Managing Farm Energy Use To Capitalise On Carbon

Maximising Efficiencies

A report for

By Ryan Smart 2012 Nuffield Scholar

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Sponsored by:

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Executive Summary

Australia is believed to be one of the world's more expensive countries to do agricultural business in, with high taxes, high labour costs and no subsidies, to name a few contributing factors.

With the nation's unpredictable climate changes and ever increasing costs, never has the importance of managing carbon and maximising efficiencies in agriculture been so relevant. This report focuses on researching and adopting management systems that increase energy efficiencies and sustainability that are practical and can be implemented cost effectively into Australian agriculture. This study aims to identify systems to better manage energy use on farms without compromising profitability and soil health. These systems need to involve a broad range of farming pursuits including cropping and livestock grown dry land and under irrigation.

It is imperative to gain a solid understanding of major areas of mixed farming, their relationship to energy use and economic productive balance. The results outlined below from the study could have a real impact on the future of Australian agriculture.

This involved:

- Exhaust Emission Technology; for reducing carbon footprints, increasing soil health and reducing input costs.
- Satellite Imagery Technology; capturing information about growth, moisture, nutrients and yield on a weekly basis, giving farmers more information on plant health and nutrition than ever before.
- Livestock; researching genetics, efficiencies and technology that is being adopted and developed to help us select the traits producers need.
- Fertiliser and Energy Inputs; looking at systems and methods to reduce the total fertiliser use and still produce the same or increased production.
- Soil Health; systems have been created for cropping and grazing that will sustain and increase soil health with the ability to spend less and increase production.

- Light Emission Technology; amazing systems that have been developed for micro-farms, such as hydroponics or green houses, which allows high production rates in extremely small areas, using 10% of the water and no chemicals, and operating at the market's front door.

The technology that has been developed for managing agriculture around the world allows us to be more cost effective, more energy efficient and more sustainable. Looking forward to the rapid progression of technology, there are some exciting times to come. The adoption of these technologies will depend on many factors, including social and health implications, costs to implement, existing management structures, environment, government and legislation, to name a few. Necessity to change will ultimately be the driver for adoption to bring the best, most efficient and sustainable future for Australian agriculture.

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Foreword

Agriculture is my future. I grew up on the property that I now manage, a part of our family business, which consists of a very diverse range of primary production. This includes broad acre cropping growing wheat, barley, milling oats, hay oats, mustard, canola, beans, peas, phalaris and coriander to name a few. Irrigated enterprises include lucerne seed and fodder production using flood, centre pivot and sub-surface drip irrigation. The livestock enterprises include a White Suffolk sheep stud and beef cattle. We also grow some grapes for wine production.

You can see that in our business, there is a broad range of sources of income; this brings with it high costs and many areas of spending, and many areas where costs can become unsustainable. This highlights the need for the business to become more energy efficient and adopt management systems and practices that tie in with each operation, to control costs and increase profits by managing efficiencies and creating sustainability.

We have been reviewing our efficiencies regularly, which is an economic necessity. This has taken on greater urgency with increased expectations from the consumer for a reduction in greenhouse emissions and knowledge of how their food is produced. Part of these reviews was to establish our current carbon position and what would we have to change. We agreed to get a carbon audit done on our business, and to this end we completed a farm gas calculator but at this stage there is limited information, which could be entered into it. It did, however, provide us with a base figure to work with. With a total of 2,500 tonne of carbon dioxide equivalents produced (64% of that being methane) which could amount to a significant potential cost, depending on the cost per tonne of carbon. Our reviews, from an energy perspective, have questioned everything we do in a mixed-farming operation, from the way we run livestock, manage our pastures to seeding technology. Whilst we have many hypotheses we did not have definite answers. This is why I needed to discover, analyse and adopt information from overseas to help create efficiencies in these areas.

Cost of production is another major factor impacting the sustainability of our farming operation. Twenty-five years ago we bought a combine that cost 500 tonnes of wheat, seven years ago we bought a combine costing us 1,000 tonnes of wheat; two years ago we bought a combine that cost us 2,500 tonnes of wheat. This is just one example of cost increases that we cannot control. In this case the capacity of the harvester has at best barely changed and yet over 20 years the terms of trade to purchase the harvester have deteriorated by 500%. This leaves us with some of the things we can control - inputs, management practices, and adoption of technologies to help us improve viability in the Australian agricultural industry. As you can see this is why we need to manage our farm energy use and to maximise efficiencies in all farming operations!

The outcomes of this research will be extremely important for our livelihood and future in agriculture. I also believe this will be the case for Australian agriculture in general no matter the size or make up of the business. All production needs to be managed efficiently to capture both profit margin and future sustainability.

Acknowledgements

I would like to thank my wife Anna for supporting me through this experience and helping make it possible. Without the full support that I had, this journey would have been extremely difficult. I also had Anna and Hugo (my 11 month old son at the time) travel with me on my private study; we were able to experience the same things together. I believe for the future of farming as a family business this was a huge advantage.

I would like to thank Nuffield Australia for making this possible and giving me the opportunity to undertake such an amazing programme. The organisation of the GFP was just fantastic and was an experience that I will never forget. The knowledge that it has given me of the global perspective is something that you cannot buy and this became evident throughout my private study.

I would like to thank my sponsor, Grain Research and Development Corporation (GRDC) for their continued support for Nuffield and the current work they are doing for Australian agriculture. This experience would not be possible without their generous support towards Nuffield and Australian farmers with a passion to pursue their hunger to learn.

I would like to thank my family and business teammates who were able to cover my absence. The ability to be able to leave your business for almost four months and have it run so well is what makes the experience that much better and enables you to give your study the full attention it deserves.

I would like to thank all the fellow Nuffield's that helped and guided me along the way. The GFP group I travelled with had such a fantastic dynamic and we will be friends and business mentors for a long time.

I would like to thank all my friends and mentors that have helped me along the way and made this possible.

I would also like to thank all the people around the world that hosted us and gave us the support, information and contacts to undertake my study. The effort that was made was just amazing and I cannot wait to repay the favour one day.

Abbreviations

3D – Three Dimensional

CIA – Central Intelligence Agencies

CO_2 – Carbon Dioxide

CT – Computed Tomography

EBV – Estimated Breeding Value

GFP – Global Focus Programme

GRDC – Grains Research And Development Corporation

GPS – Global Positioning System

LED – Light Emitting Diode

NA – Nutrient agar

PDA – Potato Dextrose Agar

PiMapping – Pixel Intelligence Mapping

PLFA - Phospholipid-derived fatty acids

PPU's – Plant Production Unit

TSA – Typticas Soy Agar

Objectives

The purpose of this study was to identify systems to better manage energy use on-farm. However, productivity, profitability and soil health must not be a casualty of these systems. These systems must be simple to implement and have ready appeal to a wide range of agricultural producers to enable rapid adoption.

It was important to analyse a broad range of farming pursuits, in particular cropping and livestock grown under dry land and irrigation. Whilst all enterprises need to coexist in a mixed farming operation the management of soil health should not be compromised.

The study had the following broad aims:

- Identify and adopt systems to better manage energy use on farm.
- Investigate options that have minimal effect on productivity, profitability, and soil health.
- Investigate new technologies that have been developed around the world to service the ability to become more efficient.

Chapter 1: Introduction

"Managing farm energy use to capitalise on carbon."

The importance of managing carbon (energy) and maximizing efficiencies in Australian agriculture has never been so relevant. The Australian agricultural industry needs to study and adopt new farming practices, both livestock and arable, in an effort to minimise our carbon footprint and become more energy efficient.

There is an increasing awareness of the role carbon has in agriculture. Irrespective of individual views on just what impact a carbon or pollution tax will have or whether we are in global warming or global cooling the industry needs to focus on sustainability of food production and the viability of the Australian primary producer. To date, most work on carbon has been more "big picture", but to really make an impact we must adopt systems that minimise emissions and maximise sequestrations at the farm level, and this cannot be done at the expense of the producer. In some cases this will result in a need to look at the energy required to manufacture fertilisers and other farm inputs. What pressure will farmers be under to measure and report emissions to companies higher in the supply chain? Regulations in our current environment will ensure this is done to a high level of integrity.

Every aspect of operations can be reviewed, including:

- Seeding technology; whether no-till or minimum till - what is the consequent effect on energy requirements?
- Pasture composition; whether perennial or annual – what are the effects of the grazing programme?
- Fertiliser use; how will different types like liquid, acidic, artificial compare, and how will timing of application work in our environments?
- Livestock composition; should they be purebred or crosses - how will genetic information change our management?
- Crop choice, or what rotation; will hybrid or GM be our best option? Should legumes be a crucial mix in all rotations?

It will be extremely important to gain an understanding of global practices that are addressing carbon and maximising energy use efficiencies on farm. With this in mind it is important to ask how many farmers are running their business with maximum energy efficiencies? How many are even thinking about it, or know how to address it? It is imperative that we know our energy efficiency position. Energy inputs represent a major and rapidly increasing cost to farmers. Energy audits will become a crucial part of the energy and environmental management processes. Australian agriculture production has been developed on high inputs, including nutrition and trace elements, to compete with the world market. The cost to production ratio is now critically high, so that change is imminent and in some cases necessary to ensure future growth and sustainability.

Fifty years from now, our growing global population will require an estimated 100% more food than we produce today. Because agricultural land and water are limited and natural resources continue to become scarcer and more expensive, we will not be able to produce enough food to feed the global population using todays farming practices and technology. According to the United Nations Food and Agriculture Organization (FAO), adding farmland will only help the industry produce 30% of the extra food that will be needed globally in 2050. This is not enough to offer a solution to the global food crisis. The additional 70% must be produced through the use of new and existing agricultural technologies ("Global Nutritional Needs", 2012). Population growth rates might have declined, but in 2013 every 60 minutes there were another 8,000 people born in the world, totaling about 75 million every year (CIA, 2013). Pressure on governments and farmers to provide cost-effective solutions will therefore be high on their list of required improvements to existing practices. With farmers managing around 61% of the total land mass in Australia and producing over 90% of the domestic food supply (Australian Government, 2013). Farmers will need to be managing their land as energy efficiently as possible. We are also competing against countries that can produce it for half the cost. Reducing costs and increasing production is necessity for Australian agriculture.

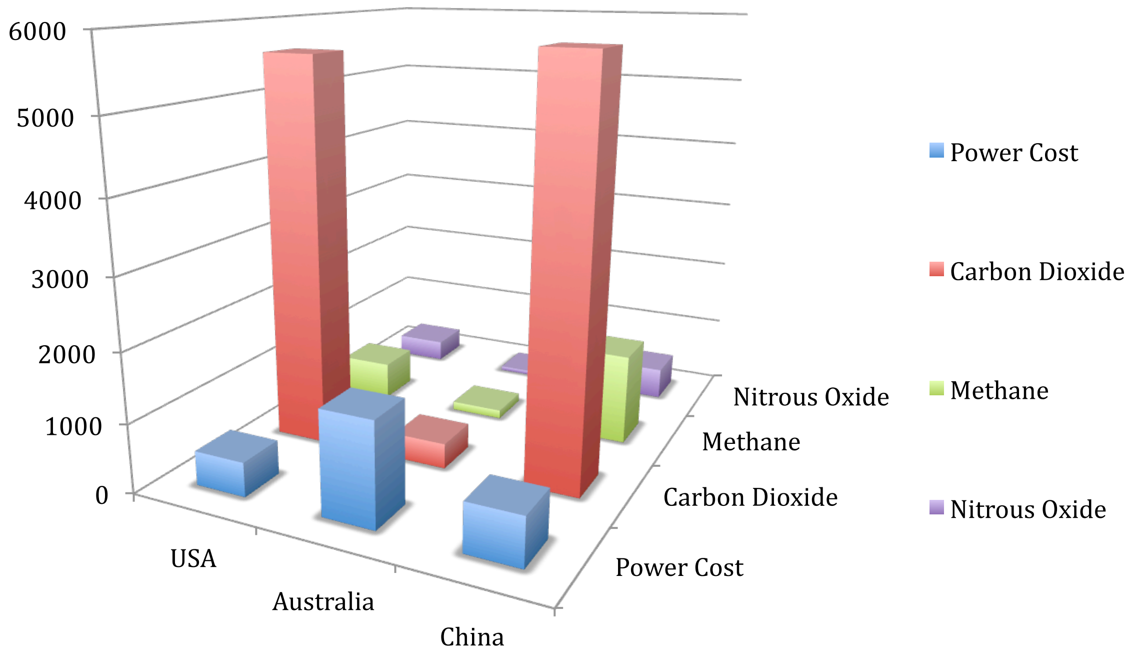


Figure 1: *This graph illustrates the imbalance among the world's leading producers, comparing total emissions and power costs. This highlights Australia's extremely low levels of emissions and high power costs. Australia's per capita level is at similar levels to USA. (Emissions Tracker, Mercury Development, LLC, World Bank, 2008)*

Some of the promising technologies becoming available to reduce emissions, maximise efficiencies and manage energy use are explained in the chapters below.

Chapter 2: Exhaust Emission Technology

Exhaust emission technology involves injecting the tractors exhaust emissions into the soil at seeding, or during cultivation, for the purpose of minimising emissions and feeding the soil. This technology has been used in agriculture around the world for many years. It is not until very recently that it has been able to be applied with greater precision and purpose.

Recent improvements in research and technology have enabled this management practice to become a practical option for farmers to adopt. With the saving of applied fertiliser, utilising a source that has already been paid for (diesel), and a zero emitting application to the farms carbon footprint, all make this a viable option.

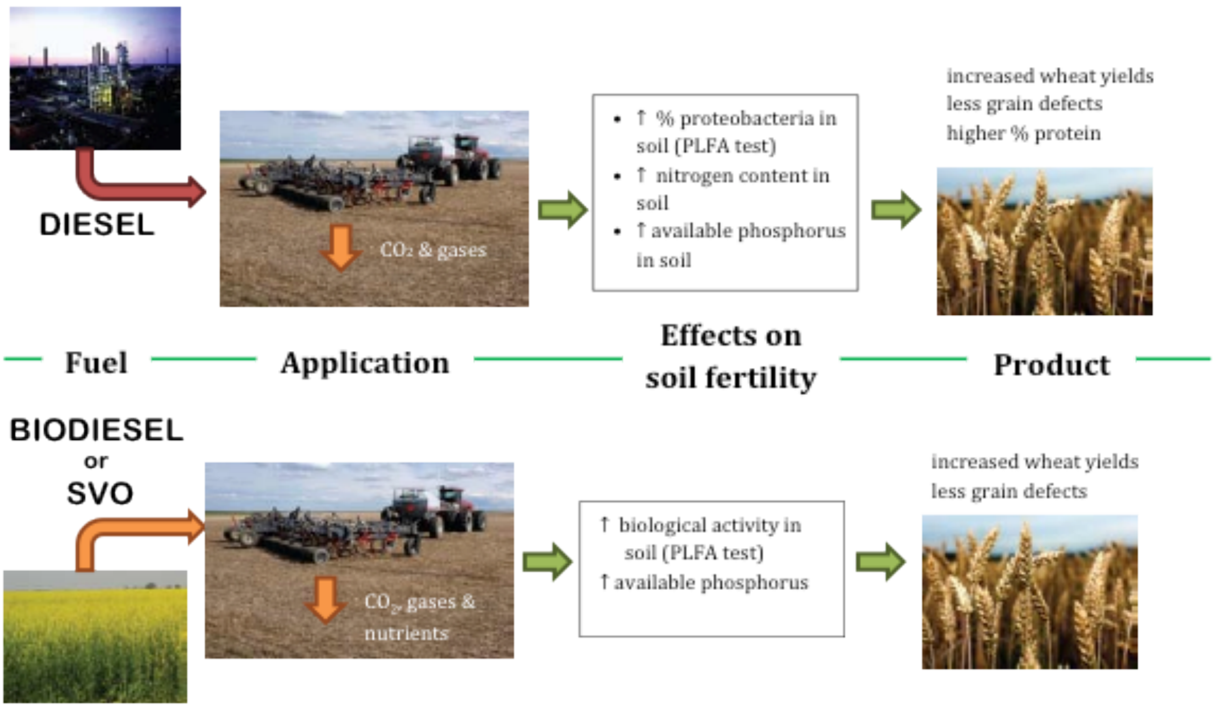


Figure 2: *Schematic illustration of the application and effects of injecting emissions using different fuels (Nestor U. Soriano, Jr., et al., Spring 2012).*

These improvements include the ability to measure and log the temperature, oxygen levels, and carbon dioxide levels of the emissions returning back into the soils. This technology has come from the motorsport industry (Drag Racing) to measure the engine’s performance; this can be done wirelessly through an application on a smart phone.

Bio-Agtive™ SEED has been successful at measuring, monitoring and verifying that the tractor emissions can be 100% sequestered into the soil during spring seeding, with the collaboration of Montana State University - Northern Bio-Energy Center, Bio-Agtive of Montana LLC and N/C Quest Inc. They use dynamometer laboratory testing to quantify the different fuel chemistries of the emissions and also carry out condensation water testing in their state-of -the-art facility. The Bio-Agtive final report has a lot of complex study information available to research found at www.bioagtive.com. To simply explain these results, the emissions are full of oxidized organic matter. The volumes and concentrations can vary depending on the type of fuel used and additives than can be added. The liquid condensate is like fulvic acid; one litre of fuel produces 2 litres of this liquid concentration, so if 14 litres per ha is burnt then 28 litres of liquid concentrate is pumped into the soil.

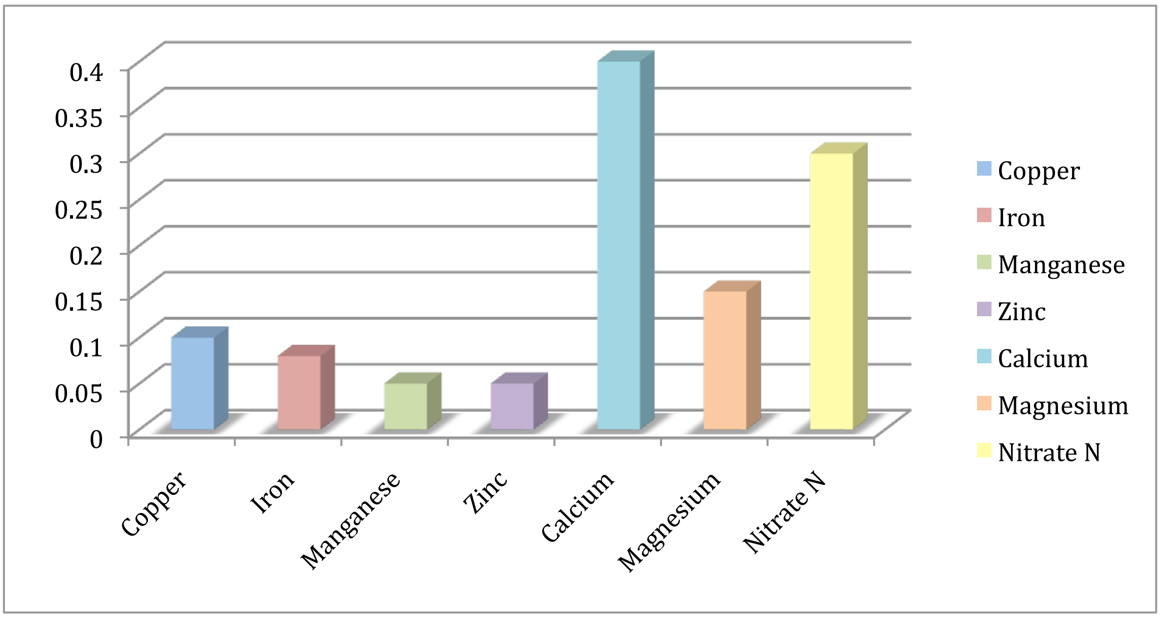


Figure 3: *This Graph shows the concentrations of some of the metals and anions in mg/L of liquid concentrate for diesel fuel only. As mentioned earlier different results come from using different fuel types. This information is from the Montana State University Northern Bio-Energy Centre.*

Further research has been done at ground level to see what impact these emissions are actually having on the soil. It was found that the soil was only able to absorb the nutrients if the emissions remained at a certain temperature; so cooling the emissions to a specific temperature was necessary to gain full use of the emissions. Also getting the correct ratio of oxygen in the system is a key factor. This technology is extremely accurate on measuring the emissions that have been placed in the soil, by taking a reading just above the soil where the emissions have been placed. The device can indicate that 100% of the emissions are getting taken up into the soil. This situation allows manipulation of the exhaust gas temperature to achieve the desired result.

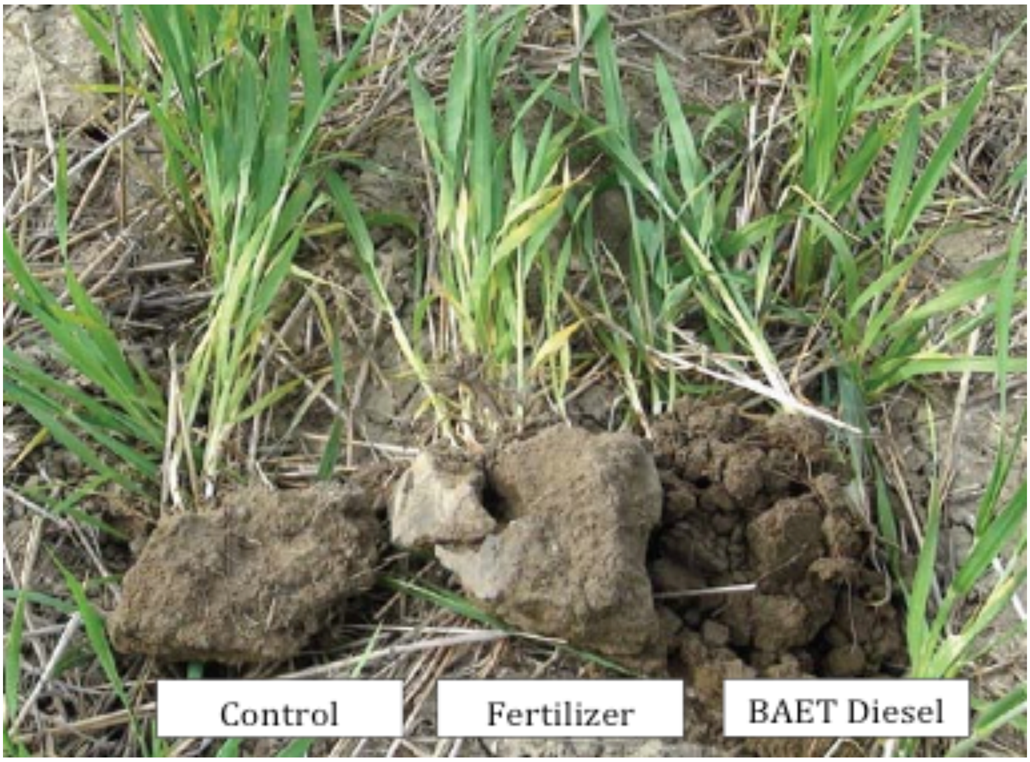
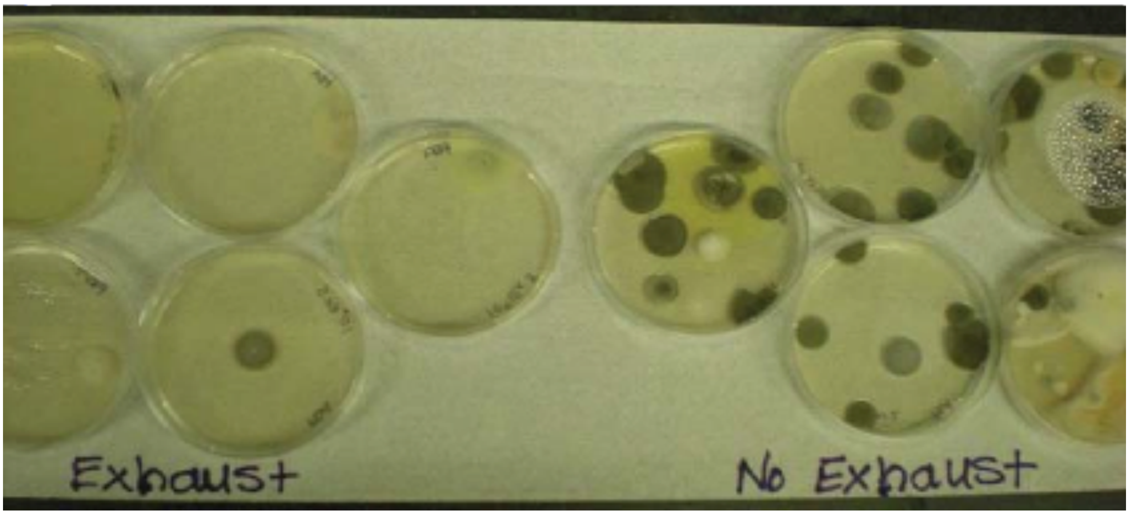


Figure 4: *This picture is showing the soil characteristics of different applications. Note that the soil seems more friable where the exhaust gases have been injected. (Alberta, Canada, 2012).*

Not all engines are the same; different levels of emissions are produced with different ranges of engine load. The nitrous oxide levels decrease as the tractors load increases. So measuring what engine load the system has is a major factor in knowing what the engines are putting into the soil. Sustained or slightly higher levels of carbon in the soil have been measured with this system, therefore, potentially having more biological activity creating more available nutrients to the plant. Taking into account that we are talking such small levels, any positive result is extremely encouraging. The difference is not how much (fertiliser) is in the emissions, it is the influence this system has on the plant to promote larger roots and increase the ability to use the suns energy photosynthesizing more carbon. Positive results have also come from tests where additives have been added to the diesel to produce more or extra nutrients needed in the soil (Bio Active, 2012).

Follow-on effects have been recorded in the production of the seed. Seed has been tested and reported with higher protein levels and better test weights, producing a higher quality seed with fewer defects. Germination tests have a small benefit also; out of 20 seeds the results show that there is a 1% to 2% seed higher germination level (Bio Active, 2012). It was quoted by the directors who completed this report that the results from these tests really show that the exhaust emissions act like antibiotics to many of the plant pathogens. This comment could be seen as biased and should be assessed with that in mind.



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New methods are now being researched from the advancement of this type of technology. There is a theory that exhaust emissions could be used to create steam and then applied onto crops or weeds to kill or desiccate them. These are the type of innovations that have the potential to be adopted into mainstream farm management.

This system has the potential to utilise the diesel that has already been paid for as a fertiliser source. It gives farmers the ability to use less fertiliser over time and in some cases no fertiliser at all. It also makes the tractor a zero emitter so that farmers are able to decrease their carbon footprint and sequester carbon at the point of the seeding application. Results discussed previously show there is an ability to improve both soil structure and soil health, becoming more sustainable in the future. Money will be saved on fertiliser bills and farmers will be making a real step towards being more energy efficient at the farm level.

Figure 6: *Picture showing a tillage machine equipped with emission technology (Alberta, Canada, 2012).*

Chapter 3: PiMapping Technology

Infrared imagery and satellite photos have been available for a long time and the information from these images has been very valuable. Now this technology has been taken to the next level for applications in agriculture. This technology has been developed in the Netherlands and is also being used in Canada, Poland and Ukraine.

PiMapping is short for Pixel Intelligence Mapping. This Technology is able to measure the target crop weekly and provide important data for management and recommendations. PiMapping uses various data sources, each containing different types of information. The most common data are sourced from satellite imagery, weather information and precipitation data. This information is then processed by the PiMapping technology. This technology is able to make each pixel “contain” various types of information, creating a “smart pixel”, providing information about cropped surfaces. These smart pixels enable the creation of dynamic and interactive applications. Over 45 components of data are analysed to create each smart pixel. The smart pixel imagery provides information on growth, moisture levels, minerals and nutrients, other stress levels and potential yield.

This technology was observed on a very large scale irrigated potato and grain growing operation in Alberta, Canada (Perry, July 2012, pers comm). They were using all aspects of the information gathered from this system and adopting that information to form and create new management practices. This user explained that the system had changed the way they had farmed for 30 years. They were able to see plant stress earlier, which made action more precise and timely and this generally was at a different growth stage than normal applications. Costs were saved and efficiencies gained by having more specific information available on plant requirements, which facilitated targeted, rather than blanket, applications of inputs.

The technology was overwhelming with the positive effect it had on this business and see a great need for this to be adopted into Australian agriculture, to monitor fertilisation and water stress for seed production, among other great benefits. The ability this tool has to recreate a management programme for our industry is extremely large. There is no doubt that every soil type and environment could benefit from the use and adoption of PiMapping.

Data is gathered weekly from any nominated field requiring only GPS markers to locate it. Accurate agronomic advice can be provided from these images. There is, naturally, a fee for service, but given the range of both crop type and agronomic analysis available it will be part of the future (Bronch, July 2012. pers comm).

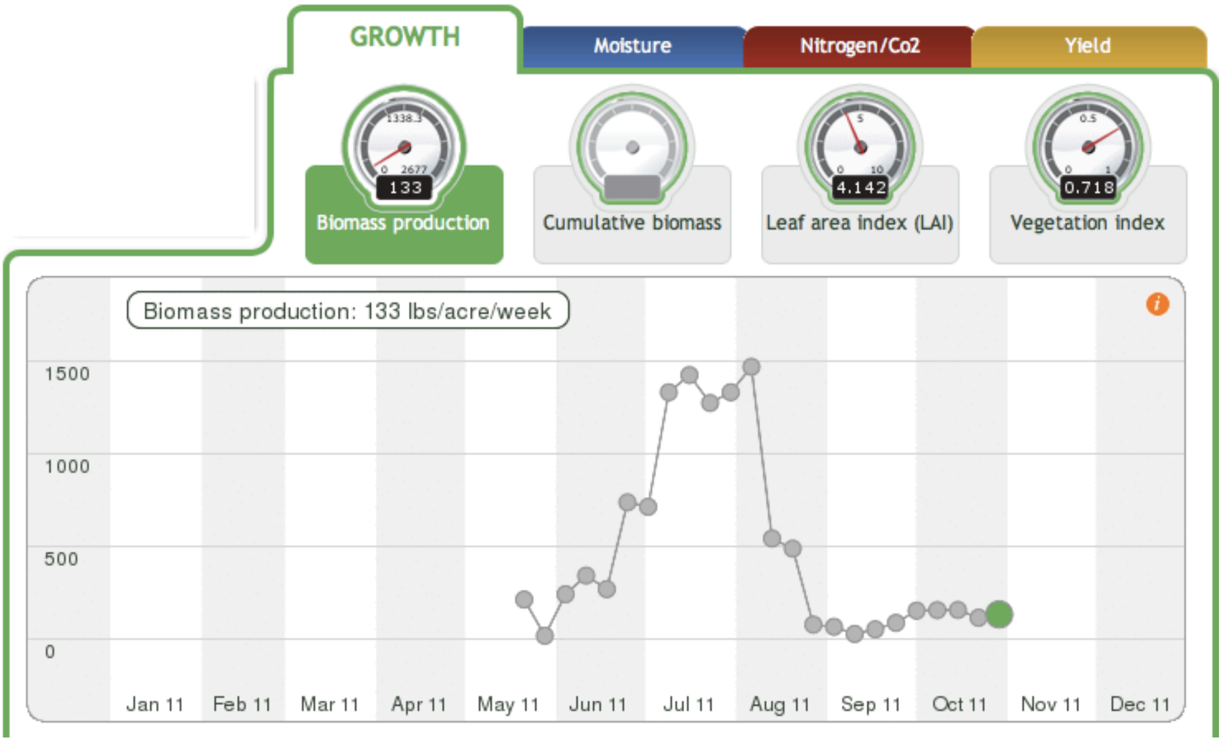

Figure 7: *This is an illustration of how this information gathered through PiMapping is presented for a particular field (Sunrise AG, Field look Canada, July 2012) .*

There are four main parameters that are measured from this image, as described below.

Growth

Four parameters are measured for this analysis of growth, which includes the entire crop above the ground as well as below.

1. Biomass: the amount of dry matter in kilograms per hectare that grows each week. This will help manage the performance of the crop. The areas with a significant variation of biomass within a field will show the need for further management inputs.

2. CO_2 intake: CO_2 is one of the key nutrients for plants, which is produced in direct relationship to growth. CO_2 intake is measured in kilograms per hectare per week.

3. Leaf Area Index: this is a measurement of the leaf area per m^2. This indicates the foliage density, or how much foliage there is on the plants.

4. Vegetation Index: this is an indicator for the vitality of the crop. A high index means healthy and strongly growing vegetation.

Moisture

Four parameters are measured for specific monitoring of the plant moisture requirements.

1. Evaporation: the actual evaporation of the plant is measured in millimeters of water over a period of one week.

2. Evaporation shortage: a lack of evaporation means less growth than with optimum conditions. The evaporation shortage is the number of millimeters of water per week the crop missed to achieve the maximum evaporation (and growth).

3. Surplus precipitation or deficit: because the actual evaporation can be measured precisely, data from weather stations can be used to calculate if more or less precipitation fell than your crop has evaporated.

4. Reference evaporation: the evaporation of crops that have sufficient water. This value indicates how much water per week would evaporate if the specific crop were growing under maximum conditions.

Minerals

The minerals that are measured are the levels of nitrogen in the above ground part of plants.

1. Nitrogen in the leaf: a measurement of the amount of nitrogen in the total leaf surface of the crop.

2. Nitrogen in the upper leaf layer: the nitrogen present in only the upper leaf layer. This measurement affects photosynthesis and is responsible for the resulting biomass production.

Yield

Ten growth parameters are measured for a number of crops within agriculture. It is possible to determine the actual yield for potatoes, cereals, sugar beet, and corn.

This PiMapping technology provides agriculture with a fantastic tool to make more informed decisions based on what the soil and the plant need. To have the ability to plan prescription fertilising and water management, among other variables, enables farmers to create the best possible outcome for the crop in its climatic environment. This drives farm management efficiencies, energy efficiencies and also has the benefit of improved risk management and financial budgeting. It will give the producer more knowledge on which to base sustainable decisions (Andriesse, M. 2012, pers comm).

Chapter 4: Livestock

Identifying the right genetics to breed the best-suited animal for a particular environment is extremely important. Breed type, frame, feed conversion efficiency and breeding performance, combined of course with economic sustainability, will be a part of the "managing for carbon tax" environment.

Historically, the selection process has been based on visual assessment as few other measurements were available. That is no longer the case as a raft of measurements are now provided, using Estimated Breeding Values (EBVs). We can now select genetics from highly rated sires that are rated against the standard for that particular breed (EBVs).

Through adoption of technology developed in 1971 for human medicine, it is now possible to scan animals using a Computerised Tomography scanner, commonly called CT or CAT scanner. These machines can now take 3D imagery of extremely small cross-sections at a time to produce a thorough and complete dissection of the body structure. From these results information about meat to bone ratio, dressing percentage, meat to fat ratio, eye muscle index, soundness of the reproductive system and a range of other traits can be accessed. Ultrasound technology has been commonly used in the industry world-wide with good results, but like most things change and progression is inevitable and the CT or CAT scan is able to feed the appetite of the industry wanting more precise and complete information.

CT scanning has been used in the industry since early 2012 on carcasses, getting measurement and information in an effort to create the perfect chop (Anderson, 2012). The next level of testing is on live sheep or cattle, which is much more difficult and obviously much more expensive. Tests have delivered some alarming results, with bone to meat ratio varying by up to 30%, indicating an area for immediate improvement, so testing entire studs alive may still be extremely efficient. Information was gathered from a sheep stud breeder that was using this technology for his entire flock (Fell,S., August 2012. Pers comm.). The cost of such a scan can be up to $200 per unit scanned, so its application cannot be easily justified for use in commercial livestock. However, consumer demand will make it mandatory for the stud or pedigree industry in time. Already the stud in which this information was gathered was taking advantage of a government subsidy for the practice. Scott, the stud principal, found the information received had a real advantage for his future sustainability and viability, and meant that decisions and change could be implemented straight away with no lag time.

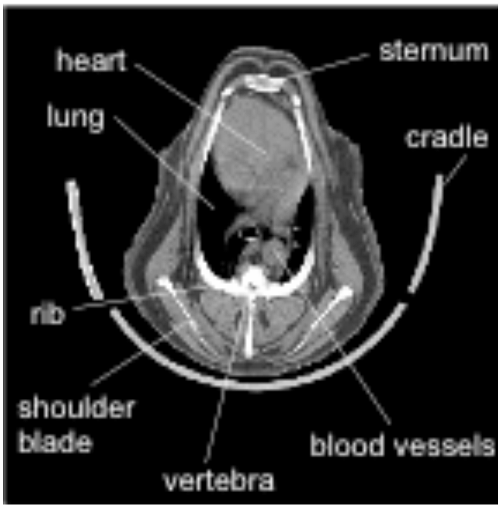

Figure 8: *This is an illustration showing a cross-sectional CT scan through the chest of a sheep. Different densities are displayed by shades of grey. (Sustainable Livestock System, SAC. UK)*

Newly developed technology can now control the sex in livestock. Laser technology locates chromosomes X and Y within the sperm and will sort them into different samples enabling the isolation of female or male chromosomes (Avis, July 2012. Pers comm).
This technology is already in commercial use for livestock production and is currently being trialed on humans, claiming a 90% success rate (MicroSort Clinical trial, 2010).

Obviously, there are ethical issues surrounding the use of this type of technology with humans, but if monitored and used correctly in the livestock industry it has huge benefits across the producer spectrum. Significant efficiencies can be gained by producing the gender required by not having to spend feed and energy on the particular gender that is not required.

Chapter 5: Fertiliser

Globally, huge quantities of fertiliser are applied each year to produce the food and fiber demanded by consumers. The sustainability of this resource and the cost of producing it is under threat. The current world consumption of fertilisers (nitrogen, potash, and phosphate) is around 122kg per hectare of arable land and rising (Figure 9). Australian consumption, at an average of 35kg per ha of arable land, is below the average and is showing a declining trend. There are many countries like Brazil that are rapidly increasing production and consumption levels (The World Bank, 2009-2013).

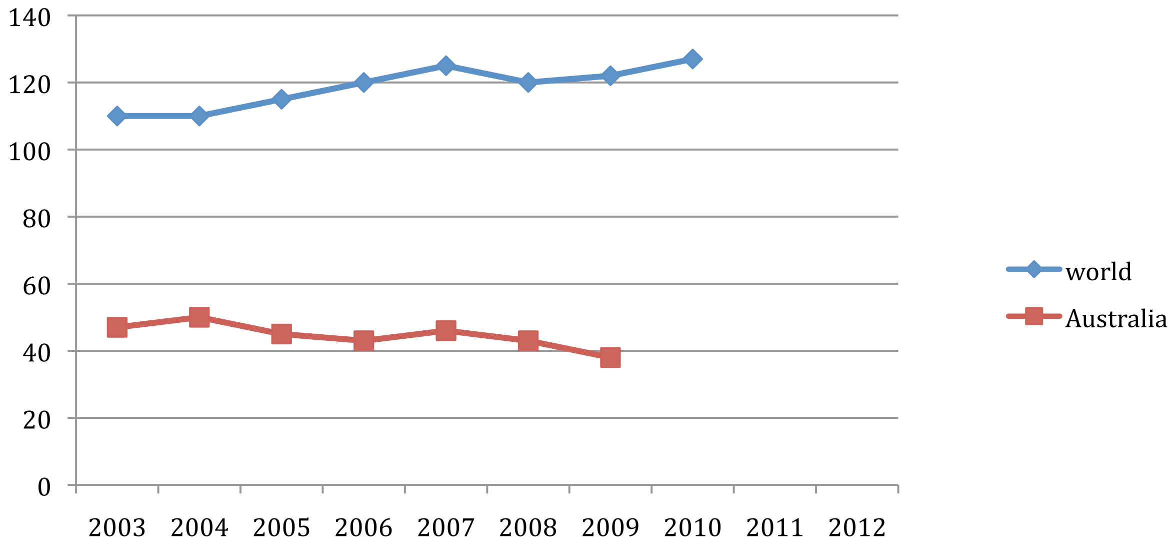

Figure 9: *This graph shows the comparison of the world fertiliser consumption compared to Australians. (Graph generated for The World Bank by World Development Indicators, 2009-2013).*

However, there are many different types of fertiliser such as petroleum based, synthetic, organic, natural, composted, biological, liquid, slow release, and even fertiliser laced with insecticide. In this commercial world each type has its merits but the reality is there are still choices available to the producer. There are also many ethical issues surrounding some of the ways these fertilisers are gathered like hydraulic fracturing (fracking) for oil and gas extraction. All methods have some form of impact on their specific environment.

Timing of application, however, or prescription feeding, has some real benefits. Traditionally crops receive an application at seeding and a post-emergence application some five to 10 weeks later. Unfortunately, the plant does not utilize all of this, with some leaching below the root zone and some lost to the atmosphere. This is both economically and environmentally unacceptable. Prescription feeding is simply feeding the plant smaller amounts of fertiliser more often throughout its growing period. This way potentially less product is wasted and the crop can achieve a constant level of growth, which in itself improves productivity. Technology is now allowing more area to be covered faster and economically with great accuracy. This can be coupled with the ability to monitor plant health and growth, with technology like PiMapping (as explained earlier). Identifying problems and deficiencies in crops well before the naked eye can see them allows for better timing, using variable rate application with extreme precision, to minimise the application rate of the fertiliser used.

Whilst application costs decrease the overall benefit from the increased production potential, risk management (fertiliser not wasted if the season turns dry), cost management and environmental care can be improved by the use of this practice. Where the climate and soil types are optimum for this, as in the Canterbury Plains in New Zealand and large parts of the UK and Europe, it would seem much easier to implement compared to the environments that the Australian producers have to work with. However, there are still areas that could benefit greatly from this and others that could change their production if managed correctly.

Chapter 6: Soil Health

Our soil is our greatest asset: abuse it and generations will pay the consequences. Regrettably, there are still far too many practices employed, globally and in particular in Australia, that do not care enough for the soil and are slow to adopt new technology. While the introduction of a carbon tax on agriculture may force a rapid improvement in farming practices, it may not be profitable if Australian farmers and landowners have to fund the change alone.

In the last 100 years, tillage has decreased soil organic levels by 60 to 70% in some areas. The remaining carbon stocks (30–40%) correlate directly with nitrogen use efficiency (in the range 30–40% correlation). To increase nitrogen and other nutrients in the soil, farmers need to increase carbon or organic matter. Carbon, as contained in the organic matter, is the glue that binds the soil and stores and recycles nutrients. Ecosystem functionality decreases as the soil carbon content decreases because carbon is the food for microbes and the storehouse for many nutrients (Hoorman,et. Al, 2009).

Soil is complex, impacted from both above and below the soil surface, by factors such as fertiliser, ground cover, crop choice, grazing and cropping management, historic management and of course the environment and weather. Traditional practices, like spraying out summer weeds in broadacre cropping to conserve moisture for the following crop, could be challenged. In reality, keeping weeds or a cover crop for as long as possible before seed-set may in fact conserve moisture and nurture the health of the soil. Conclusive trials show that soil shading creates lower soil temperatures in summer, giving the opportunity for root growth and microbes to survive and thrive, improving soil structure. This is at odds with some data that states a living plant will pump out water and be more detrimental than beneficial. This is something that needs to be managed, but the most important factor is the summer sun's energy, which can have an extremely negative effect on soil health in direct sunlight. The more plants, plant matter and ground cover there are lessens the chance the sun has to impact negatively on soil health.

The same principles apply with grazing management. Long term cell grazing or mob (large number) grazing practices can enhance both biomass production and available feed in the right environment. Current practice is to feed-off pastures to maximise production and feed value. This may be good for farm management and the livestock, but in most cases it is not optimum for soil health. There are other ways of managing soil health while maintaining a good quality pasture mix in most environments.

For best soil management the pasture should be grown to its full potential, and timing is crucial to get the value out of the feed when grazing. The plant needs to do two things; it needs to put maximum energy and sugars into the root system into the soil, building soil health, and it also needs to do the same for the livestock, so it should not be grazed too late or too soon. Properly timed grazing maximises root growth, which in turn maximises microbiological activity, critical to improving soil health. It also means less foot traffic from livestock, reducing compaction and damage to the soil. In the life cycle of plant growth, CO_2 is absorbed by the growing plant to the point where biomass production slows and the reproductive stage begins; at this point the plant begins emitting more CO_2 than it can absorb. This is the stage that needs to be closely monitored and which determines when the pasture requires heavy grazing or mob grazing. Having the ability to graze the pasture quickly is very important; a maximum of 12 hours is ideal (Chapman,T. August 2012, Pers comm; Hockey,M. July 2011, Pers comm).

By using high numbers in small areas with large biomass levels, pasture is both trampled and consumed. This generates high levels of ground cover, protecting the soil from damage, and keeps it moist and cool while providing a new food source for the soil microbes. The question has to be asked, “is there too much waste?” The answer is no! In fact, a sustainable grazing system with lower inputs and increased production has been created. The basic practice used on this farm is to grow the pasture for around 80 to 90 days, depending on the local environment, and then graze it for a maximum of 12 hours, four times per year with large numbers. So in one year the paddock will be grazed for a total of two days (48 hours) and spend the remaining 363 days growing biomass and root mass. The fieldwork and trials claimed increased production with a gradual 30% increase over five years. This producer believed it was a direct result of improved soil health. (Chapman,T. August 2012, Pers comm).

Efficient cell grazing techniques are continuing to be developed, aided by a change from traditional to virtual fencing, using wireless sensor technology. Obviously this system would be quite expensive to develop for large-scale Australian livestock producers, however, small portions could be managed this way, where the soil needs particular attention. Dairies and other intensive livestock producers are already managing their livestock this way for the benefit of the livestock. However, the subtle difference is that this management focuses on soil health and producing for the soil not the livestock. Extra production is the byproduct of focusing on managing the soil.

Conventional system

Controlled grazing

Figure 10: *These pictures are taken only 2 metres from each other and show the difference appearance of the soil from different management practices (Luton, England, August 2012).*

Chapter 7: Light Technology

Have you ever heard of the 100-mile diet? The idea is to eat food with nutrients grown within a 100-mile radius. It is extremely hard to do. Japan and South Korea are trying to develop urban greenhouses to bring production closer to the consumer. It is alarming to think that just as new technology is developed and adopted for greenhouse and hydroponic production to maximise yield, they become outdated! When the incidence of light cannot be regulated, a lot of costly moisture and CO_2 escapes when windows are opened. Sudden bright sunlight can destroy a carefully created climate rapidly.

Special Light Emitting Diodes (LED) lighting has been developed in the Netherlands, where pressure on land is so intense that extra area has been created by landfill into the ocean. This technology uses specific color spectra that are useful for growth and development of the crop, providing the plants' complete requirements. In contrast to the sun, LED lights only emit one frequency of light. No energy is wasted generating a light spectrum that is either not required or less efficiently utilised by the plant. This means the exact colors that the plant needs for photosynthesis are generated. Plants mainly require blue and red light for photosynthesis as well as "far infrared", a light frequency not even visible to the human eye, but required by the plant. The relationships between the light colors determine the form of the plant. The amount of light the plant needs is also optimised (Meeuws, 2012, pers comm.)

Production modelling (mathematical) has been developed from 15 years of research on cut flowers, pot plants, vegetables and fruit. This includes measuring fresh weight, dry matter, speed of maturity, consistency and final yield. These models are then applied to the specific crop for maximum growing efficiency (Meeuws, 2012, pers comm.)

The real breakthrough has been the amalgamation of this LED technology with new technologies in the field of climate control, moisture and light sensors, vision technology and automation. By manipulating temperature, carbon dioxide levels and light it is possible to change the taste and even nutrient values of plants. New nurseries will be built where production occurs in multiple layers in the one building using LED lighting, fully climate controlled and without daylight. These multi-layered nurseries will be close to the consumers and provide higher production level with predictable harvesting time and, importantly, a consistent product of appearance, taste and nutritional value. This will all be achieved with less water, less fertiliser, lower transport cost, and fewer weed and pest applications, resulting in lower production costs. In the Netherlands they are using this technology to great effect in otherwise waste space areas. This makes them very competitive as they do not have to buy the land and LED lighting requires very little power to run (Meeuws 2012, pers comm.) The adoption of this technology will occur initially in land-poor countries with a high consumer base in close proximity.

This technology, by recognizing the plant's specific requirements, allows the delivery of precise plant requirements without waste including controlled application of nutrients. These Plant Production Units (PPUs) deliver huge benefits by reducing water use. A PPU is a location in which these systems are installed and operated. As little evaporation is required to cool the plant and no water can escape the unit (apart from in the finished product) as little as 10% of water is required to produce the equivalent volume.

Given the controlled environment these PPU's provide, identical outcomes can be achieved anywhere, but most importantly, close to the market, thus dramatically reducing food miles. It is claimed by PlantLab that, on average, a kilogram of tomatoes travels 2,300 km to its final destination. Whilst this technology may not solve world food shortages, it has the ability to revolutionize specific types of food production and improve distribution logistics.

Figure 11*: A warehouse using LED lighting to grow herbs (Netherlands, March 2012).*

Conclusion

“It is important to be an early adopter, but beware the cost of innovation.”

Agriculture will always have innovators, they are absolutely essential; the greatest net benefit to agriculture will be by encouraging early adoption of innovation.

In order to optimise farm energy use to capitalise on carbon it will be necessary to adopt new technology and management systems that will work with, and alongside, current practices. This should be a gradual process so that sustainability, in all its forms, is not compromised but change is still the focus.

Many innovators are in the high-technology areas. Intensive production is the immediate beneficiary, where generally shorter plant life-cycles occur. Here, the technology is easier to measure, manage and generally easier to adopt. In broadacre farming, exhaust emission management and injection, PiMapping, carbon audits, soil testing, researching sequestration further, prescription fertilising and managing pasture with soil, as the focuses are all immediately achievable.

Continuing research is essential in all these areas, as too is investment in commercialising this research. PiMapping is not yet available in Australia, exhaust injection equipment could be seen as cumbersome and expensive with the level of carbon sequestration is at best subjective.

PiMapping seems to have major benefits for most farms. Prescription fertilising has been adopted and with livestock and cropping operations being re-invented to reflect the findings of this research.

Recommendations

The steps that should be taken from the key findings from the study:

- Further study, keeping a close eye on the progression of the commercial availability of PiMapping in Australia.
- Ongoing research continues to be done with exhaust emission technology within Australia. This research needs to be studied closely to see if this technology can be adopted for all or specific environments for efficiency gains and sustainability for farm businesses.
- There is a very large list of fertiliser products that are currently on the market and in the last five years there have been a lot of new products on the market. These need to be chosen on hard evidence and new technology for variable rate and prescribed applications need to be a focus for the business in the future, at a time when the business is in a position to change management practices and systems after a justified appraisal.
- Livestock management needs to focus on the overall benefit to pastures and soil health for mutual benefit. Specific soil types and climate will need close specification to achieve this. New technologies for producing genetic information are becoming a common standard to help overall flock quality and selection and this must be utilised.
- Adoption of new technologies in micro-farming systems like hydroponics is imperative; they are leading the way for food production. Often these systems can transfer from this management style into the broadacre system.

References

Alvis, J (2012). Personal communication, 1983 UK Nuffield Scholar. Regilbury Park Farm, Benches Lane. Winford, Bristol BS40 8BE.

Anderson, F. (2012). The CAT scan for the perfect chop. Murdoch University, University of New England, Armidale NSW. Pg 1-3

Andriesse, M. (2012). Personal communication. Eleaf, Wageningen, The Netherlands.

http://www.eleaf.com/#products-access-fieldlook

Australian Government, Department of Agriculture, (2013). Australian Farming and Agriculture, pg 1-2

Bio-Active™. (2012). Emissions Technology, Alberta, Canada. Pgs 2-10

http://www.bioagtive.com/?s=1&p=138

Bronch, J. (2012). Personal communication. Sunrise AG Ltd. 5209 47 Ave.,Taber, Alberta, Canada.

Chapman, T. (2012). Personal communication, 2011 UK Nuffield Scholar. Luton, England

Central Intelligence Agencies, World Fact Book. (2013). Population growth rate. Pg 2

http://en.wikipedia.org/wiki/Population_growth

Global Nutritional Needs. (2012). Elanco, Pgs 1-5

https://www.globaldairyinnovation.com/world-food-supply/Default.aspx

Fell, S. (August 2012). Personal communication. UK Rams Stud Principal. Yorkshire, England.

Fossen's Farm, (2009-2013). Field trials. Inverness, Canada.

Hockey, M. (2011). Personal communication. Australian Soil Planners. Perth, WA.

Hoorman,J. Islam,R. Sundermei,A. Reeder,D. Using cover crops to convert to no-till. Crops and Soil, November- December, 2009 pgs 9-13.

Lewis, G. (2012). Personal communication. N/C Quest Inc. Alberta, Canada.

Meeuws, G. (2012). Personel Communication. Engineer – Partner – CEO, Plantlab. WTIc gebouw, The Netherlands.

Mercury Development. (2008). LLC application, emissions tracker. World Bank data.

MicroSort Clinical trial report (2010). Genetics & IVF Institute, America. Pg 3

Nestor U. Soriano, Jr, PhD Research Scientist, Lewis, G. Alcorn, J. (2012). Emissions Technology Report. Bio-Energy Centre, Montana State University.

Perry, H. (2012). Personal communication. 2006 Canadian Nuffield Scholar. Farm owner Manager. Alberta, Canada.

World Bank. (2009-2013). World Development Indicators. Pg 1-1

Plain English Compendium Summary

Project Title:	
Nuffield Australia Project No.:	1205
Scholar:	Ryan Smart
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Objectives	The purpose of this study was to investigate systems for Australian agriculture that are being used globally to maximise production efficiencies. These technologies could be utilised within our farming systems, be cost effective and have a positive effect on the future of Australian agriculture.
Background	With Australia's potential adoption of a carbon tax and an ever-increasing cost of production, new management systems need to be harvested for the future sustainability of Australian Agriculture. Historically, Australian soils have lost significant amounts of their organic carbon levels, which mean that there is the potential to rebuild them with the appropriate management. This relies on having the correct information to put into practical management. It is imperative that this information is utilised to improve our energy efficiency position. Energy inputs represent a major and rapidly increasing cost to farmers; energy audits will be a crucial part of the energy and environmental management process.
Research	Research was conducted in New Zealand, Netherlands, United Kingdom, United States, Mexico, Brazil, Canada and France, using a combination of interviews, field visits, conferences, and personal study.
Outcomes	Farmers need to recognise that there is significant scope for Australian agriculture to improve management practices on farm by adopting a range of initiatives and new technologies, enabling a sustainable, energy-efficient farm management system. There is significant research being undertaken globally which should allow Australian farmers to become more efficient in food production, with some extremely successful results to date. Doubling food production over the next 50 years is totally achievable by rapidly adopting new technologies. However, this can only be achieved if farming businesses are sustainable.
Implications	Sometimes change can be expensive and difficult to justify. Adopting new systems take time and effort and this can be met with trepidation, as results may only be measurable in the longer term. Soil health can take many years to improve. Courage, persistence and belief in change are essential.
Publications	N/A