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CARBON POSITIVE: CAN WE REGENERATE SOIL CARBON IN SOILS USED FOR INTENSIVE FIELD CROPPING?

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To scientifically test regenerative farming principles within a typical New Zealand cropping system, we have established "Carbon Positive", a six year trial on the Heretaunga Plains. The trial at the LandWISE MicroFarm is a collaboration with the Hawke's Bay Future Farming Trust and includes a developing relationship with hapu from our neighbouring marae and input from national Mātauranga Māori experts. The information produced will increase understanding of benefits, impacts for conversion, support the development of decision-making tools and increase confidence in regenerative farming principles through the value chain.

The project sits within the Ministry for Primary Industries (MPI) Sustainable Food and Fibre Futures portfolio as part of "Regenerating Aotearoa".

> Our food and fibre sector is constantly improving the way it produces food, and New Zealand's food producers are already among some of the most efficient in the world.
>
> As we shift to a low-emissions and sustainable economy, the way we produce food, and the kinds of food products that businesses choose to sell, will change.
>
> Regenerative farming is an evolving concept focused on reducing the impacts of food production on our environment. These practices are also recognised in the Government and sector's Fit for a Better World roadmap for our food and fibre businesses.
>
> A key recent focus has been investigating what regenerative agriculture means from New Zealand's perspective.
>
> Hon Damien O'Connor
> Minister of Agriculture

Regenerative agriculture has re-emerged as a trend supported by governments and industry (Thomas, 2022). It places emphasis on sequestering carbon and reducing the use of chemicals (Grelet & Lang, 2021; Schlesinger, 2022; Danley, 2023; McCain Foods, 2023). It is seen as a production system focused on reducing the impacts of food production on the environment, a way to shift to low-emissions and a sustainable economy, and is part of the Government and primary sector's "Fit for a Better World" roadmap (Ministry for Primary Industries, 2022). The search for alternatives to conventional high-input farming is further driven by consumer preferences for chemical free food (Magnusson et al., 2003; Forbes et al., 2009; Crinnion, 2010; Hoek et al., 2017; Koch et al., 2017; Galati et al., 2019), public concern about residues in water (Bajwa et al., 2015; Hageman et al., 2019), and awareness of potential impacts of chemical treatments on soil microflora (Helander et al., 2018) and fauna (Salminen et al., 1996)

A bundle of principles rather than a set of prescribed rules, and variously described (Grelet & Lang, 2021; Ministry for Primary Industries, 2022; Thomas, 2022), regenerative agriculture advocates minimising soil disturbance, keeping living roots in the soil, enhancing biodiversity, reducing the use and impact of agrochemicals and artificial fertilisers, and integrating animals into the system. Regenerative agriculture parallels conservation agriculture which also retains greater quantities of ground cover in the form of crops, cover crops or crop residues. This makes mechanical tillage, weeding, and planting difficult (Bauer et al., 2020) necessitating alternative equipment.

Our Carbon Positive trial is a three-systems comparison, evaluating differences between a conventional high-input, high-output cropping system typical of successful conventional crop producers, a system producing the same crops managed according to regenerative practice principles, and a "hybrid" treatment that may adopt practices from either system. The hybrid models and evaluates the effectiveness of selecting only some new practices, or a transitional approach to conversion from conventional practice to a regenerative one.

Six potential project outcomes are:

1. [Increased] scientific knowledge of regenerative agriculture principles and transition
2. Increased soil health in Hawke's Bay's key cropping areas
3. Increased understanding of regenerative cropping and effects of transition
4. Showcased growing mixed crops under alternative management systems
5. Industry adoption of new best practice and decision-making tools
6. Overseas based processors confident New Zealand produce can meet future needs.

Our project deliberately rejects strict definitions of regenerative cropping in favour of adherence to the forementioned generally agreed principles: minimise soil disturbance, keep the soil covered, keep living roots in the soil at all times, grow a diverse range of crops, and introduce grazing animals. Additional principles are to minimise the use of artificial fertilisers and sprays. Importantly, we have set no "ban" on any practice should it be deemed an appropriate management response. The place of grazing animals within the system, a foundation practice for many regenerative agriculture systems, is being debated. Wintering lambs is typical in a Hawke's Bay cropping rotation, but processors seek to maximise the length of the cropping period, and have some concerns about animal waste in the vegetable food-stream.

The trial is being conducted at the LandWISE MicroFarm in Waipatu, Hastings, a site that has had almost ten years continuous process cropping. It was split into 12 mini-paddocks, each 12 m wide and 90 m long, giving four replicates of each treatment. The width enables use of conventional process cropping machinery, fitting 12 m, 6 m, 4 m, 3 m or 2 m equipment, overtly replicating the operations that a commercial grower might undertake. The plot length ensures equipment is functioning correctly and sampling can avoid ends of rows.

The science question that has been put asks, relative to a conventional "high input/high output" intensive process crop production system, does the adoption of regenerative principles have a measurable effect on:

1. Soil carbon stocks
2. Soil carbon cycling
3. Soil health
4. Crop yield
5. Farm economics

In August 2022, the Soil Health Institute (2022) announced its recommended measurements for assessing soil health. Many measurements are effective for assessing soil health from a research perspective, but a minimum suite of measurements that is practical and affordable for all land managers was sought. The various measurements were evaluated the through the lens of cost, practicality, availability, redundancy, and other filters, based on which a minimal suite of three measurements was recommended to be widely applied across North America (and likely beyond) (Liptzin et al., 2022). Those measurements include:

1. Soil organic carbon concentration
2. Carbon mineralization potential
3. Aggregate stability.

Soil organic carbon is a key component of a soil's organic matter that influences available water holding capacity, nutrients, biodiversity, structure, and other important soil properties. Carbon mineralization potential reflects the size and structure of microbial communities in soil, thereby influencing nutrient availability, soil aggregation, and resilience to changing climatic conditions. Aggregate stability describes how strongly soil particles group together. This influences whether a heavy rainfall will infiltrate into a soil or run off

a landscape, taking with it valuable nutrients that become detrimental to water quality. Soil aggregates also influence erosion, aeration, root growth and, therefore, nutrient uptake by plants.

Those three measurements form the base suite for this project, supplemented by soil texture analysis, Visual Soil Assessment, general agronomic soil testing, crop yield, (processor relevant) crop quality assessments, and gross margin analyses. In addition, frequent observations follow farm operations noting energy use, practical difficulties and features that indicate additional testing be considered.

To assess variations in soil carbon stocks, we measure the total amount of carbon in the soil:

- Total soil organic carbon
- Soil bulk density
- Total soil N

To consider shorter term effects, we are monitoring more labile carbon forms and include N & P in parallel (Prescott et al., 2021).

- Hot water extractable carbon (Curtin et al., 2020) (Commercial Labs)
- Hot water extractable N
- Olsen P
- Compare ratio of labile (HWEC) with stocks (SOC)

Prior to establishing the trial site, a baseline EM survey with assessments at 50 and 120 cm was undertaken and showed the coefficient of variance across the entire site to be less than 6%, and less within the actual plots. Carbon stocks and labile carbon (HWEC), total nitrogen and labile nitrogen (HWEN) and Olsen P were measured to 90 cm in four depth bands. The mean carbon stocks were 90.77 t ha^{-1} and the VSA tests were also consistent, showing the soils to be in “moderate” condition (mean score of 21.9), neither good nor poor. Together the results show the trial area allows for the imposed management regimes to either further decrease quality or regenerate it.

The first crop planted was process sweetcorn for McCain Foods, an industry partner. It was planted into sprayed out 18-month pasture that was left for six weeks. All plots were strip-tilled, then the conventional treatment was also power harrowed. The treatments received different amounts of synthetic nitrogen fertiliser as Cropzeal 20N and urea with the conventional plots receiving 156 kg N ha^{-1}, the recommended rate based on soil tests and expected yield (Reid & Morton, 2019). The hybrid plots received 130 kg N ha^{-1} and the regenerative plots received 75 kg N ha^{-1} of synthetic nitrogen. Compost (25 m^3 ha^{-1}), Trichoderma and biostimulants were added to the regenerative plots.

The crop emerged quickly and evenly in all treatments, although slugs and pükeko caused some early damage. The mean established population was 59,278 plants ha^{-1} with no significant difference between treatments. However the regenerative and hybrid plots, which were not power-harrowed after strip-tilling, did emerge slightly slower than the fully cultivated plots. All plots were treated with Arietta (Topramezone) herbicide, and the conventional plots also received atrazine. After harvest, crop residue will be mulched and cover crops established. Winter cover crops and their management for each treatment were not confirmed at time of writing. A Kraft-Heinz Watties tomato crop is planned for 2023-24.

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