Nuffield International Farming Scholars Research Report

Growing in uncertain times: transformative production practices to optimize farm resources and margins

Report by: Steven Archie Griffin
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Scholar Contact Details

Steven Archie Griffin
Griffin Farms Inc.
2807 St. John Church Road
Washington, North Carolina, 27889

Phone: +1(252)-945-7356
Email: Archieg190@gmail.com
Archie@Griffinfarms.biz

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

NUFFIELD International Contact Details

Nuffield International

Telephone: +61 (0) 408 758 602

Email: enquiries@nuffield.com.au

Executive Summary

With the global population expected to reach 10 billion by the year 2050, the future of the agriculture industry around the world is bright and ripe with opportunities. However, a consistent downward trend in the market infrastructure of United States agriculture has resulted in farmers experiencing a multi-year slump in commodity and livestock prices that is pushing many to the financial brink. 2017 marked the fifth consecutive year that farm solvency ratios weakened, while both liquidity ratios and working capital deteriorated to their weakest levels since 2002. In total, farmers and ranchers have weathered a "*45% drop in net farm income since its highest level of $136.1 billion in 2013, the largest four-year drop since the start of the Great Depression*" (Harvie, 2017).

Historically, the agriculture economy has traveled the path of a 'linear' model, where raw materials are used to make a product, and after its use any waste is thrown away. This model has duped agriculture producers into believing in a linear production cycle, where only inputs and outputs are considered. This mindset has led to the belief that synthetic fertilizers and high inputs equate to high yields and high profits; too often, producers fall victim to the idea that maximum profit is attained by maximizing output. In the future, in order to be successful, producers must change and adopt business models that bear resemblance to circular economies.

Alteration of traditional business models and focal points can be a daunting challenge. How does a producer effectively transform their operation without making mistakes which could jeopardize future generations?

This report aims to suggest steps and models, employed by top corporations in various industries, that can be used as supplementary assistance for a successful transformation. Many operations are already doing this to some extent by increasing their focus on the adoption of new technologies to foster further emphasis on efficiency and minimize wastes. As the world's oldest and most entrenched industry, agriculture is not easily disrupted; the introduction of technology into the industry has promised to change that by bringing it into the modern age. With innovations in the agriculture technology sector occurring at a rampant pace, the potential

capabilities of new technology are still uncertain. Newly introduced technologies promise to revolutionize age-old practices, but often fall short of expectations. Applying Moore's law to the Gartner Hype Cycle, the majority of agriculture technology is still in its infancy and is yet to deliver its technological promises.

The optimal pathway to success and sustainability for farmers facing uncertain futures, will occur when efficiency, technology, and differentiation are combined and directed towards creating a circular and synergistic relationship between all farm activities, resources and industries.

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Foreword

When I left our family farm to pursue a degree in engineering North Carolina State University, I had zero intentions of returning. It is often said that farming is in your blood and something you are born into. At the time I completed my undergraduate studies, the agricultural production was at its peak, commodity prices were at record heights, and the future was extremely bright. After discussing my intentions and future with my parents, I decided to return to the farm while I pursued a Masters of Business Administration. As the only child, it was a big deal for me to entertain the idea of returning to the farm, even for a short time.

Appreciation and love were not the only two reasons that contributed to my return. News media, scientific research, and various other publications constantly reiterate that, in order to meet the demands of the earth's growing population, our food production must increase dramatically. With farm land areas shrinking, food demands on the rise, and the estimated average age of farmers in the United States to be around 58 and rising, I believe that it was not sensible to forgo the opportunity and challenge.

When I returned to the family farm, my father told me to throw out everything I had learned at college; he was enrolling me in his "Farming 101" class. Two of the many lessons he taught were:

1. Farming is easy; anyone can farm, but not everyone can farm and make money, and
2. Efficiency is the key to everything.

These lessons became more meaningful and relevant each year.

Our operation utilized high commodity prices by improving our efficiency and investing in the rapidly improving agriculture technology. In the five years following my return, profit margins started to slowly shrink away from the record heights, but profit was still achievable and the agriculture industry was in fairly good shape. We saw exceptional return from our investment in technology and precision agriculture. Almost overnight, the outlook and demeanor in the industry changed. We were struck with back-to-back bad years due to weather, our tobacco contracts were being slashed each year, and commodity prices were at break-even or below.

Despite the efforts we took to increase efficiency, ultimately, we were at the mercy of the large conglomerates dictating our contracts and input costs.

I turned to my peers to find out how they were combating these challenges. Countless times I was told that this is just the cyclical nature of the US agriculture industry and the only solution was to 'tighten your belt' and make no mistakes. In fact, no one had any true solutions or unique ideas outside of their common practices. I felt as though our operation and others like us were trapped between a rock and a hard place. How could we improve efficiency? What could be done to improve margins? I did not have the answers to these questions, but I knew somewhere in this big world someone did and those answers were the solution to securing our farm's future.

Since the beginning of this journey, my research topic has changed course several times. It seemed as though, with each country I visited, my thoughts changed directions. Despite these shifts, in the end I find myself not far from the topic I originally set out to research. My goal is for this report is not to identify a clear-cut path that will work solely for our operation and area; the primary objective is to identify a global multi-faceted pathway to optimize farm resources and margins.

With assistance and guidance from my investor TIAA and a few of their employees, my Nuffield journey has allowed me to travel extensively through many countries including The Netherlands, Ireland, USA, Brazil, Mexico, New Zealand, China, Ukraine, UK, Israel, Zambia, Zimbabwe and Australia to meet producers and agribusiness personnel who are breaking trends and overcoming tremendous obstacles.

This report captures the ideas of these individuals, highlights their methodical approach, and suggests a pathway for producers to follow when they find their operations in unfavorable conditions.

Figure 1: The author at home on his family's farm, 2019

Acknowledgments

I would like to begin by giving thanks to my mother and father for standing beside me throughout this journey. I could not have made it without their constant support, reassuring phone calls at abnormal times when we were thousands of miles apart, and willingness to step in and fill my roles and responsibilities on and off the farm.

I would like to thank Ed Kee, Jean Lonie, Jim Geltch, Kelvin Meadows, and the multiple others associated with Nuffield International and Nuffield USA. Thank you for not only selecting me and offering this a once in a lifetime opportunity, but also for trusting and believing in me, and for the endless support and aid given throughout my studies.

I would also like to recognize and thank my investor, TIAA. Without your contribution, support, and assistance, this opportunity would never have been possible. Companies and individuals like yourself are positioned at the forefront of our industry and are helping to pave the way for the future of agriculture.

Thank you to all the 2018 Nuffield Scholars, alumni network, and those whom I had the pleasure of traveling with on the Global Focus Program (GFP). I learned more about from you all than I ever imagined possible. The memories, friendships, laughs, fights, tough times and great times we experienced will forever remind me how amazing an opportunity Nuffield is. The exposure, connections, and opportunities presented by the Nuffield organization is nothing short of incredible and unmatched.

Lastly, thank you to all who took to the time out of your busy schedules and lives to meet with me, opening up the doors to your homes and businesses to a stranger you just met. I will cherish the countless hours that you all spent providing guidance and support, insight, challenging and thought-provoking conversations over coffee or brews. This report would not have been possible without your generosity. It is a true privilege to have met you all and I look forward to repaying the favor one day.

Abbreviations

Ac – Acre
AD – Anaerobic Digestion
Ag – Agriculture
AUS – Australia
BR – Brazil
Bu/Ac – Bushels per Acre
oC – Degrees Celsius
CN – China
oF – Degrees Fahrenheit
FYM – Farm Yard Manure
GDP – Gross Domestic Product
GFP – Global Focus Program
Gw – Gigawatt
Ha – Hectare
IE – Ireland
IL – Israel
Kw – Kilowatt
Kwh – Kilowatt Hour
MX – Mexico
Mw – Megawatt
N – Nitrogen
NC – North Carolina
NCDA – North Carolina Department of Agriculture
NL – The Netherland
NZ – New Zealand
REPS – Renewable Energy and Efficiency Portfolio Standard
T/ha – Tons per Hectare
UK – United Kingdom
USA – United States of America
USDA – United States Department of Agriculture
USDA-ERS – United States Department of Agriculture Economic Research Service
ZIM – Zimbabwe
ZM – Zambia

Objectives

This report aims to provide farm operators and managers with transformative production practices to assist in optimizing farm resources and margins, necessary for attaining growth and sustainability during uncertain times and to:

- Identify diverse and unique business models and methods implemented by farm operations to attain growth, stabilize revenues and ensure the future of their assets and business.
- Identify advantages and disadvantages of early adoption versus late adoption of technology and determine the optimal stage for the adoption of technology.
- Identify methods and models utilized to increase sustainability and create circular economies.

Chapter 1: Introduction

Agriculture in the United States of America (USA) is at a pivotal point in its history. A consistent downtrend in the structure of USA agriculture has resulted in "*farmers experiencing a multi-year slump in commodity and livestock prices that is pushing many to the financial brink. 2017 marked the fifth consecutive year that farm solvency ratios have weakened, while both liquidity ratios and working capital deteriorated to their weakest levels since 2002*" (Harvie, 2017). As of 2018, "*farmers and ranchers have weathered a 46% drop in net farm income' since its highest level of $136.1 billion in 2013, 'the largest four-year drop since the start of the Great Depression' and below its historical averages, $90.0 billion and $108.0 billion, across 2000-17*" (Harvie, 2017; USDA-ERS – Farm Sector Income Forecast, 2019).

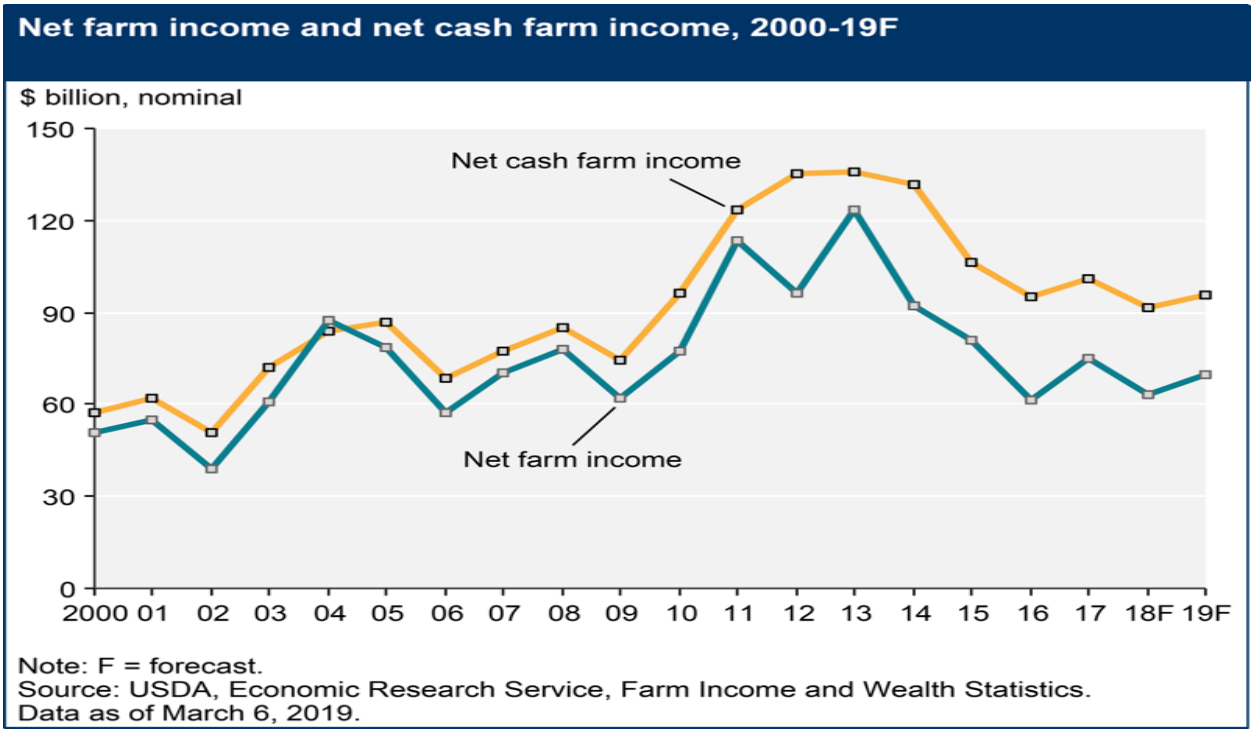


Figure 2: Net farm Income and net cash farm income, 2000- 2019F (USDA-ERS, 2019)

Net cash farm income is calculated by subtracting gross cash expenses and interest expense from the gross cash income (crop and livestock receipts, and other forms of cash income). Net farm income includes the same data, adjusted to allow for depreciation, hired labor, and other expenses.

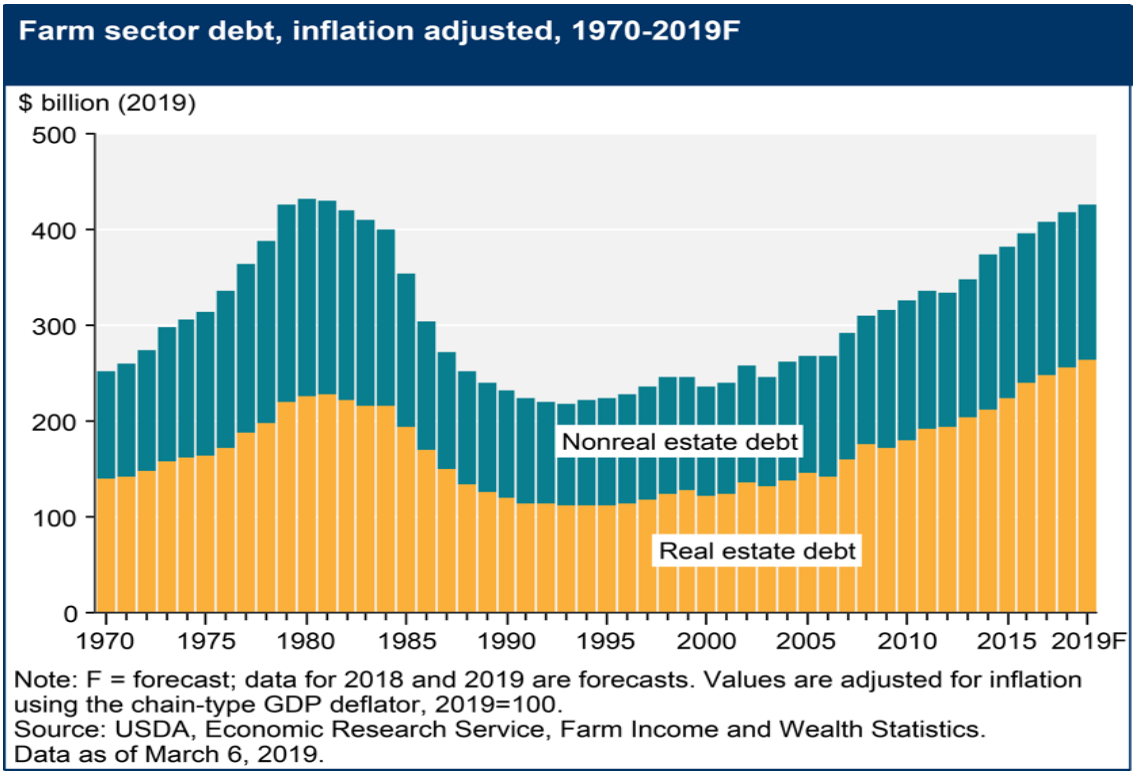


Figure 3: Farm sector debt, inflation adjusted, 1970- 2019F (USDA-ERS 2019)

Political turmoil coupled with increasing global production rates and oversupplies have had drastic and lasting negative impacts on commodity market prices, forcing many crop margins below break-even ranges at times. Trade wars and tariffs, in addition to many unnecessary regulations, are having extreme impacts on farms and their ability to fund operations and be a sustainable, successful farming operation (Figures 2 & 3). According to Farm Bureau's chief economist John Newton, "*The situation is likely to worsen. Farm debt is record-high, the debt-to asset ratio has climbed for six consecutive years, and farm debt as a proportion of annual farm income is at 97% – a 32 year high*" (Newton & Nelson, 2019).

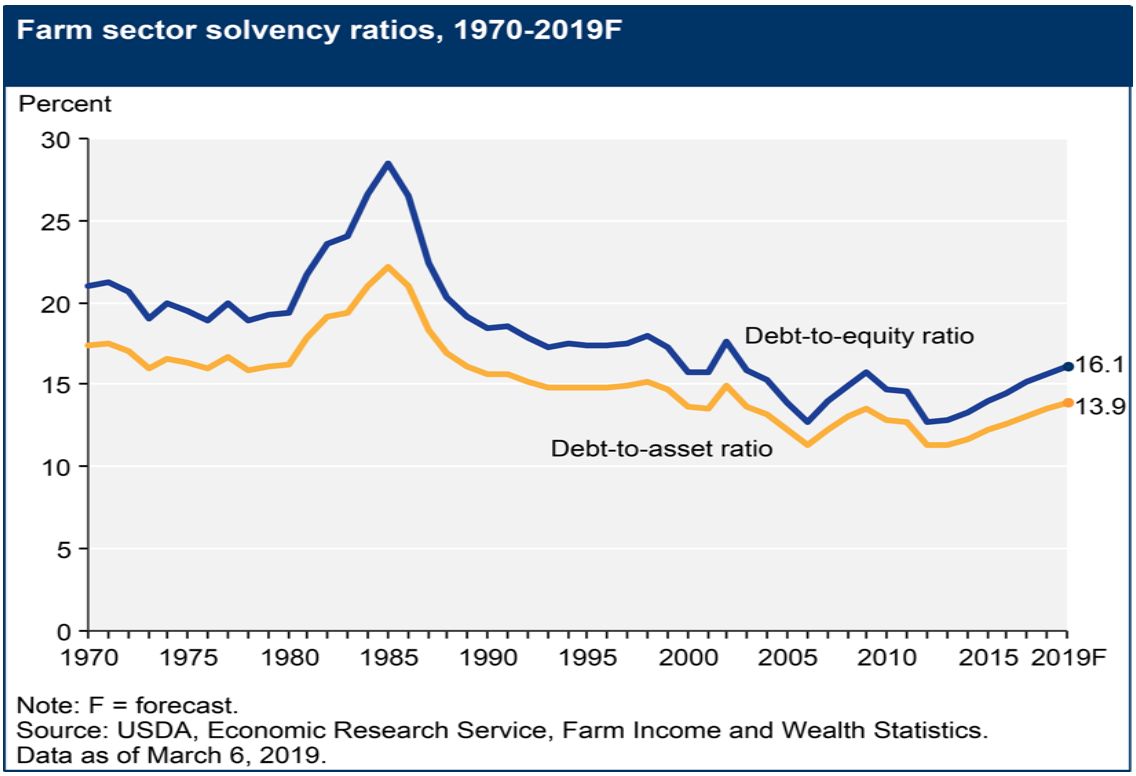


Figure 4: Farm sector solvency ratios, 1970-2019F (USDA-ERS, 2019)

The trending economic downturn in the nation's agriculture industry, coupled with progressively more uncertain weather patterns, is causing many regions across the nation to experience shorter growing seasons, consistently beginning earlier and ending earlier, and higher rates of rainfall are occurring over shorter periods of time. These changes are forcing farmers and ranchers to re-evaluate the purpose and cultivation of some historically produced crops. If adequate and timely action is not taken to correct or mitigate these challenges, the future of many farmers and farm operations across the nation will become increasingly uncertain.

The overarching goal for this Nuffield journey was to identify how modern-day farm operations could successfully weather these challenges. Speculation and curiosity are two words that arise when pinpointing how some farm operations and businesses have managed to insulate themselves from such economic volatility and adverse conditions. How and why were certain businesses able to remain successful, while others doing the same thing were failing? What

models, methods, and vision were these successful businesses implementing that gave them a competitive advantage?

It was not surprising to learn that the many of farm operations are still family-owned and operated, as farms are generally passed from one generation to the next. However, it was unexpected and intriguing to discover that many of these family farm operations were progressively adopting the characteristics of corporations and businesses by branding themselves, implementing innovative marketing techniques and establishing a competitive advantage.

While most operations visited were different, it was interesting attempting to draw parallels from their varying versions of lectures on triumphs, failures, and eventual success. To a large extent, their business models were no different from most other farm operations that raised crops or animals; eventually they all sold their product to a broker, middle-men, or processor. One of the many eye-opening discoveries came while touring an operation in the United Kingdom (UK). The President and CEO of the family business revealed that their business model was "*to the farm people and not the crops*," a unique and different approach. He stated that a farmer's primary objective is normally to produce a quality, high yielding crop; in order to do so, the farmer must meet that crop's specific demands and needs for nutrients, sunlight, and water. This family argued that the majority of farmers produced end-products that did not entirely meet the demands and basic needs of people. The products referenced: corn, soybeans, and wheat, among others; all fell into the "grains" category. These businesses believed that the demands and needs of plants, like people, were diverse; the utilization of a single uniform approach to satisfy and cater to these varying demands and needs would result in failure to reap its full business potential.

The majority of farmers today have weathered droughts, drowned crops and have survived the Great Depression and Dust Bowl of the 1980s. It is these farmers that are quick to remind their successors that agriculture is cyclical and history repeats itself and the best way to survive tough times is tighten your belt and hold on. There is no doubt that these great business men and women have experienced and survived true hardships and they are very fortunate to still be in

operation. However, there are important differences today. The internet, global connected trade markets and potential for technological disruption that is rapidly transforming the industry are new. These differences are just a snippet of the many differences that did not exist 40 years ago. While it may be sensible to follow in the footsteps of those before and listen to wise elders, it is also wise to question advice, and properly investigate and highlight differences and determine how these differences may impact the outcome. What may have worked 40 years ago might not be as successful the second time around. There are some key questions which every farmer needs to answer:

- Do you recognize that the 'family farm' is much bigger than you and it is a foundation for your children, your children's children and many generations to come?
- If the future of your operation is uncertain and the industry is rapidly changing, would you blindly accept advice from a handful of sources, while waiting for tomorrow to come knowing it is going to be much different to today, or would you attempt to prepare yourself and your business to the best of your ability?
- Would you embrace the challenge that is before you, search for opportunities to differentiate and build on what your predecessors have built, so that one day you may be able to pass on a heritage and opportunity to your heirs?

Chapter 2: Challenges to current systems

Mixed farming in the USA

The agriculture production industry in the USA is not much different to the rest of the world. Due to technology and increased global trading, we are now all subject to similar problems and hardships. A few of the major problems that we all share that stood out throughout this experience were diminishing profit margins, related to low commodity prices and astronomically high input costs and the rising cost of labor, volatile political climates, and climate change.

Figure 4 illustrates how the once large gap between nominal production expenses and inflation-adjusted expenses have continued to diminish over the years since 1970. A large factor for the margin reduction can be contributed to the continuous increase in production and machinery costs over the years, while yields have stayed relatively stable. Producers all around the world are struggling with one common goal: identifying a pathway forward for their operation that assists in optimizing farm resources and margins to attain growth and sustainability during uncertain times.

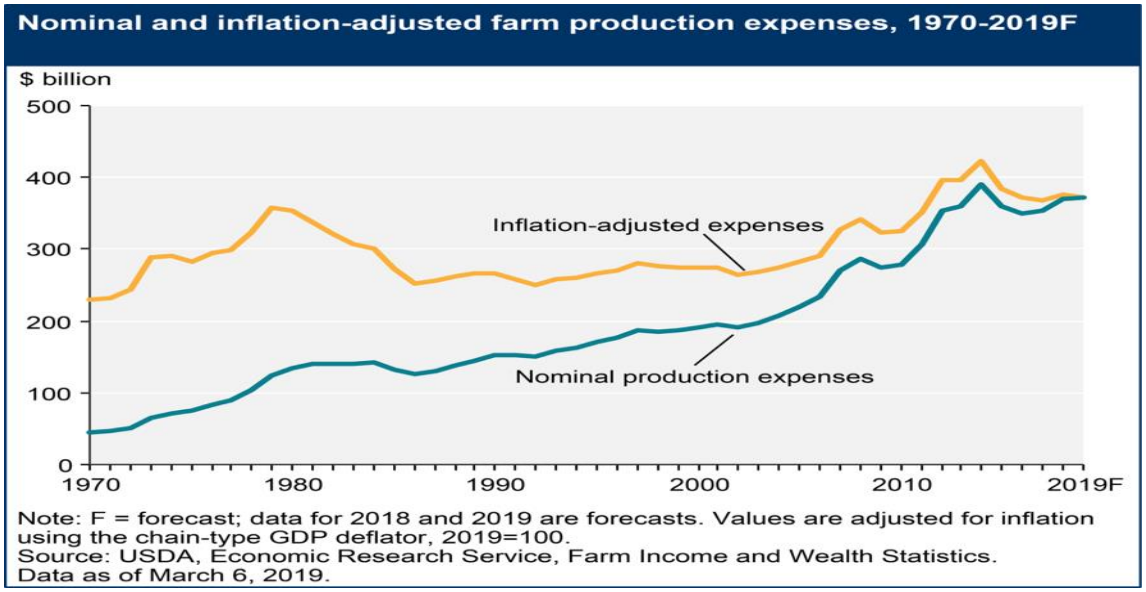


Figure 5: Nominal and inflation-adjusted farm production expenses,1970-2019F (USDA-ERS, 2019)

Stereotypes

Agriculture in the USA is often lumped into the one category of crop production and is stereotyped by Grant Wood's 1930 painting, "American Gothic" (Figure 6).

Figure 6: 'American Gothic' By: Grant Wood (1930)

American farmers and agribusinesses often are very conservative, sharing a common belief that in order to ensure a future they should specialize in one or two enterprises and no more. If you examine case studies done on some of the more successful businesses of our time, the businesses that have continued to be successful and drive forward are those that have disrupted patterns, and stepped outside of this stereotype and adapted to these changing circumstances.

The 180-degree production cycle

Productivity across the USA has tended to plateau. While total production over the past ten years has increased, the USA has continued down the well-worn path of a linear economy, meaning that we have failed to equalize total inputs and total outputs. We view fertilizers, seed, and chemicals as raw materials used to produce more seeds. This seed is then used in animal feed, oils and various miscellaneous product. Meanwhile, we treat food processing by-products and poor-quality crops as non-recyclable waste.

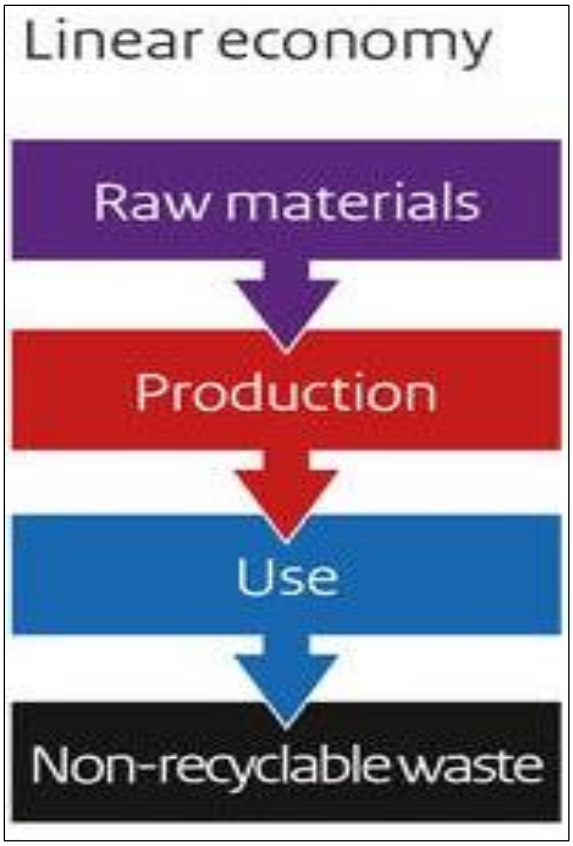


Figure 7: Linear Economy (Source: A Circular Economy in the Netherlands by 2050, 2016)

In addition to a productivity problem, agriculture faces a societal support problem, where what is farmed, and the ways to farm are under growing public scrutiny. Agriculture's current 180-degree production cycle or linear economy is under pressure around the world due to the speed of technological advancement, the complexity of a globalized economy and consumer and society demands around transparency, environment, and sustainability.

Chapter 3: What needs to be done differently?

Implementing the circular economy

With the global population expected to reach roughly ten billion by the year 2050, the future of the agriculture industry around the world is bright and ripe with opportunities, but producers are shadowed by a unique and troubling position. Agriculture producers in many countries around the globe, especially the USA, are too often at the mercy of large conglomerates controlling input prices. Producers must bear the blame for surrendering this level of control. A wise farmer, the author's father, once said that "*Those who refute change will ultimately succumb to the mercy of those embracing it."*

For years, producers have been deceived into believing in a "180-degree production cycle", where only inputs and outputs are considered. This mindset has led to the belief that high inputs equate to high yields which equate to high profits. Too often, producers are duped and fall victim to the mindset that profit is attained by maximizing output.

In early 2017, the "National Agreement on the Circular Economy" was introduced by the Dutch government. "*The world population is growing and this is affecting the environment. To ensure there is enough food, water and prosperity in 2050, we need to switch from a linear to a circular economy*" ("A Circular Economy in the Netherlands by 2050", 2016). The agreement highlights what needs to be done for the country to utilize their raw materials, products, and services in more efficient and smarter ways, thus enabling farmers to realize their ambition – a circular economy by 2050.

In summary, the agreement asserts that, in order to be successful in this industry in the future, producers must restructure their operations to resemble more of a circular economy (Figure 7). For this to occur, producers must begin by changing their practices, increase their focus on efficiency, and begin thinking in a full 360-degree circle, which recycles all waste products.

A circular economy is an alternative to a traditional linear economy or “180-degree production cycle” (raw materials, production, use, non-recyclable waste). A circular economy is one in which resources are kept in use for as long as possible, and maximum value is extracted from them whilst in use, and they are then recovered and recycled at the end of each service life.

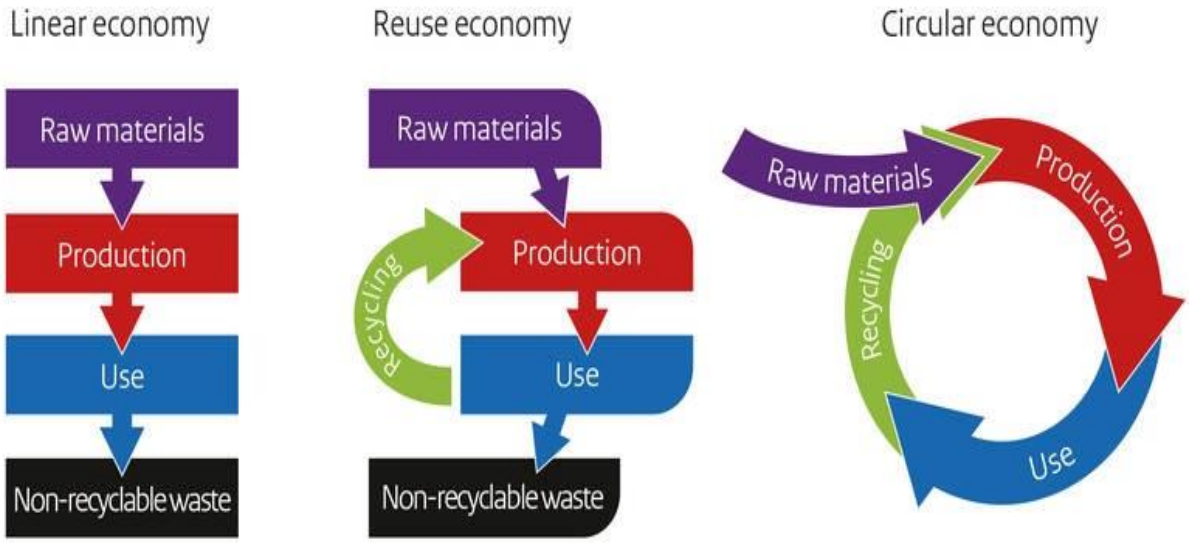


Figure 8: Three types of economies. (Source: A Circular Economy in the Netherlands by 2050, 2016)

Chapter 4: Determining how to change

Perspective, analysis, growth

The 30,000 ft. perspective

Realizing there is a need for change and implementing that change are two very different actions, with the potential for the latter to be much more difficult and complex. Accepting the idea that change is needed is a rather easy process. In order to accurately identify the changes that need to take place, it is imperative to take a step back and observe the entire operation from a distance (the 30,000 ft. perspective). This 30,000 ft. perspective allows a more complete examination and analysis of all current and future opportunities and threats to the operation, including the effect on regional, and global markets, as well as current societal and governmental trends. Performing a SWOT Analysis from this perspective will help to stimulate the thought process and may generate more in-depth ideas for changes to the operation. A key insight and take-away message from the various visits made during research for this report is that short-term thinking is critical, but those that incorporate long-term thinking, up to 30+ years into the future, often are the ones that succeed and differentiate themselves from their competition.

Porter's Five Forces of Analysis

Exploring ideas for changes to the operation and performing a SWOT analysis is only the starting point. It is a common belief that patience is a virtue; patience is applicable to business decisions too. It would be a severe mistake to jump at ideas that sound great, without performing additional evaluations and feasibility analyses.

Tools such as Porter's Five Forces of Analysis should be used to better understand the competitiveness of the business environment and identifying strategies for potential profitability. The five forces that make up the competitive environment, which can erode profitability, are: competitive rivalry, supplier power, buyer power, threat of substitution, and the threat of new entry. Figure 8, shows a graphical representation and provides more details on Porter's Five Forces of Analysis.

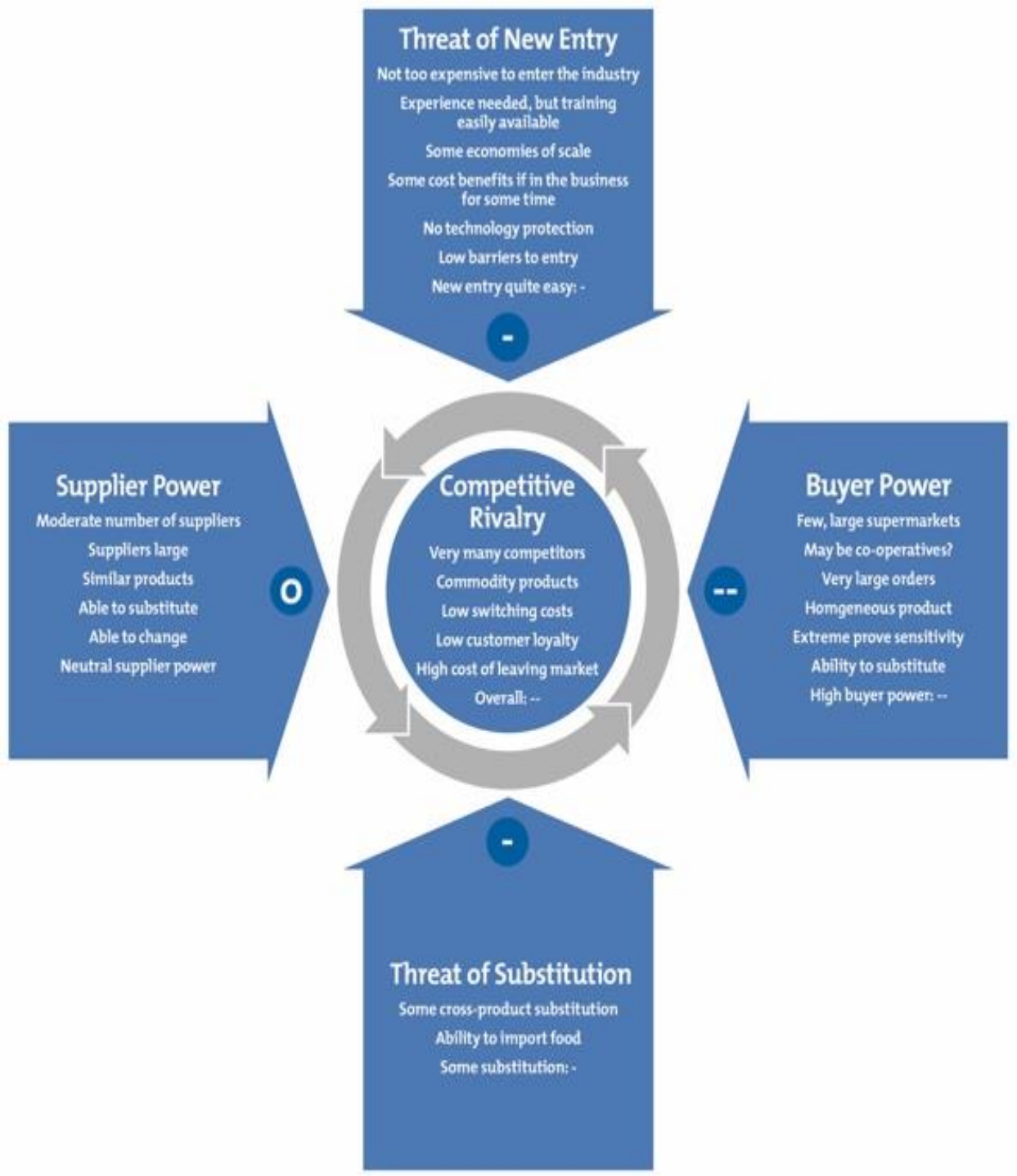


Figure 9: Porter's Five Forces of Analysis (Porter's Five Forces of Analysis, 2019)

Step Function Growth

The word change can be synonymous for growth. Literature describing how companies grow is endless and its importance is clearly defined. What is less clear are the best methods and approach to change and growth. Take the tricky, potentially paralyzing, dilemma that confronts most senior executives contemplating growth. "*On the one hand there exists a chasm between their current inventory of institutional capabilities and those required to achieve their growth aspirations; on the other, taking a discontinuous, 'bet-the-company' leap could send the company barreling down a deep and dangerous crevice, ending in the thud of extinction"* (Anandan et al., 2019). McKinsey & Company, a world-renowned management consulting firm has been advising companies since 1926. Their examination of 40 worldwide leading growth companies, identified the staircase model or Step Function model, as the best approach and implementation strategy. The Step Function model can be described as taking a series of measured steps and not big bold leaps. "*The staircase approach of continuously compounding skills and options is consistent with the competitive reality of most industries. The competitive landscape is changing so rapidly that it is impossible to predict paths several years ahead. Building a staircase explicitly recognizes that the appropriate strategy for any company depends on where it is today and on the state of the world down the road. The best a company can do under these circumstances is to build appropriate capabilities and create strategic options and opportunities without pre-empting or constraining future flexibility*" (Anandan et al., 2019). This report does not attempt to cover every change possible. Instead, it is meant to serve as a reference and to highlight the similarities found throughout my travels that were most influential and most successful. Throughout the Nuffield journey, the opportunity presented itself to meet and discuss with high-level individuals of many businesses from Australia (AUS), Brazil (BR), China (CN), Ireland (IE), Israel (IL), Mexico (MX), New Zealand (NZ), The Netherlands (NL), United Kingdom (UK), USA, Zimbabwe (ZIM), and Zambia (ZM). While the cultures and contexts are very different in each place, there were important takeaway messages to be gained in each country. When asked what area their operation should focus on going forth in the future, three subjects seemed repetitive; efficiency, technology and differentiation.

Chapter 5: Three bricks of the pathway, or the three-legged stool

A three-legged stool epitomizes the functionality of these three subjects. Think of the seat of the three-legged stool as the operation, with the legs of the stool symbolizing efficiency, technology, and differentiation. For the stool to stand alone and be balanced, each leg must be of equal length or attract equal focus. Due to time and space, this report will focus on a few country examples that best encapsulate the three highlighted themes in this section.

Moore's Law states that technology and technological innovations are increasing exponentially over time, roughly every two years. Because the vast majority of ag technology has been introduced over the past 40 years; the question we find ourselves faced with is: when is the optimal stage/time to adopt a certain technology?

Determining the optimal stage for adoption of technology is a key objective that this report originally aimed to identify. The adoption life cycle of technology is best illustrated by "Rogers bell curve" (RBC), seen in Figure 10. RBC is a sociological model that derives from "the diffusion process," a model developed at Iowa State University with the original purpose to track the purchase patterns of hybrid seed corn by farmers. The RBC model is divided into five stages: innovators, early adopters, early majority, late majority, and laggard.

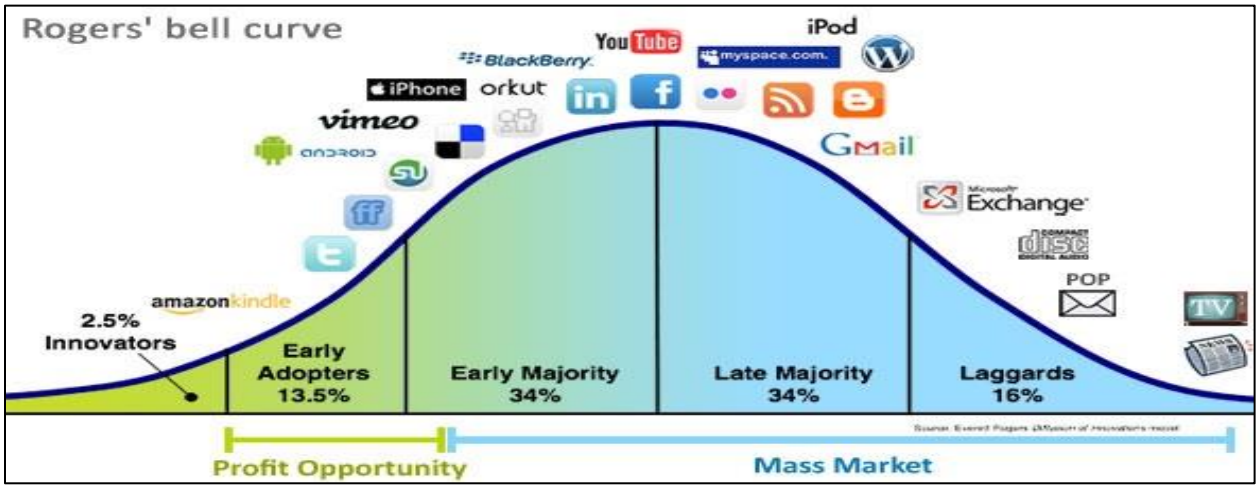


Figure 10: Rogers Bell Curve (Tsai, 2019)

While RBC is best suited for illustrating when individuals adopt technologies, The Gartner Hype Cycle (GHC) shown in Figure 11 follows the pattern of a person's expectations when exposed to a new idea or technology. In essence, the cycle states that once a new idea/technology is introduced it typically is associated with inflated expectations and "*demands a huge amount of hype, so that the expectations/hype rise well beyond the technology's current capabilities, so that users are then disillusioned until the technology climbs out of the trough of disillusionment and exhibits its usefulness*" (Leclerc, 2016). Expectations are constantly oscillating, while, according to Moore's Law, the actual technology and technological innovation is increasing exponentially over time. If Moore's Law is overlaid on the GHC, it can be concluded that the large majority of agriculture technology is still to be realized and the expectation/hype curve has yet to deliver on its technological promise. "*In other words, there is a lot of technology that is exciting to the public, but it is only in its first innings and iterations. We'll need to wait for the real innovation to come, but once it does, it will be transformational"* (Leclerc, 2016).

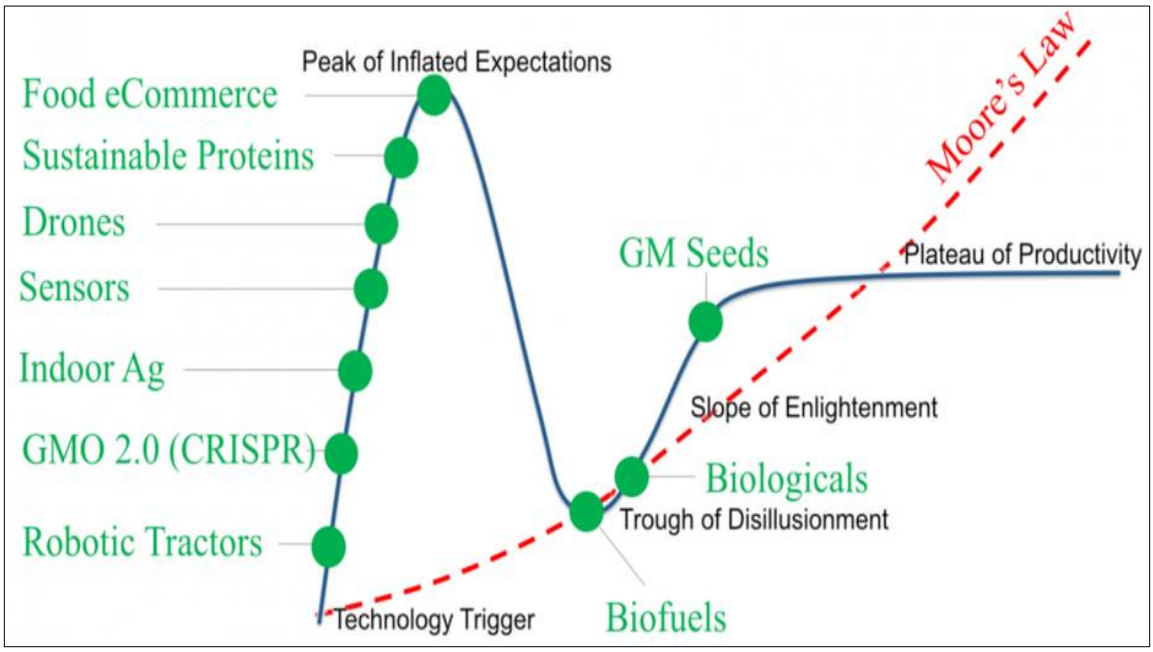


Figure 11: Gartner Hype Cycle (Leclerc, 2016)

Case Study 1: Israel – Efficiency and technology

Agriculture in Israel was remarkable and surreal. Apologies to the Dutch, but it is the author's opinion that Israeli farmers epitomize the concepts of efficiency and innovation. With only 20% of the total land area classified as naturally arable, Israeli farmers have been able to successfully adapt to their extreme climate and geography to effectively "*produce 93% of their country's own food requirements*" (Fedler, 2002).

Figure 12: Maayan Kitron, head researcher of VARC, Israel (Photo by the author, 2019)

Maayan Kitron, seen in Figure 12, is a head researcher of the Vidor Agriculture Research Center (VARC) in the Arava Desert. The Arava Desert is a desert valley spanning from the Dead Sea to the Red Sea. Faced with a multitude of challenges, production agriculture here is truly a farming miracle! One can imagine that access to water is incredibly challenging in a desert, as is feed for animals, among a long list of other items. Maayan claims combating all challenges of Israeli agriculture can be summed up in three words: adapt, innovate, overcome. To overcome these challenges farmers concentrate their focus on efficiency and technology to ensure that zero water or nutrients go to waste.

As one can imagine, access to quality fertile soil is a big challenge throughout Israel's deserts and tumultuous terrains. In order to overcome this challenge, many farms have been forced to move large quantities of suitable soil to more advantageous locations. Some farms have gone an extra step by utilizing hydroponic and aeroponic production systems. Many hydroponic systems utilize mediums such as perlite or other soil like substances that have relatively high water holding-properties. Aeroponics is a system where roots are continuously kept in environments where misters spoon feed water and nutrients to the root systems at optimal times to prevent them from drying out; any excess is recycled and reused. An example of bell peppers grown in an aeroponic system at VARC can be seen in Figures 13 and 14. As a result of their focus on efficiency and the utilization of technology, farmers have been able to increase profit margins by increasing production roughly 26% and decreasing inputs and resource utilization by 12%.

Figure 13: Root of a Bell Pepper plant in an Aeroponics system, Israel (Photo by the author, 2019)

Figure 14: Bell Pepper plants grown in an Aeroponics System at VARC, Israel (Photo by the author, 2019)

"*Agriculture is the world's oldest and most entrenched industry that has survived centuries; it is not easily disrupted. It is tied to regulatory schemes; influenced, and in many ways controlled, by the incumbent seed and chemicals companies and has worked through the same distribution channels for decades*" (Leclerc, 2016). Many people hope that technology is the golden ticket to disrupting these age-old channels.

Agriculture may be one of the world's oldest industries, but recent developments and uses of modern technology has hugely transformed production agriculture. Currently, technology plays an enormous role in most farm's day-to-day operations and this role will continue to increase as time goes on. Precision agriculture technologies have been instrumental in the ability to minimize input expenses, maximize yield potential, and the ability to return a profit. Technology has allowed synchronization of all of farm activities, allowing farms to identify inefficiencies and optimize all operations. The data collected from yearly activities and daily weather conditions provides more accurate revenue predictions, and can identify potential year to year weather patterns occurring due to incremental climate change. Technology's role on farms has improved management efforts and can be set up to monitor farm activities from thousands of miles away, ensuring that all important and time-sensitive activities are running smoothly. Provided the farm operation incorporates appropriate foresight, implementation of technology on farms has allowed the ability to order supplies, check prices, buy or sell grain, and keep up with the tumultuous and volatile political climate at any given second of any given day, improving the potential to optimize management across all present and future activities of many farms. These developments and transformations have allowed producers to be more precise and less wasteful in the use of fuel, seed and fertilizer, but they are expensive.

Ofier Langer, Chief Executive Officer (CEO) and Manager of The Israeli Dairy School, helped to find answers to a number of questions regarding agriculture technology and how Israel has managed to rise to the top of the food-chain and be regarded as one of the leaders in innovation and technology. The conversation took place over the course of a few hours and can be summarized in one sentence, "*Efficiency is the most important aspect of farming. Yes, technology is expensive, but it is a vital component to maximizing efficiency*."

Case Study 2: ADM Farming – efficiency and differentiation

Besides being caught in the middle of a country-wide riot, tear-gassed and losing outside communication; traveling in Zimbabwe and Zambia was another focal point of the Nuffield journey. It was difficult to comprehend the sheer scale of commercial farms, despite their lack implementation of modern technology, persistent reliance manual labor and the lack of environmentally sound and sustainable practices.

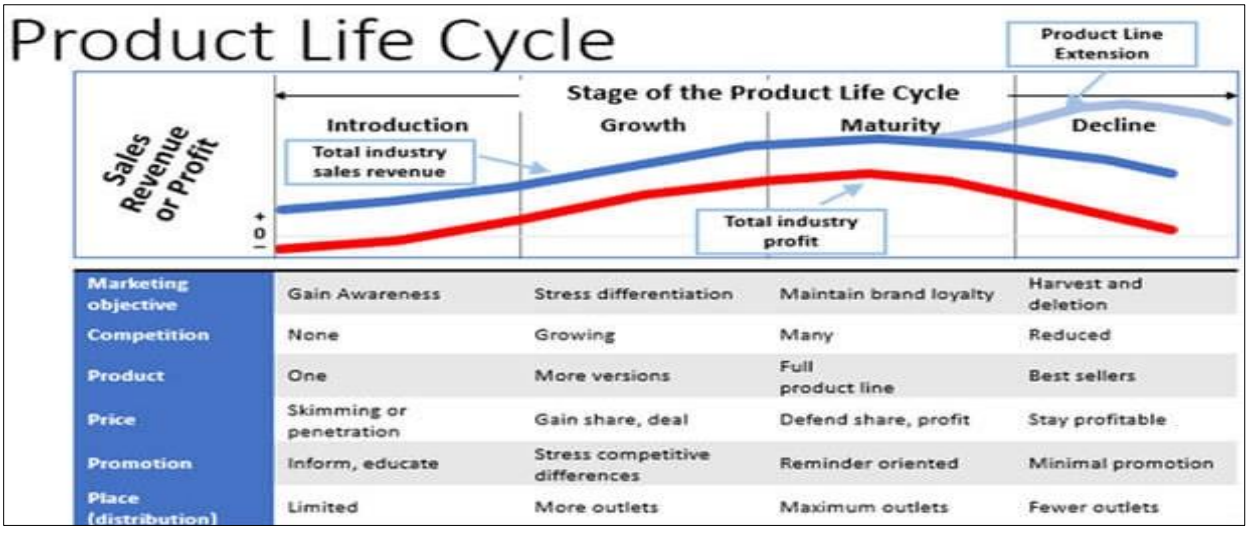
Due to the climate and geography throughout the old Rhodesian countries, many of the crops grown in Zimbabwe and Zambia are similar to production in North Carolina (NC), but the challenges faced are slightly different. For much of history, tobacco has been the king of Zimbabwe agriculture, contributing to roughly half of all people employed in commercial agriculture. Tobacco exports are 20% of the world's flue-cured tobacco, and the source for 30% of the nation's foreign currency and 12% of the nation's gross domestic product (GDP). In short, as the largest grower of tobacco in Africa, and the fourth largest grower worldwide, the "golden leaf" crop, has been (and still is) the major crop produced in Zimbabwe, acting as a springboard for the production of other crops.

Comprising less than 5% of Zimbabwe's population, white farmers owned almost half of the country's arable land in 1979. In 2000, the Zimbabwean government led by then President Mugabe, began forcibly seizing white-owned farmland without compensation and redistributing the land back to black citizens. Due to the fear of being killed, the land reform forced many white farmers to abandon everything they owned and emigrate out of the country. In addition to lacking the skillset and experience needed to farm tobacco, the new black settlers did not hold the title to the land, effectively lacking the collateral needed to obtain a bank loan. In summary, the land reform led to a drastic decrease in the nation's total level of cultivated farmland and a virtual collapse of the country's agriculture industry. As a result of the land reform, both black and white farmers in Zimbabwe and white emigrants were faced with the major challenge of acquiring funding and operating loans for their farms. Access to these funds are possible, but often are associated with outrageously high interest rates, or are subject to governmental interference. It was a remarkable to learn that every farmer visited had budgets for every

operation that occurred on their farm. Adam Gordon, a farmer from Chisamba, Zambia, said that a major challenge confronting many operations is that the crops they have grown for generations are simply not profitable anymore. The margins have become too small and there is virtually no room for mistakes or bad years; thus, more precise budgets for each field, crop and business activity, no matter the size, are a necessity to ensure efficiency.

In order to overcome these challenges, Adam referred to three steps: adjust, adapt, and execute. Many farm operations, including Adams, are doing exactly this, by adjusting their operations to have less reliance on the historically grown crop, adapting to the market demands and rapidly diversifying into unique or niche crops, such as macadamia nuts. In addition to macadamias, Adam also diversified his operation by producing passionfruit and other exotic fruits which were then used to create juice concentrate for bottling and marketing at a local vintage coffee shop, restaurant and bakery, and also in a fruit and vegetable market that was owned by his wife.

Determining how to adjust and adapt, Adam and others began by identifying potential crops and how they would fit in their farm's production cycle, as well as the crop's current position within the agriculture industry in Zambia and Zimbabwe. Identification of these two points determined what type of competitive advantage would be best suited going forward and establishing a strategy for competing.



Marketing objective	Gain Awareness	Stress differentiation	Maintain brand loyalty	Harvest and deletion
Competition	None	Growing	Many	Reduced
Product	One	More versions	Full product line	Best sellers
Price	Skimming or penetration	Gain share, deal	Defend share, profit	Stay profitable
Promotion	Inform, educate	Stress competitive differences	Reminder oriented	Minimal promotion
Place (distribution)	Limited	More outlets	Maximum outlets	Fewer outlets

Figure 15: Product Life Cycle and Differentiation Strategy (280group.com, 2019)

While people and the products used by them have stark differences, they share one similarity, both have life cycles. The Product Life Cycle and differentiation strategy, seen in Figure 15, provides description of how the six segments of a differentiation marketing strategy shift throughout the four stages of the product life cycle. The six segments that make up the differentiation strategy are: marketing objective, competition, product, price, promotion, and place. Depending on the stage of the life cycle the product is in, these six segments can reveal a lot about what the next strategic moves are. The product, price, and promotion portions of marketing mix help identify the best opportunities for establishing a competitive advantage for the product. "*The four distinctive stages of the product life cycle are: introduction, growth, maturity, decline. This concept is commonly used by management personal and marketing professionals as a factor in deciding when it is appropriate to increase advertising, reduce prices, expand to new markets, or redesign packaging*" (280group.com, 2019). According to Porter's Generic Competitive Strategies, there are "*two basic types of competitive advantages: low cost or differentiation. Four generic strategies for achieving above-average performances are generated when the two competitive advantages are combined with the scope of activities, these are: cost leadership, differentiation, cost focus, differentiation focus. The focus strategy has two variants, cost focus and differentiation focus. Cost focus exploits differences in cost behavior in some segments, while differentiation focus exploits the special needs of buyers in certain segments*" (Porter, 2019). Adam's introduction of niche crops such as macadamia nuts and exotic fruits, not only allowed his operation to be less reliant on the historical crops, but it provided the farm with the opportunity to fill the special needs of select buyers, thus generating a competitive advantage that concentrated on differentiation and differentiation focus.

Case Study 3: Uncle Henry's – the synergy of efficiency, differentiation, and technology

Since visiting a few anaerobic digestion (AD) plants on the study tour, the author realized their potential in the USA. In the UK, many AD plants were visited, ranging in sizes from large-scale commercial to small scale on-farm. One of the most interesting and practical operations visited was at Uncle Henry's in Gainsborough, Lincolnshire. Owned by Steve and Meryl Ward, Uncle Henry's provided a perfect example of a sustainable 360-degree production cycle and what is attainable when operations adopt a synergistic approach that combines efficiency, differentiation, and technology. Originally a livestock and mixed arable farm, the Uncle Henry's seen today now consists of a farm shop, butchery, café, piggery, arable farm and two AD plants. According to Steve, it has taken many stages of gradual growth over a number of years to develop Uncle Henry's to its current state, dating all the way back to when he began his Nuffield Scholarship.

Figure 16: Uncle Henry's entrance sign (Photo by the author, 2018)

The Ward's claim to be always observing ways in which they can reduce their carbon footprint, become more efficient or create more synergism within their operation. The operation can be described as a highly integrated system, where cereal crops grown on the farm are used to provide feed for the pigs, the straw is used as bedding and any manure produced is used as feedstock for their two AD plants.

Figure 17: Plug flow AD plant at Uncle Henry's in the UK (Photo by the author,

Figure 18: Dried digestate from AD plant at Uncle Henry's (Photo by the author, 2018)

The AD plants are fed solely with Farm Yard Manure (FYM), maize silage, beet pulp from a neighboring processor and various wastes generated from on-farm business operations. The digester is a Plug Flow system which utilizes a First In – First out (FIFO) method, which resembles a tube of tooth paste. Their feedstock ratios did vary throughout the year but on average they fed 30% corn silage, 60% beet pulp, and 10% FYM. With a 30-day run time and capacity of 4,000 cubic meters, the digester requires average daily feedstock inputs to be 12 metric tons or 26,400 pounds. The digester requires 70 cubic meters of gas per hr. to produce at its maximum energy output of 125 Kwh. As a by-product of the digestion process, the digester produces around 184 Kilowatt-Hours (Kwh) of heat. Roughly seven Kw of heat is required to dry the digestate, so it can be more easily applied to cropland. Feedstock inputs for the year equate to roughly 4,380 metric tonnes or 4,300 imperial tons. One of the most fascinating features discovered regarding the AD process was that the nutrient value of the digestate is generally the same as the original feedstock. An analysis conducted on the digestate from Uncle Henry's two digesters determined

that 5,593 kg per ha (or 4,990 lbs. per ac.) of dry digestate applied to their crop land would be equivalent to 250 kg per ha. of N.

In summary, the biogas produced generates electricity for use on the farm, reducing their dependence on imported electricity. The heat produced by the plant is used to heat the whole of Uncle Henry's and any excess electricity or heat produced is purchased by the government through feed-in-tariffs at 15 cents per Kwh. Ultimately, this addition to their operation has allowed the Wards to reduce or eliminate multiple lines of input expenses, adopt a 360-degree production cycle and complete the circle of sustainability, in addition to adding alternative sources of revenue.

Conclusion

Drawing from visits to 13 countries and interviews with some of the most innovative farmers and agribusinesses each location had to offer, this report identifies three fundamental stepping stones that are critical for agriculture producers to consider when facing uncertainty in the future of their usual main crops, such as corn, soybeans, wheat or high value niche crops.

With the global population expected to reach roughly ten billion by the year 2050, the future of the agriculture industry around the world is bright and ripe with opportunities, but producers are shadowed by a unique and troubling position. Agriculture producers in many countries around the globe, especially the USA, are too often at the mercy of large conglomerates controlling input prices. The blame for this control is no one's fault but the producer. As the author's father once said, "*Those who refute change will ultimately succumb to the mercy of those embracing it.*"

For years, producers have been deceived into believing in the "*180-degree production cycle*," where only inputs and outputs are considered. This mindset has led to the belief that high inputs equate to high yields which equate to high profits. Too often, producers are duped and fall victim to the mindset that profit is attained by maximizing output. This has brought about a decline in competitiveness amongst farms and agribusinesses.

Competition for market share can be broken into three layers: reputation, distinguishing features, and commodity. Competition in the reputation layer can be contributed to brand loyalty, competition in the commodity layer is mediated through price wars, while the majority of battles are fought in the distinguishing features layer. In agriculture, competition typically occurs in the commodity layer, where the products are the same and the lowest price wins. In order to break out of the commodity level and compete for increased market share, product innovation must develop unique features to attract and capture customer attention. As a result of replication of the features by other competitors over time, all distinguishing features that matter to customers eventually become standard or part of the commodity-level offering. In other words, eventually they add to the cost of the product, but no longer command a premium price.

Strategies for competition can be placed into one of two types: red ocean or blue ocean. A traditional or red ocean strategy seeks to compete in existing markets for existing demand by beating the competition. Blue ocean strategy seeks to create uncontested market space, make the competition irrelevant, and create and capture new demand. Four ways a blue ocean strategist is different from red ocean strategist are: they do not take industry conditions as given and seek to reshape them in their favor; they do not seek to beat the competition, but make them irrelevant; their focus is on creating and capturing new demand, not fighting over existing customers; they pursue differentiation and low cost. The majority of farms and agribusinesses exhibit a red ocean strategy because they compete for existing demand, on the same basis as their competitors, with the same emphasis on the same factors; thus, their strategy canvases all look the same.

Creation of a strategy canvas is done by mapping each factor that is strategically important in a particular industry or business against the level of value customers receive from it. Typical factors present for a conventional farm would be: price, pesticides, water, insurance, labor, land, freshness, energy, fertilizer and distribution. Mapping all factors on the strategy canvas results in development of a value curve. Red ocean strategy canvases force consumers to choose between value or cost, while blue ocean strategy canvases pursue ways to allow consumers to have both by developing a new value curve.

Eliminate, reduce, raise, and create are four actions of framework to consider in order to develop a new value curve. Questions that need to be asked are: which factors that the industry has long competed on should be eliminated; which factors should be reduced well below the industry's standard; which factors should be raised well above the industry's standards; and which factors should be created that the industry has never offered. Eliminating factors associated with cost and reducing costly factors below the industry's standards, while also raising other factors above the industry's standards and creating factors that the industry has never offered lead to development of another new value curve. Vertical farming is a prime example of a blue ocean strategy that utilized the four actions of framework. Vertical farming raises factors such as price to the consumer, product freshness, energy consumption, and distribution costs, while

eliminating or reducing use of pesticides, water, fertilizer, insurance, labor and land. Vertical farms have been able to create a factor that conventional farms are unable to offer: year-round availability.

Farms and agribusinesses with unique blue ocean strategies for competition, willing to embrace new ideas and practices outside of the box or different to their competitors were not only seen as innovators and revered, but held a much larger portion of the market share. They witnessed increases in profitability during tough times compared to those with standard strategies.

In order to ensure competitiveness and resiliency of farm operations, efficiency and diversification of organizational structure and products should be a top priority. Drawing from interviews and personal visits with agribusinesses and agribusiness owners, evidence led to the conclusion that agribusinesses which placed efficiency and diversification (with an emphasis on sustainable and regenerative practices) were in a far better position to capitalize on future opportunities. In addition, agribusinesses positioning themselves slightly ahead of the peak of the technology adoption bell curve resulted in significantly higher efficiency, productivity and profitability levels. They were also positioned to capture higher salvage values when upgrading older equipment and technology compared to those considered early adopters, late adopters, or laggers.

In the future, in order to be successful in this industry, producers must change their practices, increase their focus on efficiency, and begin thinking in a full 360-degree circle. Further research and analysis should be conducted before implementing changes in practices, focus or operational processes. As my father likes to say, "*Farming is easy, anyone can farm, but not everyone can make money*."

If today's world was thrust into a crisis tomorrow, food would be one of the most important commodities. Without access to food, the majority of the world's population would be hopelessly lost. Countries and governments have always exhibited their willingness to support and ensure that the food industry never disappears, fails, or becomes overpriced.

Agriculture producers are positioned to be world leaders in the future. When combined, efficiency, technology and differentiation are the three key factors that make up the transformative pathway to optimize farm resources and margins for farmers, who are facing uncertain times due to declining consumption, value, and profit margins.

Recommendations

This report has aimed to be a practical distillation of the research considered relevant to American row crop and general production operations today. It is not intended to be a policy recommendation reference, but it would be negligent to not offer recommendations that could expedite the adoption of the topics discussed.

On-farm recommendations:

Top management staff should: Discuss and draft the current competitive strategies and strategy canvas. This could then be compared with potential different strategies and canvases that employ transformative methods of production, with emphases on a circular economy rather than linear economy. These managers should:

- With support from all farm business members and personnel, discuss in-depth all actions, resources, and major financial line items of the entire farm operation and explore potential alternatives. Also, discuss the current and prospective products and target markets, as well as their future potential markets.
- Discuss and consider employing alternative designs, ideas, and markets that target business-to-consumer (B2C) transactions if the operation historically has been business-to-business (B2B) and vice-versa.
- With the support of your financial partners and lenders or finance teams, perform an in-depth feasibility analysis to ensure that the proposed project or ideas can produce a return on investment (ROI), with ROI projections covering at least three to five financial years from the date of the proposed investment.

Industry recommendations

Industry members should: Be careful when considering the adoption of new and innovative technologies, and not rush into costly investments and believe the implementation of brand-new, “fresh off the assembly line”, unproven technologies will solve problems instantaneously; this is a frequent misconception.

- Focus on the development of business operations, industry channels and systems that place synergism at the core and foster a circular economic model.
- Take immediate action to establish a blue ocean strategy and change long-time industry standards by innovating new methods of production that optimize resources and margins.

Government Recommendations

Governments should:

- Recognize that new and old industries require regulatory leniency but not a complete free-for-all.
- Offer increased tax or research and development incentives to agriculture businesses that employ sustainable or regenerative production practices aiming to optimize farm resources for the future.
- Identify policy initiatives which will remove obstacles and impediments to biogas development and provide incentive to encourage synergism between the agriculture, consumer, and energy sectors.

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Plain English Compendium Summary

Project Title:	*Growing and Sustainability in Uncertain Times: Transformative production practices to optimize farm resources and margins*

Nuffield International Project No.:	1802
Scholar:	Steven Archie Griffin
Organization:	Griffin Farms Inc.
Phone:	+1 (252)-945-7356
Email:	Archieg190@gmail.com

Objectives	This report aims to provide farm operations and managers with transformative production practices to assist in optimizing farm resources and margins necessary for attaining growth and sustainability during uncertain times.
Background	There has been a consistent downtrend in the structure of USA agriculture. As of 2018 farmers and ranchers have weathered a 49% drop in net farm income since 2013, the largest four-year drop since the start of the Great Depression. Farm debt is record-high, the debt-to-asset ratio has climbed for six consecutive years, and farm debt as a proportion of annual farm income is at 97% – a 32 year high.
Research	Research was conducted across 13 countries over two years consisting of interviews with producers, farm managers, policy makers, multi-national agriculture companies, venture capitalists, and research institutions who are introducing new models and technology. Emphasis was placed on questions with references to methods for improving efficiency, rates for adoption of technology, and competitive strategies. Observation and inquiries were performed of on-farm revenue streams, growth percentages and margins.
Outcomes	If the American family farmer is to survive, they must increase efficiency to new levels by strengthening technology's on-farm presence, and diversifying operations to become less reliant on historical main revenue streams. To capture increased market share and exposure to new revenue streams, farms should increase competitiveness and alter their competitive strategies. Competitive strategies should be transformed from a traditional, red ocean strategy to a blue ocean strategy, utilizing innovation, and willingness to innovate and not accept current industry standards. Quality assessment and implementation of the suggested transformative practices on farm, will ensue opportunities to attain growth and sustainability through optimization of farm resources and margins.
Implications	This report outlines a few key considerations for farm operations that face declining consumption, value and profit margins and should be used a reference point for anyone looking to transition their operations to be more successful and sustainable. Opportunities for farms to transform production practices that lead to optimization of farm resources and margins could arise as a result of proper consideration and implementation of suggestions within this report.
Publications	Presentation at the 2019 Nuffield Contemporary Scholars Conference in Des Moines, Iowa