-uniform under normal tillage/planting conditions, because field operation can't start after rain until the surface soil is trafficable. The surface layer is usually quite dry, but soil within the tilled layer will be at a moisture content below field capacity, having drained for some days after rainfall. Soil at the bottom of this layer, and at the top of the sub-tillage layer might be at a greater moisture content. The precise moisture profile will depend on several factors, including time after rain, but moisture content and previous disturbance largely determine a soils susceptibility to deformation.

When trafficed, energy lost in the traction process is absorbed in deforming soil. At the dry surface, this is likely to amount to a grinding/powdering action, although tyre lugs can sometimes cause some loosening. As Peter Walsh has demonstrated, most soil·movement occurs within the tilled layer, but some movement also occurs in the sub-tillage zone. In moist soil this will usually be a damaging shearing and densification, which will be a problem in soils that do not self-repair rapidly.

The implement following the tractor hides the surface and tilled layer wheeltrack effects very efficiently. We identify a "compaction" problem in the sub-tillage zone only because we can see it, i.e. we did not operate at sufficient depth to remove all of the wheeltrack effect. Its easy to forget that most soil 'compaction' occurs in the tilled layer and is broken up immediately by the implement.

Only recently have we started making measurements of the increased energy required to till trafficed soil. Initial measurements were made simply by lifting and lowering the wheeltrack tines of a chisel plough. The draft effect was so large, that we doubted our technique. Subsequently we have made a 3 point linkage unit which allows direct comparison of the draft of the wheeltrack tines with the draft of identical (control) tines, at the same depth, but well outside the wheeltrack.

At very shallow tillage depths, the draft of the wheeltrack tine can be less than that of control tines. At normal tillage depths (~100 mm) the wheeltrack effect can more than double tine draft, and when tines operate at depths >150 mm, the increased draft can be very substantial. In recent measurements, for instance, narrow (50 mm) tines operating at a depth of 220 mm required an additional 4 kN of draft each to till the wheeltrack centreline behind 16.4 x 38 tyres with an axle load of 5 t. The magnitude of this effect has varied with tillage depth, moisture content and prior tillage.

Our results suggest that the best generalisation of wheeltrack effects in normal broadacre tillage conditions is an increase in the draft of wheeltrack tines by a factor of two. At greater tillage depths the additional draft is often similar to the apparent rolling resistance of the tyres ahead of the tines. There is a nice symmetry in the thought that the additional draft of wheeltrack tines might be similar to the rolling resistance of the wheel that created the wheeltrack, when the tine is operating deep enough to break up most of the wheeltrack.

Wheel Traffic Costs

We can use data from our performance/reliability survey to assess the significance of this wheeltrack energy effect. These show, for instance, that the average broadacre 4WD tractor of 160 kW available power was delivering 120 kW to its axles, of which 90 kW was transmitted to the implement. The tractor was moving at 7.2 km/h, its mass of 13.0/tonnes carried on dual tyres wheeling a 1.8 m strip. The typical implement was a 9 m chisel plough requiring 45 kN pull, with a mass of more than 5 tonnes, itself wheeling a 1.2 m strip.

If we look carefully at this situation, in terms of where the power is going, our data indicates that the specific draft required for chisel tillage on non-compacted soil would be only 3.3 kN/m, which is 30 kN for the whole 9 m implement. In other words if we could fit our chisel tines to the linkage of a Nebraska-tested hovercraft, it would need a pull of only 30 kN!

This would represent a drawbar power of 60 kW. The other 30 kW were used in the wheeltracks produced by the tractor and implement, because:-

- prior wheeling doubled the draft on a 3 m strip, increasing pull by 10 kN, requiring 20 kW.
- rolling resistance of the 5 tonne chisel plough frame would exceed 5 kN, requiring 10 kW.

In other words, 30 kW, or one third of what we regard as implement input power, is used to no good purpose in the wheeltracks. These have already absorbed a 'tractive inefficiency' of 30 kW from the tractor, so the total power input to making and breaking up wheeltracks is 60 kW.

These figures are based on some approximations, and they have been rounded to keep the argument simple. It is nevertheless broadly true that <u>half</u> the power delivered to a tractor's wheels is wasted in compacting and decompacting wheeltracks.

The bad news becomes worse when we remember that our broadacre tillage doesn't remove deeper compaction, and re-loosening of compacted surface soil is unlikely to provide an optimal seed bed.

The good news is that <u>if</u> we can effectively control field traffic, we will achieve the same work rate doing the same job, with a tractor of half the size. This represents a major economy, which gets even better when we consider the reduction in tillage depth and intensity which will occur in the absence of wheeltrack effects.

<u>Compaction - Problems and Solutions</u>

Soil compaction has been identified as an important factor affecting yield of intensive crops, but information relevant to the broadacre situation is less convincing. For the purposes of this paper I regard it as a problem because:-

- Compaction does not always reduce yield, but it almost never increases it.
- Traffic compaction increases tillage/planting costs, as outlined above, <u>and</u>
- Compaction reduces infiltration, with negative effects on erosion and soil water availability.

Compaction is only loosely defined here in terms of the effect of existing tyre/track options on soil and crop. Options for avoiding soil compaction fall into three general categories:

- Reducing ground pressure: Current problems occur with tyre pressures of 80-120 kPa (i.e. 12-18 psi), so reducing pressure should reduce the problem. Some success has been achieved with lower pressures tyres, but these appear impractical for large tractors or harvesters. Within the range of pressures permitted in conventional tyres, most research indicates that soil damage is a function of axle load, rather than tyre pressure.

- Avoid operation on wet soil: Irrigators have some capacity to schedule operations in relation to soil moisture, but broadacre agriculture has no such flexibility. Tractor/implement operating capacity is determined by the time available between the ground first being trafficable, and the point when soil moisture content is too low. The fixed end point to this process means that delay in starting requires a bigger tractor to complete the job in time.
- Reduce trafficed area. We can reduce this by reducing the number of field operations with minimum or zero till, or by reducing the width of the traffic zone in relation to implement width. This is what we achieve by replacing dual tyres with steel or rubber tracks. It is effective in reducing trafficed area, but at some cost in terms of equipment purchase price. It is a step in the right direction, but we still have the problem of heavily loaded implement and grain harvester wheels.

Each option has major problems. We've got to get on the paddock at the right time to carry out cropping operations, and farming equipment is too heavy to carry on hovercraft, but the costs and consequences of random traffic are excessive. Controlled traffic, or the use of permanent traffic lanes, becomes the best option.

In most controlled traffic systems we sacrifice production from the soil zone used as a wheeltrack. This means there is some loss of area in which to grow crops. Yield loss is likely to be compensated by improved production from untrafficed soil, and reduced costs, but it is obviously desirable to minimise traffic lane the area. This can be achieved by spreading the lanes further apart, reducing lane width and improving steering accuracy. Given the practical minimum tyre width of 0.5 m, we could set our traffic lanes at 2 m, and sacrifice 25% of potential crop area, but if we need furrows at 2 m for irrigation, this is no loss. If we could spread wheels to 4 m, the area lost reduces to 12.5%.

Practical considerations will dictate the choice of spacing used, but it will usually be more flexible and convenient to have a modular system, in which wheeltracks are uniformly spaced across the paddock. Spacings around 3 m are often compatible with commonly available tractors and harvesters, although some modification is usually needed to one or the other.

Precision Controlled Traffic

Implement wheels currently serve to carry the weight of the implement and to provide depth control. In controlled traffic systems permanent traffic lanes are likely to be below the paddock surface. Unless they are depressed by a precise distance, some alternative depth control system will be required. Precision in steering and depth control represents the major problem and the major opportunity of controlled traffic.

- A problem, because without some reasonable level of steering precision, traffic cannot be effectively controlled.
- An opportunity because effective guidance and depth control will provide a range of new options for crop-soil management.

These are exciting times, because practical, precision guidance systems are being developed to reality at USQ, while UQG is looking at what can be achieved given greater precision. Precision controlled traffic will allow us to treat narrow-spaced crops like rowcrops in terms of weed and insect control. Planting between the previous crop rows will allow simpler planters to work in heavy residue conditions, and accurate depth control will change the nature of tillage.

Controlled traffic will also affect timeliness. In many cropping situations, the first time at which an operation can take place is determined by trafficability considerations. We can't plant immediately after rain, not because the planter won't work, but because the tractor would make too much mess. Controlled traffic on compacted, fixed laneways will allow access to a paddock more rapidly after rain, always provided those traffic lanes are self draining. Similar considerations apply to spraying, and even harvesting after rain.

Like any new system, controlled traffic sounds wonderful in theory. The problem is to put it into practice, and growers are rightly cautious about a new technology with some obvious risks. Fortunately controlled traffic will not usually entail a major investment in the initial stages: its more likely to involve a new implement than a new tractor, although tractor/implement guidance systems will be recognised as increasingly valuable. The first priority is to get controlled traffic going using modified tractors, but the gantry will increasingly be seen as the obvious next step.

Controlled traffic will have a major effect on the farm equipment industry. Currently it would be easily to believe that weight and robustness are the most important characteristics of their products, but robustness and weight are really required largely as a consequence of the unpredictable loads caused by soil compaction and poor depth control. As controlled traffic systems become more common, we can expect to see a rapid increase in the level of technology used by the farm equipment industry. Precision controlled traffic will rely on guidance, rather than brute force, to provide optimum conditions for crop production.

Conclusion

Current random traffic cropping systems waste energy, money and good soil structure in the continuing conflict between the requirements of traffic and crop production.

Controlled traffic will enhance the economic and environmental sustainability of agriculture, as we manage permanent beds for optimum crop production, and compacted laneways for traffic and runoff control.

Australia has probably made greater strides than other countries in the development of extensive controlled traffic. It would be good to think this might result in economic opportunities for both farmers and machine manufacturers.