Reflections on Western Australia's Farming Systems' Resilience and Sustainability
Donald Oration 2024

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Abstract

In this paper I outline some of the key lessons I have learnt to develop agronomic skills that contribute to producing resilient, sustainable and profitable farming systems for individual businesses and agricultural regions. These lessons include developing professional networks with your peers around Australia and the world to keep at the cutting edge, plus having a range of mentors and role models to help guide you through your career. I demonstrate how these relationships and collaborative groups can drive innovation and adoption of changes in farming systems to produce greater resilience and sustainability. It then shows how listening to farmer observations, interrogating computer models through sensitivity analysis, determining the value of seemingly impractical treatments and treatment combinations, questioning assumptions in data and economic analyses can produce innovations that transform farming systems and farm business profitability.

I then focus on the innovations and contributions to the resilience and profitability of an individual client from their perspective. Describing the four major contributions to their business's development through:

- Machinery upgrade decisions to improve timeliness, plant health, plant and input efficiency,
- Earlier crop establishment by dry sowing, setting a finish date and dates to modify paddock enterprise,
- Benefits of soil testing and reallocation of nutritional and ameliorant resources and
- Paddock specific weed control strategies and tactics to minimise weed seed banks and resistance development.

These experiences, over my career, highlight how a combination of technical insight, critical thinking, and strong professional relationships can directly enhance farm business outcomes. By applying these principles, agronomists can support innovative, site-specific strategies that deliver measurable improvements in resilience, sustainability, and profitability- both for individual clients and the broader agricultural sector.

Introduction

Thank you to my proponents and the Australian Society of Agronomy for selecting me to receive the prestigious CM Donald Medal for 2024 and to join the previous recipients who I class as some of the most influential agriculturalists in the field of Agronomy. I am humbled and honoured to have received this award and to join this group of esteemed Agronomists.

On my professional journey I have had many mentors and influencers, beginning with Professor Walter Stern (C.M. Donalds first PhD student) who was my Honours Thesis supervisor at the University of Western Australia. Then, Mr. Steve Trevenen, Officer in Charge, Merredin Office of the Western Australian Department of Agriculture, and the team including Dr. Mike Ewing and Dr. Bill Porter guided me through my formative advisory years. I have never forgotten Steve Trevenen saying to me – "Foz, nothing in agriculture is black and white, but it is all shades of grey". This statement I think encapsulates how Agronomy is so multi-faceted and influenced by weather, soils, people's personalities (farmers and farm labour), farm inputs, machinery, fluctuating commodity prices and numerous other factors. To this day this statement is absolutely true.

I would like to also thank my farmer clients and groups who grilled me about the agronomic advice I was providing and kept me grounded in the practical realities of my advice on broadacre farming systems and their businesses. To my past and present members of the Farm Focus Consultants team I thank them for their dedicated contributions, but particularly to Joanne Hunter who has been with the team since the beginning for providing the most wonderful office support over our journey.

Finally, to my family thank you but, particularly to my wife, Allison, who knows when I am having a "Foz thought bubble" at 4 a.m. and kicks me out of bed and says to get up and write it down, THE BIGGEST THANK YOU.

Lesson –

Seeking and listening to mentors' experiences and knowledge provides a foundation and continued development of one's professional and agronomic skills.

The Passion

My father was a bank manager, and we moved location every two to four years around Western Australia. This involved living in several rural communities including the town of Corrigin from when I was nine till 11 years old. I had several friends who came from farms, and I was often invited out to visit for the weekend and then catch the school bus back into town on Monday morning. It was on an October Monday morning in 1971 that we were waiting for the school bus that I turned around to look at a very good-looking Beecher barley crop and thought to myself that is what I want to do "grow food to feed the world". From then on, I was focused and had a passion to know and understand how to grow plants and in particular broadacre crops and pastures. That passion still drives me to this day.

The Foundation of my interest in building resilient farming systems

In my undergraduate years I always appreciated the information being taught to be put into an agricultural system context. It showed me how many relationships and interactions occur within a farm system. Changing one variable could have negative or positive effects on many components of soil, animal, financial, and plant outcomes. This gave me a great appreciation of the complexity of the many systems of agriculture and to listen, observe, analyse, and sieve information from numerous sources including practitioners, business professionals, scientists and farmers. I have selected a few specific components of farming systems that have been crucial in developing resilient and profitable farming systems throughout my career.

Weed and crop competition

My honours thesis at the University of Western Australia saw me compare the competitive abilities of old tall wheats with new semi dwarf varieties against annual ryegrass under different levels of nitrogen and phosphorus. During my literature review I came across some work by McNamara (1976) (table 1) which determined the effect of duration of wild oat competition at various densities on wheat yield. He found that significant yield loss was occurring even when the wild oats were removed at the 2 to 3 leaf stage with a variation from 17 to 57% of final yield loss (when no wild oats were removed). On average a 34.5% yield loss had already occurred when the wild oats were removed at the 2 to 3 leaf stage.

Table 1: The effect of time of removal of wild oats on wheat yield (t/ha). McNamara (1976),

Treatment	1967 D1	1967 D2	1969	1970	Average Yield Loss %
Control – no wild oats	2.25	2.25	2.27	3.05	
Wild oats removed @					
2-3 leaf	1.97	2.10	1.86	2.76	12.3
5-6 leaf	2.06	1.91	1.80	2.34	19.0
Flag leaf	1.89	1.70	1.32		31.1
Wild oats not removed	1.76	1.38	1.26	1.86	37.9

Wild oat densities: D1 = 37 plants/m², D2 = 110 plants/m², 1969 = 72 plants/m², 1970 = 72 plants/m²

Upon graduating my first job was with the Western Australian Department of Agriculture at the Merredin district office as a general adviser in 1981. A young and vibrant team of research and extension personnel was being assembled to develop a profitable, resilient and sustainable farming system for the eastern wheatbelt. The team was led by Mr Steve Trevenen and when I arrived there were 15 staff. As the farming systems developed over the next few years the team grew to more than 50 and moved to new premises at the Merredin research station which was named the Dryland Research Institute. By 1984 the research, development and extension program increased to include over 200 on farm and research station trials annually.

Building a direct drilling crop establishment system was the first team goal and one of the biggest potholes on the road to farm adoption was managing the weed burden particularly during the transition from multiple pass to single pass crop establishment. Our biggest problem weed was annual ryegrass, which had moved from highly germinable on the first rains to provide excellent early stock feed in the 1960's and easily controlled with some cultivation, to a crop weed with multiple cohort germination over several weeks which made it "resistant" to control by cultivation. Physiological mechanisms developed by ryegrass in response to multiple cultivations from the 1960's to 1980's included a cold requirement prior to germination and up to 20% of the seed bank having dark dormancy (Gramshaw, 1974, PhD thesis). To manage this dark dormancy form of escape by ryegrass required seed to be buried (cultivation), flashed with light (cultivation) and buried again

(another cultivation). With these multiple cultivations the soil was left in a susceptible state for wind erosion. I remember watching a dust storm arriving prior to the opening rains of the early 1980's while playing football in Merredin. Playing football in raining mud is no fun! The loss of fertility and movement of some weed seeds would have been significant.

One of my first tasks was to develop management systems to minimise the effect of annual ryegrass and weeds in general. I soon learnt that it was possible to win a few weed battles but to win the weed management war I needed to understand the enemy - annual ryegrass. I had learnt a lot about ryegrass during my honours thesis but needed more local and in-depth knowledge which required discussions with weed researchers and specialists including Dr Gurjeet Gill, Ric Madin (ICI), John Holmes and Dr David Bowran.

Cultural management of weeds through the effects of crop row spacing and density on weed competition are often spoken of and can be easily adopted. However, my discussions with these weed specialists and reviewing literature provided me with numerous common weed management options but there were two that were not common knowledge.

Firstly, rarely was the relative time of emergence of a weed relative to the crop discussed but this has a large effect on the crop and weed's relative competitive ability. Research by O'Donovan et al (1985) and adapted by Associate Professor Gill shows the large influence of time of emergence of weeds relative to wheat and their effect on grain yield. From this data I derived the **rule of thumb** that for each leaf the wheat is ahead of the grass weed then it will halve the competitive yield loss from that weed.

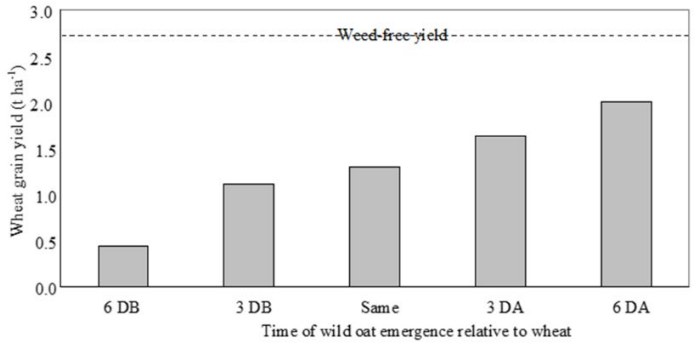

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Figure 4.7. The effect of time of emergence of wild oats on its competitiveness with wheat (adapted from O'Donovan *et al.* 1985). DB and DA refer to 'days before' and 'days after' the emergence of wheat, respectively.¶

Figure 1:- The effect of time of emergence of wild oats on its competitiveness with wheat (Courtesy of Assoc. Prof. G Gill, University of Adelaide).

Secondly, the placement of pre-emergent herbicides (like the 1970's released herbicide Trifluralin) in a direct drilling system also warranted investigation. We found in our trials that some of the available herbicides could be applied and incorporated by sowing and provide better efficacy and/or greater crop safety. Some of these results helped develop herbicide label changes that are still used today.

These two pieces of knowledge and experience pushed me to have a bias towards the use of pre-emergent herbicides and to chase moisture with deeper crop placement at seeding to allow earlier crop emergence when there was little sign of a follow-up germinating rain to minimise early weed competition.

Lesson –

Understand the biology and genetic variability of a pest population - as battles may be won without this knowledge, but the war against the pest will never be won.

Soil Amelioration (Sodicity and Acidity)

Gypsum - In the middle of the 1982 season the office received an enquiry from a Narembeen farmer, Brian Cusack, who wanted someone to see the amazing crop establishment and growth results from a gypsum application on his hard setting soil. Dr Bill Porter (soils researcher) and I visited the farm and came back convinced we needed to investigate the use of gypsum. I spent a day in the Department of Agriculture's library in South Perth and found trial data from the 1960's and 70's where there had been some positive responses from gypsum on hard setting soils. However, the conclusion was that it was not going to be economic as the gypsum source was assumed to be the byproduct of superphosphate production and had to be freighted to the wheatbelt from Kwinana.

The gypsum Brian Cusack had at Narembeen had come from a saltlake near Yelbini, some 140 km distant, not from Kwinana (320km away). How many other salt lakes in the wheatbelt had gypsum? I found a Mines Department report printed in 1957 in the library that day. This report had analyses and maps of numerous salt lakes identifying precise locations of gypsum deposits all over the wheatbelt. The **lesson learnt that day was** – question the assumptions when considering economic analyses. Armed with this information, I was allowed to develop an exploratory research program for the following few seasons.
The results were positive in the first season but not as great as expected. We observed the gypsum treated plots seemed to lack adequate nutrition. In the second season additional nitrogen was applied and yield improvements jumped from 10 to 30% up to 30 to 50% (Fosbery and Howell, 1985). **Lesson learnt** – Don't forget Lieberg's law of the minimum – response to one improvement will only occur until the next constraint is encountered, in this case nitrogen. These results were used to obtain funding for a research officer to work on understanding and improving sodic soil management for the next nine years.

In the early 1980's many farms only had low break out pressure tines on combine seeders therefore found direct drilling many soils, particularly after a pasture phase, difficult to establish crop well. Applying gypsum to these hard setting sodic soils could allow for better crops to be established with direct drilling and then with continued direct drill crop establishment maintain the improved soil structure (Fosbery and Howell, 1985; Howell, 1987).

Figure 2: Water infiltation on untreated (left) and gypsum treated (right) after the same rainfall event. (from Howell, 1987).

Lessons –

1. Question assumptions when analysing and interpreting data and economic analyses as they can be too simplistic and as new information is found can mislead future decisions.
2. A positive treatment response will only continue to improve till the maximum rate response is reached in perfect conditions or the next constraint to yield is reached.

Lime application and incorporation – Transformational soil amelioration

Dr Bill Porter identified that the major constraint on the so called "Wodjil" soils was a natural sub soil acidity problem that released Aluminium into the soil solution and severely restricted wheat root growth (Porter, 1980). These "Wodjil" soils were estimated to constitute 200,000 hectares of the lower rainfall wheat belt area of Western Australia with an additional 960,000 hectares with significant acidity problems producing a total area of 1.16 million hectares of responsive soils to liming (Porter, 1980). To determine how large a response may be possible if the sub soil acidity could be ameliorated the "44 gallon drum" trial was designed where all subsoil constraints but particularly sub soil acidity were ameliorated to 1.6 metres. Yield increases were variable over two sites and three seasons but yield increases due to the amelioration varied from 68% to 174%.

Lime application slowly became an integral component of most farming systems on the acid sands and loam soils of the wheatbelt. However, responses to lime were slow and rates of lime were conservative as it was cheaper to purchase better class land than it was to ameliorate the acid poor soil land already on a property. Over the next 20 to 30 years land prices began to rise, longer term large scale lime trials were showing significant differences in yield, weed populations and crop health. Gazey C. et al (2014) returned to a 1994 lime trial near Mingenew in W.A. and found significant effects on wheat yield (Table 2) and soil pH (Figure 3).

Table 2: 2013 grain yield response to 1994 lime treatments at a trial near Mingenew, WA. Subsequently each treatment received 4 t/ha of farmer applied lime. (from Gazey *et al*, 2014)

1994 Lime treatment (t/ha)	2013 wheat grain yield (t/ha)
0	4.43 a
1	4.56 ab
2	4.69 b
4	4.85 c
LSD (p=0.05)	0.14

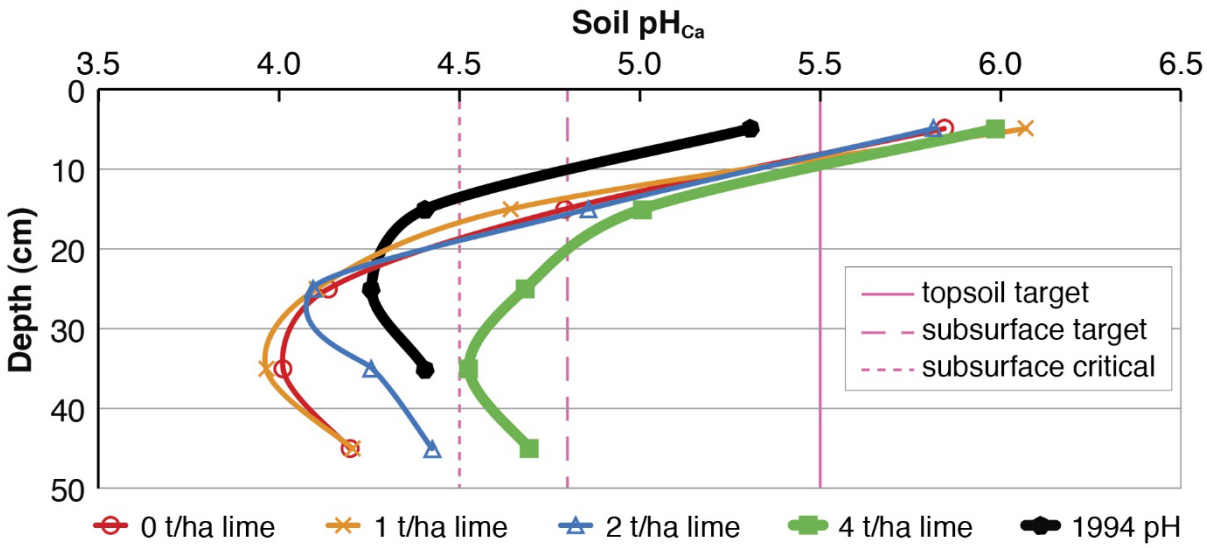

Figure 3: Soil pH profiles in 2013 for different lime treatments compared to the starting pH 20 years ago in a trial near Mingenew, WA (from Gazey *et al,* 2014).

The problem was waiting the time required for the lime to move into the subsoil without assistance! The time to obtain an acceptable return on the lime investment was considerable in most areas. Researchers and farmers knew they needed to mix the applied lime into the subsoil but how to do it on a range of soil types and at an acceptable cost to ensure an adequate return on investment?

Ultimately it was farmers with their practical machinery experience who determined which tactics were feasible to achieve the transformational soil amelioraton. These tactics to ameliorate sub soil acidity together with a range of other paddock constraints including soil compaction, non wetting surface soils and herbicide resistant weeds included: mould board ploughing, delving, spading, deep ripping (>50cm), claying and Plozza ploughing. Often a combination of these tactics produced the best returns on investment.

It was and still is today, extremely important to determine all the constraints in and on a particular paddock before deciding on which soil tactics, ameliorants and/or nutrients need to be applied to obtain the best result from a transformational soil amelioration package. In my experience you will find a need in most paddocks to carry out more than one package of these tactics to achieve an acceptable result. In practical terms on a paddock by paddock basis, I have learnt that rarely is anything a perfect solution but have learnt to live with an 80% result. I say to many of my farmer

clients who like to get everything perfect that an 80% mark is a High Distinction at University so be very happy when the results are not quite perfect. This realisation often ensures farmer clients are more accepting of their paddock results and reduces their stress levels. Interestingly, I now hear this comment being reflected back to me by farmer clients.

It has taken many years for this transformational system to come together and has taken much co operation between farmers, researchers, industry and extension personel both public and private to achieve adoption on many farms. Experimentation and improvements continue to this day. The variety of soil amelioration techniques deployed have significantly increased soil plant available water in many circumstances resulting in higher yields and much greater farm business resilience and profitability.

Lessons –

1. No matter the percieved impracticalities of a treatment, researchers should always have a "reach for the ultimate" attitude to determine how large a response is possible, as over time what was once impractical in the paddock may become practical.
2. People (Researchers, Farmers, Consultants etc) who try to attain the maximum and/or perfect results in often difficult, complex and variable farming systems can develop significant stress and sometimes depression. Therefore, setting realistic and achievable goals is extremely important for the business and people who operate within it.

Influence of MIDAS – A bioeconomic model of a dryland farm system

During the 1980's, and often still today, annual gross margins drove a lot of the decision making in a farm business as to which enterprises were to be continued, ratios changed or culled. The use of comparing simple annual gross margins between enterprises in a particular farm business does not take account of the numerous real and practical interactions between farm enterprises. There are often domino effects from changing one enterprise area to another and these consequences are not often predictable. Using rotational gross margins as a metric improved this decision making but still didn't take account of the biological complexity from soil type to soil type.

At the Dryland Research Institute in the early 1980's we often had long discussions about the positive and negative interactions between the cropping and livestock enterprises and what we should be extending to farm businesses to help them be more sustainable and resilient. As a result it was decided to work with the economics branch of the Department of Agriculture to develop a farming systems bioeconomic model that took account of as many of the interactions between enterprises on a range of soil types and compare cropping to livestock enterprises.

The model was not used as a replacement for the models stored in the minds of agricultural professionals and rotational gross margin economists, but all the models (minds) were used interactively and the computer based model provided additional insight for open minded researchers, economists, consultants and advisers (Morrison, 1987). No MIDAS analysis involved a single run to determine an optimum, but was a series of analytical runs to examine an aspect of

research, farm rotation, enterprise comparison by soil type and/or change in commodity price. The model included about 150 constraints and 280 activities (Kingwell, 1985) and was so complex for the time (early 1980's) it could only be run on the biggest computer in Australia, based in Canberra.

Known as Model of an Integrated Dryland Agricultural System… or MIDAS and like all models it was not perfect and its biggest criticism was that it did not allow for risk (Pannell D.J., 1994). This was addressed in the late 1980's with the building of MUDAS (Model of an Uncertain Dryland Agricultural System). Asking the "what if the cropping percentage was X" question of MIDAS in an average season and on an average farm with an average soil type mix provided a net profit response curve. The highest net profit was at 80% crop but there was less than a 10% drop in net profit between 50% and 90% crop (Morrison *et al*, 1986). The most reliable soil types in any season were the ones that were kept in crop while the lowest yielding crop soils with a reasonable livestock carrying capacity and the ones with the greatest seasonal crop yield variability were the soil types dropped out of crop.

It was these insights into the effects of farming systems by soil type on farm profitability and resilience that set the foundation for my future research, extension and consulting directions and goals for individual farm businesses and farmer groups.

Lessons -

1. Farm businesses need to invest in the present season for the resilience and profitability of future seasons.
2. Often net profit on a whole farm basis plateau's over a wide range of a particular variable so there is little reason to be exact with all decisions. Eg rate of nitrogen on crop can often be within 20% of the optimum and still be within 5% of maximum profit.

My leap into independent technical farm consulting

After nine years in the Western Australian Department of Agriculture I decided to leave and join Elders as one of their first Agronomist intakes in Western Australia. I was asked where I would like to be based and chose Northam as it was close to the city for our childrens future education, higher rainfall areas were under performing and I was covering some of my old Department of Agriculture advisory area.. This was an eye opening experience and taught me there is just as much politics and fixed culture in private enterprise as there is in government. After almost two years with Elders I gave up on trying to improve their agronomy business model and resigned. I had been encouraged by numerous farmers through my previous years to start my own advisory business and in fact when I had left the Department of Agriculture several farmers asked me to contact them if I ever decided to go private.

I sent out about 40 letters to individual farm businesses that I had had dealings with previously and I thought I could work with well. My letter outlined the services I planned to provide and that I would contact them by phone in the following few weeks to discuss the opportunity. After completing the phone calls I had 35 individual farm clients to service. This resulted in me starting my own business as Farm Focus Consultants based out of Northam in January 1992.

Within the first month of establishing the business, I was approached by an independent Wesfarmers reseller agent who informed me that he had a group of local and independent reseller businesses that wanted to start farmer discussion groups for their clients. They wanted an independent person to present to them at least three times a year for a half to full day on all aspects of broadacre farming. This arrangement grew from 6 to 10 groups of 20 to 40 farm businesses within 2 years and lasted till 2022 (30 years). Of the original 35 individual farmer clients in 1992 about half of those businesses were still with Farm Focus Consultants when I moved out of the central wheatbelt in 2022 after 30 years of service.

Farm scale scientifically rigorous trials

Within a few years of starting Farm Focus Consultants and working intensively with individual farm businesses I could see numerous research holes in the regions farming system's that no one was addressing. Therefore, I started applying for funding from research organisations but discovered I did not have time for the politics of funding organisations. After several years of trying, I gave up. I needed to find a new research way forward to address these holes.

Having spent tens of thousands of dollars of time on research grant applications annually, without success, I decided to ask a group of farmers, both client and non client, around Kellerberrin to see if they would be willing to participate in on farm scientifically rigorous research to improve their farming systems. I was willing to donate a similar value of my team's time that we had used to apply for research funds if they would pay for our travel and the groups general functioning costs. From the farmer participant side they had to be willing to host on their farm replicated trials, sow and manage the trials and participate with us in trial measurements, like crop development scoring, plot ratings, weed and plant counts. All members had to host at least one trial a season that they were interested in for the benefit of their farm business.

We had relatively few trial failures I think due to this vested interest by each farm business. When in season trial measurements were required all members available would attend a field walk where trials would be inspected, observations discussed and plot measurements taken. I remember early on a very experienced farmer said to me as we were doing wheat plant counts together that doubling seed rate certainly doesn't double plant density. Something relatively simple but a new fact for a very experienced farmer to learn.

At the end of each season a results book was produced and we held a review of the results and made decisions as a group as to the research priorities for the following seasons. I utilised these results in presentations to numerous farmer discussion groups and participating farmers were happy to share with interested others in their community.

After a few seasons, researchers began to hear about the Kellerberrin research group and some beneficial long term relationships began to develop. Particularly with CSIRO, starting with Dr Mike Robertson and his team. They would help in trial ideas, design, and take measurements, especially soil measurements. They helped in determining a soils crop moisture lower and upper limits to determine the plant available water on various soils. Farmer members were extremely helpful in providing water tanks, additional vehicles/equipment, a helping hand when required and were happy to do so as they could see value to their business from the research outcomes.

The groups data was freely shared with farmers, researchers and on numerous occassions was utilised as part of data sets to produce scientific publications and farmer information. This was an extremely synergistic participatory relationship that began in 1997 and concluded in 2022. Over the Kellerberrin research groups life there were 15 to 25 trials a year, so I would estimate more than 500 large scale scientifically rigorous research and demonstration trials were carried out that helped improve the resilience and sustainability of farming systems in the wheat belt.

Lesson –

If you are willing to put your time and resources into a research relationship where there are agreed objectives that fulfill the participants goals then great synergies and outcomes can be achieved by all participants.

The human side of family farming businesses

Very quickly after beginning the Farm Focus Consultants business I learnt a valuable lesson. When dealing with family farms I had to be part psychologist to understand the family dynamics and who were the key decision makers for various parts (finances, cropping, livestock etc) of the business.

Farm businesses could operate from a single person dictatorship to a total family democracy which made for either quick decisions or on the other hand, taking forever to decide. It was this variation in styles of decision making that could create enormous problems within the business and between the family members involved. Therefore, I had to learn how to navigate these variations by trying to be inclusive of all family members and getting everyone involved to actively listen, participate, comprehend our thinking and come to an agreed action, time to complete the action and a person or persons to manage the action.

I never got it 100% right as I recall failing with one particular business where the farmer would get focussed on getting the job exactly right when getting it 80% correct given seasonal variability, would have been adequate. He spent so much time on one job that he was extremely late in getting the most time critical jobs done on time. After a few years, his wife would say to him as I walked in the door for our planning and review meeting that “You know what Geoff is going to set as one of your major goals for this season don’t you”. After five years of bashing my head against a brick wall we decided to amicably part ways and move on. Some personalities never change, while others are more open to change.

Lessons –

1. Your objectives and the clients don’t always align.
2. Sometimes you won’t be able to achieve your’s or the client’s targets which can cause significant stress to yourself and the client. Some times the best way to address this dilemma after trying several times to address the problem/s is to amicably terminate the relationship.

Agreed fallback positions in the farm system

The process of consulting with family farm clients usually began with the basic agronomic decisions on weed contol, rotations, nutrition for plants and livestock. After a period to develop trust and understand the individual businesses financial situation and attitude to risk, my involvement moved onto bigger business decisions. In fact, I would say to be a good technical farm consultant without an understanding of a clients financial position in particular, can lead to poor agronomic advice being provided to the client. Some of the bigger business decisions that I have had significant input into included land purchase, machinery purchases, land lease and share cropping arrangements. As with many agronomic decisions nothing was black and white but all shades of grey. To try and cover most eventualities there would always be an agreed fallback position developed that was written down and agreed to by all participants in the business in case the worst case scenario occurred.

Business expansion fallback positions

Having an understanding of some of the financial parameters utilised by financial institutions and agricultural business consultants can really inform the nature of the technical advice provided. Assessing a clients business situation can determine how much risk can be taken to ensure that a change brought about through new technical advice doesn't stretch the businesses finanaces too far. Metrics like a businesses equity percentage, debt to income ratio (long term debt to average gross income ratio), and land value ratio (peak of all debt annually as a ratio of land value) should be sought and understood together with the clients attitude to risk. A businesses attitude to risk can vary from totally risk averse, where a client will have sleepless nights even if there is vitually no risk, to large risk takers who want to grow their business almost regardless of the risks.

This resulted, on one hand providing encouragement and support for the risk averse, explaining the benefits to the businesses farm system, efficiencies and the subsequent lifestyle improvements (the benefit of the benefit). Whilst on the other hand, for those willing to take larger risks, it is important they understand the potential consequences of several poor financial seasons following a major investment, and developfallback strategies – such as selling assets, generating off farm income, or drawing on prior investments like the soil phosphorus bank. As I keep saying, consensuson these decisions and fallback positions needed to be written down to help manage the business and personal stresses of all parties involved in the business.

Having a broad knowledge and understanding of the variability in farm profit Earnings Before Tax (EBT $/ha) on mixed farm enterprises throughout the wheat belt of Western Australia or even more localised data helps improve advice to individual clients. Bringing this information to the discussion table when business decisions of great consequence are being made is invaluable. It helps provide perspective on probabilities and possibilities of some outcomes of the decision. This is illustrated in (Figure 4) which shows where a nineteen year run of mean farm profits per hectare for between 130 and 150 farm businesses, depending on the season, courtesy of the ConsultAg group of consultants. It shows that on average 1 in 3 seasons are a loss or close to breakeven and that 75% of profits are produced in 20% of seasons. This sort of information can provide a valuable context, resulting in more tailored advice to individual clients. It also shows the importance of preparing for and taking advantage of those seasons where profitability is likely to be higher than normal.

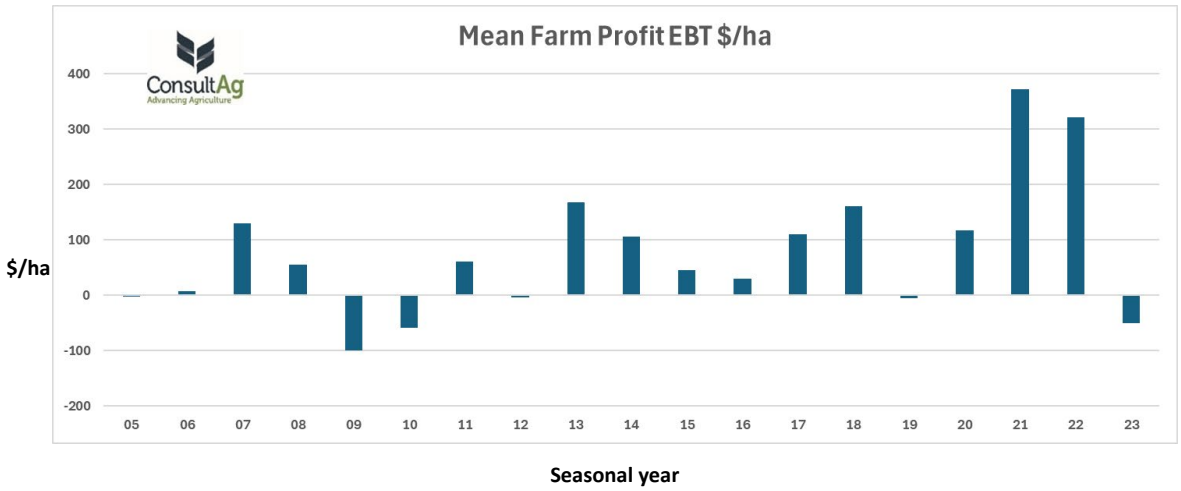

Figure 4: Mean farm profit (EBT) $/ha from 2005 to 2023 for the wheatbelt of Western Australia (Courtesy of the ConsultAg Group of Consultants)

Seasonal start fallback positions -
To this day I use fallback positions in seasonal farm plans to address several seasonal start scenarios. Depending on the characteristics of a paddock these seasonal plans will have paddocks that stay in their rotation no matter the seasonal start while other paddocks may flex from one crop and/or variety to another to a pasture or fallow based on plant available water, paddock reliability for a given crop or pasture and how long a dry seasonal start is expected to last.

Cropping –
Rainfall forecasts are only reasonably reliable three to four days out from a given day, however, when the weather site that always over estimates predicted rainfall says there is no significant rain for the next two weeks for several days in a row then the likelihood of significant rainfall in the next two weeks is extremely unlikely.

This weather information will trigger changes in the farm program at particular dates decided upon during the planning process for that farm business. These dates will vary depending on the rate of seeding the program to achieve a targeted finishing date. The finishing date moves by district and soil type to minimise the effects of frost, heat shock and moisture stress on an individual crop and/or varieties performance.

In combination with these dates is a requirement to have available on farm a range of crop species and varieties that can be germinated over a wide window of germination dates. A useful rule of thumb is to have in store or quickly available 1.5 times the amount of seed required for a seeding program. This significantly increases the resilience of a farm business through having greater flexibility at the critical planting time to take a germination and growing opportunity from late March to early June.
Table 3 shows a range of plant species and varieties that might be in store and ready to be sown on a germination opportunity for Mingenew in Western Australia.

Lessons –

1. Growers should have in store at least 1.5 times the amount of seed planned to be used in the seeding program.
2. Growers should have available a range of plant species and varieties that can take advantage of germination opportunities over a wide sowing window (Wheatbelt W.A. = April to June).

Table 3: Prefered germination windows for selected crops and varieties grown at Mingenew.

Variety	March		April						May						June			Preferred germination window
Canola																		
GT53																		20th March – 15th April
4022P																		5th April – 30th April
Hunter TF																		15th April – 15th May
Emu TF																		25th April – 25th May
Barley																		
Maximus CL																		25th April – 20th May
Beast																		20th April – 15th May
Wheat																		
Mohawk																		20th March – 25th April
Valiant CL																		20th April – 15th May
Scepter																		5th May – 31st May
Vixen																		10th May – 10th June
Oats																		
Bannister																		15th April – 10th May
Lupin																		
Jurien																		15th April – 15th May
Legend	Each box is approximately 5 days																	
	May be sown but avoid areas of stress like frost prone, problem weeds and poor plant available water areas. Variety can yield acceptably but often several other variety/specie can outperform it.																	
	Preferred germination time but BEWARE many varieties can "flex" their flowering time up to at least 10 days dependent on seasonal temperatures. Warmer = faster maturity!																	

Source: Advice provided to a client in 2023 by G. Fosbery.

Livestock –

As with the cropping program setting a calendar of decision dates for a farm businesses livestock program can improve the farm businesses resilience and help manage stresses of people working in the business. There is a big difference for many people between stressed plants and stressed animals. Livestock are mammals like humans so farmers tend to "feel" the livestock stresses more than those on a plant. Setting the dates and lengths of time of mating, birth and weaning need to be adapted to the whole farm system to take account of time management, labour availability, the enterprises risk parameters and profitability plus available paddock and stored feed.
It is a complex management arrangement and highly individual to each farm business.

I had one case looking at a businesses time management balance where a young farmer wanted more time for his family commitments. Labour was tight and he analysed his diary over 12 months

and determined that about 30% of his time was spent on the sheep enterprise which at the time was only producing 10% of the farm businesses gross income. He rightfully questioned the place of the sheep entreprise in their family business for him to achieve his family goals. We discussed some of the opportunities to reduce the time needed to manage the sheep enterprise and/or how to make it more profitable and resilient. Also and perhaps ultimately we questioned "why did the business need to have sheep as part of their farm business?" These are some of the discussions that come up and need to be worked through for each farm business.

In the spring of 1994 (20 months after starting my consulting business) I did my first fact finding and network building tour to the eastern states. I have kept attending international and interstate conferences and conducted fact finding tours out of Western Australia at least once every year or two ever since. This helped me develop and nurture an excellent peer network and challenged my farming systems thinking from outside the norms of the environment where I was working in Western Australia. When visiting an environment and set of farming systems outside my norms, I needed to look deeper than the surface data and dig into what thinking was the foundation of the research or farming system to be able to utilise and challenge our research directions and/or farming systems of my clients in Western Australia.

My targets for my first forae into fact finding in South Australia were visiting Dr Alan Mayfield based in Clare, South Australia, who ran the Hart research site and visiting some of the 1992 South Australian farmers drought feedlot setups through Brian Ashton's (Port Lincoln, PIRSA, at the time) contacts. Ashton and Morby (1994) had just released a book on how farmers innovated their livestock enterprise to better survive through the drought of 1992. One of the keys was setting up a few respite feeding (feedlots) areas over a farm businesses property/s. This made the limited grain and fodder available more efficient, minimised soil erosion risks, maximised the survival of emerging pasture plants at the break of season and reduced the time taken to feed retained stock. Many of the feeding areas were basic and utilised numerous small fenced off areas.

Speaking to the farmers and Brian plus seeing and photographing actual examples was invaluable in helping design respite feeding areas. I also learnt many simple tricks to make it easier to manage feedlot areas. When I returned to Western Australia I was convinced that every farm business with livestock as one of their enterprises, in at least the medium to low rainfall wheatbelt, needed to have several respite feeding areas. Respite areas rarely took out significant areas of arable land and they could be utilised at the break of season, feedloting lambs for market, and as a drought fallback position. By the end of the 1990's I think all my low and medium rainfall clients had respite feeding areas in place and being utilised as part of their livestock business.

Figure 5 shows a basic respite feeding area utilising a holding pen near a shearing shed, second hand steel belted conveyer belt with a raised edge, 200 litre blue drums cut in half to supply minerals in the diet, bales of hay and some natural bush on the outside of the lot to provide some protection from wind.

Figure 5: A basic respite feeding area from the mid 1990's

One of the other lessons I learnt about livestock and drought was that grain supplies were relatively easily obtained but fodder was extremely difficult to find and ultra expensive, often due to the freight cost. Another significant concern was that someone elses weed seed population was often introduced to the farm business through the bought in fodder. These introduced weeds may have been new species or new biotypes that were resistant to weed control tactics that would normally control weeds presently endemic to the property.

All these learnings from my fact finding tour to South Australia enabled me to develop livestock feed availabilty targets for my farmer clients. Firstly they needed to have on hand enough grain to feed all their livestock with grain through a drought by the end of the previous seasons harvest. Secondly, and often not easily accepted, was to have two seasons worth of fodder for an average season on hand by the end of the hay cutting season, or sometimes some straw of reasonable quality that could provide some gut fill and rumen scratch. This could be obtained off a client's own fields (preferable) and/or off nearby paddocks of trusted farming businesses where the paddocks had been inspected prior to final acceptance of the fodder to minimise the risk of problem weed importation.

Lessons –

1. Travelling to personally visit fellow researchers and consultants in other states is essential to be at the cutting edge of farming systems. It allows for discussion of "gut feels", "what ifs" and "best estimates" that are rarely discussed in research journals, conference papers or with people with whom they have no relationship. You put yourself out and they will put themselves out.
2. All Livestock enterprises should have fallback positions in their farm system that includes respite feeding areas, drought levels of feed grain and at least two seasons of fodder on hand by the end of season.
3. Prior Preparation Prevents Poor Performance! (The 5 P's).

CASE STUDY: A client's perspective of the major farming system achievements of our 40 years of working together

The following describes a client from the central wheatbelt of Western Australia feedback to me when I asked the question - What are the four biggest achievements that have positively influenced their farming system and business resilience over our 40 years of working together?

- Machinary upgrade decisions to improve timeliness, plant health, plant and input efficiency.
- Earlier crop establishment by dry sowing, setting a finish date and dates to modify paddock enterprise.
- Benefits of soil testing and reallocation of nutritional and ameliorant resources
- Benefits of soil testing and reallocation of nutritional and ameliorant resources

1. Machinery upgrade decisions to improve timeliness, plant health, plant and input efficiency.

1990's

In the early 1990's the major seeding machinery items were a low pressure spring tine 12 metre airseeder with a seed and fertiliser box, single shoot placement of seed and fertiliser down to a super seeder point and covering harrows, an 18 m tow-behind boom spray and a tow behind fertiliser spreader. The low pressure spring tine airseeder could sow directly into most stubbles as there was little livestock compaction when the soil was dry post-harvest. Unfortunately, pasture paddocks grazed over winter suffered from surface compaction in many cases which precluded them from being direct drilled dry as the airseeder bar tine pressure was not sufficient to produce an acceptable seed bed. This meant these paddocks often had to be worked up with a scarifier after rain and could delay sowing of the crop.

Having a single shoot seeding system to a superseeder (inverted T point system - <10% seed bed utilisation) restricted the quantity of nitrogen that could be banded with most crops seed to a maximum of 15kg nitrogen/ha to minimise any crop establishment problems. Therefore, there was a significant reliance on the topdressing operation to ensure adequate nitrogen was received by the crop into the root zone. Unfortunately, in many seasons there was inadequate early rain to get applied nitrogen into the crops' root zone and wet to enable plant uptake.This meant there was a great variability in response to topdressed nitrogen and a nervousness about nitrogen's return on investment.

To minimise the need for stubble burning the tine spacing was increased to 25cm but the harrows in greater than 2 tonne/ha patches of stubble in a paddock could still cause significant crop establishment issues. Hence, sometimes stubble burning still had to occur to allow an acceptable crop establishment.

2000's

To overcome some of the 1990's short comings a high breakout pressure spring tine airseeder bar with wide curved press wheels was purchased along with a three bin airseeder box including a double shoot system to be able to deep band fertiliser away from seed. The airseeder bar had a 30 cm tine spacing which allowed for greater stubble clearance but reduced the crop's competitive ability against weeds. To address the poorer crop competition with a single seeding row on each tine

we moved to a splitter seeding boot system that would provide a 25cm and 5cm seed row planting system. Having the split planting row could be accomodated by the curved 10cm wide tyre press wheel. The higher breakout tine allowed for a significantly greater area being able to be dry sown. This increased the efficiency of seeding larger areas resulting in less capital per hectare for crop establishment.

By moving to a double shoot seed and fertiliser system a good separation between seed and fertiliser allowed us to drill higher rates of fertiliser away and deeper than the seed thus minimising any crop emergence problems. Through placing fertiliser deeper it also reduced the risk of positional unavailability by having applied nutrients in moist soil for longer and in close but safe proximity of the crop root system.

Drilling urea instead of topdressing prior to sowing increased the nitrogen use efficiency often significantly with wheat yields increasing by five to 10% when urea was drilled versus topdressed and incorporated by sowing at the same rate. The three bin airseeder boxes held seed, compound fertiliser and urea seperately. To minimise the hygroscopic properties of the two fertilisers in the delivery tubes that may cause blockages, an air heating system was implemented. It allowed for much more paddock presciption nutrition to be applied rather than a broad brush nutrition program. Having the higher breakout and wider tines allowed for increased no till crop establishment with virtually no stubble burning. Seed could be sown shallow and the point work deep to break up fungal hyphae like rhizoctonia root rot which in some no till crop establishment systems had become a big problem.

By the early 2000's we had soil tested all paddocks at least once and often twice . It showed that we could redistribute the fertiliser investment more towards nutients like nitrogen and potassium rather than the previous focus on phosphorus. They also showed a need on numerous paddocks for the application of lime. Initially a contractor was employed to apply lime but as the area and amount of lime that was needed plus a labour unit was returning home from working off farm then it was decided to upgrade the spreader. This was in the form of a much larger sized (8 tonne), due to the high rates of lime per hectare, and belt driven (to be able to spread lime) spreader.

In the late 2000's, the proportion of herbicide resistant TT canola, as the dominant type of canola in crop rotationswas increasing. Initially, standard machinery was adequate to handle canola on a small scale but as areas expanded the need for a high clearance boom spray became apparent for the application of fungicides and insecticides for disease and pest management. Boomsprays at the time were too narrow and the wheel track and drawbar damage to these taller crops was becoming too great. Therefore, a 50% wider (28 metre), high axle clearance tug-along boomspray with a gooseneck drawbar hitch to the tractor was purchased to reduce the crop damage, increase efficiency and improve time management.

2010's

The high breakout pressure spring tine airseeder was still not strong enough to sow the "tighter" soils dry and produce a good seed bed for the crop. The next step was to go to a hydraulic tine on a parallelogram seeding system with a tractor set up with a GPS system for less overlaps and more efficient use of fertiliser and seed. Depending on the shape of paddocks and run lines this change reduced fertiliser and seed used on a paddock by 3 to 8%. Having a guidance system on the tractor at seeding also allowed for significantly greater hours in a day to dry sow as the dust level could be significantly greater before seeding needed to stop for the day.

The effects of lime applied 10 to 20 years previously had slowly started to reduce the effects of sub soil acidity but it was still a problem. On farm research was showing excellent results from a combination of ameliorants (Lime and Gypsum), soil mixing and deep ripping to break up the compaction layer. It was decided that the area of soils that had compaction problems and sub soil acidity had been reduced significantly. After two years of on farm replicated trials to determine if compaction was now the main soil constraint on these loamy sand soils it was decided to do a commercial area.

Contract deep ripping was compared to purchasing a deep ripper and the decision was to go with the purchase of a deep ripper. This soil amelioration program combination has turned paddocks that were on a pasture (livestock) and cereal rotation and least profitable into some of the most reliable, profitable and diverse rotation paddocks on the farm. It resulted in about a 40% reduction in livestock numbers over about three seasons.

Over the decade canola moved from a profitable break crop to service the following cereal crop to the profit driving enterprise for the whole farm business. As such management in crop and at harvest had to improve to reduce the riskiness of producing the crop, ensuring timely harvest and delivery. It was deemed that an additional boomspray was required with even higher clearance and less wheel tracking. To achieve this, a self propelled boom spray with a 120 foot boom, a set of narrow tyres and crop dividers was purchased. This allowed for selective croptopping of canola to allow earlier grain harvesting.

2020's

As usual the weed population adapted to our farming system and began to avoid the farming systems weed control measures. They did this by not emerging until our pre emergent herbicides used on our earlier and earlier emerging crops had broken down to a non controlling concentration, particularly in furrow. The dry sown and/or earlier emerged crops relative to the weeds were very competitive against the weeds but weed seed set was still a problem. The post emergent registrations of prosulfocarb and pyroxasulfone in some cereal crops and the introduction of Truflex canola helped to minimise the effect on the weed seed bank of these later emerging weeds. In the case of Truflex canola it allowed the safe application of glyphosate through to 10% flowering of the Truflex canola crop which was normally an additional three to four weeks later in the growing season relative to the previously utilised Roundup Ready canola varieties.

The risks of wind, rain and hail on slowly maturing canola can be dramatic in reducing the amount of grain actually harvested. Therefore, numerous methods of improving harvest efficiency were investigated. The feeding of the standing crop into the harvester front was identified as a major reason for losses and slow speed of harvest. Eventually the engineers found the best front design to harvest canola and a significant investment was made into vario fronts for the harvesters.

An investment into a liquid cart system increased the area sown per fill of the sowing equipment by 20 to 30% and allowed the application of in furrow fungicides much more easiliy and safely through the liquid injection system. Also the move to RTK GPS systems for control traffic allowed for seeding dry 24 hours a day through the dusty seeding conditions.

Machinery upgrade summation

In summary, over these four decades, advancements in machinery, technology, farming systems, crop species and varietiessignificantly expanded the germination window. In the 1990's the farm business typically operated within a seven-week germination window – from April 26th to June 5th
All these changes in machinery, technology, farming systems, crop species and varieties over each decade have increased the germination window out to 9 weeks (March 23rd to May 25th) in the 2020's relative to 7 weeks - April 26th to June 5th . By the 2020's, this window had extended to nine weeks, starting as early as March 23rd and continuing till May 25th (see table 4). This shift was enabled by improvements such as dry sowing techniques, rotational flexibility and precision agriculture tools like GPS guidance.

The practical implications for this farm business, and others, was substantial. One seeding unit – such as an 18-metre airseeder- can now operate efficiently for longer each day and over a longer sowing period. This not only improved the return on machinery investment but also reduced the need to purchase additional seeding equipment as the farm business expanded. In other words, farmers could increase their cropped area without a proportional increase in capital costs, making their operations more scalable and cost-effective over time (see table 4).

Lesson –

Machinery availability through contractors or purchase have a large bearing on a businesses ability to adopt farming systems and crop species.

Table 4: Changing seeding program goals and parameters through the decades

Decade	Finish sowing target date	Dry sowing start date	Earliest wet sowing date & crop type	Dry sowing hours/day	Rotation set up to target what % of potential dry sowing area	Area an 18m airseeder bar could efficiently sow (ha)	Crop requisites on hand by date
1990's	June 5th	April 26th	April 15th Lupin	12hrs/day	40%	4,000 ha	April 20th
2000's	May 31st	April 15th	April 8th TT Canola	12hrs/day	60%	5,000 ha	April 1st
2010's	May 25th	April 7th	April 1st TT Canola	18 hrs/day	80%	6,000 ha	March 20th
2020's	May 25th	April 1st	March 23rd Truflex Canola	24 hrs/day	90%	7,000 ha	March 15th

Source: Fosbery (2024) observations and estimations while working with this and other farm businesses over 40 years.

2. **Earlier crop establishment by dry sowing, setting a finish date and dates to modify paddock enterprise.**

Over a period of thirty years, the target completion date for the sowing program moved two weeks earlier to May 25th for the location of this client (see table 4). As the rotation became more diverse and species and varieties could be established earlier on a germination opportunity so the potential yield cost of germinating crop in late May and early June became greater than would be normally accepted. The earliest emerged crop needed to be more profitable than the last germinated crop. To have this ability a range of species and varieties (see table 3) are required to be in store ready for rapid deployment.

As the seasonal break develops, having flexibilty in the sowing program for as long as possible through crop/variety diversity and setting of "flexi dates"has increased profitability and decreased risk to the business. In particular, the area of canola as a proportion of the farm decreases in poorer start seasons (2018 and 2020) and the percentage of gross income relative to the percentage of each crop area sown also decreases (Table 5). In this clients business the gross income generated over this eight year period by canola is on average 35.7% higher per hectare than wheat (Table 6).

Table 5: A clients' percent of gross income of each crop versus percent of land used for each crop over the last eight seasons.

Farm Income Vs Land Use								
	2016		2017		2018		2019	
	% Income	% Crop Area	% Income	% Crop Area	% Income	% Crop Area	% Income	% Crop Area
Canola	42%	28%	30%	32%	21%	24%	23%	21%
Wheat	43%	60%	52%	58%	59%	64%	54%	66%
Oats	1%	2%	1%	2%	1%	2%	1%	1%
Barley	4%	7%	5%	5%	7%	8%	6%	9%
Lupins	1%	2%	1%	2%	1%	2%	2%	4%
	2020		2021		2022		2023	
	% Income	% Crop Area	% Income	% Crop Area	% Income	% Crop Area	% Income	% Crop Area
Canola	17%	24%	44%	27%	50%	41%	39%	35%
Wheat	63%	66%	49%	61%	46%	54%	49%	59%
Oats	2%	2%	1%	1%	2%	2%	4%	2%
Barley	2%	3%	1%					
Lupins	4%	5%	5%	8%	2%	3%	2%	3%

Source: Fosbery 2024 modified actual client data provided by central wheatbelt W.A client.

Table 6: The ratio of percent of gross income relative to the percent of farm area sown to canola and wheat over an eight year period.

Year / Crop	2016	2017	2018	2019	2020	2021	2022	2023	Average
Canola	1.5	0.94	0.88	1.10	0.71	1.63	1.22	1.11	**1.14**
Wheat	0.69	0.90	0.92	0.82	0.95	0.80	0.85	0.83	**0.84**

Having a minimum percentage of canola in the farm system (21% in 2019) no matter the seasonal start provides a foundation and resilience to the farm system for future seasons. Also, having the flexibility to increase the proportion of the most profitable crop in a good season helps to achieve excellent returns when the seasonal opportunity arises without over exploiting the rotation and

longer term farm system. Through my experiences around the state with variations in germination opportunities, with canola in particular, I have a series of rainfall criteria on a range of soil types that defines how much soil moisture plus rainfall is required to germinate canola and allow it to survive well from a given date with minimal risk. This client has utilised this data and participated in testing its parameters and ultimate definition. They now believe that they can obtain a good canola emergence prior to May 1st in at least 75% of seasons based on their previous years rainfall records. Although stressful at the time of making these early canola establishment decisions they believe it is the biggest driver of their business resilience and profitability over the last decade.

3. Benefits of soil testing and reallocation of nutritional and ameliorant resources

Soil testing to depth (initially 0 to 30cm in 10cm increments but now 0 to 50 cm in 10cm increments) at selected GPS located sites over time has allowed this and many other businesses to monitor the effects of their nutritional and ameliorant management practices on their soils (Figure 6 and 7). The application of lime to the soil surface and its movement with cultivation and time is slowly improving the sub soil pH at depth. Figures 6 and 7 show how the application of lime has increased pH below the top soil to much more plant root friendly levels resulting in much more resilient crops to climatic stresses.

They can now variable rate nutrient and ameliorant applications to ensure the soil is providing a good soil environment and adequate nutrition to the growing crop. This has not necessarily decreased average inputs but has ensured the highest producing areas of the paddock are not mining the soil which will ultimately reduce yield from previously consistently high yielding areas.

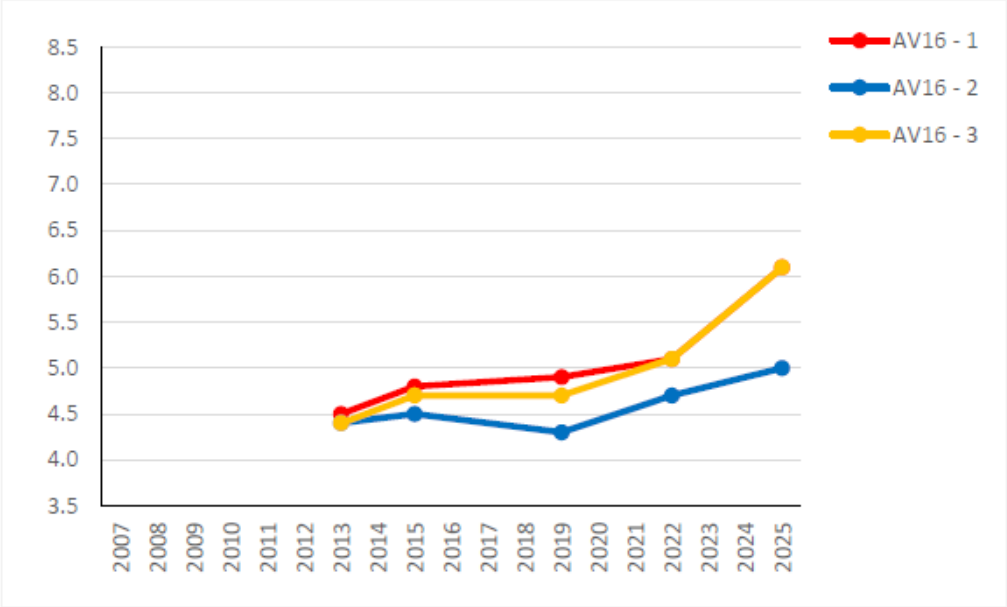

Figure 6: Change in pH (CaCl2) over the years on Paddock AV16 at a depth of 10 to 20 cm at sites 1, 2 and 3.

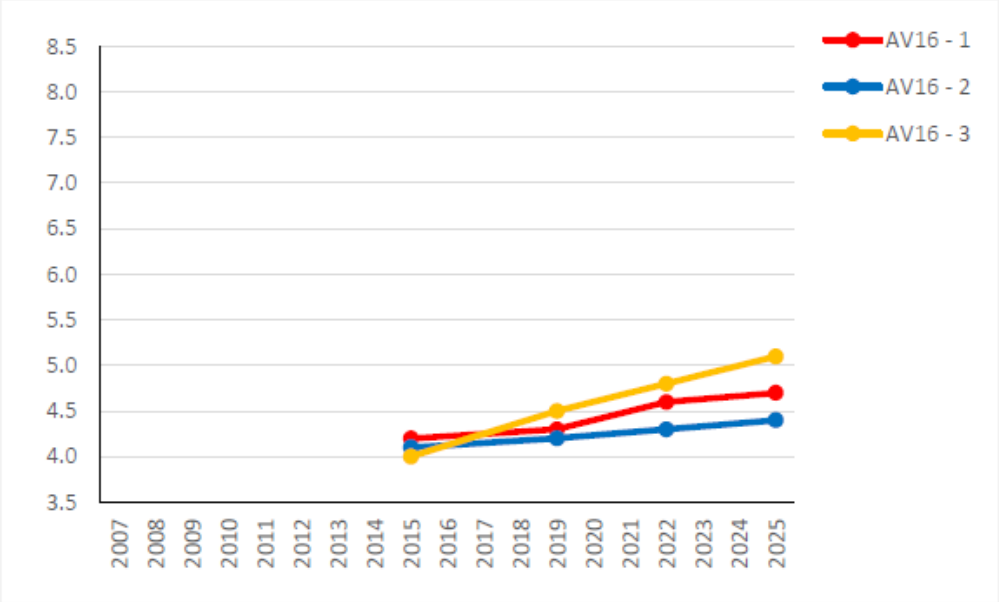

Figure 7: Change in pH (CaCl2) over the years on paddock AV16 at a depth of 20 to 30 cm at sites 1, 2 and 3.

Lesson –

Monitor to manage.

4. Paddock specific weed control strategies and tactics to minimise weed seed banks and resistance development

Understanding the biology of the major weeds was a necessity as one could win some battles without this knowledge but ultimately the weeds would win the war if you did not use an informed approach. Simple long term rotations like continuous wheat and wheat: lupin rotations eventually became infested with weeds that avoided the relatively low diversity of weed control tactics applied in these rotations. Weeds like annual ryegrass and wild radish became major problems. To minimise the influence of these weeds a diverse rotation was required that had at least three or more complimentary components for each paddock or land management unit on the farm. These components of the farm system changed through time as developments in new technologies, plant varieties and species, soil amelioration and transformation, prices of inputs change and farm enterprise market movements occurred over time. Table 7 outlines the rotational components through the decades that this business utilised. As the weeds became adapted to the more simplistic and least diverse rotations so more components were introduced to the farm rotation to increase the diversity of weed control tactics and strategies and increase the businesses resilience and profitability.

Table 7: Components of the central wheatbelt clients farm rotation utilised in each decade.

Decade	1980''s	1990's	2000's	2010's	2020's
Components of rotation utilised	Natural Pasture	Natural Pasture	Natural Pasture	Natural Pasture	Soil renovation manure
	Sub Clover	Sub Clover	Sub Clover	Sub Clover	Sub Clover
	Burr Medic	Burr Medic	Burr Medic	Burr Medic	Burr Medic
	Wheat	Wheat	Wheat	Wheat	Wheat
		Lupin	Lupin	Lupin	Lupin
			TT Canola	TT Canola	TT Canola
				Fallow	Truflex Canola
				Barley	RR Canola
				Oats	Oats
					Fallow
					Barley

Source: Fosbery 2024 – from records and discussion with central wheatbelt client

The cornerstone to our no till farming system was the activity of the herbicide glyphosate. When weeds and particularly annual ryegrass became resistant to glyphosate in the early 2000's I again flew to the epicentre of the growing problem, northern New South Wales and southern Queensland for fact finding visits in 2006 and 2008. I utilised my network of professionals in agriculture to visit farmers, consultants, researchers and extension people that had or were managing paddocks with glyphosate resistant weeds. My visits and discussions with Greg Giblett (OutlookAg), Richard Daniel (Northern Grower Alliance) and Andrew Storrie (Agronomo Consulting) were invaluable in helping me prepare myself, clients and farmer groups for the inevitable onset and management of glyphosate resistance in our farming system. The role of green on brown weed management on long and summer fallow was being developed and implemented on farms and I could see that application system becoming an integral part of weed control systems. Glyphosate had become relatively cheap and was being over utilised by farmers and many agronomists throughout the year on all weeds.

After returning from my 2006 visit I began a glyphosate resistance awareness campaign with my farmer groups and individual clients. We all needed to modify our use patterns of glyphosate to extend its use life. This involved convincing farmers that they had to contol summer and winter weeds at younger growth stages with alternative herbicides to glyphosate and reap the benefits of additional moisture and nutrients for the next winter crop (again extolling the benefit of the benefit). Contolling the weeds earlier, more than paid for the herbicides that were more costly than glyphosate.

My goal over the next few years was to re introduce and promote the safe and reliable use of paraquat into the knockdown space prior to sowing a winter crop and to minimise the application of glyphosate. With the adoption of Roundup Ready Canola the use of glyphosate as a post emergent herbicide was going to become even more important to the farming system and rotations than its' place as a major knockdown herbicide. We needed to find alternatives to glyphosate use through our fallow periods and as a knockdown and that was to be through the use of green on brown technology and the increased use of paraquat and paraquat mixes prior to crop establishment.

Convincing clients to commit funds and resources to weed seed bank management rather than economic weed competition thresholds was the most difficult. This was because they would not see or measure a benefit in the season that the weed control decision was made. It often took several seasons to get the message across to clients and farmer groups. The best way was to get a client or farmer group member to do a few trial strips of weed seed set control in a season and then return to the same site the following season or two and see the results. Seeing was believing and now there is rarely any hesitation in contolling the seed set of any remaining and/or later emerging weeds. This results in less selection presssure on the following seasons weed control tactics and slows the rate of resistance development.

Lessons –

1. Need to invest in the present season's weed seed set control for the benefit of following seasons.
2. Increased rotational diversity increases a farming system and businesses resilience.

Conclusions and the future challenges

There is no question that the farming systems of broadacre Western Australia have become more resilient, sustainable and profitable over the 40 years of my professional life. The combined adoption by most farm businesses of no till crop establishment, dry sowing practices, broadleaf crops (Lupin and Canola), appropriate soil amelioration tactics (lime, gypsum, deep ripping and soil mixing to depth), and strategic utilisation of new pesticide active ingredients (herbicides, insecticides and fungicides) has provided the majority of this improvement in business resilience.

While adopting these tactics and strategies having the ability within a farm business to be flexible within a season and playing each season on its merits is a must to make the most of the good seasons and to be frugal in the higher risk seasonal starts. Consultants, agronomists and farmers need to be wary of last seasons results dominating decisions (recency bias) when making present season decisions.

As a measure of how well broadacre farming has become more resilient and sustainable over time Figure 8 shows how, on average, wheat belt farm businesses have improved their water use efficiency (WUE) by 5kg/mm/decade from 2002 to 2020 (Data courtesy of the ConsultAg group of consultants). This includes data from the 2005, 2008 and 2016 seasons which is when crops were badly affected by frost. The highest WUE seasons tend to occur in lower production seasons like 2002, 2012 and 2020.

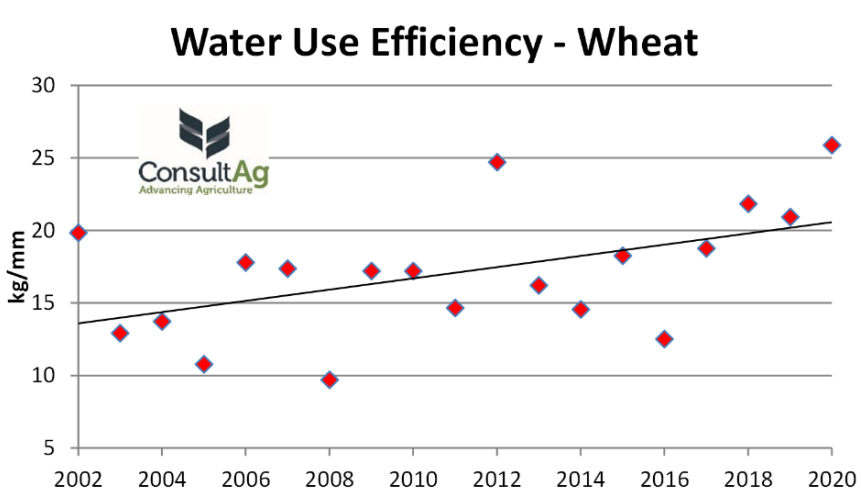

Figure 8: Average annual Water Use Efficiency (WUE) of wheat from a group of (>120) farm businesses from the wheat belt of Western Australia from 2002 to 2020. (Courtesy of the ConsultAg group of consultants)

From a financial resilience point of view, the average wheat belt farm business position has improved significantly particularly over the last four seasons (Figure 9, Courtesy of the ConsultAg group of consultants). Having an average equity percentage in the high 80's or low 90's means they are in a very solid, sustainable and resilient financial position.

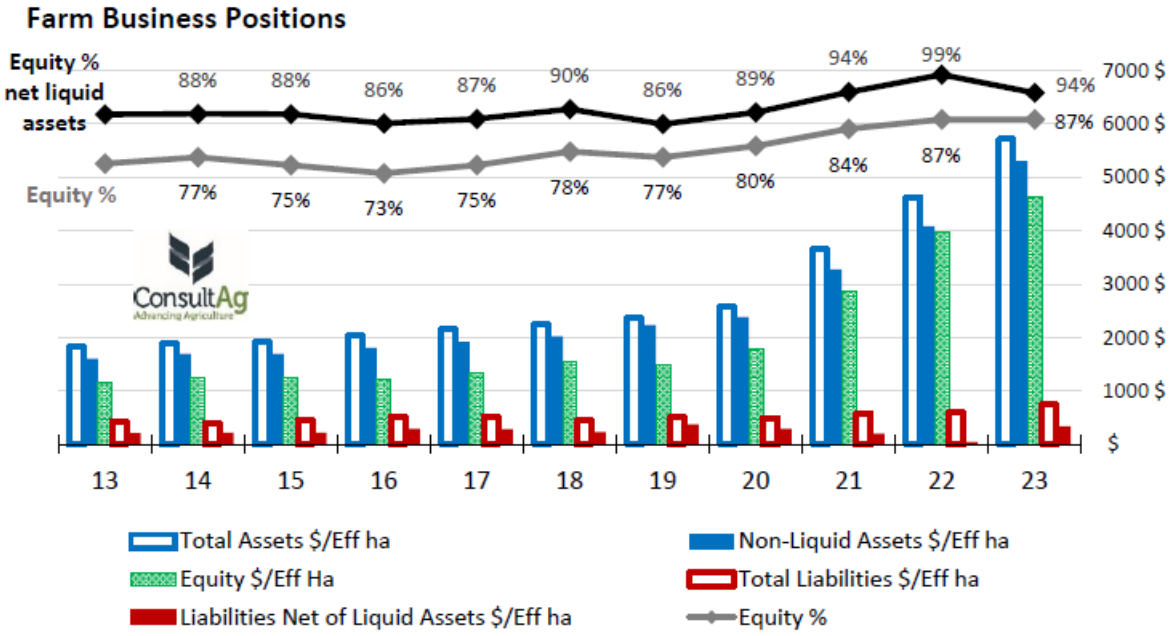

Figure 9: Average annual business positions of (>120) mixed broadacre farms in wheatbelt Western Australia over the last 11 years. (Courtesy of the ConsultAg group of Consultants)

Over my forty years of being involved in this innovative, challenging, resilient and ever changing industry there has never been a time where you could say we have achieved the perfect farm system.

The climate, environment, economics, regulations, risks, people and community attitudes are always in a state of flux which results in the research, development and extension goal posts continually changing and evolving. This also makes it a rewarding industry in which to work.

Therefore, everyone in our wonderful agricultural industry needs to build a business and/or institution where they are flexible enough to react positively and innovatively to the challenges presented to them and as often as possible turn a negative into a positive.

I conclude by encouraging the next generation of agronomists to bravely face these challenges. To do this by developing networks, listening to farmers, learning from the past and progressive research to build an even more resilient and profitable farming systems. To utilise new technologies to improve decision making on farm and throughout the agricultural industry.

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Acknowledgements

Many thanks to Sue Knights and Steve Curtin for their edits and suggestions for improving this paper.