

Permanent Beds for Vegetables Farmer Guidelines



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Overseas people helped build our knowledge too, including John Luna, Paul Blackwell, Don Yule, John McPhee and Chris Bluett.

Introduction

During the life of a crop many different machines and wheels may pass over the soil surface. Under conventional cropping systems, it is common for machines to have different wheel track and implement widths.

As a result, most of the paddock may be driven on and compacted. Most compaction damage occurs with the first pass. Compacted soil causes poor plant growth, poor water infiltration and is costly to restore.



Figure 1 Harvester and trailer making use of permanent tracks.

With conventional techniques, operations can be imprecise and row spacings are variable. This can result in overlapping with wasted inputs and gaps in which yield is lost and pests and weeds are encouraged.

When new rows are established for the following crop, remedial tillage is required to address wheel track compaction. This is energy intensive and expensive, and is often only partially successful.

Permanent bed cropping

Permanent bed cropping keeps all traffic to defined wheel tracks. Like tramlining or Controlled Traffic Farming, it allocates separate areas for machinery and plants, so that ideal conditions are maintained for both driving and growing.

Permanent bed systems establish wheel tracks or tramlines that are retained year after year. The beds themselves may be

temporary (established for a given crop and removed after harvest), semi-permanent or permanent.

All traffic and compaction is kept to defined wheel tracks that provide the best surface for machinery operation. The un-driven-on soil remains in optimal condition for plant growth, reducing or eliminating the need to cultivate.



Figure 2 Onion beds are a form of Controlled Traffic by default

Permanent beds can provide beneficial changes in soil quality, reducing cultivation requirements and costs while potentially lifting yields. The benefits gained will depend on the level of system adoption.

Permanent bed cropping does not always use GPS. But

high accuracy GPS and machine guidance makes controlling traffic easier, and offers many other revolutionary opportunities.

Advantages

Perhaps the first benefits of permanent beds are that it reduces soil compaction and reduces fuel consumption because less cultivation is required to create suitable tilth.

Flow-on benefits as soil structure recovers include measurable improvement in water infiltration and storage, and healthier biology.

Better Soils

Growers have observed that runoff is cleaner from permanent beds, indicating reduced loss of fine sediments and nutrients.

Keeping traffic off the growing area helps keep soil in prime condition for crop growth. Fewer passes are required.

In non-compacted growing areas, minimal cultivation, if any, is required to obtain a suitable seed bed.

Soil with improved structure has better internal drainage, and copes better with adverse weather conditions. Crops experience less stress, resulting in higher yields.



Figure 3 Untrafficked soil requires less cultivation and remains in top condition after harvest

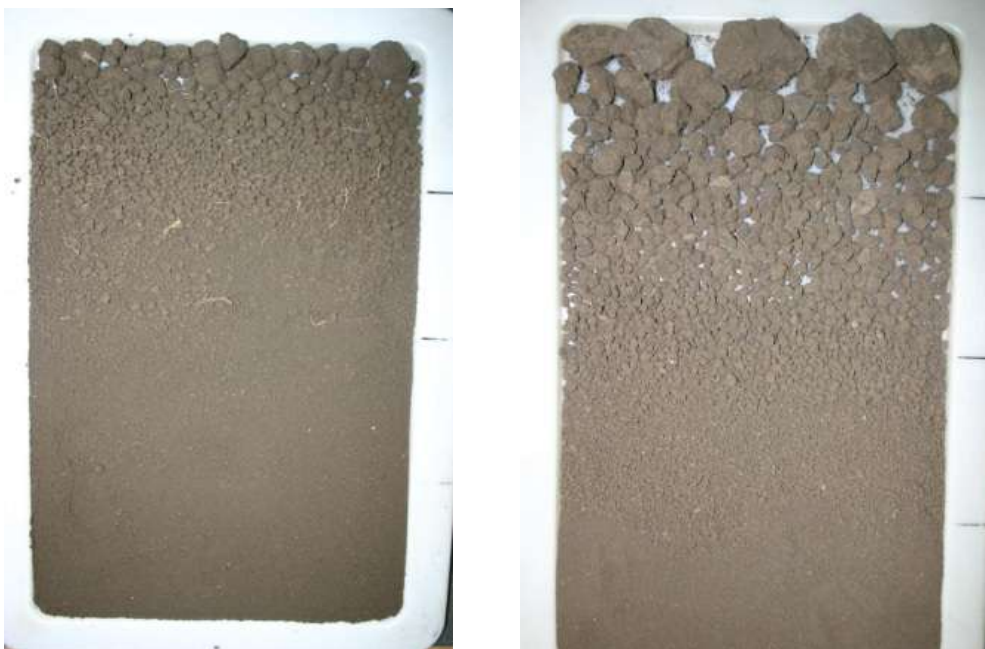


Figure 4 On the left, the soil from permanent beds shows less compaction and better structure compared with compacted soil under conventional management. Note: Heavy peds provide a poorer root environment and take more energy to cultivate.

Better Trafficking

Consolidated wheel tracks have lower rolling resistance and wheel slip than cultivated soil. Firm ground is able to support higher axle loads, so tramlines also allow safe machinery access in wetter conditions.

Under normal conditions, narrower tyres can be used to carry the same loads.

Consolidated wheel tracks increase traction and un-compacted growing soil reduces cultivation draught. Less draught horsepower, less time and less fuel are required. All lead to better gross margins.

Firm tramlines reduce rolling resistance and carry traffic better than less compacted tracks or beds

Accurate tramlining enables the use of other techniques, such as band spraying and mechanical weeding.

Band spraying allows more expensive agrochemicals to be directed to specific areas, with cheaper products used in inter-rows.

Highly accurate mechanical weeding offers an alternative to herbicides, reduces need for herbicides and reduces the amount of hand labour needed.

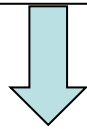


Figure 5 Tramlines provide a solid driving surface that reduces rolling resistance and better supports vehicle weight

**Permanent Beds and
Controlled Traffic Farming**

Better growing conditions

Better machinery conditions



Less total compaction
Better drainage
More uniform crop
Higher reliable yield
Compatibility with

- Raised beds
- No-till

Less tractor capital
Lower input costs

- labour
- fuel
- fert

Less driving fatigue
Apply row techniques

So **BETTER INCOME**

LOWER COSTS



BETTER GROSS MARGIN

**Better Yield & Quality + Lower Costs
Better Profit**

Relative soil compaction

Most compaction (80%) occurs the first time a vehicle passes over the soil. Subsequent passes have less additional impact.

A simple exercise illustrates the difference between conventional and permanent bed approaches. Consider a crop requiring a single cultivation pass, planting, single spray and harvest.

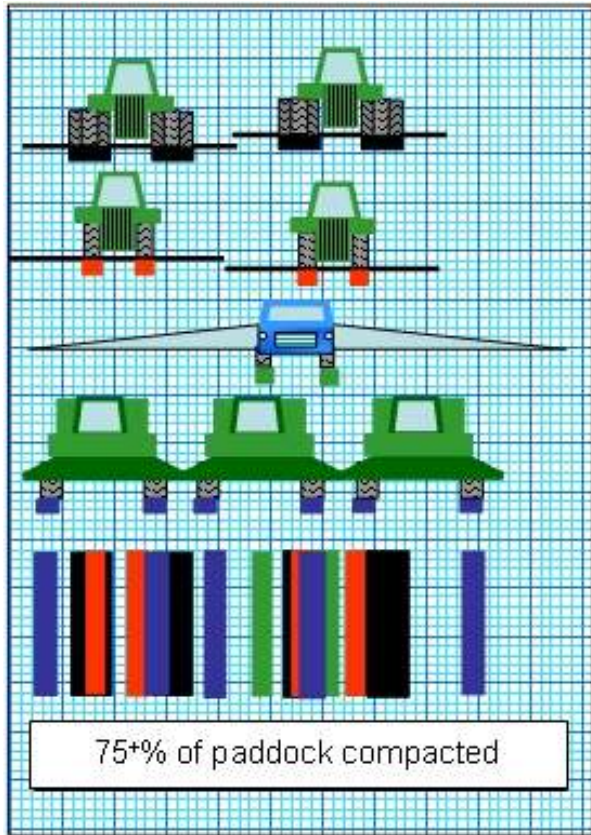
In a conventional system (Diagram A), a 3 bed cultivator, 2 bed planter, 5 bed sprayer and 1.5 bed wide harvester were used. These compacted 70% or more of the soil with no chaser bin being used. Around 50% was compacted before or during crop growth.

A permanent bed solution (Diagram B) would match cultivation, planter and harvester widths at 3 beds, with tractor wheel centres that match the harvester. The sprayer could cover 8 or 12 beds, by traveling on alternate pairs of tramlines.

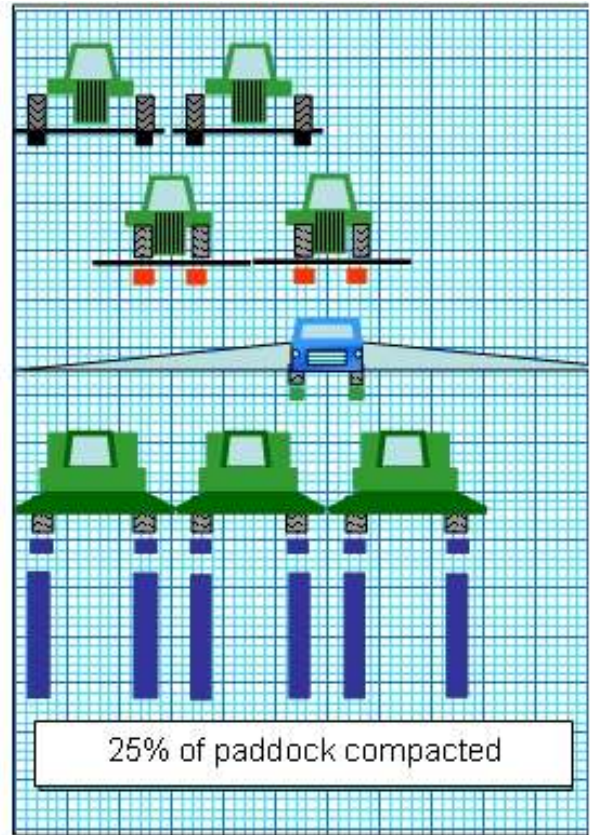
Under this scenario, compaction is reduced to only 25% of the ground. Shifting the system to eight rows will reduce compaction to 19%. Also as tramlines are well consolidated, tractors could run on narrower tyres, further reducing the area compacted.

Permanent Beds for Vegetable Growing

Diag A: Conventional (random)



Diag B: Controlled Traffic Farming



Creating & maintaining wheel tracks

Permanent wheel tracks become an asset. If formed in optimal conditions (some moisture but not too wet) wheel tracks will compact into a durable state that will best support traffic.

Permanent wheel tracks are however, subject to wear and tear from use. Maintenance will ensure that traffic is best supported by the tracks, especially in wet conditions.

Compacted wheel tracks form virtual 'beams' across the paddock. These are naturally oval in section, with a convex upper surface that may cause wheels to slip off tracks. Growers have found that shaving the curved top off the wheel track provides a flat surface for traffic, reduces slip-offs, and also provides loose soil to rebuild beds.

Recovering soil from tracks may require some force and cutting action to allow the bedformer to pick up the compacted soil.

Machinery matching

Machinery matching is a critical element of the permanent bed system. Only when each machine has the same bout width, or works to multiples of the same bout width, is tramlining possible. And only when wheel tracks are the same can the same lines be used.

A key decision is the standard bed width to adopt for all crops in the rotation. Then ensure equipment fits to this width of multiples of it.

Planning crop rotations can provide for maximum alignment of crops with similar bed width. This will maximise the benefit from permanent beds.

Conventional cropping typically has a wide variety of machinery working widths. Plant row spacing varies between crops and the number of rows per pass varies between operations.

Tractor and equipment wheel track widths vary considerably, even in a single tractor machine combination. So converting to permanent beds can mean significant changes are required.

However, experience so far suggests that in many cases, far less adjusting is required than first expected. As some operations are dropped or substituted, fewer operations required, so less (unmatching) equipment is needed.

Heavy cultivation equipment often works independently of the bed width, as beds are formed after those operations are completed. However, in permanent beds systems, no heavy cultivation should be required, so the issue resolves itself.

Equipment used for bed forming, planting and crop care will fit a standard bed width, so tracks are already matched.

It is harvesting machinery that often creates initial limitations in a permanent bed system. This is because the harvesters often do not fit the bed widths and are usually most limited when modification is required.

Harvesters for cereals or maize, often have a 3m wheel track. So if those crops are in the rotation, that may define bed width. This is the same as a standard outer wheel track on a tractor fitted with dual wheels.

Rather than reduce the width of the harvester, common practice increases the width of the tractor. For wider beds, the simplest modification is to remove the inner wheels, and retain the outer ones with the track width that matches the harvester.

Usually the rear wheels are easy to set without significant engineering. Similarly, the front wheels on two wheel drive tractors can often be altered quite easily.

NOTE: It is essential that checks are made to ensure manufacturer warranties are not invalidated, and that any such modifications are safe. This can entail design or assessment by a qualified mechanical engineer.

With permanent beds and well-formed wheel tracks, duals or extra wide tyres are not normally needed. There is opportunity to reduce tyre width, and the width of the compacted tramline, leaving more un-



compacted soil for plant root development.

Figure 6 Axle extension to widen front track to 3 metres

Vegetable harvesting equipment has many wheel track variations, often not matched to bed width. And if trucks or forklifts are used to collect harvested produce, matching wheel tracks can be difficult.

In many cases, field harvest trailers, gondolas or chaser bins are used, and trucks kept to defined loading areas at the gateway. This makes wheel track matching relatively simple, and greatly reduces soil damage at harvest.

Most trailed equipment, including potato and onion harvesters and trailers, can be built or adapted as required.

Costs

Some direct costs apply to conversion to permanent beds and controlled traffic farming. Making machinery fit the wheel tracks and investment in guidance systems may require extra investment.

Machinery working widths and wheel track widths should be the same and some method of establishing and keeping to the tramline is required.

The speed with which changes are made determines the rate at which the new system can be fully implemented. Machinery replacement policy should recognise this, with a plan to guide purchase decisions, which eventuate in a fully compatible permanent system.

LandWISE case studies have shown that actual costs are often less than anticipated, and a relatively simple and inexpensive alteration can unlock the door.

Guidance systems

There are various forms and levels of accuracy with guidance systems. They range from simple mechanical marker arms to complex satellite Global Positioning Systems.

Simple guidance such as marker arms do not unlock the full benefits of permanent beds. Once beds are formed, drivers can follow tracks easily, but the precision of high accuracy guidance offers many important flow-on benefits.

Global positioning systems (GPS) can guide the driver with light bars or computerised driven automatic steering on the machine.

Real Time Kinematic (RTK) GPS uses base stations and radio links for very accurate (sub-2 cm) positioning. This is more accurate than even a very good driver can maintain, so computer assisted automatic steering is used – freeing the operator for other tasks.

High accuracy GPS with automatic steering is the ‘full adoption’ solution. All operations can be repeated along exactly the same wheel tracks. GPS allows very precise tracking time and again even

through full ground cover or in the dark. It is also repeatable, even years later.

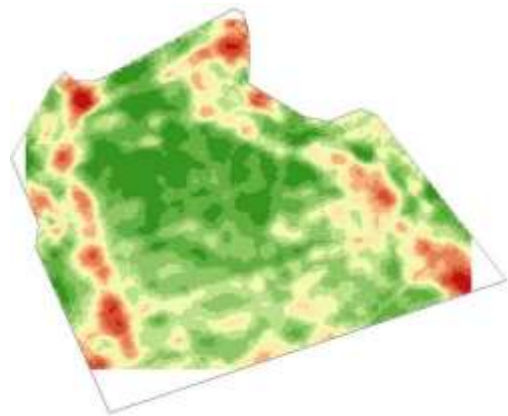
Flow on benefits

Once GPS is adopted, the door is opened to a whole range of new management options. These are based on the ability to pin-point, map and record operations anywhere at any time.

Yield Maps

Yield mapping is well developed for combinable crops, but less so for vegetables. Methods of recording unit loads are increasingly available, and if combined with GPS do offer yield map capability.

The benefit of yield mapping is that it allows farmers to look at why certain areas are performing better or worse.



Yield maps identify variation, allowing further investigation of causes (Massey CPA image)

Product application and traceability

GPS enables guidance and recording of chemical and fertiliser placement. All machinery movements and applications can be automatically recorded and mapped



Recording applications not only satisfies customer and regulatory authority requirements, but can quickly highlight any missed areas or double ups.

Figure 7 Automation of spray application avoids overlaps and gives record of application.



Automatic Recording brings the advantages of traceability without anyone having to physically do anything (much). Real-time mapping shows work done and helps avoid misses or overlaps

Variable rate technology

In some cases, such as when different yield-potential areas are identified, GPS allows variable rate technology to accurately adjust inputs on the go. Most activity is related to adjusting plant populations or fertiliser additions to optimise rates in different 'management zones'.

Remote sensing



Figure 8 EM38 Soil scanner mapping soil variability, enabling detailed soil water holding maps to be prepared

An increasing array of tools is allowing a range of factors to be cheaply monitored. Among these are soil sensors that allow detailed soil zone maps and crop biomass maps to be prepared. These may be combined with yield maps to increase understanding of identified variability at paddock scale.

On farm trials

The highly accurate recording of position and a range of measurable factors increases opportunities for on farm trials. These are easily combined with geographic information systems (GIS) for analysis.

Making a Success of Permanent Beds and CTF

Many people have made the move to applying permanent beds and controlled traffic farming in Australia. LandWISE is thankful to Chris Bluett, Paul Blackwell, John McPhee, John McKenna and other researchers for sharing their information with us.

Many farmers changed their working width and/or wheel centre widths several times in the conversion process. In hindsight they all say, “Decide on the best width for you and go there in one step.” They also recommend the highest level of GPS accuracy.

New Zealand growers have also tried and adopted permanent bed systems in recent years, with considerable and rapid success.

We are particularly grateful to Chris Butler at SnapFresh Foods, Simon Wilcox, Andy Luxmore, Bruce Budge and the team at A S Wilcox, and John Clarke and staff at Woodhaven Gardens for sharing their experiences.

The bed systems the New Zealand growers are using do involve a significant amount of soil disturbance. The permanent part of permanent beds is the wheel tracks and headlands.

Operations such as potato harvesting obviously involve digging.

Salad crop rotations require shallow cultivation to destroy old crop residues and reduce disease carry over, but interestingly, there is much less disease carry over than was anticipated.



Figure 9 Permanent beds improve returns in salad greens

Other lessons learnt along the way

- **Have a strategic plan** –have a goal and a plan of how to get there. E.g. purchase new machinery to fit the new system, even if the system is yet to be fully implemented.
- **Repair any soil compaction first.** If the soil needs ripping, do it at the beginning. Soil takes a long time to recover on its own. If possible remove tines where tramlines will run.
- Setup the beds in the best possible soil conditions, preferably not on soil that is wet or has just been deep ripped or ploughed.
- Use cultivation and planting equipment with which you are familiar - try not to change too many things at once!
- Use them or lose them – if not driven on, wheel tracks tend to lose strength over time.
- The reduced draught requirement allows farmers to reverse tyres, reducing tyre wear, fuel consumption and damage to tramlines.
- Very wet tracks carry far less load and may become rutted. If it is vital to carry out an operation, lower tyre inflation pressures to the minimum recommended and minimise the load being carried.
- Repair any damaged wheel tracks. Pull soil in and compact when dry to prevent water ponding in rutted wheel tracks.
- Expect rain and irrigation to infiltrate your soil much more easily. The bed areas will allow water to soak in and drain away and you should find less ponding than before.



Figure 10 Rutted wheel tracks



Figure 11 Prongs pull soil into wheel tracks after rutting has occurred

Case Study: AS Wilcox and Sons

A.S. Wilcox has been working to adopt permanent beds for their Pukekohe-based cropping operation.

The company is pursuing a permanent bed system in order to improve soil quality and overall productivity. They also hope to reduce their fuel use.

AS Wilcox grows onions, potatoes and oats on 3 year rotations. The heavy volcanic clay soils they farm at Pukekohe are prone to compaction and soil damage, especially when wet. Wet soil also leads to delays in operations and slows the harvesting process.

A seven hectare site was allocated to the first year trial. Set up with support from LandWISE and Plant and Food Research, half the area was managed as permanent beds and half using conventional practice.

How Permanent Bed Systems Work

The key is keeping all traffic on the same wheel tracks and never driving on the productive 'garden' areas.

Under a permanent bed system, the vehicle traffic is restricted to permanent wheel tracks. The wheel tracks are not removed at the end of a crop, they are retained to carry future traffic.

These solid 'roadways' are better able to carry traffic. They also allow access sooner after rain and reduce rolling resistance and energy demand.

As a result, there is no need for the deep ripping and powered cultivation that is often required to remove compaction caused by random traffic during the season and at harvest.

Trialing Permanent Beds

The trial site is on clay loam at A. S. Wilcox's property in Pukekawa. The site has been intensively cropped for almost 15 years, typically to their standard 3 year rotation of onions, potatoes and oats.

Heavy cultivation has been required to remove compaction and prepare beds for successive crops. Harvesting operations are often difficult in these soils, especially during wet conditions.

The permanent bed and random traffic areas both received the same primary cultivation.

In the controlled traffic area, all harvest equipment remained in wheel tracks, whereas in the conventional random traffic area, equipment also travelled on bed tops.

What has been learnt so far?

There was no measurable difference in onion yields achieved using either approach. In time A.S. Wilcox hopes the controlled traffic approach will deliver a deeper, better-structured soil that can either support larger crops or require fewer fertiliser or irrigation inputs.

Field staff noted the effective rooting depth was much greater in the permanent beds.

After onion harvest, water infiltration was measured and under controlled traffic had increased by about 30%.

This was an encouraging observation which is in line with expected improvement. This was also consistent with visual observations made during the season by the Wilcox team.

The benefits of improved infiltration are that the tracks stay drier and less soil and nutrient is lost through surface runoff.



Figure 12 Heavy clays are prone to compaction and loss of structure in the wet.



Figure 13 Sampling is showing improving soil condition under permanent beds

Improving soil conditions

Rain often keeps soils wet and can delay operations. A permanent bed system with its improved internal drainage, means that operational windows are likely to get bigger. This means fewer delays and better utilisation of equipment.

Results

The effects of the different traffic approaches at harvest are still emerging. Under the conventional random traffic practice there were a greater number of big, clumpy aggregates – a sign of residual compaction. By contrast, smaller aggregates were formed with less cultivation under controlled traffic.

If these soils become better drained and structured, as expected, this will lead to more favourable lifting conditions during the challenging winter period.

In addition to the emerging soil benefits, the Wilcox team estimates they can reduce fuel use by about 50% by managing their traffic.

Convinced of the benefits of permanent beds, A. S. Wilcox have increased their controlled traffic area, implementing it on 44 ha in 2010

The time, fuel and cost savings are significantly in favour of permanent beds. Staff estimates are a 50% saving in machinery, fuel and labour.

Soil conditions are being monitored in a program of sampling to determine whether changes occur through time since adoption of permanent beds.

An example of conventional practice is being retained alongside and monitored for comparison of soil properties vs the permanent bed practice.

MORE INFO

See the LandWISE website and seek out LandWISE Notes, fact sheets and guidelines for successfully implementing permanent beds and controlled traffic.

Publication

Bloomer, D.J. and J. Powrie. 2011. *A Guide to Smart Farming*. LandWISE.

Web Resources

Available as downloads www.landwise.org.nz/projects/resilience

LandWISE Booklets

- Strip-Tillage
- Controlled Traffic Farming
- Permanent Beds for Vegetables
- Protocols for GPS Guidance

Resilient Cropping Fact Sheets

- Resilient Energy Handbook
- Energy Use in Cropping
- Energy Use in Irrigation
- Reducing Energy for Irrigation
- Resilient Irrigation Handbook
- Quick GPS Drainlaying
- Resilient Soils Handbook
- Assessing Soil Condition
- Soil Compaction
- Soil Carbon
- Nutrient Losses
- Nitrogen Leaching
- And more

