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# Resilient Cropping

*Resilience is the ability to bounce back from adverse events. Farms handle adverse events better if the soil is healthy, water available, and infrastructure (and capital) in place.*

FAR · Horticulture New Zealand · Tāhuri Whenua National Māori Vegetable Growers Collective · Ministry for Primary Industries Manatū Ahu Matua · LandWISE Incorporated

# About Resilient Cropping

Resilience is the ability to bounce back from adverse events.

When we are generally happy and healthy we can handle most things nature (or life) throws at us. If we are run down, tired and sick, the slightest thing seems to knock us for six.

Farms are very much the same. They handle adverse events better if the soil is healthy, water available, and infrastructure (and capital) in place. And the reverse is true too. Beaten up soils, lack of water, inadequate or poorly maintained infrastructure and high gearing leaves a farm (and its people) at higher risk when bad things happen.

The "Resilient Cropping" initiative aims to build resilience into crop farming. It is a joint venture between LandWISE, the Foundation for Arable Research, Horticulture NZ and Tahuri Whenua the Maori Vegetable Growers Collective. The work is funded by the Ministry for Primary Industries.

# Events

The main focus of "Resilient Cropping" is preparing for adversity such as extreme weather events, fuel cost spikes and restricted access to irrigation water.

In-field workshops across the country allow local growers to share experience and ideas and propose local solutions for local conditions. Among the topics are soil quality, irrigation efficiency, nutrient management and energy use.

A common question is, "How can we best prepare for uncertainty?"

An alternative is, "How should we farm knowing with certainty that adverse events will happen, and possibly more often?"

# Contents

# Resilient Soil

Resilient soils have the capacity to recover well when subjected to stresses, either natural or man-made.

Two keys to resilience are inherent soil strength and good porosity, both closely related to soil structure. Strength means soil can hold together even when very wet. Porosity means water and gases can get in, through and out of the root zone, and plant roots can explore the full soil volume.

Despite what is thrown at them, resilient soils:

- cope well in heavy rain
- are less prone to washing away
- cope better with floods or droughts
- hold together in wind
- resist collapsing and compaction
- carry traffic better
- withstand cultivation
- grow good crops

**Understanding soil quality is a step toward better productivity and profit**

## Soil Quality

Soil quality is a relative measure of fitness for purpose. It is not a fixed, one-answer-fits-all issue. We generally talk of indicators which help build an overall assessment of quality.

What may be acceptable for one farming system may not be suitable for another. In fact, what is good quality in one part of a paddock may be poor in another – think controlled traffic farming, where we deliberately compact wheel tracks, but preserve un-compacted soil in gardens.

# Assessing Soil Condition

How do I assess soil quality?

Scientists use a range of soil quality tests, many requiring detailed sampling and expensive laboratory testing. Farmers want a cheap and easy alternative.

Soil quality indicators are often broken into three categories:

- physical
- chemical and
- biological.


**1. under a fence**
**2. the cultivated part of the paddock and**
**3. the wheel track.**

## Physical indicators

The physical indicators describe, for example, how well and how strongly the particles are bound together and how easily air and water can move through pores.

One of the key physical indicators is **soil structure**. Structure refers to how soil particles are bound together into aggregates – the lumps we find when we dig soil over.

For best plant growth, well-structured soil has mid-range aggregates which hold together well, even when wet, but can be broken into a seed bed tilth. A poorly structured soil may collapse into individual silt and sand grains or form large, impenetrable lumps.

Physical qualities change. A wet soil is weaker than a dry soil and does not carry traffic as well. And the longer the soil has been wet, the weaker it may become. Because of this, well drained soils are often more resilient than poorly drained soils.

## Chemical indicators

Most people are familiar with soil chemical testing for fertility and nutrient planning. As well as the main nutrients (N, P, K and S) there are other macro and micro nutrients required for healthy plants and animals.

Soil acidity (pH) and cation exchange capacity (CEC) are also important. pH affects nutrient availability. CEC affects nutrient holding and release.

## Biological indicators

There are many biological indicators, including organic matter content and worm numbers.

**Counting and recording worm numbers while assessing soil quality**

Soil physical quality and soil biology are closely related. Worms and other species recycle material and create pores and the glues that hold soil aggregates together are particularly important.  Good soil physical conditions are better for worms, which find compacted, water logged or droughty soils hard work.

## Visual Soil Assessment (VSA) Method

Growers often want to know if soil quality is improving or not. To have real use, a method should be scoreable for recording to compare results between areas and over time.

Visual assessment of soil condition is a good way to follow change, as paddocks can be monitored and scored each year.

The tests must be recorded, so they can be repeated over time, scores compared, and significant changes in soil quality detected. This gives growers the opportunity to monitor how practices like cover cropping, reduced cultivation or controlled traffic improve soil quality.

## Actions

On-farm actions can moderate the effects of adverse climate and reduce negative impact on crops. Three factors under grower control are:

- returning organic matter
- drainage
- cultivation, and
- compaction (includes stock as well as vehicles).

Organic matter is a critical component of healthy soil. Burned off by cultivation, it is replaced by growing plants. About half of plant matter is below ground. Returning plant residues such as stubble can add to the amount of organic matter returned and increase soil health. Cover crops also protect soil and add valuable organic matter.

Drainage can have immediate effect on crop production and is critical in preserving soil resilience by protecting soil structure. Surface and internal drainage are both important. Ensuring water can soak in or move away in a managed fashion is essential. Slowing water helps stop erosion.

Cultivation damages soil. It can be beneficial in addressing compaction, can incorporate residues and can manage weeds. But it breaks up natural soil structures and burns off the organic glues that give soil its natural strength. And by reducing porosity it reduces drainage, increasing water logging and ponding. Cultivation should be a last resort.

Compaction physically deforms soil structure. Unnecessary compaction reduces crops and makes them more at risk during adverse climatic events. Compaction prevents roots exploring the soil so makes plants more at risk in dry periods. Compaction reduces internal drainage putting plants at risk during heavy rains or prolonged wet periods.

## Further information

Managing the quality of the soil resource is a key to profitable and sustainable cropping systems.

Visual soil assessment allows growers to benchmark where their soil quality is currently at and offers a structured approach to follow changes in soil quality over time.

For a copy of the VSA booklet and a full description on how to perform a VSA of your paddocks, check:

- Landcare Research (www.landcareresearch.co.nz),
- BioAgrinomics site (www.bioagrinomics.com)
- or your regional council.

## Other resources

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

- Resilient Cropping Fact Sheets:
    - Managing Soil Impacts – drainage
    - Managing Soil Impacts – cultivation
    - Managing Soil Impacts – compaction
- Visual Quality Assessment by Graham Shepherd
- LandWISE Fact Sheet: Assessing Soil Quality on Farm
- LandWISE Fact Sheet: Visual Soil Assessment – a simplified look
- LandWISE Fact Sheet: Visual Soil Assessment – test process

Practical steps to protect soil are given in fact sheets from the SFF project "*Holding it Together*" are available from http://www.landwise.org.nz/projects/hit/hit-fact-sheets/

# Irrigation for Resilient Cropping

Irrigation increases certainty of crop yields. That allows confidence that contracts can be met, and that other resources such as land, labour, energy, agrichemicals and fertiliser will be used most efficiently.

## Need for excellence in irrigation

Good irrigation has significant benefits for the wider community and for individual irrigators. Competition for water increases the attention the community and potential irrigators place on existing irrigation practice.

Irrigation adds value to cropping, at a cost. The cost has environmental and financial aspects. Both must be minimised.

### Environmental costs

Environmental costs relate to removing the water from its source, and potentially losing nutrients to surface or ground water.

Much resource management activity, including consenting, is to minimise adverse effects of take. It seeks to maintain ecosystem functions and avoid conflict between users.

The National Policy Statement for Fresh Water Quality puts more attention on "receiving waters", the surface or ground water that receives leached nutrients from runoff or drainage.

**The environmental impacts of irrigation must be managed to minimise effects**

When irrigation enables intensified land use, the risk of leaching can increase. Excellent management is the key to avoiding such risks.

### Financial costs

Irrigation is expensive. Careful consideration of costs and returns is needed before investing in an irrigation system, and for each irrigation event. The cost of irrigating may not be covered by better yield or quality.

When irrigation is restricted, carefully assess which crop to irrigate first. Tools such as AquaTRAC provide financial analysis for alternative crops.

Financial costs include:

- capital outlay of the irrigation system and its associated infrastructure (bores, pumps and pipes)
- running costs (energy, labour and maintenance)
- depreciation
- cost of obtaining and retaining a resource consent or water share
- resource management charges for investigations
- increased land price
- and more . . . .

## Input Use Efficiency

Input use efficiency measures the amount of production for each unit of input. If yield is halved, the diesel use efficiency relating to cultivation is halved. The same is true for labour and chemicals.

A full-yield crop will use the nutrients provided while a drought stressed crop cannot. As well as reducing nutrient use efficiency, it increases the risk of nutrient loss to ground water or surface water.

Drought risk is significant across New Zealand, and particularly in eastern regions. Every season is different, both in timing and intensity of drought experienced. Some climate modelling predictions indicate an increasing risk of drought especially in the already drier regions.

## Good agricultural practice

Good agricultural practice makes sure a suitable irrigation system is designed and installed, that it is correctly managed, and records demonstrate compliance.

Irrigation New Zealand has a range of resources to support excellence in irrigation. Guidelines, Codes of Practice and Standards cover:

- System Specification
- System Design
- System Installation
- System Commissioning
- Irrigation Management
- Irrigation Operation
- Irrigation Evaluation
- Irrigation Scheme Environmental Management Systems

www.irrigationnz.co.nz

These and other resources are available via the Irrigation New Zealand website *www.irrigationnz.co.nz* and *www.everythingirrigation.co.nz*.

## Components of Good Practice

Good practice includes:

- planning ahead to avoid stress and minimise impact of restrictions
- maintaining the system to avoid leaks and energy waste
- applying the right depth of water at the right time
- ensuring suitable application intensity and good uniformity
- monitoring system performance
- demonstrating that good practice has been applied

Achieving these requires good management, maintenance and operation.

## Actions

On-farm actions can:

- moderate adverse climate impacts
- reduce negative impact on crops
- minimise costs and
- avoid environmental impacts.

## Developing or upgrading irrigation

Ensure a complete irrigation specification process has been completed. That involves:

- soil and climate assessments
- enterprise intentions
- full farm plan consideration and
- water supply availability

Use a qualified designer and an accredited design company. They will follow the Code of Practice and Standards for Irrigation Design and Installation.

## Managing Irrigation

Ensure a system Operation Manual is prepared, available and followed. It will include how to maintain and operate the system. Ensure all staff follow the right procedures

Use a formal irrigation scheduling system, including soil moisture monitoring and soil water budgeting. Use both. Tools such as AquaTRAC provide assistance.

Monitor system performance regularly, including event flow, pressure and visual checks and completing a seasonal system calibration.

Use an Irrigation Log to record applications, operation monitoring and maintenance.

# Further information

Excellent irrigation is an important aspect of many profitable and sustainable cropping systems.

# Other resources

## Resilient Cropping

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

- Resilient Cropping Fact Sheets
- LandWISE Fact Sheets
    - Controlling runoff with furrow dyking
    - Crop loss from ponding
    - Arriving at optimal water use through precision irrigation by Stephen Raine

## IrrigationNZ

- Resources available for download via *www.irrigationnz.co.nz*
    - Specification Checklist and Guidelines
- Everything irrigation *www.everythingirrigation.co.nz*
    - Weather information
    - Soil and soil water maps and information
    - Electronic tools

## Page Bloomer

Downloads from *www.pagebloomer.co.nz*

- Irrigation Calibration Guidelines
    - Centre pivot/Linear move
    - Traveller/Boom
    - Sprayline
- Energy efficiency in irrigation
    - Pumping efficiency

# Managing Nutrients for Resilient Cropping

Resilient nutrient use is achieved when environmental losses are minimised and the crop has a sufficient supply to reach its potential yield.

Plant nutrients come from a number of sources. Inorganic and organic fertilisers can be selected to supply a range of nutrients to the crop, but their supply rates can be very different. Crop debris and animal excreta play an important role by recycling nutrients to soil.

## Nutrient availability

The availability of nutrients depends on the source, the weather, the soil characteristics and farm management practices. Soluble nutrients such as urea, may be immediately available to the plant, however under some environmental conditions there is a risk that they will be lost through volatilisation and leaching. Nutrients from organic sources and crop debris are supplied over a longer time frame.

Soil processes and management practices play an important role in the supply of nutrients to the crop.

Plants access dissolved nutrients from the soil water through their root hairs. Soil environments that are water-logged or compacted restrict root growth and the plant's ability to access nutrients is limited. These inaccessible nutrients may then leached in water moving through the soil profile.

Soil microbial processes continually cycle nitrogen within the soil. The micro-organisms are dependent on the soil environment providing air, moisture and nutrients to support their growth. Cultivation and irrigation practices can have both positive and negative influences on this environment.

# Nutrients and the environment

Society expects farmers will manage the use of nutrients in ways that will minimise losses to the environment.

Nitrates and phosphates are appearing in our rivers and lakes and greenhouse gas emissions are increasing. Agriculture has a part to play in reducing these negative environmental effects.

The National Policy Statement (NPS) for Freshwater Management which came into effect on 1 July 2011 sets out the objectives and policies for freshwater management under the Resource Management Act.

Local governments will be responsible for managing the fresh water in streams, rivers and lakes in their regions. They will employ a catchment based approach, and consider all the activities within the catchment that could affect water quality.

**T**he environmental outcome for fresh-water in a catchment will be determined by a consultative process with the community.

There are two stages in developing a fresh water management plan.

The first stage determines what the community expectations are. These may include things like: retention of mauri; the ability to swim in the river in summer; or to use the water for stock watering without treatment.

The second stage determines what level of water quality is needed for these outcomes to be achieved.

Regional councils will set limits on nutrient losses to maintain water quality. Keep abreast of what's happening in your region.

# Good agricultural practice

Properly managed fertilisers support cropping systems that provide economic, social and environmental benefits.  In contrast, poorly managed nutrient applications can decrease profitability and increase nutrient losses.  These losses have the potential to degrade water and air**.**

The sustainable use of nutrients can be achieved by considering the 4Rs of nutrient stewardship.

These are:

- **Right fertiliser source** supplied at the
- **Right rate** at the
- **Right time** and in the
- **Right place**

4R nutrient stewardship provides a framework to achieve cropping system goals, such as increased production, increased farmer profitability, enhanced environmental protection and improved sustainability.

The sustainable nature of 4R stewardship encompasses economic, environmental and social aims.

**Economic aims** include:

- Improving net farm income
- Improving regional economic development.

**Environmental aims** include:

- Reduce unwanted losses to the environment such as:
  - erosion of nutrient containing soil particles;
  - emissions of volatile ammonia ($NH_3$);
  - nitrous oxide ($N_2O$) emissions from nitrification/de-nitrification.
- Reduce energy use per harvested unit of farm production.
- Improve recycling of crop nutrients from crop residues and livestock manures.

**Social aims** include:

- Production practices that are acceptable to local communities and to final product markets

# Nutrient Management Plans

A nutrient management plan (NMP) is a written plan that describes how the major plant nutrients (nitrogen, phosphorus, sulphur and potassium, and any others of importance to specialist crops) will be managed.

A good nutrient management plan;

- Is a valuable farm management tool that considers the land manager’s personal objectives for the sustainability of the farm business.
- Ensures that the m nutrient management on the farm meets all legal and industry requirements.
- Includes an annual nutrient budget which compares the nutrient inputs from all sources with all the nutrient outputs.
- Identifies changes in soil nutrient levels to meet production and environmental aims. Develops a nutrient-application plan to achieve these changes.
- Minimises the cost of supplying nutrients and avoids wasted spending on unnecessary or nutrients that won’t be used.
- Minimises the risk of damage to the environment.

Implemented correctly, a Nutrient Management Plan can result in an increase in production and profitability while at the same time protecting the environment.

# Resources

## Resilient Cropping factsheets

- Drainage
- Nitrogen leaching
- Nitrous oxide emissions
- Nutrient losses
- Soil Carbon
- Urease and nitrification inhibitors
- Urea
- Volatilisation

Available as downloads from the FAR and LandWISE websites:

*www.far.org.nz*

*www.landwise.org.nz/projects/resilience*

## Nutrient management tools

- FAR Focus on Nutrient management plans
- Code of Practice for Nutrient Management
  FertResearch www.fertresearch.co.nz
- Spreadmark Certified operators www.fertqual.co.nz
- AmaizeN Forecasting software for yield and N fertiliser of maize silage and grain crops. www.far.org.nz
- Wheat Calculator Forecasting software for yield, N fertiliser and irrigation of wheat cropswww.far.org.nz

# Energy and Resilient Cropping

This section discusses the use of energy in cropping, giving a breakdown of relative consumption and areas where efforts to make reductions might have greatest effect.

Total energy includes direct and indirect uses. Direct energy consumption includes fuel for driving tractors and electricity for pumping irrigation. Indirect uses include the energy in extraction, manufacture and delivery of that fuel, along with the embodied energy in fertiliser, agrichemicals and capital items such as tractors and other equipment.

## How is energy measured?

On-farm, energy is often thought of in terms of litres of diesel or kilowatt hours (kWh) of electricity.

A common unit for energy statistics is the megajoule (MJ). Converting diesel volume into MJ equivalents and doing the same for electricity, gas and solar allows total energy to be determined and comparisons made.

*1kWh = 3.6 MJ    OR    1 MJ = 0.28 kWh*

Energy use is often measured on a per hectare base which does allow comparison of different production systems such as wheat versus potatoes or milk.

It is also useful to measure energy use per tonne of yield, known as energy use efficiency. That allows comparisons of systems used to produce the same crop.

**Converting values for typical fossil fuels to usable energy values**

In New Zealand:

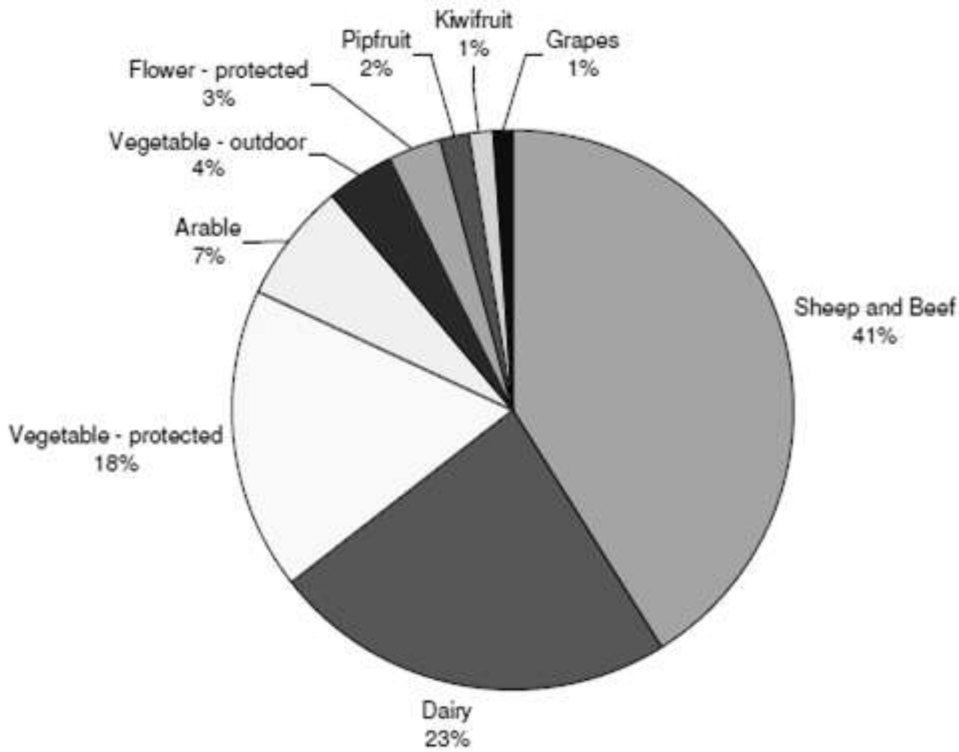
- diesel contains 10.4 kWh per litre, but only about 3.5 - 4.0kWh/L of useful energy are generated.
- 91 petrol contains 9.69 kWh per litre but only about 2.5 - 2.8kWh/L of useful energy is generated.

[These *usable energy* values for diesel and petrol are already adjusted for engine efficiency.]

# How much energy is used?

By national standards agriculture is a low energy consumer. In 2004 New Zealand agriculture consumed approximately 13.6 million MJ to the farm gate, or only 2.6% of national consumption.

Relative energy use by agricultural sectors (from Barber)




Most on-farm energy was used in the pastoral sector. Arable used only about 7% and outdoor vegetables about 4% of the total agricultural use.

# Total energy use

Total energy considers that used to make agrichemicals and fertilisers, produce seeds and transport everything to the farm. These can account for four times as much energy as the fuel used for cultivation.

A generic herbicide uses the equivalent of about 7L of diesel per kg of active ingredient. Nitrogen fertiliser needs the equivalent of 0.7 - 1.7 L diesel/kg N.

# What is energy used for?

## Cultivation

Cultivation is often the largest use of on-farm direct energy on a dry land farm.

The energy consumption ranges widely depending on what systems are used. Full cultivation requires much more than no-till.

Cultivation is the largest user of energy on dry land cropping

## Irrigation

Irrigation can account for a large part of total cropping energy use especially in drier seasons.

Consumption varies widely with deep wells requiring a lot of energy to get water to the ground surface. High pressure systems also use more energy – double the pressure, double the demand. Estimates suggest 400 kWh/ha for a single 35mm irrigation application. This equates to about 100L of diesel.

## Transport

Energy for transporting crops depends on farm layout and locations. In Pukekohe where fields can be spread over a large area, Barber suggested 25% of vegetable growing fuel use was transporting crop from field to shed. In the South Island with mostly single large properties, much less fuel is used for internal transport.

Post-harvest processes can use high amounts of energy for drying or cooling produce.  Grain drying arable seeds uses 2,500 – 5,600 MJ per tonne of water removed, depending on drying system used.

## Where can savings be made?

Energy optimisation measures range from reduced tillage and tractor driver education to irrigation efficiency and split fertiliser applications.

While direct energy use is often less than 5% of expenditure, cost savings from a 15% improvement in diesel and electricity use can boost profits significantly. Beside direct cost savings other benefits include lower labour costs, reduced repairs and less capital depreciation.

### Cultivation

Cultivation energy can be reduced through correct tractor set up, including ballast and tire pressure. Modern tractors seek to optimise engine management automatically.

Controlled traffic and minimum cultivation offer major money, energy and time savings

The biggest savings are made by reducing cultivation operations, especially high draft activities such as deep ripping and powered cultivators. Moving to controlled-traffic or minimum or no-till systems offers major savings.

### Irrigation

Irrigation energy use is highly variable, depending on location and season.

Save energy by:

- selecting the correct pump and pipe size
- running lower pressure systems
- only applying water when needed (careful scheduling)
- maximising capture and use of rain (free irrigation)

# Further information

Energy efficiency is an important aspect of many profitable and sustainable cropping systems.

Barber, A. 2004. *Seven Case Study Farms: Total Energy & Carbon Indicators for New Zealand Arable & Outdoor Vegetable Production.* AgriLink

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

# Web Resources

### Resilient Cropping

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

- Resilient Cropping Fact Sheets
    - Energy Use in Irrigation
- LandWISE Fact Sheets
    - Controlled Traffic Farming
    - Strip-Tillage

### Page Bloomer

Downloads from *www.pagebloomer.co.nz*

- EECA Energy efficiency in irrigation
    - Pump efficiency – Guidelines and Worksheet

Delivery system efficiency – Guidelines and Worksheet

# Contacts for more information


## Diana Mathers

Foundation for Arable Research

Phone: 06 877 9435

Mobile: 0 275 442 236

Email: mathersd@far.org.nz

*www.far.org.nz*

## Dan Bloomer

LandWISE

Phone: 06 650 4531

Mobile: 021 356 801

Email: info@landwise.org.nz

*www.landwise.org.nz/projects/resilience*