Sustainable Organics

Improving certified organic production techniques in the Australian industry to provide consistency for the end consumer

A report for

By Nathan Free

2015 Nuffield Scholar

June 2018

Nuffield Australia Project No 1519

Supported by:

Hort Innovation

Scholar Contact Details

Nathan Free

Evolution Agriculture P/L

391 Cumnock Road, Lake Boga 3584

Phone: 0427178626

Email: nathan@evolutionagriculture.com

In submitting this report, the Scholar has agreed to Nuffield Australia publishing this material in its edited form.

NUFFIELD AUSTRALIA Contact Details

Nuffield Australia

Telephone: (02) 9463 9229

Mobile : 0431 438 684

Email: enquiries@nuffield.com.au

Address: PO Box 1021, NORTH SYDNEY NSW 2059

Executive Summary

The focus of this report is around obtaining a successful crop rotation in organic agriculture, enhanced with modern technology, processes and knowledge to deliver the sustainability Australia's organic industry will need to bypass the negative comments aimed at it.

The most important factors for the organic farming industry are:

- Having a good technical knowledge of organic farming systems.
- Access to organic inputs.
- Consistent supply to the market.

This industry observation is confirmed by an IBIS World (2016) survey. The IBIS World identifies 250 key success factors for a business.

Validating the finding within this report are observations derived from visiting the United States of America (USA), Netherlands and France from a diverse range of businesses and organisations whose primary role was within the certified organic supply chain.

Table of Contents

Table of Figures

List of Tables

Foreword

From the age where I could reach the clutch on our old Massy Ferguson, I have been developing my passion for agriculture. During my development, I am thankful for the long piece of rope I was given enabling me to learn about production agriculture, but also marketing, fabrication and the biological side of plants and soils.

When our family farm converted the production of stone fruits and vegetables to certified organic we discovered knowledge was hard to find or, if found, very expensive. This was like the availability and price of inputs that were required for basic plant nutrition and barriers for pest and disease. This in one way was a blessing in disguise, as we started producing our own compost and pushed us to extend our networks to obtain the products that we could not go without.

Then I started to question myself, because even during my travel around the United States of America (USA), it was second nature for farmers to have a good handle on their crop rotations, organic inputs were easily accessed and there was always a consistent range of produce in most retailers.

My research topic, 'Sustainable Organics', was born after combining all my current frustrations with the organic industry here in Australia. Inconsistencies in supply, lack of credible knowledge and a fractured industry were all not sustainable traits of a successful certified organic industry in Australia. My initial idea when I left Australia on my around-the-world research study was to discover the silver bullet, something that would fix everything.

From early on in my personal travels I quickly noticed some key similarities. At most visits we always saw some mechanical weeding taking place or at least spent time looking over the equipment that did it. Equal to the pressure of keeping the weeds at bay was the importance of correct crop rotation and this area of organics was as close as I was going to get to a silver bullet. With the additions of cover crops, humus compost and strategic tillage practices, I could see a more sustainable production system suitable for our Australian conditions.

My topic of sustainable organics is meant to deliver a report that explains some of the principles, practices and processes that certified organic businesses are employing to drive

efficiency and productivity overseas. Obvious climatic differences have to be taken into account throughout this report because growing areas like The Netherlands do not have many similarities to the cereal belts throughout Australia, but a producer with irrigation water and infrastructure can utilise some of the ideas mentioned throughout this report.

Acknowledgments

I wish to thank the following for their support:

Nuffield Australia for allowing me to be part of such a life-changing experience and enabling me to study my passion.

My investor Hort Innovation for their investment in Nuffield and myself, also AUSVEG for their stake in this scholarship.

My colleagues left to keep the ship sailing back at the farm. A big thanks to Braydon for filling my shoes and developing the business goals, and Lauren for keeping the I's dotted, the T's crossed and keeping the packing team in line.

To my parents Kelvin and Deanne Free and their families for their support during my 16-week travel.

To my girlfriend Anais, who I left to move to a new house during my travels, as well as keeping the office at the farm functioning. Thank you very much.

All my visits meant a great deal to me throughout the Nuffield program, but I would like to specifically thank two gentlemen:

- Mr Gerjan Snippe, Principal at Bio Brass, and his welcoming family. This was a very inspiring visit and opened my eyes into the European organic supply chain; and
- Mr Edwin Blosser, Principal at Mid West Bio Systems, and his generous family. Edwin's knowledge on soils, compost and plant agronomy was outstanding and will continue to be a key contact within my network.

Abbreviations

C: Carbon

CO2: Carbon Dioxide

FST: Farming Systems Trial

GPS: Geospatial Positioning System

HVFH: Hudson Valley Farm Hub

Ha: Hectare

N: Nitrogen

USA: United States of America

Objectives

The objectives for this research were primarily to discover sustainable certified organic production techniques or processes suitable for Australian conditions.

In addition, other objectives included:

- To investigate crop rotation principles that can adapt to the Australian climate.
- Research efficient methods to enhance a crop rotation system.
- Show the support given to international organic farmers from government, research institutions and universities that could be replicated back in Australia.
- Find new equipment and or practices that will assist farmers in developing sustainable production systems robust enough to continue through agricultural adversity.

Chapter 1: Introduction

Crop rotation is the backbone to agricultural production systems for both organic and traditionally grown produce. For organic production, crop rotation plays an integral role in sustainable production.

> *"Rotation is the practice of using the natural biological and physical properties of crops to benefit the growth, health, and competitive advantage of other crops. In this process, the soil and its life are also benefited. The desired result is a farm which is more productive and to a greater extent self-reliant in resources."* (Kretschmann, 2015)

The key to the sustainable development of a certified organic industry in Australia is the correct management of crop rotations. Countries like the USA and The Netherlands practice, or have good knowledge of, what is required for good crop rotations, for the long-term sustainability of their respective organic industries. Table 1 below has some basic statistics for Australia, Netherlands and the USA.

Country	**The Netherlands**	**Australia**	**USA**
Year	**2012**	**2014**	**2014**
Country's Hectares in Production	48,038	17,150,000	1,652,592
Country's Annual Gross Revenue from Organics ($ AUD)	$1,433,692,482	$1,728,000,000	$57,227,184,600
Number of Certified Organic Producers	1,600	1,707	13,174
Area Planted in Hectares of Cereal Grain Crops	4,075	N/A	303,450.60

Table 1: Statistics of Organics in The Netherlands, Australia and USA

Source: USA USDA's 2014 Organic Certifier Data, Australia Australian Organic Market Report 2014 and The Netherlands Bio next 2012 Industry Snapshot

Compared to countries like the USA and The Netherlands, Australia is quite inefficient in its gross revenue per hectare in production of certified organic area. Australia has over 50% of the certified organic land globally, putting them in the best position to build on their production efficiencies. The amount of land Australia has and its comparative return per

hectare compared to the USA and the Netherlands is very poor and would be affecting the long-term sustainability image of certified organic production.

In the above statistics (Table 1), comparisons can be made between the USA's deeper understanding of organic production strategies compared to Australia where the knowledge, if it exists, is not utilised by the whole industry.

To divide the national retail revenue of certified organic by the number of certified organic hectares for each country gives the values shown below in Table 2.

Country/ Year	National Gross Revenue	National Certified Hectares	Revenue per certified organic Hectare
Netherlands 2012 ($ AUD)	$1,433,953,834	48,038	$29,850
USA 2014 ($ AUD)	$57,227,184,600	1,652,592	$34,628
Australia 2014 ($ AUD)	$1,728,000,000	17,150,000	$100

Table 2: National Retail Revenue of Certified Organic

Data, Australia Australian Organic Market Report 2014 and The Netherlands Bio next 2012 Industry Snapshot. Source: USA USDA's 2014 Organic Certifier

The numbers above are used as an example only. It is not a true indication of the organic industry in Australia, The Netherlands and the USA, but a reasonable example to show the unsustainable nature of organics in Australia currently.

Within these numbers, The Netherlands has 58.9% of its certified organic land as grazing land where the USA's percentage is 36%, which they refer to as pasture/rangeland.

The Australian organic industry needs to see greater measures put in place to increase its long-term financial sustainability across all sectors. To improve the short-term prospects of organics in Australia, the sector which has greatest responsiveness to change and adaptation to new farming practices with minimal cost and greatest ability to save on costs associated to inputs are the industries providing cereals, oilseeds, and vegetables for both fresh market and processing.

Crop rotation is the greatest requirement for a certified organic business. No matter if it is in the production of annual crops, perennial crops or livestock feed, great care needs to be

taken to ensure that crop rotation planning meets the requirements for continued plant and soil health, personal and business goals and financial stability.

One of the greatest costs to organic crop production is in-field weeds, either as a direct financial cost due to hand weeding or an indirect business cost due to lower yields. Weeding technologies have developed and there is now a vast range of equipment for small acreage to very large acreage. This aspect is directly related to crop rotation. A business will have a greater reliance on weeding equipment during the conversion process or if there are issues in the rotation planning.

Soil ameliorants are an avenue to chemically balance soil imbalances, quickly replace carbon or humus compounds, or increase soil life such as bacteria or fungal populations.

Developments made in the production of compost, particularly humus compost developed and practiced by Edwin Blosser of Mid West Bio Systems, ensures sustainable organic growth.

Organic No Till is a highly technical concept where good preparation, planning and commitment are needed. The Rodale Institute developed a document “Beyond Black Plastic cover crops and organic no-till for vegetable production” (Feeser, Zinati & Moyer, 2014). This document provides a good understanding of organic no till and some of the risks associated with it, from trial work done on the Rodale Institute’s farm near Kutztown, Pennsylvania, USA.

Chapter 2: Crop Rotation in Organic Agriculture

2.1 Basics of Crop Rotation

Building a crop rotation that is correct for business goals and long-term profitability is shown in Figure 1 below, shown in Crop Rotation on Organic Farms (Mohler & Johnson, 2009).

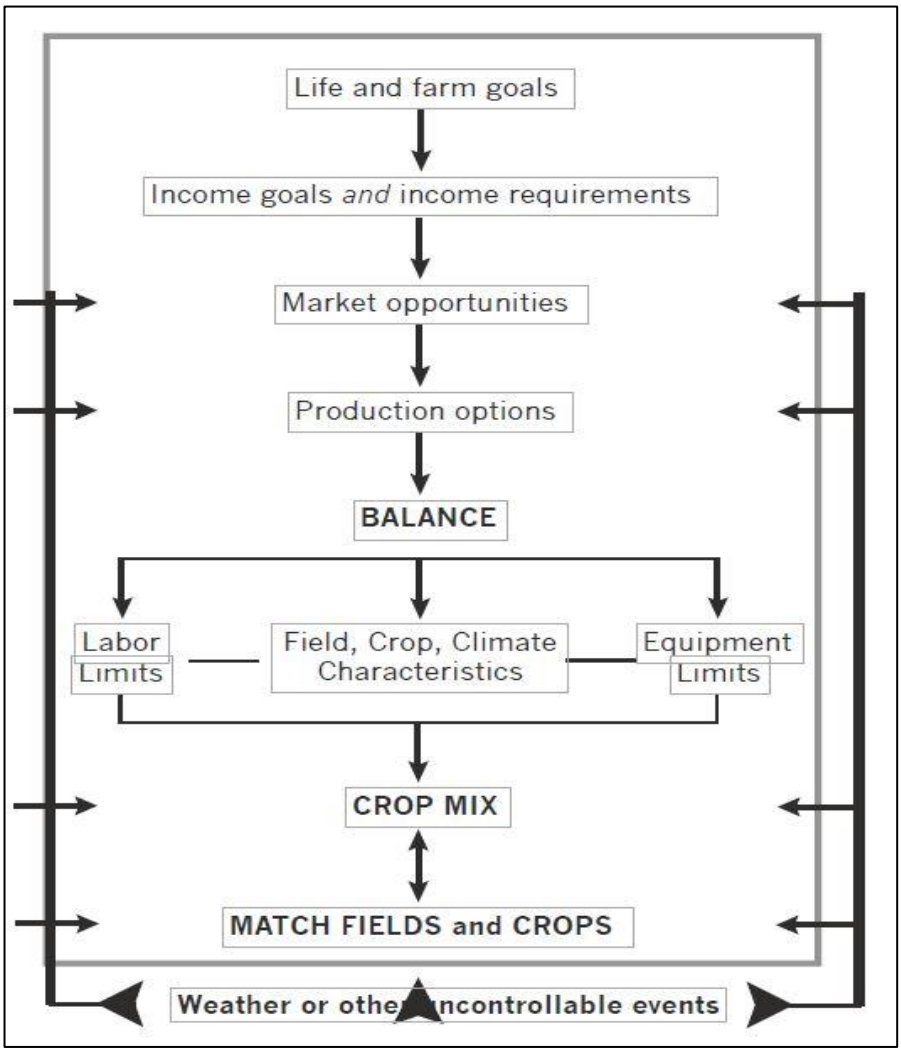


Figure 1: Crop Rotation on Organic Farms (Source: Mohler & Johnson, 2009)

There are two types of crop rotations: cyclical where the same sequence of crops is rotated indefinitely, and non-cyclical where there is no regular sequence to the crops.

During visits in the USA and in The Netherlands, there were not many occasions where cyclical rotations were used as the organic market is still quite young and producers were not in a position to lock in a rotation as businesses were still adapting to consumer demands.

Growers of cereals and contract vegetable crops had better forward planning on their crop rotation, but there was no consistency noticed during visits other than legumes being used for their nitrogen fixing capabilities and hard grain cereals used to mine deeper nutrition from the soil.

2.2 Crop Rotation: Lake View Organic Grain, and ERF case studies

The author visited the USA where, following the first day on campuses, hosted by Betsy Anne Leonard, there was a visit to Lake View Organic Grain about one-and-a-half-hours from Cornell University. At Lake View Organic Grains Mill, Mary Howell Martens, who controls the milling and distribution of the 250 tonnes of grain handled weekly, provided insights (Martens, M H, personal meeting, 2015). The two predominant markets for Lake Views Organic Grain is seed for sowing and milled seed for animal feed.

The author also met with Klaas Martens from the USA organic seed growing industry (Martens, K, personal meeting, 2015). He has been building the production of organic seed in New York State from a few fellow farmers around his kitchen table to a point where he can now fill Cornell University lecture hall.

Within their farming group, Klaas works on crop rotation strategies so that stubble or residue from the previous crop does not interfere with weeding techniques and plant dates to ensure strong crop emergence before weed competition.

Klaas mentioned in the production of cereal grains, barley should be planted around August or September, whereas all wheat sowing should be done in September. Winter barley yield will be determined by the number of strong tillers set in the fall (autumn), where wheat can set tillers in the fall and spring so poor early growth will not equal poor yield. A general rule Klaas mentioned was sowing poorer fertility soil earlier in the sowing window and higher fertility soil later in the sowing window. Table 3 below mentions some of Klaas' rotation tips.

Following	Preceding
Do not plant small grains after	Corn
Winter grains follow	Oats
Only Rye or Triticale	Barley
Winter Barley	Winter Wheat
Avoid Small Grains in fields with	Volunteer vetch

Table 3: Rotation tips from Klaas Martens

Source: K.Martens, USA Organic Seed Growing Industry

Figure 2: Cereals being harvested in USA. Note the strong red clover understory fixing nitrogen to the soil (Source: author)

Above is a picture of the cereals during harvest take special note of the strong red clover understory fixing sufficient nitrogen to the soil to sustain a corn crop later in the year.

Klaas also discovered his own soybean variety that had come up in the field named “Boyd” after a local agricultural leader, Bill Boyd.

Theo Heijboer (personal meeting, 2015) is the production manager of ERF, an agricultural farming business and has the largest agricultural land holding in The Netherlands at 1,800 hectares of which 80% was in organic production. Producing forage and vegetable crops as well as cereals it was a good opportunity to see a large scale organic crop rotation system.

Theo's cereal crops average around eight metric tonnes per hectare. Cereal crops are always followed by a legume cover crop producing 70-80kg of nitrogen per hectare. After the vetch cover crop a cash crop will follow cash crops grown by the business are potato, onion, carrots, beetroot, parsnip, peas, beans, spinach for freezing, cabbage and pumpkin. ERF do have good access to liquid cow manure which is a low-cost nitrogen supplement. The manure would be spread at 30 cubic metres per hectare, costing about $12 Euro per cubic metre.

2.3 Crop Rotation: Frederick Thomas, France

During a visit with Frederick Thomas in Clermont Ferrand, France, the engineering side of developing a sustainable organic production system was explained (Thomas, personal meeting, 11/10/15). Engineering side refers to building a successful cover cropping system within the crop rotation. Fredrick was also trialling organic no till principles.

More sustainable production techniques are very desired in France. Within Frederick's presentation, his key take home message is a three-point relationship between agronomy, environment and economy which fits in well with the direction organic agriculture in Australia needs to track along.

Frederick's presentations are cautious of farmers who are converting to organic or just farmers wanting to improve their soils so there is encouragement for the use of strip till in this process. This keeps an area of soil undisturbed following no till processes, but then cultivates strips within the fields. Where the commercial crops are sown, they are in most cases the original sowing equipment which saves on unnecessary cost during the conversion process.

Obvious advantages are held in developing a cropping rotation system within a French climate that is not like parts of Australia with its temperate climate. A suggestion would be to use overhead irrigation technologies on organic farms to provide rainlike events to sustain off season cover crops or double cropping possibilities.

A quote by Frederick Thomas (2012):

> "*During the period between cash crops, seeding any cover crop is a big step forward in restoring water quality, maintaining and developing soil fertility and in the long*

term saving fertiliser inputs and reducing the need for tillage. There is no such thing as a bad species and neither are there any specifically bad ones. Each plant has its own attributes that fit specific or diverse situations. So, it is very important to have a good knowledge of each one of these important "agronomic tools" in order to use them properly and gain the maximum benefits".

Table 4 below shows some cover crops more suited to Australian conditions and associated comments from Frederick on their "agronomical tool" status.

Cover Crop Type	**Comments**
Spring or winter oats	Not very expensive, easily established suited mainly to autumn sowing if sown to early lower biomass may be produced.
Fodder radish	A versatile plant suited to most soil conditions, can produce a large biomass, is reasonably drought tolerant and establishes good soil structure.
Rye	Due to its high biomass capabilities it is a good mulching crop to proceed the rolling and sowing of an organic no-till crop. Plant is very aggressive and aids in developing good soil structure.
Oil seed rape/canola	Also, inexpensive as a cover crop, the plant is aggressive contributing to the development of good soil structure. Sufficient nitrogen needs to be available for strong growth.
Sunflower	Suited to hot and dry conditions if planted early in the summer, it absorbs nutrients like nitrogen, phosphorus and potassium well so provides a good mechanism to supress weeds even though it does not cover well.
Flax	Establishes well under dry conditions, produces a low biomass but still competes well with weeds.
Turnip	Absorbs residual nitrogen in the soil, can be suitable for grazing. Nitrogen will be available to following crop later whilst being depleted early.
Spring or winter vetch	It is slow to establish but due to its climbing nature it will smother out most weeds, it fixes nitrogen well. It has a shallow root system, enabling good biology development. Easily controlled by most tillage systems.
Forage pea (not grain pea)	Very versatile legume, it is harder than grain pea and produces a larger biomass.
Lentil	Prefers calcareous and non-acidic soils, does not produce a high biomass but is competitive against weeds with a high seeding rate it is a good companion to canola.
Fenugreek	Plant and seed smell like curry and is suited to clay or calcareous soils and quite hardy conditions. It is not an aggressive plant but companions well with canola.

Table 4: Cover crops suited to Australian conditions and associated comments from Frederick Thomas (2015) (Source: Author)

2.4 Crop Rotation: Cornell University, USA

In addition to ensuring that a crop rotation and cover cropping decisions are sustainable, Australian farmers need to continually keep abreast of work being done on new varieties suited to organic production in Australia and overseas for the cereal or cash crops used in the rotation. The author has two examples of plant breading work being done to promote yield in organic cropping systems.

In a meeting with Dr Margaret Smith (personal meeting, 23/07/2015), an insight into traits needed for forage and seed corn was established. Margaret's breeding and trialling site is within the Cornell University's farming site where commercial validation of the work is ensured by planting and growing the corn using industry best practice. 30-inch (76 cm) spacings are used in the variety trial sites, and 5 % Nitrogen- 4 % Phosphorus -5 % Potassium chicken manure is used as additional nutrition. The results noticed during the meeting were severely affected by the spring rains, but certain varieties had prevailed in the conditions.

This trialling was done over a number of different sites within the USA and the full publication can be found at: http://plbrgen.cals.cornell.edu/research-extension/crop-variety-trials/corn-variety-testing

The second example is from one of the USA's leading breeders in cucurbits, Dr Michael Mazourek (personal meeting, 23/07/15) from Cornell University, where he completes most of his work breeding cucurbit varieties suitable for organic production. These varieties both carry traits making them easier to grow in organic agriculture as well as new produce types that will appeal to consumers in the USA and overseas. Some of these developments include trombone squash and avocado squash which are named generally on their appearance not on their eating characteristics. Cucurbits are a difficult plant type to breed bug resistances to as many insects that eat or chew on the cucurbit leaves do not have any known predators due to compounds found in the cucurbit plant.

Soon after the visit, an organic tomatoes variety selection evening was due to be held and since then, a number of different twilight or daytime information sessions scheduled to provide answers to the farmers or industry problems.

Chapter 3: Weeding Technologies

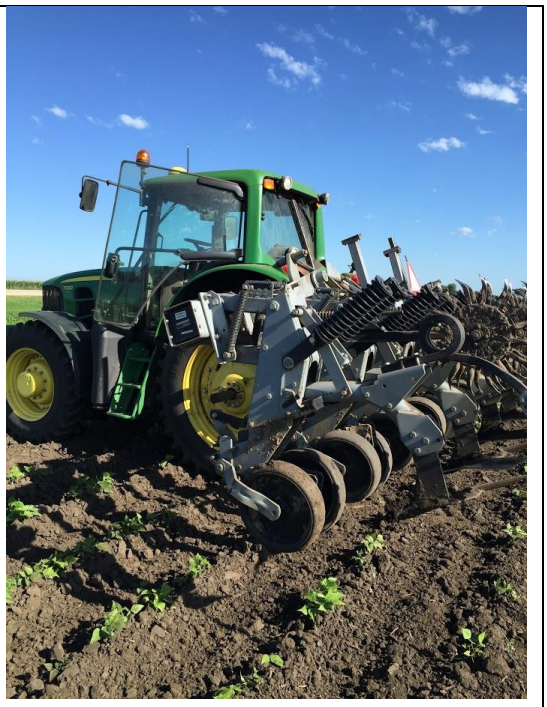
During the visit to Hudson Valley Farm Hub (HVFH), part of Cornell University's College of Agriculture and Life Sciences, a weeding equipment field day was being held.

Machinery manufacturers and farmers were brought together on the site so a true demonstration could be shown. All the weeding equipment on the day was mechanical equipment with the purpose of disturbing the soil to kill or prevent weeds from growing. All the machinery was demonstrated without GPS making it suitable for the smaller producers in the audience but allowing the larger GPS type farmers to let the mind imagine the possibilities on what was on display.

From the observations at the HVFH, Table 5 below explains some of the equipment displayed and weeding equipment observed.

Type: Basket Weeder **Location: Hudson Vallee Farm Hub, USA** Description: The baskets rotate at a different speed to the speed of the tractor. A basket weeder weeds up close to normally young high value crops; for this reason, the baskets are mounted under the engine of the tractor as shown in this image. If it were to be mounted on a 3-point hitch it would need GPS or steering assistance.	

Type: Spring Tine Weeder or Blind weeder **Location: Lake View Organic Grain, USA** Description: A blind weeder or a spring tine weeder is traditionally a 3-point hitch implement, followed by a low horsepower tractor. The implement has a configuration of long ¼ inch steel tines tensioned with a spring that is normally adjustable. The action of the weeder is to disturb the soil shallow. Due to this light movement, the tine can deviate around young plants. The reason for the name blind weeder is that (as long as everything is set correctly) drive forwards and do not look back as it looks aggressive.	
Type: Parallelogram Knife weeder (hand controlled) **Location: Hudson Vallee Farm Hub, USA** Description: Wheel assisted parallelogram knife weeder with second operator steering assistance. This type of implement is used on smaller scale production or specialised crops. The knife in the image is set to disturb the soil between the rows but does not disturb the soil near to the plant. In this scenario, hand weeding or a second pass would need to occur to clean the field of weeds.	

Type High Speed Solid Shank Knife weeder, GPS guided. **Location: Illinois, USA** Description: This solid mounted, high-speed knife is mounted on a parallelogram but with large wheels and heavier construction. The image shows the knives set up on 30-inch centres for weeding black beans. There is a straight disc leading the knives designed to cut through any trash so that the soil can flow through the knives correctly. The knife is normally set quite shallow disturbing small weeds and cutting larger weeds at the surface normally as close to three inches from the growing crop. To achieve this GPS needs to be fitted to the tractor.	
Type: Ridged frame, beet shank knife weeder Description: A beet shank knife weeder can be used on small to large row crop production systems (dependent on the frame size). The shank has manual adjustment horizontally and vertically on the tool bar, with a small amount of row width adjustment normally done from the tractor cabin.	
Type: Parallelogram mounted spade feet on curley tine shanks, followed by finger weeders. **Location: Hudson Vallee Farm Hub, USA** Description: This precision weeder is designed to be a one pass weeder with abilities to also control larger weeds or high levels of trash in the mid row due to the spade type feet on the S shaped spring tines with depth control by a parallelogram. These are followed by finger tine weeders that could detach if not required as they can only be used at specific times during a plants development. When the plant is still quite young with 5-8 true leaves and an established root system, the finger weeder has the ability to disturb weeds in the plant row but require loose dry soil to complete this task.	

Type: Self Propelled, Weeding Aid. **Location: ERF Organic, Netherlands** Description: This is a self-propelled weeding aid; this similar principle can come as tractor drawn or three-point hitch attachment. The employees lay on the padded benches, similar to a massages bench where they can remove weeds from the plant row that may have been missed by mechanical methods. This style of weeding is used in higher value crops or mechanically harvested fresh market crops where weed contamination is not acceptable. The picture shows a solar powered self-propelled weeding aid, with high purchase price but negligible running costs.	
Location Hudson Vallee Farm Hub, USA Description: this weeder is used single row planted crops on raised beds with the centre to centre of row measurement greater than 24 inches. The front disc cuts away soil from near the plant within 2-3 inches of the stem; following this are larger discs that replace the soil back in to the previous shape of the raised bed. Speed is not an issue due to shields protecting the plant from flying soil. This style of weeder has abilities to control larger weeds in more mature crops. As there is a high soil disturbance using this method, timing is critical so that full canopy could be achieved soon after the pass.	

Type: Hydraulically driven, harrow. **Location: Illinois, USA** Description: This hydraulic power harrow style weeder is a quick efficient way to remove weeds from the plant row. This is a cost-efficient way to remove weeds on larger scale row crop operations. This machine was being used in black beans where a high-speed knife did the primary pass and then this eight-row hand operated power harrow utilised the loosened soil from the knife pass to spin out the remaining weeds from close to the plant. These harrows are set very shallow, to grab the weed roots. The employee seated on the 3-point hitch attachment steers two of these rotating heads in and around the growing crop to remove unwanted weeds, the hand operator can adjust width to compensate for plant maturity, soil conditions of driver instruction. GPS is not essential for this type of weeder but high hydraulic abilities are required.	

Table 5: Some of the equipment displayed and weeding equipment observed *(Source: Author)*

Klaas Martens (personal meeting, 24/07/15) from the USA organic seed growing industry has divided up the fight against weeds into four main areas for the successful production of organic cereals and legumes.

Tillage: Before the planned sowing date, tillage needs to commence well in advance, so the soil is in the correct state when a pre-sowing tillage pass occurs removing possibly millions of potential problems (weeds) from the production cycle.

Planting: At planting, ensure the planting equipment is in good working order. Lower or higher seeding rates to the desired level will complicate the production season. Get out and check seeding equipment regularly to ensure it is consistent.

Blind Cultivation: Early season blind cultivation is done soon after sowing and well before emergence. The aim of this pass is to aerate and disturb the top 3 to 5 cm (1-2 inches) of soil (the soil above the sown seed). Blind cultivation can be done with all kinds of tractor mounted implements, coil tine cultivator, Lilliston weeder, rotary hoe or shallow working harrows.

Row Cultivation: The last stage is between row cultivation and its importance is different from season to season and per plant type. As soil conditions change so should the adjustment of the equipment. If the soil goes undisturbed it may create the perfect environment for later weed pressure.

During the same visit, the author also met with Ryan Maher (personal meeting, 23/07/15), Extension Specialist Reduced Tillage. His research work focuses on mulching systems using a control crop of cabbages. The trialling consisted of bare soil, straw mulch, compost mulch at a depth of 1.5cm, permanent beds, and heavy covers removed pre-planting. Pelletised chook manure was used as a control fertiliser over the plot. Mechanical and hand weeding approaches were used in line with commercial benchmarks. Out of all the trials, heavy black plastic covers that were layered over the bed during the spring before being removed pre-planting had the best results compared to the straw trials that were very nitrogen deficient and far weaker.

This study was in its first year of four and on an annual basis there will be a rotation with peppers or a cucurbit type plant. This will give opportunities to the poorer performers in the first year to see if the added carbon in the straw mulch adds stability to the soil in later trials.

Figure 3: Hudson Valley Farm Hubs Weeding Equipment Day (Source: Author, 2015)

Figure 3 was taken at the Hudson Valley Farm Hubs Weeding Equipment day. A representative from K.U.L.T Cultivation Solutions explained the results from one pass with a close small knife weeder.

Chapter 4: Soil Ameliorants

Mr Edwin Blosser (personal meeting, 31/07/2015) is the principal of Midwest Bio Systems in Illinois. He and his family run a very successful compost turner engineering company, soil agronomy services and productive agricultural row crop business producing cereals, black beans, corn and soybean. On the author's family property in Northern Victoria, Australia, Midwest Bio systems compost is used, so when the opportunity arose to visit during the travels in the USA the author jumped at it.

A workshop was held over three days called the 'Humus Advantage Workshop' (Blosser, 2015). Due to design characteristics only known to the aero master range of compost turners made by Midwest Bio Systems, humus can be created. Edwin outlined how compositing is an art, but once learnt the principles will stay for life and a compost turner is only one part of the picture. Input stocks need to achieve a 25:1 Carbon (C): Nitrogen (N) Ratio, meaning if there is a sawdust stock that may be 40:1 C: N then this may need to be limited and mixed with a manure product that is 15:1 C: N Ratio. In addition to this, each compost stock will need to be treated differently so that it is at the same stage in the compost row when mixed together which is known as synchronising. Wood chips compared to fresh manure are very different but need to be synchronised in a way before the composting process takes place so that they will react similarly within the compost row. Without taking this care early in the composting process there will be a variation throughout the compost pile that could lead to poor quality compost not containing humus.

Figure 4: Compost row being turned at Edwin Blosser's composting site in Tampico, Illinois (Source: Author, 2015)

Figure 4 shows a compost row being turned at Edwin Blosser's composting site at Tampico, in Illinois, USA.

The composting process needs to be monitored consistently for the production of Carbon Dioxide (CO2) and physical analysis of the moisture content. These factors are important in obtaining high grade humus compost. The CO2 reading is representative of the activity within the compost pile, as every second there is organic matter being broken down there is a large population of biota digesting and being digested within the compost pile. All these biotas need to respire which increases the CO2 reading. Once a high point has been reached for CO2 within the compost row, turning will need to be completed and the turning process needs to be monitored. If the compost turner is not set up correctly, it will not fully remove the CO2 requiring a revisit of the pile for turning earlier than if the CO2 had been removed correctly.

The author also learned about soil health from Edwin, specifically that the production of high quality compost is still only a piece of the pie within the agricultural system. During the three-day course Edwin used a term 'connecting the dots' which is explained well by the below quote 'In this work shop, we will connect the conversion of organic matter to humus

compost then connect the use of humus compost to sustainable soil fertility' (Blosser, personal meeting, 2015).

Table 6 shows an example of improved soil fertility equalling improved profitability and less reliance on synthetic fertilisers, creating a more sustainable production system.

<table>
<tr><th colspan="2">Production Season 2001, No till Corn</th><th colspan="2">Production Season 2007, No till corn with compost at retail price of $120 per ton</th></tr>
<tr><td>NH3 151.4 kg./ Ha

MAP 168.4kg. /Ha

POT 168.4kg / Ha</td><td>Program cost Dec 2001

USD$263.67 ($106.75/acre)</td><td>NH3 89.8kg./ Ha

MAP none. / Ha

POT none. / Ha</td><td>Program cost Dec 2007

USD$195.80 (USD$79.27/acre)</td></tr>
<tr><td colspan="4">Synthetic Fertiliser Saving USD $67.87/Ha (USD $27.48/acre)

<u>Yield Benefit USD $178.33/Ha (USD $72.20/acre)</u>

Saving plus Benefit USD$246.21/Ha (USD $99.68/acre)</td></tr>
</table>

Table 6: Example of improved soil fertility improving profitablity Source: Author, 2017

In addition to Table 6, a long-term user of humus compost Alan Dale of Walnut Illinois, stated:

> *"I have been a no till farmer for over 20 years and a humus compost user for the last five years. I have noticed that humus compost not only increases soil structure but helps the soil manage water. I have less standing water after heavy rain and more moisture retained in the soil. I have been applying humus compost to 1,000 acres of my crop land for the past five years. In that time, I have been able to eliminate all my P & K fertiliser and reduce my N to 80lb/acre in corn. Over the same five years my corn yields have increased 10% over my five-year running average."* (M0hler & Johnson, 2009)

Chapter 5: Organic No Till

Cover cropping, and more predominantly organic no till, was the main topic of Jeff Moyer's presentation at Rodale (Moyer, 2015). Jeff is a world-renowned authority in organic agriculture and Executive Director at the Rodale Institute in Philadelphia, USA.

Jeff explained that to use organic no till in an organic production business, it needs to be accompanied by a great deal of knowledge and ability to financially wear trial and error.

At the Rodale Institute, trials are done using corn and soybean as these crops comprise 49% of the acreage in production in the USA. From the same 2007 statistics, (Blosser, 2015), vegetables made up 1.5% of the USA acreage under production.

Figure 5: Roller Crimper at Rodale Institute, Philadelphia (Source: Author, 2015)

Figure 5 shows a roller crimper attached to a tractor using the front linkage points, the roller crimper rolls over a green cover crop at a specified age generally just before the tilling leaf emerges using an oat crop as an example.

Once the cover crop has been roller crimped a seed drill can follow to sow the commercial crop. An extra addition to the seed drill is a triple disc trash cutter. This comprises of two

outside rubber discs 2-3 cm wide and a centre flat disc that cuts through the trash. This action requires 50kg of force either by weight or spring loading.

The concept of organic no till enables great sustainability for the organic agricultural sector because of the cost saving and soil structure benefits compared with bare soil cultivation, including the continued weeding pre-and post-emergence. Also, using a bare soil cultivation limits the acreage one business can sow per season due to the heavy reliance on cultivation equipment required for weed management and aeration of the soil.

As mentioned above, a farmer needs to have a good working knowledge of the commercial crops so that decisions can be made into what type of mulching crop is used before the commercial crop is sown. This decision needs to consider legume vs cereal, summer vs winter, the predominant weed pressure and already existing nutrient availability of the soil.

The positives of sustainability, improvement to soil health and reduced cost do come with some negatives. This includes poor cover due to a poor growing cover crop leading to increased weed pressure. This issue impacts the commercial crop greatly as there is still some residual cover and standard cultivation practices cannot be used. The roller crimper does not kill off the whole cover crop the first time. Confidence needs to be gained in using the roller crimper so the operator can be sure of an effective result.

The organic no till presentation was done within the Farming Systems Trial (FST) (Moyer, 2015). This trial plot began back in 1981 to study what happens during the transition between chemical to organic farming. However, this trial grew as yields on the organic crops surpassed the chemical controls. The trials consisted of organic manure, organic legume, conventional synthetic and no till systems. Other noticeable differences during the FST were organic and conventional soybean and corn were of equivalent yield in the tilled soil trial, and in the drought years, the organic corn yields were 30% higher than the conventional while GMO drought tolerant varieties were only 6-13% better than the conventional option. The organic corn and soybean tolerated a higher level of weed competition compared to the chemical approach. This gives more flexibility to the farmer compared with chemical or GMO production practices.

To quote Jeff (Moyer, 2015) at the Rodale Institute:

> "*Crop rotations in the organic system are more diverse than in the conventional systems, including up to seven crops in eight years compared to two crops in two years. This means that, while the conventional system produces more corn and soybeans because they occur more often in the rotation, organic systems produce a more diverse array of foods with a broader range of nutrients and are better positioned to produce yields, even in adverse conditions*."

No matter what crop is being grown, if it is for commercial harvest or a cover crop to improve the soil, care needs to be taken to ensure it fits in with the business model.

Rodale Institute is a very progressive organisation leading in organic research as well as benchmarking against commercial alternatives. Overall, at Rodale Institute the author made a number of observations in cover cropping, composting, plant varieties, diversification and crop rotations.

Conclusion

Sustainable organic production is a combination of many and numerous factors explained in this report. The notion of organic farming being unsustainable, or even a farming practice that achieves production by the neglect of production crops, is entirely incorrect.

Organic farmers are informed, supported and resourced in the USA and the Netherlands. The four following principles are observations made throughout all visits confirming the sustainability of organic agriculture for both soil and profitability.

A basic crop rotation plan that combines business and personal goals, financial stability and development of healthy soils. Within this crop rotation it was noticed throughout the USA and The Netherlands that farmers would allow fields to go into cover crop within the rotation anywhere from every two-to-four years.

Use of weeding equipment was more apparent in the production of higher value crops except for the blind weeder in cereal crops. With the development of higher soil fertility and less cash type crops in the rotation, weeding equipment will not be relied on as heavily or only required in emergency situations.

Soil ameliorants such as compost play a big part in the production of successive cash crops or in crops that feed heavily like corn (sweet or maize), or when converting traditionally farmed soils or poorer soils into organic production. Due to the expansive nature of Australia, care needs to be taken with the cost of possible inputs for compost recipes. Diversity is the key to composting but ensure compost is required in the crop rotation as even lower diversity compost may be $30-40 per tonne once completed.

Looking to the future needs to be a key part of any sustainable organic business. GPS guidance, crops tailored to consumer preferences and organic no-till should be of particular focus. Throughout the visits and countries visited, organic no-till was still being put through its paces by some of the most experienced organic and sustainable farmers. As seasonality and climate play a big part in its success, if irrigation is not a possibility, an organic farming business looking to adopt organic no-till practices needs to be in a strong position.

The basics of a farming business and the goals of the business need to be clear as without this, building sustainable crop rotations with the correct addition of ameliorants and equipment will not be possible. Successful farmers were spending equal or greater time in the office crunching the numbers on new techniques or processes to improve productivity and for profitability, as they did implementing those initiatives.

Recommendations

Certified organic agriculture in Australia has a great future if producers can take on practices and processes followed throughout the world with or from information contained within this report. Recommendations include:

1. Time should be taken for producers to sit down and develop their **crop rotation plan** as without this, it will be difficult to keep on track making progress along the sustainability road. In building a crop rotation, take into consideration the life and farming goals of all participants in the business in addition to the principal farmer. This will ensure the time spent planning is not wasted and good successes are achieved.
2. The visit to Hudson Vallee Farm Hub, part of Cornell University, was an example of what is needed in Australia to help develop the industry and move it forwards from its static position. **Develop community groups of likeminded farmers**, utilise a corner of a member's paddock to trial ideas the group may come up with using current members equipment or utilise the groups common purpose to approach machinery manufactures to do trials on the plot. This ability will minimise cost individually and enable greater development of ideas having a greater cross section of producers. Community groups of likeminded farmers with similar but different objectives enables trials to be kept local and specific to the region and local issues. This enables answers to trials that are relevant.
3. For the production of most organic broadacre or row crops **the addition of a blind cultivator** is recommended as it can be used in a number of different scenarios throughout the crops life; light cultivation, pre-planting and post-planting before emergence and post emergence once the root system has established.
4. The **use of soil ameliorants and weeding equipment** need to be seen as possible additions to a cropping system and used sparingly rather than seen as a cornerstone of the program. Correctly preparing the soil before planting within a suitable crop rotation enhances the three main aspects to soil health (physical, chemical and biological) and should result in sustainably grown profitable crops.
5. In the sustainable production of organic crops, **choosing the correct crop for production area** is important. Planting the incorrect crop can result in poor

agronomical results. Before planting new varieties or crops, consult local advice or documentation.

6. Sustainable organic or traditional farming businesses need to be **searching for new or existing knowledge** to improve or maintain the businesses goals and profitability.
7. **Developing a national, regional and local sustainable organic farmer group** will be an essential part of the development of certified organic in Australia.

References

Blosser, Edwin, Principal of Midwest Bio Systems, Illinois, USA (personal meeting) 31/07/2015 – 3/8/2015

Burros, Marian, Quote, FEB. 17, 1999 of the New York Times

Feeser, J., Zinati, G. and Moyer, J. (2014) Beyond Black Plastic - cover crops and organic no-till for vegetable production, Rodale Institute, PA, USA

Heijboer, Theo (2015) Production Manager of ERF, The Netherlands (personal meeting) 26/08/2015

Kretschmann, Don (2015) Farmer, Kretschmann Farm, USA (personal meeting (2015)

IBIS World (2016) Survey - Organic Farming in Australia. Date Published: October 2016

Maher, Ryan (2015) M mulching Trials, Cornell University (personal meeting) 23/07/15

Martens, Klaas (2015) USA Organic Seed Growing Industry (personal meeting) 24/07/15

Martens, Mary Howell (2015) Lake View Organic Grain, USA (personal meeting) 24/07/15

Mazourek, Dr Michael (2015) Plant Breeding and Genetics, Cornell University (personal meeting) 23/07/15

McKay, Steve (2015) Farming Manager, Cornell University (personal meeting) 23/07/15

Mohler, C. and Johnson, S. (2009) Editors. Crop Rotation on Organic Farms: A Planning Manual, NRAES 177 Published by Plant and Life Sciences, NRAES, July 2009

Moyer, Jeff (2015) Executive Director, Rodale Institute, Philadelphia, USA (presentation) 20/07/15

Schindelbeck, Dr Bob (2015) Soil Health, Cornell University (personal meeting) 23/07/15

Smith, Dr Margaret (2015) Plant Breading and Genetics, Cornell University (personal meeting) 23/07/2015

Snippe, Gerjan (2015) Principal at Bio Brass, (personal meeting) 25/08/2015

Thomas, Frederick (2015) Presentation in Clermont Ferrand, France (personal meeting) 11/10/15

Thomas, Frederick (2012) TCS Magazine, 7 May 2012

Plain English Compendium Summary

Project Title:	Sustainable Organics

Nuffield Australia Project No.:	1519
Scholar:	Nathan Free
Organisation:	392 Cumnock Road Lake Boga, 3584 Victoria
Phone:	+61 (0) 427 178 626
Email:	nathan@evolutionagriculture.com

Objectives	• To investigate crop rotation principles that can adapt to the Australian climate. Research efficient methods to enhance a crop rotation system. • Requirements for Australian consumers. • Show the support given to international organic farmers from government, research institutions and universities that could be replicated back in Australia • Find new equipment and or practices that will assist farmers in developing sustainable production systems robust enough to continue through agricultural adversity.
Background	This report focuses on obtaining a successful crop rotation in organic agriculture, enhanced with modern technology, processes and knowledge will deliver the sustainability Australia's organic industry will need to bypass the negative comments aimed at it. This industry needs a good technical knowledge of organic farming systems, access to organic inputs, and consistent supply to the market.
Research	Research was conducted throughout the USA, Netherlands and France in the areas of sustainable organic crop rotations for both dryland farming and irrigation. Soil ameliorants, humus compost and cover crops, weeding technologies that are being used in organic production and gaining insights into the processes involved in organic no till production of crops. Interviewed persons range from doctors, industry representatives and primary producers with their main focus in the production of sustainably grown crops in Australia.
Outcomes	Building a crop rotation system that encompasses the business and life goals whilst building on the three pillars of soil health which are chemical, physical and biological. Utilising soil ameliorants such as humus compost can assist with development of soil health characteristics. Using best practice equipment in the production of sustainably produced organic crops is essential.
Implications	The production of certified organic food and fibre crops in Australia needs to develop in line with international producers. Continual sourcing of new or existing knowledge needs to be a key goal for the business so that they can keep abreast of industry change or improvements. An Australian Organic framework needs to be established to assist organic farmers to adopt new more efficient or sustainable farming methods and or processes so that they can keep in line with international benchmarks.
Publications	Presentation, Nuffield Australia National Conference, September 2017 .