# MITIGATING CLIMATE CHANGE BY LOW-DISTURBANCE NO-TILLAGE


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- At the 2015 Paris Convention on Climate Change the French Minister of Agriculture suggested increasing the carbon content of the world's soils by 0.4% per year for the dual purposes of reducing the amount of $CO_2$ in the atmosphere and increasing the world's ability to feed itself *(Chambers et al, 2016)*.

- The single most important function that the recent practice of no-tillage (sowing agricultural seeds into soils that have not been ploughed) can perform in relation to climate change is to recapture $CO_2$ from the atmosphere by photosynthesis and sequester it back into the world's 1.4 billion hectares of arable (cropping) soils.

- 85% of the world's food comes from annually-sown arable crops.

- Nature's way of sequestering carbon back into such soils from arable crops is largely by microbial decomposition of the straw and stubble (residues) from previous crops although root exudation during crop growth also contributes. The organic compounds are combined with clays and coated onto mineral particles in the soil to form soil structure. Earthworms and other soil fauna take both the residues and products of their decomposition into the soil with minimal mechanical disturbance of either.

- The common practice of burying the residues in the soil by mechanical cultivation (or tillage) based on ploughing does more harm than good by maximising soil/residue contact and causing more rapid oxidation of existing soil carbon into $CO_2$, which is lost to the atmosphere, than is gained from the buried residues (*Reicosky, 2006*).

- This is why continuous cultivation of the world's cropping soils has cumulatively depleted their carbon contents, structure and biological life to unsustainably low levels. By the year 2050 with present methodologies, it is predicted that the world's arable soils will no longer be able to grow sufficient food to feed the anticipated increase in world population, which some sources estimate will be 50%.

- The Paris Convention recognised that rebuilding soil carbon levels is not only a fundamental pre-requisite for the regeneration of soil health, it is also an inexpensive and effective way of removing significant amounts of existing $CO_2$ from the atmosphere.

- Achieving these complementary outcomes requires special seed drills that can:

  (a) Penetrate through the mulch of crop residues remaining on the surface of the soil after harvest of the previous food crop and sow the next crop, while simultaneously minimising mechanical soil disturbance, and

  (b) Leave the mulch of crop residues in situ so that it covers as much of the soil surface as possible after seeding to reduce soil erosion. A mulch cover over the newly-formed slots created by the seed drill in the course of sowing the next crop also traps soil water vapour that virtually guarantees seed germination, crop establishment, and residue-decomposition, even in dry soils.

- Very few seed drills can achieve this.
- Cross Slot® low-disturbance no-tillage seed drills, developed at New Zealand's Massey University over a period of 30 years and now marketed by Baker No-Tillage Ltd in Feilding, NZ, *(Baker et al, 2006)* is the most effective known design that can achieve these objectives.
- Most of the world's "minimum tillage", "strip tillage", "conservation tillage" and "high-disturbance no-tillage" machines do not regularly achieve net increases in soil carbon during seeding. This is both because some cannot handle surface residues without blocking and others disturb too much soil during the seeding process. While such machines might reduce the carbon emissions otherwise caused by conventional cultivation, achieving a consistent net ***increase*** in soil carbon content at seeding time requires more sophisticated designs than most farm machinery companies are currently offering (Reicosky, 2015).

*Fig. 1. Visual differences between high-disturbance and low-disturbance no-tillage seed drills plus two forms of conventional tillage, are illustrated below.*

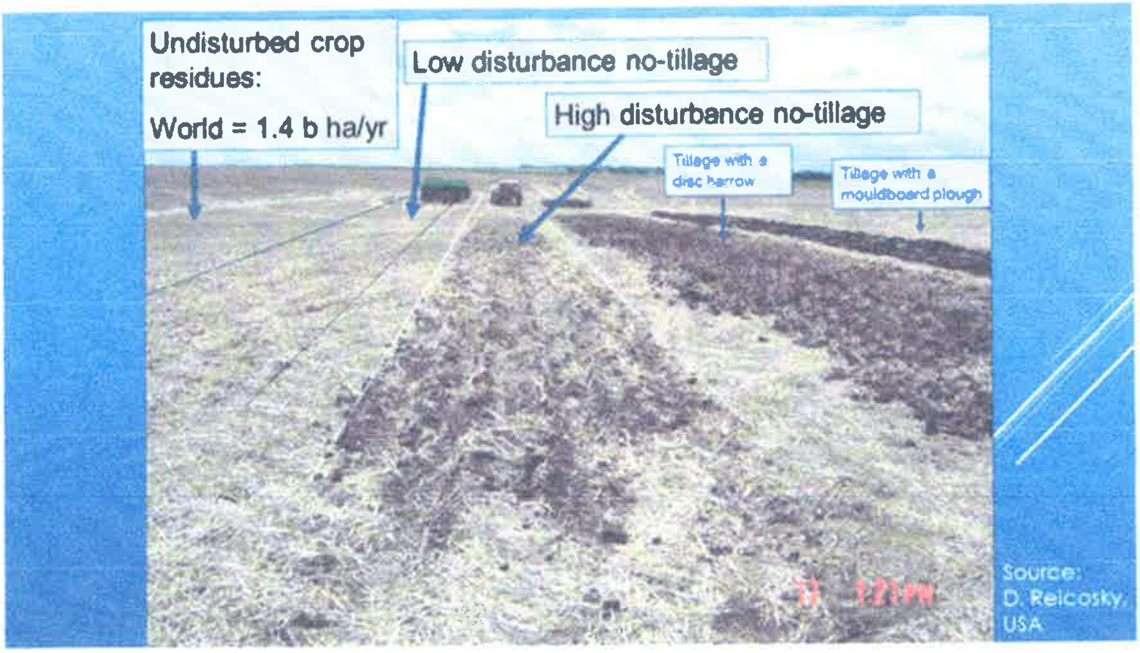


*Fig. 2. Close-up views of low-disturbance no-tillage.*


# What the numbers mean

- The world's total carbon emissions in 2015 were approximately 11 billion tonnes C (*Rattan Lal pers.com. 2015*) or 40.4 billion tonnes $CO_2$-equivalent (based on molecular weights, I tonne of carbon is equivalent to 3.67 tonnes $CO_2$-equvalent).

- New Zealand's total carbon emissions in 2015 were approximately 22 million tonnes C (or 80.2 million tonnes of $CO_2$-equivalent) of which approximately 48% (10.6 million tonnes C, or 38.9 million tonnes $CO_2$-equivalnet) was from agriculture.
(*Ministry for the Environment on-line data, 2017*).

- The French target at the 2015 Paris convention was 0.4% increase in global soil carbon per year.

- The French goal is probably unachievable because most of the world's soils are not accessible to direct manipulation by mankind because of topographical or climatological limitations or alternative uses such as urbanisation or nomadic livestock farming (*Rattan Lal pers.com. 2015*).

- But the world's 1.4 billion hectares of **highly-accessible arable land** is (by definition) accessible to mankind on an annual basis and comprises approximately 25% of all agricultural land (*Wikipedia, 2011*).

- Cross Slot® low-disturbance no-tillage has been shown to be capable of adding a minimum net* 500 kg C/ha/yr (or 1.8t $CO_2$-e/ha/yr) - (*Ghatohra, 2012*) to the soil when used to grow arable cereal crops followed by either a forage or cover crop in the same year, whereas conventional tillage loses up to net 2,000 kg C/ha/yr (or 7.3t $CO_2$-e/ha/yr) growing the same rotation.

  * Comprises total gains in carbon from decomposition of the residues of the previous crop, minus the measured field emissions of carbon from all sources (including respiration by decomposition microbes, oxidation from soil disturbance, burning or removal of residues prior to conventional tillage, and tractor exhaust gases) during the same period (*see Attachment A*).

- **There is therefore a cumulative gain of 2.5t C/ha/yr (or 9.1t $CO_2$-e/ha/yr) created from substituting Cross Slot low-disturbance for conventional tillage in New Zealand.**

- The 2.5 t C/ha/yr difference is partly comprised of the $CO_2$ that is emitted from the soil by oxidation during multiple tillage processes; and partly because the carbon-rich residues of both the harvested crop and cover crop are required to be removed from the field to avoid tillage machine blockages, whereas they are allowed to decompose on the ground when low-disturbance no-tillage is substituted.

- **Applied to New Zealand's 1 million hectares of annual seeding of all soils (involving arable crops, forage crops and new pastures, *Baker unpublished data 2002; NZ agricultural statistics, 2015*) Cross Slot low-disturbance no-tillage alone could offset 24% of New Zealand agriculture's annual carbon emissions and 11% of NZ's total carbon emissions from all sources.**

- **Applied to all of the world's 1.4 billion hectares of arable soil, Cross Slot low-disturbance no-tillage could offset 32% of the world's total annual carbon emissions of 11 billion tonnes from all sources.**

*The basis of estimates – continued/*

# Attachment A: The basis of estimates of carbon gains and losses

Estimates and measurements of gains and losses of soil carbon (**"carbon-in" versus "carbon-out"**) are as follows:

## For the spring-establishment of a barley crop in NZ after a pasture:

## By low-disturbance no-tillage:

**"Carbon-in" from low-disturbance no-tillage** results from decomposition of 1,000 kg Dry Matter (DM) of residual pasture with a measured carbon content of 45%, which is killed by glyphosate application in spring and allowed to decompose in situ on the ground surface. All of the carbon present is assumed to be added to the soil and any respiratory losses are accounted for by measurements of "carbon-out" below.

**Estimated "carbon-in"** at establishment of the barley crop is 450 kg C/ha.

**"Carbon-out" from low-disturbance no tillage** was measured (*Ghatohra, 2012*) as above-ground emissions of carbon dioxide from all sources during and after the seeding process by a Cross Slot no-tillage seed drill. The barley seeds were drilled through the decomposing pasture residues in a one-pass seeding operation that caused minimum disturbance to the soil and residues.

**Measured "carbon-out"** is 2,215 kg C/ha for establishment and harvest of the barley crop.

## By conventional tillage:

**"Carbon-in" from conventional tillage** results from physical incorporation of 1,000 kg DM of residual pasture with a measured carbon content of 45%, which is killed by glyphosate application in spring. Soil incorporation occurred with a powered rotary cultivator.

**Estimated "carbon-in"** at establishment of the barley crop is 450 kg C/ha.

**"Carbon-out" from conventional tillage** was measured (*Ghatohra, 2012*) as above-ground emissions of carbon dioxide from all sources during and after the tillage process and drilling by a Cross Slot seed drill operating in the tilled soil.

**Measured "carbon-out"** is 2,580 kg C/ha for establishment and harvest of the barley crop.

## For the autumn-harvest of the barley crop and autumn-establishment of a subsequent cover crop, forage crop or pasture*:

*The barley grain was harvested and removed. Its carbon content and the carbon emitted during its harvest, is ignored.

### By low-disturbance no-tillage:

**"Carbon-in" from low-disturbance no-tillage** results from decomposition of an assumed 8 tonne/ha* DM of barley residues after harvest, containing 40% carbon (Smil, 1999).

> *In NZ, the weight of harvested seed from small grained cereals crops is approximately equal to the weight of straw, stubble, roots and chaff remaining as crop residues after harvest. Up to 11 tonne/ha of barley grain has been harvested in this district from Cross Slot low-disturbance no-tillage, but in this example 8t/ha is used as an achievable yield. The 8t/ha of crop residues is comprised of 3.2 t/ha (40%) roots and 4.8 t/ha (60%) aerial residues)

**Estimated "carbon-in"** is 3,200 kg/C/ha.

**"Carbon-out" from low-disturbance no tillage** (*Ghatohra, 2012*). Carbon is removed by (a) harvest of the grain from the crop for food purposes, and (b) as measured above-ground emissions of carbon dioxide from all sources during and after the harvest of barley together with seeding of the next crop by a Cross Slot no-tillage seed drill. In this case, the following crop was new pasture that was drilled through the decomposing barley residues with minimum disturbance to the soil or residues.

**Measured "carbon-out"** is 2,877 kg C/ha for re-establishment of a following pasture crop.

### By conventional tillage:

**"Carbon-in from conventional tillage** is mainly the carbon contained in the roots of the previous crop (40%) because it is common for the aerial residues of a harvested barley crop to be removed (by baling, burning or burial) to permit passage of the tillage implements. The roots component of the crop residues are also partly destroyed by any tillage process and their carbon is oxidised and captured in the measured above-ground emissions listed below.

**Estimated "carbon-in"** is 1,280 kg C/ha

**"Carbon-out" from conventional tillage** (*Ghatohra, 2012*). In addition to the harvested grain, was measured as above-ground emissions of carbon dioxide from all sources during and after the tillage process and drilling by a Cross Slot seed drill operating in the tilled soil.

**Measured "carbon-out"** is 3,330 kg C/ha for re-establishment of the following pasture or cover crop.

## For the growth and winter-harvest of the following pasture crop

In NZ, because animal agriculture is commonly integrated with arable farming, it is assumed that both **Low-disturbance no-tillage** and **Conventional tillage** will experience the same net gain of soil carbon after establishment of a 5,000 kg DM/ha forage crop with 40% carbon content. In both cases it is assumed that the forage crop is consumed by animals in situ and the carbon content of the animal excrement is returned to the soil.

Alternatively, a 5,000kg DM/ha cover crop is grown and killed prior to drilling the next crop. In this circumstance, the carbon content of entire crop is available as carbon-in for the next crop.

**In most arable rotations sown by conventionally cultivation, cover crops are impractical unless animals are available to consume and recycle each cover crop. In the absence of animal-consumption and recycling, it is necessary to remove the cover crop residues before tilling the seedbed for the next arable crop.**

**By contrast, low-disturbance no-tillage adds the carbon content of the cover crop to the soil at the start of the next cropping cycle.**

**Estimated "carbon-in" for both treatments** arising from a winter forage crop in NZ = 2,000 kg C/ha but in any case is assumed to be similar for both low-disturbance no-tillage and conventional tillage.

## SUMMARY

### Net carbon balances for the year in NZ (kg C/ha/year):

**By low-disturbance no-tillage: (450 + 3,200 + 2,000) – (2,215 +2,877)**
**= positive 558 kg C/ha/year**
*(say, an annual increase of approximately 500 kg soil C/ha/year).*

**By conventional tillage: (450 + 1,280 + 2,000) – (2,580 + 3,330)**
**= negative 2,180 kg C/ha/year**
*(say, an annual decrease of approximately 2,000 kg soil C/ha/year).*

**The main difference between the two options (tillage and low-disturbance no-tillage) occurs at step 2 when the carbon in the straw and residues of the barley crop is either returned to the soil (with low disturbance no-tillage and minimum soil/residue contact) or largely lost within a year (because of oxidation and maximum soil/residue contact from conventional tillage).**

**In arable situations with no animals, there is likely to be a further "carbon-in" opportunity for low-disturbance no-tillage from the ability to retain and drill through the cover crop residues. By contrast, cover crops are largely**

**impractical with conventional tillage because of the need to dispose of the aerial residues before tillage can take place without machine blockages.**

**There are also differences in carbon *emissions* ("carbon-out") between the two methods of crop or pasture establishment. But these differences are smaller than the net gains to be made in carbon sequestration ("carbon-in") from retention of crop residues made uniquely-possible by low-disturbance no-tillage.**

## Conclusions:

The above figures firstly explain why the soil organic matter and soil carbon levels of most of the world's 1.4 billion hectares of arable soils have steadily declined over centuries as a result of intensive tillage with all of the negative environmental consequences (including soil erosion, sedimentation of waterways and declining – or at least the levelling off – of crop yields) that the world is now experiencing.

These soil effects are mirrored by excessive carbon in the atmosphere with its consequent negative effects on climate change.

The data also demonstrate that both processes can be reversed by the widespread application of low-disturbance no-tillage practices, the planting of cover crops and the retention of crop residues between successive crops.

Indeed, unless the figures are reversed or some other (as yet unrecognised) factor is able to increase crop yields from the world's degenerating arable soils, the world will simply not be able to feed all of its inhabitants by 2050.

The most important point is that the technologies and knowledge to implement low-disturbance no-tillage practices in the world's arable soils already exist and can be implemented almost immediately. Farmers simply need to change their methodology, which they can do at the same time as increasing profitability.

It's a classic win-win for agriculture and New Zealand's Cross Slot® is leading the way!

## HOW YOU CAN HELP?

- **Recognise that soil is a living biological system that requires carbon as its main source of energy to maintain food security for the survival of mankind.**

- **Recognise that carbon in the atmosphere and carbon in the soil are connected via the carbon cycle and the process of photosynthesis undertaken by green plants.**

- **Recognise that approximately 1/3 of the carbon captured from the atmosphere by photosynthesis goes into our food supply and 2/3 into maintaining the soil biological processes *(D C Reicosky, pers.com. 2016)***

- **Recognise that no amount of reduction in atmospheric carbon will help the world feed itself unless that carbon finds its way back into the soil.**

- **Recognise that the photosynthesis undertaken by the world's 1.4 billion hectares of food-producing arable crops is both an effective way of re-capturing carbon from the atmosphere and can be influenced positively or negatively by mankind.**

- **Recognise that all soil disturbance and removal of crop residues when growing arable crops works against carbon finding its way back into the soil.**

- **Recognise that the carbon cycle that Cross Slot® low-disturbance no-tillage enables, can be repeated endlessly, sustainably and indefinitely in virtually any arable soil.**

- **Help proliferate New Zealand's unique Cross Slot® low-disturbance no-tillage technology, which works with nature to enable the transfer of re-captured atmospheric carbon back into the soil.**

## References:


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