NUFFIELD UK

A Nuffield Farming Scholarships Trust Report

Award sponsored by

The Company of Merchants of the Staple of England

Improving the success and sustainability of grass based livestock systems

Charles Russell

July 2014

NUFFIELD FARMING SCHOLARSHIPS TRUST (UK)

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A Nuffield (UK) Farming Scholarships Trust Report

Date of report: 31st July 2014

"Leading positive change in agriculture. Inspiring passion and potential in people."

Title	Improving the success and sustainability of grass based livestock systems.
Scholar	Charles W. Russell
Sponsor	The Company of Merchants of the Staple of England
Objectives of Study Tour	To determine the attributes of successful and sustainable grass based farmers and their relevance to UK agriculture.
Countries Visited	England, Ireland, Denmark, New Zealand, Uruguay, Chile and Brazil
Findings	True business success and sustainability is achieved through managing the triple bottom line - a process by which businesses manage their financial, social and environmental risks, obligations and opportunities. The three P's: profits, people and planet. Successful and sustainable pasture based livestock farmers of the future will need to adapt and engage with an evolving political arena. They will need to align their production to their consumers' demands, reduce their impact on the environment and optimise the production and utilisation of grass. They will need to improve the feed efficiency of their livestock and effectively and efficiently grow the people within their business, whilst continually strengthening their business to cope with increasing volatility. Profitability, Sustainability and Success are a choice and change is inevitable.

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DISCLAIMER

This report has been prepared in good faith but is not intended to be a scientific study or an academic paper. It is a collection of my current thoughts and findings on discussions, research and visits undertaken during my Nuffield Farming Scholarship.

It illustrates my thought process and my quest for improvements to my knowledge base. It is not a manual with step-by-step instructions to implement procedures.

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CONTACT DETAILS

Charles Russell,
Glenapp Manse,
Glenapp Estate,
Ballantrae,
Girvan,
South Ayrshire,
KA26 OPG.

Tel. : 01465 831210
Email : charlie_russell@btconnect.com

Nuffield Farming Scholars are available to speak to NFU Branches, Agricultural Discussion Groups and similar organisations

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Southill Farmhouse, Staple Fitzpaine, Taunton TA3 5SH
Tel : 01460 234012
email : director@nuffieldscholar.org
www.nuffieldscholar.org

1.0. Introduction

I am a farmer and road haulier's son, originally from Aberdeenshire in the north east of Scotland. Having been schooled in Edinburgh I returned home to Aberdeen to study Rural Business Management and Farm Business Organisation Management at The Scottish Agricultural College and Aberdeen University, graduating in 1998.

Me, Charlie Russell, at the Glenapp Estate

I was then fortunate to work in South Africa, Australia and New Zealand gaining experience in a variety of different agricultural systems. In 2000, I returned to Scotland and was appointed to combine the roles of Farms Manager and Estate Factor on a 5600 ha upland rural estate where I live with my wife Jill and our young family.

Over the last 14 years, we have evolved the estate to include a diverse range of enterprises including an intensive grazing block milking Jersey, Friesian and New Zealand crossbred cows, a spring calving suckler herd, a flock of "easiercare" sheep, varied forestry interests from ancient woodland to commercial plantations, a renowned sporting business, residential and commercial property, and biomass and solar electricity generation enterprises.

My wife and I also farm in partnership on a 350 acre lowland farm in Aberdeenshire where we have grown a variety of crops and livestock.

I am a passionate grass farmer, who believes that some of our recently achieved production improvements are only starting to unlock the true potential of our grassland. The opportunity to use my Nuffield Farming experiences to understand how to rewrite the cost structures associated with beef, sheep and milk production in the UK is one that I am relishing.

2.0. Background to my study

I unashamedly enjoy making money but not at the expense of habitat, environment or welfare.

In 2005, I was particularly delighted with myself over a deferred grazing wintering system developed for beef cows at Glenapp which reduced our wintering cost by 95% and improved biodiversity on the hill grazing. However, the more research I did, the more I came to realise that it wasn't in fact new. This practice had been commonplace over the hills of the UK for centuries previously.

This discovery showed me two things:

1. The profitability of pasture based livestock was intrinsically linked to the pasture utilisation.
2. There are very few genuinely new ideas; most are simply the evolution/rediscovery of some forgotten practice or adaption following the discovery of new technology.

This inspired my quest to improve my knowledge of the advantages of grass based livestock systems.

More recently, I have become increasingly frustrated with the word "sustainable". It seems to be hotly contested by government, environmentalists, farmer's representatives, retailers and consumers with wide ranging debate over its overuse, its definition and certainly its relevance to farmers.

It is unfortunate that livestock farmers are now experiencing government and retailer policy decisions on sustainability which translate as stocking limits, input limits or additional cost burdens which negatively affected the sustainability of their businesses.

I have been working in the UK livestock industry for 14 years and have watched potential worldwide markets for meat and milk products grow, and global prices for livestock products increase. Yet UK pasture based livestock numbers have steadily decreased as enterprises have generally failed to capture the increased revenue at bottom line.

Undoubtedly the European subsidy system, and the Common Agricultural Policy (CAP) reforms, combined with the lack of successors/new entrants, poor profit margins and inheritance tax relief have dis-incentivised change. However, stagnating or reducing enterprise margins are unsustainable and over an extended period of time will be terminal to any business.

Livestock farmers in the UK were cheered recently following consumer rallying which helped to increase base milk prices. However, the relentless global alignment of commodity prices and their forecasted volatility will continue to challenge UK margins in the downturns. I am an optimist but even as such, I am concerned that our currently disengaged and recession-recovering consumers will not pay the increased price required for average livestock enterprises to achieve sustainable returns on capital invested.

I am particularly interested in what farmers can do to '*Speak Up For Agriculture'* and what they can achieve inside and outside the farm gate to rewrite the costs of production of meat and milk products.

3.0. The study tour

Denmark: September 2013

This particular part of my tour was sponsored by DFL Trifolium. They generously provided interpreters and tour guides from within their research and marketing departments. I visited contractors specialising in precision application to grass, dairy farmers, trial plots and their research and marketing departments.

This was particularly relevant to understand where plant breeding and technology were currently being focused and how that would affect livestock farming in the future.

New Zealand: October and November 2013

New Zealand has been considered to be the master plan for successful grass-based livestock farming. I am fortunate to have worked and visited twice previously. I spent 6 weeks in New Zealand on this occasion learning from the successes and failures of others whilst trying to understand their differences from the UK.

Ireland: January 2014

A simple short skip across the water exposed me to farmers and research institutes operating in relatively similar climates and political pressures; however with a proven track record in grass based systems.

South America: February 2014

I visited the agricultural powerhouses of Chile, Uruguay and Brazil. I was particularly interested to see their research and development programmes for livestock, how farmers were managing grass in extreme climates and how they were developing soils.

England 2013-14

Taking full advantage of travelling without the need for a passport, I visited numerous grass and intensive systems, gleaning knowledge and experience from farmers operating under similar climate, cultural and political pressures.

4.0. Political and cultural arena

New Zealand is considered to be the Mecca of successful grass-based livestock farming. In an attempt to understand the reasons for its success, Nuffield Farming Scholars, farmers and industry experts have beaten a well-trodden path to its sunny climes. Although it is undoubtedly a worthwhile endeavour to learn from the successes of others, it can be dangerous to emulate what others have achieved without understanding some of the differences.

New Zealand possesses a very similar climate to the UK for grass growth, which is the reason for most of the comparisons. However, in 1984 New Zealand's Labour government took the dramatic step of ending all farm subsidies. At that time the New Zealand agricultural subsidies consisted of 30 separate production payments and export incentives accounting for more than 30 percent of the value of production. So this was a truly striking policy action, because New Zealand's economy was five times more dependent on agriculture than is the UK economy, measured by either output or employment.

Interestingly, it was New Zealand's farming leaders who first proposed alterations to their subsidy regime. They did however, stop short of advocating the total elimination of agricultural subsidies. They believed that there was:

- Resentment among farmers, some of whom felt that the subsidies were applied unfairly.
- Resentment among non-farmers, who paid for the system once in the form of taxes and a second time in the form of higher food prices.
- Encouragement of overproduction, which then drove down prices and required more subsidisation of farmers' incomes.
- Related encouragement to farm marginal lands, with resulting environmental degradation.
- The fact that most subsidy money passed quickly from farmers to farm suppliers, processors, and other related sectors, again negating the intended effect of supporting farmers.
- Additional market distortions, such as the inflation of land values based on production incentives or cheap loans.
- Various bureaucratic insanities, such as paying farmers to install conservation measures like hedgerows and wetlands—after having paid them to rip them out a generation ago, while those farmers who had maintained such landscape and wildlife features all along got nothing.

Subsidy elimination in New Zealand was swift and the government simply offered one-time "exit grants" to those who wanted to leave farming when subsidies ended. It forced farmers and farm-related industries to become more efficient, to diversify, to follow and anticipate the market. Eight hundred farms went out of business.

However New Zealand has a number of advantages that facilitated the significant sustainable growth of their grass-based industry since 1986, which the UK does not share. The UK is 15 times more densely populated than New Zealand (see Table 1), allowing large tracts of land in the latter country to be developed into agriculture without competing land use requirements.

As a relatively young country in colonial terms, there are significantly less historical ties to the land in New Zealand than in the UK. This meant that people were happy to sell the family farm and move to new areas where larger, less-expensive tracts of land were available. (On average a farm will sell every 7 years compared to - in Ireland - once every 200 years.)

A significant proportion of the population still feels attached/engaged with the land and its farming activities. This affiliation offers a level of protection from government policy.

There have been no hindrances to growth historically and the banking sector willingly used re-valued land as collateral for further lending; most of this lending was not amortised (i.e. debt was interest-only).

On average a farm will sell every 7 years compared to - in Ireland - once every 200 years.

There is no capital gains tax; this encouraged the accumulation of assets and facilitated an easier transition between farm sizes.

There is no Agricultural Inheritance Tax Relief which reduces non-agricultural investment and increases farm sales.

New Zealand has a tradition of succession planning. Lower order share-milking to 50:50 share-milking partnerships has facilitated the smart asset accumulation of young farmers and an exit strategy for those ready for retirement.

Marginal/unprofitable land was returned to conservation areas, improving the “green credentials” of the industry.

Farm Co-operatives control a majority share in processing and export facilities, returning increased margins to their owners who are also their suppliers.

The contribution of agriculture to the economy as a percentage of GDP is 7.1% compared to the UK at 0.5%. This high level and increasing percentage of exports demands a higher level of government interest.

This environment has created some issues. The relatively cheap interest-only loans; large capital appreciation on land converted from beef and sheep to dairy with no capital gains tax; large steady co-operatives providing confidence in the long-term viability of the industry; relatively high commodity prices plus a competitive streak which is matched by very few other industries, has encouraged farmers to borrow heavily to expand.

For example, on average in 2009-10 dairy farm term liabilities peaked at 47% of asset value resulting in a situation where many farmers were fortunate that the downturn in commodity prices to date has been short-lived.

See below for agricultural contribution to GDP for several countries

Country	Size ('000 km2)	Population (Million)	Population/000km2	GDP (Billion USD)	Agriculture % GDP
UK	244	64.1	262705	2435	0.5
New Zealand	268	4.5	16791	181	7.1
Brazil	8516	203	23837	2253	5.8
Chile	756	17.6	23280	268	4.9

Table 1. Agriculture Contribution to GDP

Brazil and Chile share many of New Zealand's advantages combined with a relatively low land price. They are rapidly emerging as the next area of intense growth in areas suited to pasture based agriculture.

In the UK we have witnessed the contribution of agriculture to the economy continue to decrease to 0.5% of Gross Domestic Product (GDP) and the farming workforce decrease to 525,000 (1.76% of the workforce). This unfortunately makes agriculture less important to the UK than it is in any other country in the world other than the USA.

This potentially explains our government's political indifference to agriculture confirmed by the rapid changeover in ministers at The Department for Environment Food & Rural Affairs (DEFRA) and the continued and rapid deficit in the balance of trade in foodstuffs.

Whilst it would be interesting to have a government and policy more aligned with our pasture based competitors, I concluded that there are other business improvements more easily secured during times of change and undoubtedly change is coming.

"*If you don't like change, you're going to like irrelevance even less*". General Eric Shinseki.

I believe that there is considerable scope for industry improvement. Farmers and our elected representatives must proactively engage with the government with solution-based proposals that will grow agriculture's contribution to the economy through GDP and job creation.

However, pasture-based agriculture in the UK has another huge issue that is very different to our pasture based competitors. The increasingly diversified industry within our country and the urban based population has little connection or understanding to the agriculture in the countryside that surrounds them.

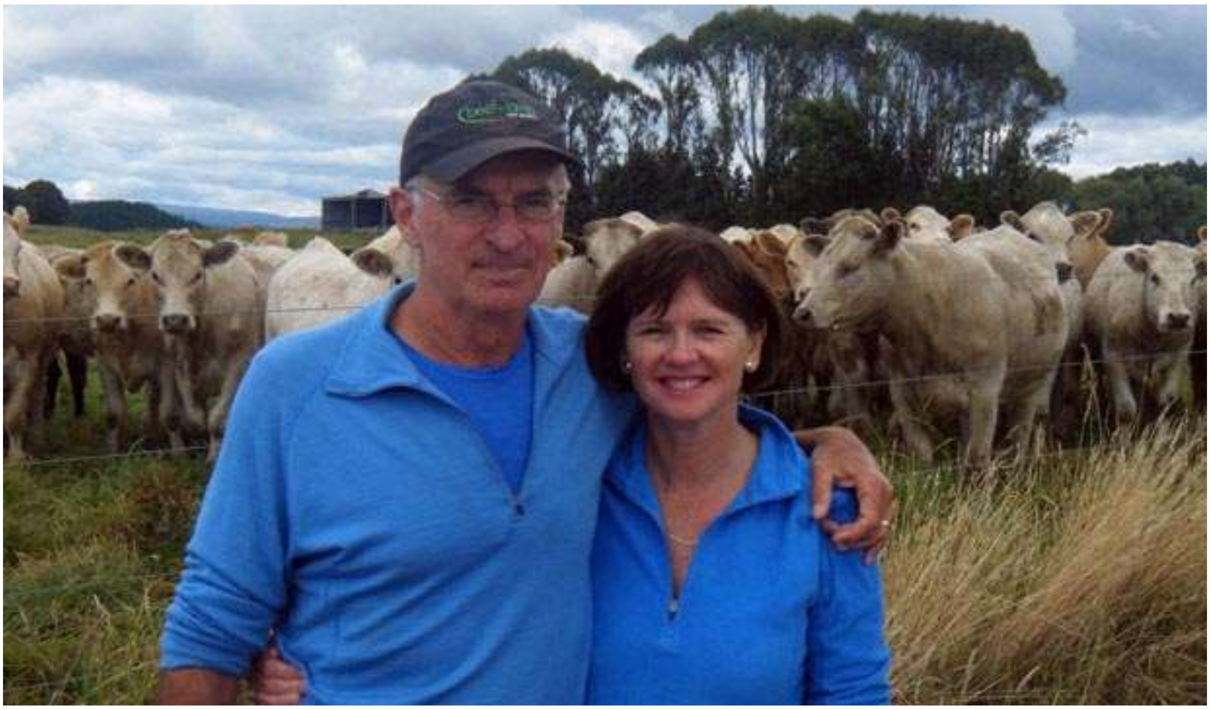
Their perception of ageing, angry, controlling land owners with little interest in the biodiversity of the land that they farm needs to change. As farmers, we need to engage with our fellow countrymen and instil the values of UK produce and their affinity with it.

There are thankfully now many educational, quality assurance, and promotional programmes which are helping to break down this cultural rural urban divide.

The quality assurance needs to offer real value to our consumers and farmers alike. Programmes that are simple tick box exercise don't instil pride or faith in the product.

The educational and promotional programmes require a united front with all farmers' assistance. If we can't get our own home grown consumers to believe in our products, any export opportunities will be short lived.

Buy-in from consumers leads to brand loyalty and, in turn, recognition as a premium product, and the opportunity to charge it as such.



Mike and Sharon Barton, Glen Emmreth Farm, Taupo, New Zealand.
founders of Taupo Beef and Supreme Winners of
New Zealand 2014 Ballance Farm Environment Awards

5.0. Environment

5.1. Reducing greenhouse gas emissions

Twenty per cent of UK greenhouse gas emissions (GHGE) comes from agriculture, and ruminants are a significant contributor. Food and Agriculture Organisation of The USA report "Livestock's Long Shadow" revealed that, globally, livestock systems emitted a similar volume of GHGE to the transport industry.

Several studies have highlighted the potential to reduce GHGE through supplementation of livestock diets with oil or improved grassland management techniques. However, most studies only assess the effect of a single source of GHGE. This can move the focus and increase emissions from other sources, thereby resulting in a net increase.

Thus a whole-farm GHGE model is required to evaluate the effect of any mitigation procedures on all major GHGE. Teagasc in Ireland has developed such a model for use on dairy farms.

This model through evaluating GHGE mitigation strategies has demonstrated that improving the efficiency of production reduces GHGE per kg of output (kg MS) and increases profitability. (MS = Milk Solids)

The key on-farm strategies that can be readily applied to reduce GHGE are:

5.1.i. Improving genetic merit via estimated breeding values (EBVs)

The analysis showed that for every €10 increase in EBV, GHGE/kg MS decreases by 2 %. This was achieved through improving the genetic herd traits for fertility and survival which reduces costs and the GHGE from replacements required to maintain the herd.

5.1.ii. Extending the length of the grazing season

By extending the grazing season by one day, GHGE reduce by 0.16 % / kg MS. This is achieved through reducing energy use required to maintain housed livestock. It also reduces the proportion of grass silage in the animal's annual diet which improves digestibility. This in turn increases animal productivity and reduces the proportion of dietary energy lost as methane.

5.1.iii. Increasing Nitrogen (N) efficiency

Increasing N efficiency by decreasing the farm N surplus by 10 kg/ha reduces GHGE by 1%/ kg MS. This is achieved through improving the utilisation of slurry, synchronising slurry and fertiliser applications with grass growth and incorporating clover into the grass sward.

Reports by the Food and Agriculture Organisation of The USA and the European Union joint research commission documented that grass-based dairy systems in temperate regions emit the lowest GHGE/unit of milk (884 kg CO_2-equivalent/kg MS). However, these reports only considered the average performing dairy farm in the nation or region. The Teagasc model revealed that through the above improvements GHGE could be reduced by up to 10% (804 kg CO_2-equivalent/kg MS).

Interestingly when the model was extended to cover confinement dairies as a comparison it showed little difference between the systems until sequestration was included. This revealed confinement systems emitted 10% more GHGE/unit of milk due to the large proportion of feed that is derived from arable land that does not remove carbon.

Internationally there are 2 main methods of assessing carbon footprints. The Intergovernmental Panel on Climate Change (IPCC) method is used to assess compliance with national GHGE targets, whilst Life Cycle Assessment (LCA) considers on and off farm GHGE. To compare Carbon Footprints of competing agriculture produce the LCA should be used.

5.2. Conservation

Conservation, biodiversity and agriculture can develop hand in hand. However, UK governments have placed a strong emphasis on delivering perceived environmental outcomes which benefit the people, thus helping to make the UK 'greener, wealthier, fairer, healthier and smarter'*. (Scottish Government: What is SRDP*)

Funding allocations have been directed to where it is perceived they will provide the greatest public benefits. Each region has to set its own priorities, by adopting local solutions to deliver national outcomes. Whilst this practice is laudable, the outcomes need to be reviewed to ensure they are delivering what the public desires.

It is worth remembering that woodland is the natural climax vegetation over much of the UK. Indeed, the greater part of the UK was historically covered with woodland until large-scale forest clearances instigated by human activities began around 5000 years ago. I believe the public's idyllic view of the countryside is a managed countryside.

Without active management land quickly reverts to unattractive scrubland. Agriculture delivers the required management and with it a deep culture of nurturing nature, developing biodiversity and conservation.

Throughout my travels I have witnessed many successful conservation projects either enforced under law, for example in Brazil where 20 % of all owned land must remain in its natural state and not be used for any commercial activity. Or enforced under product purchase: for example Fonterra, a New Zealand farmer-owned co-operative's self-imposed deadline to have farm waterways fenced off, which has led to a huge increase in biodiversity on the dairy farms. Or, simply, farmers acting as custodians of the land, designing and funding on-farm programmes to conserve species, aesthetic view points, historic sites or enhancement programmes.

However, I concluded that it was only in the countries where schemes were regularly and objectively reviewed, and encouraged to evolve to deliver the objectives, where sustainable conservation was actually achieved. This was particularly true when considering ecosystems with a legally protected apex predator.

Apex predators are predators with no natural predators of their own, residing at the top of their food chain and have a crucial role in maintaining the health of their ecosystems.

It is interesting to review how a non-agricultural species can have a significant impact on conservation and livestock farming. For example in the 1850s European settlers, aiming to establish a wild source for food, fibre and fur pelts for clothing, introduced the common brushtail possum from Australia to New Zealand.

Unfortunately, the introduction of possums has been ecologically damaging because the native vegetation had evolved in the absence of mammalian omnivores. Possums selectively browse native vegetation causing particular damage to broadleaved trees. This leads to competition for food with native forest birds, changes in forest composition, and eventually canopy collapse. Possums are opportunists and will predate the eggs and chicks of native birds. Horrifically, by the 1980s their peak population had reached 70 million.

The (NZ) Animal Health Board operates a nationwide programme of cattle testing and possum control with the goal of eradicating M. bovis from wild vector species across one quarter of New Zealand's at-risk areas by 2026

Possums are also vectors of bovine tuberculosis, which is a major threat to the dairy, beef, and deer farming industries. The disease is endemic in possums across 38% of New Zealand. In these areas 70% of new herd infections can be traced back to possums.

In 1983 the Bio Security Act established a National Pest Management Strategy to control TB in New Zealand. The Animal Health Board operates a nationwide programme of cattle testing and possum control with the goal of eradicating *M. bovis* from wild vector species across one quarter of New Zealand's at-risk areas by 2026 (2.5 million hectares) and, eventually, eradicating the disease entirely.

The TB-free New Zealand programme is regarded as world-leading. It has successfully reduced cattle and deer herd infection rates from more than 1700 in 1994 to fewer than 100 herds by July 2011. Much of this success can be attributed to sustained possum control reducing cross-infection and breaking the disease cycle. For example, at Hohotaka, in New Zealand's central North Island, control work from 1988 to 1994 achieved a sustained mean reduction of 87.5% in the density of Tb-infected possums. As expected, annual Tb incidence in local cattle herds consequently declined by a similar amount (83.4%).

From 1979–1984, possum control was stopped due to lack of funding … the number of infected herds snowballed and continued to increase until 1994.

From 1979–1984, possum control was stopped due to lack of funding. In spite of regular and frequent TB testing of cattle herds, the number of infected herds snowballed and continued to increase until, by 1994, from 10-40% of herds in areas where TB was present in wild animals were infected.

There are obvious similarities between New Zealand's possum and the UK's badger. However the badger is native. Presently in the UK the badger has no natural predators, but in other countries the population is limited by predators such as wolves, lynx, bears, wolverines and eagle owls. This has led to a situation of significant population increase (77% between 1980s and 1990s) to a population of 300,000 in the UK.

The badger is a highly adapted and opportunistic omnivore, whose diet encompasses a wide range of animals and plants. This rapid population increase has obviously increased their population density and the pressure they exert on their ecosystem.

For example badgers are a natural predator of hedgehogs and hedgehogs actively avoid sites where badgers are present in high numbers. They can coexist when habitat provides sufficient cover and good foraging opportunities. However there is no safe refuge for hedgehogs when the prey that the two species compete for is scarce. This is one of the reasons that hedgehogs numbers are decreasing at 7 %/annum over the last ten years. *(David Wembridge: the State of British Hedgehogs)*

Unfortunately, this population density increase has resulted in the increasing rates of bovine tuberculosis in badgers. This is a major mortality factor in badgers, although infected badgers can live and successfully breed for years before succumbing to a particularly horrific death.

Whilst the actual number of cattle infected directly from badgers is constantly debated, due to the fact that once an outbreak occurs cattle-to-cattle infection is most likely to be the main route of infection, it is now accepted that the badger population is a significant reservoir of bovine Tb.

Bovine Tb cost the UK government £12.47 million in 2012/13 a 12 % increase from 2011/12 (£11.11 million) and a 94% increase on 2010/11 (£6.4 million) (*DEFRA 5708)* and it is expected to exceed £1 billion over the next decade. This is unsustainable.

Unfortunately, livestock farmers and conservationists have become entrenched on opposing sides of a debate with a very inappropriately named government “Badger Cull” in the middle. The reality is that the majority of stakeholders want the same thing - populations without TB. This has been proven to work across the globe only through targeted and evolving control whilst utilising the best science available.

Bovine Tb cost the UK government £12.47 million in 2012/13 … (and) it is expected to exceed £1 billion over the next decade. … we are discussing an issue which is consuming the same amount of investment as 2% of the education or health budget

It is accepted that initially this may be a difficult action; however we are now discussing an issue which is consuming the same amount of investment as 2% of the education or health budget of the UK and causing untold misery on animals and farmers alike.

Badgers are not the only apex predator that needs review in the UK. There are many other species of animals and birds that are having a significant impact on conservation and livestock farming in the UK. Mechanisms are in place, e.g. licenses for culls, but rarely are they issued or applied for, due to concerns over retaliation. This topic and its relevance to the future of agriculture in the UK really deserves to have a whole Nuffield Farming Scholarship report devoted to it.

What I did observe nationally and internationally was that, in the absence of legal enforcement, sustainable farm systems will generally seek to conserve what wildlife, biodiversity and beauty they have. With a small amount of targeted encouragement, sustainable committed enhancement is a certainty.

With a small amount of targeted encouragement (to farmers) sustainable committed enhancement is a certainty.

Farmers and our representatives must proactively engage with government and conservationists, with solution based enhancement proposals that show agriculture's true role in conservation and how to reduce government spending long-term.

5.3. Nutrient usage

Responsible and efficient use of nutrients is essential for sustainable agriculture. With a perceived over use it is undoubtedly only a matter of time before nutrient budgets expand from Nitrate Vulnerable Zones and become an enforced reality around the UK. These budgets could translate into constraints on stock policies and numbers. So, where does that leave livestock farmers who currently rely on increased productivity to maintain profit margins?

Mike and Sharon Barton had been coming to Taupo, New Zealand for 40 years - fishing, hunting and spending time in the mountains - prior to purchasing the farm on 2000. It is in an area of outstanding natural beauty on the shores of Lake Taupo. It is in this area of New Zealand where discussions around farm profitability versus environmental sustainability are at their most advanced. The couple has been heavily involved in the process of balancing farming viability with lake protection ever since.

From 2006 to 2009, Mike was chair of Taupo Lake Care, which represented the interests of affected farmers. During this time he negotiated with Environment Waikato as the stakeholders worked through the need to balance lake protection with the economic viability of the surrounding farmland.

In 2007 he presented evidence at the Environment Court. Part of the evidence was a statement around the effect of a cap on stock numbers over a 10-year period. He modelled six farms, including his own, and the modelling revealed that in all situations they would be insolvent within nine years, if they had any level of debt. It was essentially a case of declining returns and increasing costs.

If you are denied the conventional model for dealing with increasing costs … you must increase the value of your produce.

If you are denied the conventional model for dealing with increasing costs, i.e. you can only produce a certain amount of product per hectare and are not fully compensated to remain sustainable, you must increase the value of your produce.

Mike and Sharon investigated the issue and talked to chefs and restaurants and came up with "Taupo Beef". The brand is built on the principle that consumers are prepared to pay a premium for meat produced in a way which protects the environment – in this case, the iconic lake.

It is not the solution for everyone, but as New Zealand exports 85 per cent of their meat it demonstrates an important point. It has allowed them to test the concept that people are prepared to pay a premium to protect the environment. It was about getting the story right, the verification process in place to support that the beef was actually grown in that way, and the processing and aging consistent.

The brand has gone from strength to strength and in 2011 was in three restaurants as the most expensive option. Over three months in one top-end restaurant, Taupo Beef at $42.50 outsold the Angus eye fillet at $38.50, by four to one.

The property is 118 effective hectares and runs 440 head of Charolais-Angus cross cattle. The Bartons need a farm policy which grows young animals as quickly as possible, as young animals are the most efficient. To do this they buy in 300 weaner heifers, utilising the hybrid vigour to finish them before the second winter. Heifers achieve the primal cut size and marbling they want and enable them to be finished by 20 months of age at 280-320kg carcass weight. The farm is in the top Beef + Lamb quintile for beef production.

Nutrient limits have already arrived in the UK with NVZs. Farmers are generally ill prepared for it and do not quite understand the effort that is required to come up with a solution.

Nutrient limits have already arrived in the UK with NVZs. Farmers are generally ill prepared for it and do not quite understand the effort that is required to come up with a solution

Farmers and farmer representatives need to take the lead and discuss with government in a constructive way – with give and take to understand the issues, understand the science, recognise the regional impacts, then working together to determine an appropriate outcome that addresses both the environmental and economic realities.

Alongside this, the industry needs a 10-15-year strategic plan. And it will require our meat processors and marketers having far more intestinal fortitude than they've shown to date. We need to stay away from the agricultural commodity space. The two – protecting the environment and commodity trading – are mutually exclusive.

It's time to start selling our food at its true price, which reflects farming, water quality and biodiversity values.

However, there is much livestock farmers can do to reduce production costs ...

6.0. Step 1: Grow grass.

*"**We begin by growing as much grass as we can**": Colin Armour, CEO Armer Holdings.*

Grassland is the UK's most important crop by area, covering just over half of the entire UK landmass - nearly three times as great as all other crops combined. This dominance in area derives from the relatively wet temperate climate of the UK which favours grass and its growth. In the UK there are few natural climax grasslands - nearly all have resulted from man's past activities.

Grass is a fantastic renewable resource and successful/sustainable ruminant farming is all about growing good grass. However, we consistently see farmers across the globe under performing with this most basic procedure.

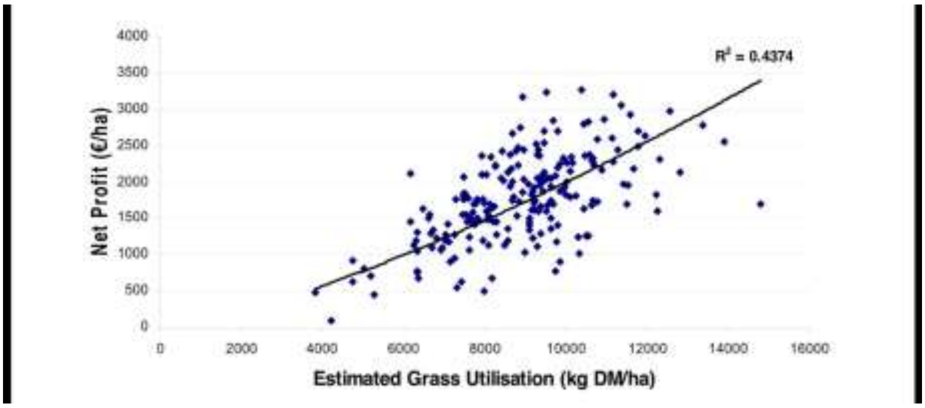
Increasing the amount of grass grown per hectare is one of the simplest ways to increase productivity and/or soil fertility, with fertiliser being key to growing large quantities of quality grass. Having travelled extensively studying grassland agriculture I accept that every farm situation is unique; due to its location affecting climatic conditions and soil types; farm management capabilities; stocking rates and stock type.

However, grass in temperate and tropical regions is the cheapest source of non-food waste quality animal nutrition. The table below shows the competitive advantage high quality grass has across other potential feed sources.

Feed	Utilised DM Total Cost (£/t)	Cash Cost £/t	Relative to Grass
Rotational Rye Grass 80% utilisation	75	43	1.00
Rotational Rye Grass 75% utilisation	78	44	1.04
Rotational Rye Grass 60% utilisation	104	59	1.39
18% Dairy Cake	224	274	3.65
18% sheep Roll	224	274	3.65
Processed Barley	188	188	2.51
Zero Grazing	117	80	1.56
First Cut Silage	185	83	2.47
Conventional 3 cut Silage	124	85	1.65
4 cut high feed value silage	141	99	1.88
Big Bale Silage	119	83	1.59
Fermented Whole Crop	116	72	1.55
Urea- Treated Whole crop Cereals	121	78	1.61
Forage Maize with Mulch	114	73	1.52
Forage Maize without Mulch	123	76	1.64
Crimped Wheat (grain only)	136	84	1.81
Fodder Beet	118	70	1.57

Table 2: Typical UK Utilised DM Costs of different feeds, (Dairy Co Grass + & Finneran 2013)

Realisation of the importance to the profitability of our enterprises of grass in ruminants' diets, is one of the keys to improving sustainability, as on all systems using grass. Increasing grass utilisation/ Ha is undeniably positively correlated to profit, as can be seen in the Graph 1.



Graph 1: Net Profit vs Grass Utilisation, Shalloo 2009

To improve grassland production we need land that is suitably contoured, drained and reseeded to support intensive grazing and sunshine to "fire up nature's solar panels" to drive production.

I was left in no doubt by the highest performing pasture-based farmers - whether assessed on grass utilised or profit - that they had identified any barriers restricting the grass growth on their farm and removed them at the earliest opportunity.

I was left in no doubt by the highest performing pasture-based farmers - whether assessed on grass utilised or profit - that they had identified any barriers restricting the grass growth on their farm and removed them at the earliest opportunity.

These farmers identified the barriers in their pre-purchase analysis, and included the remedial works in the capital spend on the property and their business analysis. If the proposed return of the venture exceeded their investment hurdle (the return on capital deemed acceptable to the investor), the works would be carried out upon completion of the purchase - and quite often pre-changeover to make sure that the land was performing immediately.

It is undoubtedly important to understand and formulate a plan to remove any barriers limiting grass growth - such as soil fertility, drainage, nutrient deficiency and unsuitable grass types. Delays in this will simply delay production responses and your farm's productivity.

continued overleaf

6.1. Soil fertility

6.1.i. Measuring

"Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it."

H. James Harrington, Business Process Improvement.

Soil fertility and/or fertiliser are the key to growing more grass. However, fertiliser should be seen as a discretionary expenditure on farms and therefore it is imperative that soil fertility should be monitored regularly. Unfortunately the staggering majority of 'grassland' soils are inherently infertile and fertiliser inputs are required to increase productivity and sustain this production. Soils need to be treated with care - they are storage banks for animal and plant nutrients. **Like all investments the bank of nutrients should be monitored, and the only way to do this is through soil testing.**

It is important to appreciate at what stage of development the soils you farm are. Initially or if soil reserves have been depleted the nutrient reserves in the soil are low; when fully developed top soils contain large amounts of nutrients. There is no right or wrong answer - we have what we have. Knowledge is key and will aid us to make decisions that will make a sustainable difference to our production costs and return on capital.

This was summed up well by Mark Townsend, a dairy farmer from New Zealand, a past director of Fonterra and current director of Chilean Dairy Business Manuka, who said whilst discussing the purchase of lower production farms: "*There is no such thing as a bad farm, only a bad price*".

If soils have been depleted or you are at an early stage of development, capital fertiliser will be required to release the potential of your soils. Capital fertiliser is the amount required above annual maintenance to increase the nutrients in the soil to their required levels. This should be done as soon as possible after purchasing land or identifying an issue. This will increase productivity and the return on capital of your land.

However, as soil tests, like all biological measurements, are variable, a single soil test taken at one time is of limited value, as can be seen in the table of result variations of some of the main soil tests.

Soil Test	Variation
Soil pH	2-5%
Olsen P	15-20%
QT K	20-30%
QT Mg	10-15%
Sulphate S	20-40%

Table 3. Soil Test result variations. ***Dr D.C Edmeades, Fertiliser Information Services Ltd.***

Maximum advantage from soil analysis will be achieved by repeated testing over a number of years. In this way a picture of soil fertility trends on the farm can be built up.

It is important to understand the soils we farm. The Cation Exchange Capacity of a soil is the measure of its ability to hold and release positively charged elements (cations) and compounds.

The major plant cation nutrients are: Calcium, Magnesium, Potassium and Sodium. All the nutrients in the soil need to be held there somehow, or they will leach out of the soil. Clay particles generally have a negative charge, so they attract and hold positively charged nutrients and non-nutrients. Organic matter has both positive and negative charges, so it can hold on to both cations and anions.

The Cation Exchange Capacity of a soil is the measure of its ability to hold and release positively charged elements (cations) and compounds.

The Cation Exchange Capacity (CEC) of your soil can be likened to a bucket: some soils are like a big bucket (high CEC); some are like a small bucket (low CEC). Generally speaking, a sandy soil with little organic matter will have a very low CEC while a clay soil with a lot of organic matter (as humus) will have a high CEC. Organic matter (as humus) always has a high CEC; with clay soils, CEC depends on the type of clay.

From the 1920s to the late 1940s, a great and largely un-sung hero of agriculture, Dr. William Albrecht, did a lot of experimenting with different ratios of nutrient cations, the Calcium, Magnesium, Potassium and Sodium mentioned above. He and his associates, working at the University of Missouri Agricultural Experimental Station, came to the conclusion that the strongest, healthiest, and most nutritious crops were grown in a soil where the soil's CEC was saturated to about 65% Calcium, 15% Magnesium, 4% Potassium, and 1% to 5% Sodium. This ratio not only provided luxury levels of these nutrients to the crop and to the soil life, but also strongly affected the soil texture and pH. (*Michael Astera, The Ideal Soil: A Handbook for the New Agriculture*)

A best practice soil fertility monitoring programme should be set up as follows:

a.) For farms which vary in soil type and altitude - divide the farm into areas of similar soil type, slope and grazing management history. If soil types vary considerably or the history is unknown, this can be achieved through GPS soil testing which in turn would assist with variable rate applications if required.

b.) Set up sampling lines within each area avoiding gateways, fences, trees, hedges and water troughs: ideally, three sampling lines per area.

c.) Collect a soil sample (15 or more cores at 75mm deep) along each sampling line every three years

d.) Sample in the same month each time, two weeks pre initial annual fertiliser application

e.) Graph the average soil tests results (and the highest and lowest) for each area

f.) Follow the trends and adjust fertiliser requirements

6.1.ii. pH.

Spreading lime on soils increases the soil pH and has many effects on the soil, pasture establishment and maintenance:

1. At low soil pH levels (< 5.5) aluminium (Al) and manganese (Mn), which are normally part of the soil minerals, become plant available. Small amounts of these elements are toxic to pasture plants and especially clovers. Liming soils with an initial pH below 5.5 eliminates this problem. Soils with a pH > 5.5 will have no available Al and Mn.

2. Soil microbial activity is optimized at pH levels around 6.0-6.5. Thus liming soils can increase the biological activity and hence nutrient cycling in the soil. For example it has been shown that liming enhances the breakdown of organic N in the soil releasing a flush of plant available N.

3. The plant availability of molybdenum (Mo) increases as the soil pH increases. Thus liming soils that are deficient in available Mo can significantly increase clover growth by increasing the amount of plant available Mo (Mo is required in small amounts for the process of clover N fixation).

4. Increasing the soil pH can, on some soils, decrease the availability of zinc (Zn) and manganese (Mn). This is why over-liming (liming to soil pH levels to > 6.5) can have detrimental effects on plant growth, particularly on coarse soils.

5. Liming also increases the availability of Nitrogen (N), Phosphorous (P) and Potash (K) on acidic soils.

Ph	Inefficiency *		
	N	P	K
5.1	51%	64%	43%
5.2	44%	61%	38%
5.3	38%	58%	38%
5.4	31%	55%	28%
5.5	23%	52%	23%
5.6	21%	51%	21%
5.7	18%	50%	18%
5.8	16%	50%	16%
5.9	14%	49%	14%
6	11%	48%	0%
6.1	9%	38%	0%
6.2	7%	28%	0%
6.3	5%	20%	0%
6.4	3%	10%	0%
6.5	0%	0%	0%

Table 4: The Inefficiency of N, P and K caused by pH: *Soil Smart and Nutrient Wise, British Grassland Society*

Maintaining soils at optimal levels is critical to optimising grass growth. On mineral soils, trials show that as the soil pH increases the pasture response to liming declines; whilst peat soils in an unimproved state are very different to mineral soils. They do not contain the Al and Mn minerals and can be operated at much lower soil pH levels. As peat soils are developed they begin to act increasingly like a mineral soil and the Anion Storage Capacity (ASC – the ability of the soil to retain phosphorus and sulphur) increases from < 20 up to about 60. Once the ASC reaches about 60 the developed peat should be treated just like a mineral soil. The optimal soil pH for clover-based pastures on mineral soils is 6.0-6.5.

pH	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5
%	87.9	89.0	90.0	91.1	92.1	93.2	94.2	95.3	96.4	97.5	98.0	98.5	99.0	99.5	100

Table 5. % of Optimal grass growth as restricted by pH. Averaged yield over the period 1969-2008 showing the differential sensitivity to pH on grass, Woodlands pH Rotation plots, *SRUC Craibstone*

However, there are many biochemical reactions in the soil that generate acid. For example, the microbial breakdown of soil organic matter to ammonium and then to nitrate (the nitrification process), the leaching of clover-fixed nitrogen, and the dissolving of some fertilisers.

The net effect of all the acid-producing reactions is that the soil pH declines over time. The rate of acidification increases with the increasing pasture production and so for many high production farms, 400-500 kg/ha of lime is required annually to 'mop up' this acidity.

Contrary to popular belief, research with DairyNZ has shown that is does not matter whether lime is applied in small amounts often or large amounts infrequently. This is due to lime being relatively insoluble – it takes about 12-18 months to fully dissolve in the soil and has a long residual effect. For this reason the general practice on farms is to apply 2-2.5 tonnes/ha of lime every 4-5 years for maintenance. Again, initial capital lime should be spread as soon as possible.

It is therefore surprising that the British Survey of fertiliser practice 2013 reveals the continual decline in the use of lime on grassland

It is therefore surprising that the British Survey of fertiliser practice 2013 reveals the continual decline in the use of lime on grassland and, of all grass under 5 years old surveyed, only 7.8% received lime and at a rate of 4t/ha (All Grass 4.8% at 3.8t/ha).

This means that the majority of grassland in the UK is operating at sub optimal levels of pH. This is backed up by a summary of grassland pH tests collated from across the UK from a major laboratory revealing that 20.7% of tests had a pH below 5.5, 30.4% below 6, 26.3% between 6 and 6.5 and 22.6 % >6.6.

Many farmers complain about the capital cost of lime. If however, the return on capital is investigated and pH is found to be the limiting factor on N,P,K and grass growth, the payback period on applying lime can range from 1 to 2.2 years (see Appendix 1).

The key to liming is good quality lime. When purchasing lime, it is worth considering its effective neutralising value (the ability for a unit mass of lime to change soil pH) and reactivity (speed of reaction).

10 t/ ha of good quality limestone is required to increase pH by 1 unit.

6.1.iii. Plant nutrients.

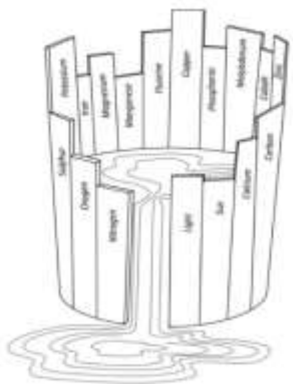
The plant nutrients taken up by crops during the growing season may come from many sources, including soil reserves, applied fertiliser, farm yard manure (FYM), and crop residues. Nutrients such as N, P, and K are required in large quantities, whilst sulphur (S), calcium (Ca), and magnesium(Mg) are required in intermediate quantities and the micronutrients in small quantities . However, **all** the nutrients listed in the table below are **essential** for plant growth

Primary Nutrients	Secondary Nutrients	Micronutrients	Other Essentials
Nitrogen (N)	Sulphur (S)	Iron (Fe)	Sunlight
Phosphurus (P)	Magnesium (Mg)	Manganese (Mn)	Oxygen
Potassium(K)	Calcium (Ca)	Boron (B)	
		Chlorine (Cl)	
		Zinc (Zn)	
		Copper (Cu)	
		Molybdenum (Mo)	
		Nickle (Ni)	

Table 6. Essential elements for grass growth.

During my study travels, I twice came across graziers with double the grass utilised /ha of comparable neighbours. Ruben Campochico, a non-irrigated Uruguayan grass-based dairy farmer grazing 3.42 cows/ha on 70 has was growing 20-25t/ha annually compared to his neighbours at 9t/ha. Whilst in the Waikato of New Zealand, Hendry Hendrix was growing 26t DM/ha compared to his neighbours averaging 13.6tDM. The difference between these farmers and the rest started with their understanding of balancing their soils to provide all the nutrients the grass required.

For plant growth to be optimised the minimum quantity of each of the essential elements is required and the rate of plant growth will depend on the nutrient that is the most limiting. This is Leibig's famous "Law of Minimum".



Leibig likens the potential of a pasture to a barrel with staves of unequal lengths. The capacity of the barrel is limited by the shortest stave and can only be increased by lengthening that stave. When that one is lengthened, another one becomes the limiting factor.

6.1.iii.1. Nitrogen (N)

There is increasing pressure stemming from EU directives to reduce agricultural emissions into the environment. Nitrogen has become a dirty word in agricultural political circles, with farming being blamed for eutrophication, algae blooms and health scares.

However it is the main nutrient required by grass as it is a critical component of proteins, which control the metabolic processes required for plant growth. It is also an integral part of the chlorophyll molecule and thus plays a key role in photosynthesis. An adequate supply of nitrogen is associated with vigorous vegetative growth and a plant's dark green colour. Nitrogen can be can be sourced by the plant from the atmosphere by leguminous plants, soil N, fertilisers and rain, as can be seen from the nitrogen cycle below.

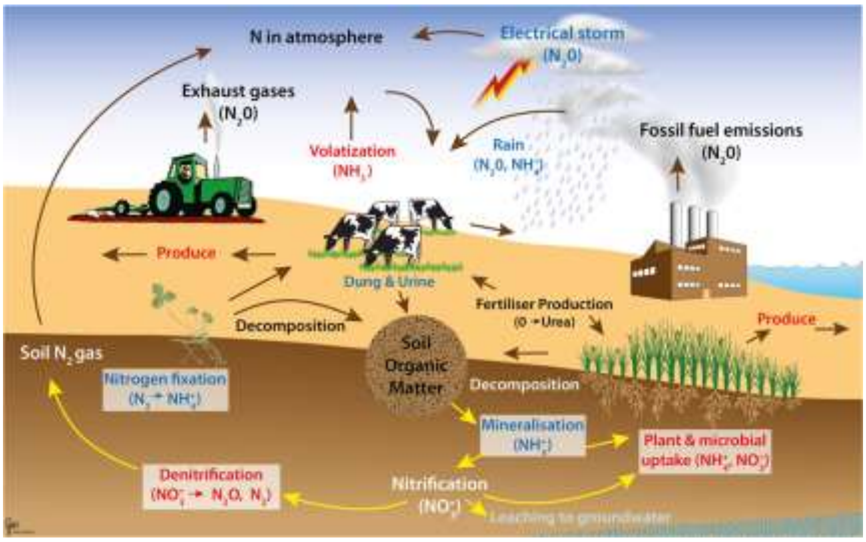


Diagram 1. The nitrogen cycle.

Nitrogen deficiency is characterised by reduced plant growth and a pale green or yellow colour. This yellowing generally begins at the tip of the leaf and goes down the middle of the leaf. If the deficiency is severe, the affected area eventually turns brown and dies. Since nitrogen is mobile in the plant, older leaves show the first symptoms of nitrogen deficiency. Nitrogen behaviour is extremely dynamic in the soil and very dependent on the weather. Much of the soil N is in the organic matter and must be mineralised into soluble forms by microbes before it can be taken up by plants.

There can be no doubt that excessive or irresponsible use of nitrogen in any form can damage the environment. However, a responsible fertiliser plan optimising the use of home produced farm yard manures (FYM) combined with purchased nitrogen for grass growth can reduce the requirement for the purchase of other feeds and increase profitability.

Maximising pasture legumes to fix atmospheric N requires a high soil fertility status but once the soils are developed to sufficient levels, strategic use of N can reduce production costs further and drive grass growth.

N fertiliser should be treated as a management tool to produce additional feed during the growing season. In fact, N fertiliser in pasture based farming should be treated as a form of supplementary feed.

N fertiliser will not provide additional pasture production if soil N is already adequate or if climatic conditions are limiting growth. The largest responses to applications of N occur when growth rates peak but grass does respond during slower growth rates and can be useful to build up feed supplies for deficits created during periods of slow growth (winter/drought).

The reliability of obtaining N responses can be expressed as the likelihood of achieving a response of 10kg DM/kg N applied.

Likelihood (%probability) of achieving a 10:1 response to N			Cost of additional 1 t/DM produced by N response
Season	%	Average	0.55 *1
Late Winter / Early Spring	60-80	70	78.57
Spring / Early Summer	80-100	90	61.11
Autumn	20-40	30	183.33

Cost £0.55/kg N worked out based on Urea at £255.00/t
Table 7. Nitrogen response

As we can see from Table 7, even when nitrogen response is low at 3:1, in autumn it can be a more cost effective solution to purchasing other feedstuffs including silage and processed barley.

To maximise responses, N fertiliser should be applied to pasture with some re-growth (1600-1800 kg DM/ha, [50mm]) at 25 to no more than 75 kg N ha. I saw many examples of temperate ryegrass mixtures growing over 16t DM carrying over 3.3 LU/ha on less than 300kg N/annum.

The 2013 British Survey of Fertiliser Practice revealed the reducing trend of N applied to grass to average 96 kg/ha on field applications.

6.1.iii.2. Phosphorous (P)

Phosphorous is commonly one of the most limiting nutrients in grass production. It is a critical component of nucleic acids and therefore plays a vital role in reproduction. Phosphorus is essential for the biological energy transfer processes that are vital to life and growth. Adequate phosphorus is characterised by improved crop quality, greater stem strength, increased root growth, and earlier crop maturity. Phosphorus deficiency is indicated by reduced plant growth, delayed maturity, and small seed set. These symptoms may be accompanied by a purple colouring, particularly in young plants. Like nitrogen, phosphorus is mobile in the plant; therefore, any deficiency symptoms show up first on older leaves. Most soil P occurs in relatively insoluble minerals and organic matter in the soil. The availability of these forms is very sensitive to soil pH. Phosphorus availability can be reliably estimated within soil through soil tests.

We can conclude that in the UK, P is either being supplied by alternative sources or grass is being grown with sub optimal levels of P.

In contrast to nitrogen, the atmosphere does not provide phosphorus. Instead, orthophosphates originate largely from primary and secondary minerals and/or from organic sources. However, the phosphorus cycle is by no means less complex than the nitrogen cycle, and there are many factors that affect the availability of phosphorus in the soil. The diagram below is an illustration of the phosphorus cycle.

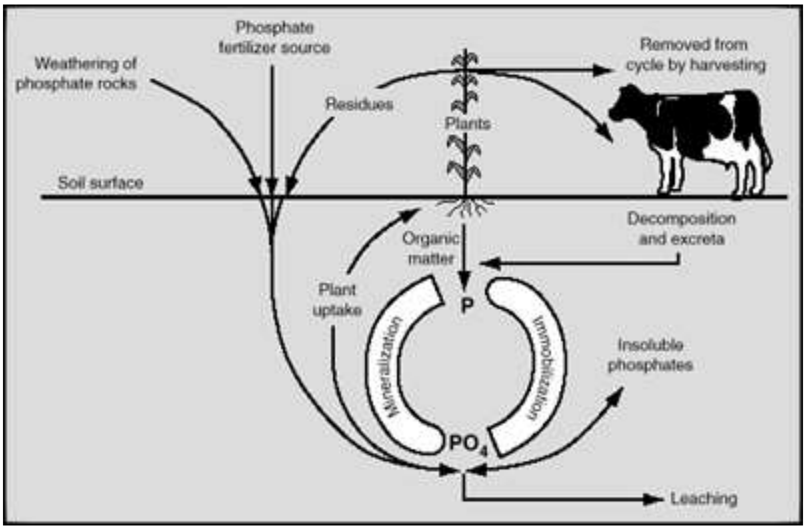


Diagram 2. Phosphorous cycle. (*University of Hawaii)*

The critical P level for pasture which will ensure 97% of maximum pasture production is dependent on soil type, but in the UK generally index 3, or in light soils an index 2, can be acceptable.

We can conclude that in the UK, K is either being supplied by alternative sources or grass is being grown with sub optimal levels of K.

GP revealed the reducing trend of P applied to grass to average 22 kg/ha on field applications. We can conclude that in the UK, P is either being supplied by alternative sources or grass is being grown with sub optimal levels of P.

6.1.iii.3. Potassium (K)

Potassium is not an integral part of any major plant component. It does however play a key role in a vast array of physiological processes vital for plant growth, from protein synthesis to maintenance of plant water balance. Potassium deficiency is characterised by reduced plant growth and a yellowing and/or burning of leaf edges. Since potassium is mobile in the plant, the symptoms appear on the older leaves first. Another indication of potassium deficiency is reduced stalk strength, which results in lodging problems, reduced disease resistance, and reduced winter hardiness. Excess K in the soil can lead to excess K in plants which can, in some cases result in animal nutrition/health problems. Potassium in the soil is mainly in the form of insoluble minerals and as the K+ cation on the soil CEC. Soil tests can estimate available K usually by measuring the K+ cation on the soil CEC.

The critical K level for pasture which will ensure 97% of maximum pasture production is not dependent on soil type. Quick K test of 7-10 or Index 3 is ideal.

Grass requires 19.2 kg of K /t/DM produced. The 2013 British Survey of Fertiliser Practice revealed the reducing trend of K applied to grass to average 29 kg/ha on field applications. We can conclude that in the UK, K is either being supplied by alternative sources or grass is being grown with sub optimal levels of K.

6.1.iii.4. Magnesium (Mg) and Calcium (Ca)

Magnesium is a key component of chlorophyll and plays a critical role in photosynthesis. Magnesium deficiency is characterised by white stripes between the leaf veins. Calcium is an integral part of plant cell walls.

It's still a little-known fact that the Calcium: Magnesium ratio determines how tight or loose a soil is. The more calcium a soil has, the looser it is; the more magnesium, the tighter it is, up to a point. Other things being equal, a high calcium soil will have more oxygen, drain more freely, and support more aerobic breakdown of organic matter. A high magnesium soil will have less oxygen, tend to drain slowly, and organic matter will break down poorly, if at all. In a soil with magnesium higher than calcium, organic matter may ferment and produce alcohol and even formaldehyde, both of which are preservatives. However, if you get the calcium level too high, the soil may lose its beneficial granulation and structure and the excessive calcium will interfere with the availability of other nutrients. If you get them just right for your particular soil, soil compaction is no longer an issue if farmed under good environmental conditions.

> *It's still a little-known fact that the calcium: magnesium ratio determines how tight or loose a soil is.*

Remember Albrech's generalised "65% calcium, 15% magnesium" ideal soil, and the fact that calcium tends to loosen soil and magnesium tightens it. Therefore, in a heavy clay soil this should be adjusted to a 70% calcium and 10% magnesium ratio; in a loose sandy soil 60% Ca and 20% Mg which will tighten up the soil and improve water retention. If together they add to 80%, with 4% potassium and 1-3% sodium, that leaves 12-15% of the exchange capacity free for other elements, and an interesting thing happens. 4% or 5% of that CEC will be filled with other bases such as copper and zinc, iron and manganese, and the remainder will be occupied by exchangeable hydrogen, H+. The pH of the soil will automatically stabilise at around 6.4 , which is the "perfect soil pH" not only for organic/biological agriculture, but is also the ideal pH of sap in a healthy plant, and the pH of saliva and urine in a healthy livestock and humans.

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6.1.iii.5. Sulphur

Sulphur (S) is relatively cheap compared to the major nutrients. It is not a pollutant and hence the appropriate attitude towards S deficiency is to eliminate. It is nonsensical to limit the expression of other more expensive nutrients by operating at non-optimal soil S levels.

Clover has a higher requirement for all nutrients including S, relative to the grasses. Thus, if a soil is S deficient the clover vigour and abundance will be poor. Correcting S deficiency results in an increase of clover growth and production.

The soil stores S in two pools. Long-term (months to years) S is stored as organic S and is the largest and most important pool of S. It is not affected by leaching or by the addition of fertiliser S and normally makes up over > 95% of S in soil. Through mineralisation the organic S can be made into plant available Sulphate S. Sulphate S levels fluctuate over time due to the addition of sulphate fertilisers, dung and urine, and loss of sulphate S during leaching events and soil temperature.

Providing there have been no recent additions of fertiliser S or leaching events, the two S pools will remain in equilibrium and the concentration of sulphate S will be directly related to the amount of organic S. For this reason the optimal ranges for pasture production are the same at 10-12 ppm (parts per million).

In most organic soils if the S level is > 10-12 it means that the soil has sufficient organic S. Therefore the amount of sulphate S mineralised during the year will be sufficient to meet the annual pasture S requirements without the need for additional fertiliser S. However in some drier sedimentary soils it is simply not possible to increase the organic S levels up to and above the optimal. For these soils, applications of fertiliser S are essential to meet the annual S requirement.

Sulphate S is mobile and hence susceptible to leaching, but non organic S is not. After a leaching event, the soil bugs in a healthy soil will via mineralisation restore the equilibrium sulphate S concentration.

Under prolonged cold, wet conditions, such as the end of winter and beginning of spring, the soil bugs which break down organic S will not be active and hence the pool of sulphate S can become depleted and is not restored via mineralisation. For this reason, additional sulphate can be beneficial at that time of year.

3.1.vi.6. Micronutrients

There are eight main micronutrients essential to plant growth and health but these are only required in very small quantities. In all my visits except on one occasion in South America where grass was being trialled on undeveloped sand, I didn't witness deficiency in pasture or increased production of the pasture due to supplementation of micronutrients. (This is not true for livestock).

Boron is believed to be involved in carbohydrate transport in plants; it also assists in metabolic regulation. Boron deficiency will often result in bud dieback.

Chlorine is necessary for osmosis and ionic balance; it also plays a role in photosynthesis.

Copper is a component of some enzymes. Symptoms of copper deficiency include browning of leaf tips and chlorosis - a condition in which leaves produce insufficient chlorophyll. As chlorophyll is responsible for the green colour of leaves, chlorotic leaves are pale, yellow, or yellow-white.

Iron is essential for chlorophyll synthesis, which is why an iron deficiency results in chlorosis.

Manganese activates some important enzymes involved in chlorophyll formation. Manganese deficient plants will develop chlorosis between the veins of its leaves. The availability of manganese is partially dependent on soil pH.

Molybdenum is essential to plant health. Molybdenum is used by plants to reduce nitrates into usable forms. Some plants use it for nitrogen fixation, thus it may need to be added to some soils before seeding legumes.

Nickel is essential for activation of urease, an enzyme involved with nitrogen metabolism that is required to process urea. Without Nickel, toxic levels of urea accumulate, leading to the formation of necrotic lesions.

Zinc participates in chlorophyll formation, and also activates many enzymes. Symptoms of zinc deficiency include chlorosis and stunted growth.

6.2. Reseeding

Reseeding can be one of the most cost effective on-farm investments. Research has shown that, economically, pastures with a low proportion of perennial ryegrass are costing farmers up to £240/ha/year due to loss of DM production and reduced N efficiency during a growing season. (*Harvesting the Potential, Teagasc, 2013*). However, if the total cost of reseeding is estimated at £560 ha/year, the increased profitability of the reseeded pasture would cover the cost of the investment in just over two years. But, to optimise the establishment and growth potential of the reseed soil fertility, pH, drainage, seasonal conditions and reseeding method need to be considered.

6.2.i. Method of reseeding

How fields are prepared for reseeding comes down to soil type, amount of underlying stone, depth of top soil and machine availability. Research undertaken by Teagasc investigated the method of reseeding impact on future pasture production. Direct drilling, discing followed by a single pass; one pass with a power harrow; and ploughing were all compared. The results revealed that the different modes of action all compared favourably with all techniques being equally effective.

6.2.ii. Timing of reseeding

The majority of reseeding in the UK occurs in the autumn. Whilst this does make sense from a feed budgeting point of view, the lower soil temperatures can decrease seed germination and poor weather reduces the chances of effectively grazing the new sward.

Research has shown that autumn sown reseeds in their first year of production will out-yield old permanent pasture by 11.3 t/ha vs 10.4 t/ha in their first year, increasing to 12.7 t/ha in year 2; whilst spring shown reseeds will show virtually no difference in year 1 and increase to 12.4 t/ha in year 2.

	Reseed pasture production vs Permanent Pasture t/DM	
Sward Establishment	**Year 1**	**Year 2**
Autumn	0.958	2410
Spring	0	2033

Table 8. Reseed pasture production vs Permanent Pasture.
(Harvesting the Potential, Teagasc 2013)

The key finding of this research is that there is no loss in production in the establishment year when reseeding in spring, and that is irrespective of timing. Swards require time to settle and allow the perennial ryegrass hierarchy to establish in order to optimise the advantage of reseeding.

6.2.iii. Management of reseeds.

It is vitally important that soil fertility is at recommended levels to ensure high performance of the reseeded sward.

Care needs to be taken when initially grazing - 6 weeks post sowing at the earliest, but as soon as the new grass plant roots are strong enough to stay anchored in the ground when pulled during grazing. This will encourage tillering. Light grazing using calves, weanlings or sheep is advantageous if ground conditions are at all fragile. This first grazing can be completed at 2000 kg/DM ha and frequent grazing over the first year of establishment will be beneficial.

If at all possible, newly reseeded swards should not be closed for a heavy cut of silage in their first year. The shading effect of heavy grass covers will inhibit tillering, encouraging the development of an open sward and potential weed ingress.

When reseeding, it is essential to ensure all grass varieties are from the recommended lists, where varieties have been trialled and tested under UK conditions. UK recommendations are to sow 34.5 kg/ha to ensure good establishment; however on my travels I witnessed incredible sward establishment with significantly less seed. This is obviously an area of research that would benefit UK pasture based farmers.

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6.3. Grass varieties

Rough grazing is uncultivated grassland that is found on the mountains, hills, moors and heaths of the UK. For the most part it is "unimproved" receiving no fertiliser and suffering from difficulties such as poor drainage, steep slopes and physical obstructions. Rough grazing covers approximately 5.6 million hectares -about 23% of the UK land area, and is relatively unproductive with livestock grazing extensively.

While sward composition, especially for these older unimproved pastures, is often complex, ***perennial ryegrass*** and ***white clover*** are the key components of the most productive pastures. Genetic improvement of these species by breeding varieties with superior yields and quality, is a valuable contribution to increasing the potential productivity of pastures.

Whilst selection to date has concentrated on yield, composition and sward density the continued development of genomics will rapidly evolve grass breeding techniques. Genomic selection is achieved by selecting individuals based on the profile of their DNA, rather than waiting to access performance data of their offspring. This shortens the generation interval and reduces costs. What is extremely exciting about this process is it will bring back varieties - originally discarded on past selection criteria - into the breeding programme for specific individual traits (e.g. salt tolerance, disease resistance). It will undoubtedly increase the rate of genetic gain.

Photograph 1. Grass Variety Comparison Testing, DFL Trifolium, Denmark 2013

6.3.i. Perennial ryegrass.

Ryegrass plants are made up of several parts called tillers. Each tiller has a growing point from which new leaves are produced. The growing point is found at the base of the tiller, close to the soil surface. This means it is rarely damaged during grazing, allowing the tiller to re-grow after grazing.

At any one time each tiller has up to three live leaves and one or more dying leaves. Persistence of pastures is strongly linked to how tillers respond to the frequency, severity and timing of grazing and the growing conditions (i.e. temperature and moisture) at the time.

Perennial ryegrasses mainly reproduce asexually through daughter tillers which become separated from the parent tiller and result in a new plant. Under existing management few new ryegrass plants emerge in established pasture through seed germination.

For pastures to persist, each tiller must leave behind at least one offspring. The survival, size and number of tillers in a pasture depend on the rate of new tillers appearing and old tillers dying.

Plants will respond to stress by stopping tiller production. Ryegrass pastures can change between having many small tillers per m^2, resulting from frequent intense grazing, to fewer larger tillers per m^2, resulting from less frequent grazing. The resulting dry matter (DM) production is similar in both pastures.

Grazing management also impacts on pasture production and quality. Understanding the principles of grazing management for optimal pasture growth and quality is required. These are briefly summarised as the following general rules:

- Graze between the two and three leaf stage - at the three leaf stage if short of feed and at the two leaf stage if there is plenty of feed.
- Graze to a consistent, even post-grazing residual of 3.5- 4cm height (1500-1600kg DM/ha, to maximise pasture yield and quality, and animal production. Lower residuals will reduce pasture re-growth (except in winter). Higher residuals reduce pasture quality for subsequent rotations.

Breeding and selection of perennial ryegrass is done at two ploidy levels - diploid and tetraploid. The principal objectives are:

- Increased total annual yield
- Improved seasonal yield in Spring and Autumn
- Increased persistence
- Improved sward density
- Reduced stem in the aftermath regrowth
- Improved quality
- Improved disease resistance (mildew, drechslera, rust, rhynchosporium)

The main difference between diploid and tetraploid ryegrass is the number of chromosomes per cell. Diploid plants have two sets of chromosomes per cell whilst tetraploids have four. Tetraploids have an increased cell size due to this and have a higher ratio of cell contents (soluble carbohydrates) to cell wall (fibre), indicating that they have a higher water content per cell. Diploid plants have more tillers per plant and due to the lower water content per cell have a higher dry matter per kg of feed and also more energy than tetraploid plants.

Diploid and tetraploid plants have similar protein levels.

Tetraploid ryegrasses offer several benefits in terms of animal performance. This is due to the higher ratio of cell contents to cell wall in the tetraploid plants. One benefit is that it is more palatable to animals which improves intake and therefore increases animal production. In addition tetraploid cell contents consist of rapidly available nutrients, such as sugars and starches necessary for more efficient rumen function. (Cows grazing tetraploid cultivators produced an additional 5% milk solids in Mary McEvoy's Teagasc research.)

It is however important to remember that tetraploids have a higher water content in the cells so when livestock are full from grazing the actual dry matter intake could be lower compared to that of diploids plants. A mix of tetraploid and diploid ryegrass can achieve a more balanced pasture retaining a good level of dry matter production and an improved balance of quality feed. A combination if used for silage is more easily ensiled, compacted and fermented than a pure tetraploid pasture.

It is important to monitor grazing pressures on tetraploid ryegrasses as they are sensitive to overgrazing because of their excellent palatability. If grazing occurs to a lower level than with diploid ryegrasses it may compromise persistence.

Tetraploid ryegrasses have higher establishment costs than diploids as the recommended sowing rate for tetraploids is higher due to the larger size of the seed (2-3 times heavier). If planting tetraploid ryegrass in a mix, the plants will allow up to 10% more clover in the pasture due to the reduced tiller density promoting an increased pasture quality. However, the reduced tillering density of Triploid grasses does decrease the potential carrying capacity of the sward in wet conditions.

Standardised grass mixes including multiple varieties with variable heading dates can assist with disease resistancy; however increasing the spread of heading dates will increase the difficulty of maintaining pasture quality and the persistency of the individual varieties.

6.3.ii Hybrid ryegrass

Hybrid ryegrass is a cross between Perennial and Italian ryegrass combining yield, quality and persistence**.** Types range from Perennial ryegrass, intermediate and Italian types. Hybrid ryegrass has improved drought tolerance of Italian ryegrass, especially the very dense hybrids. Spring growth is similar to early perennial ryegrasses whereas the heading is more like intermediate perennials. This increases flexibility in the spring and yields additional high quality forage.

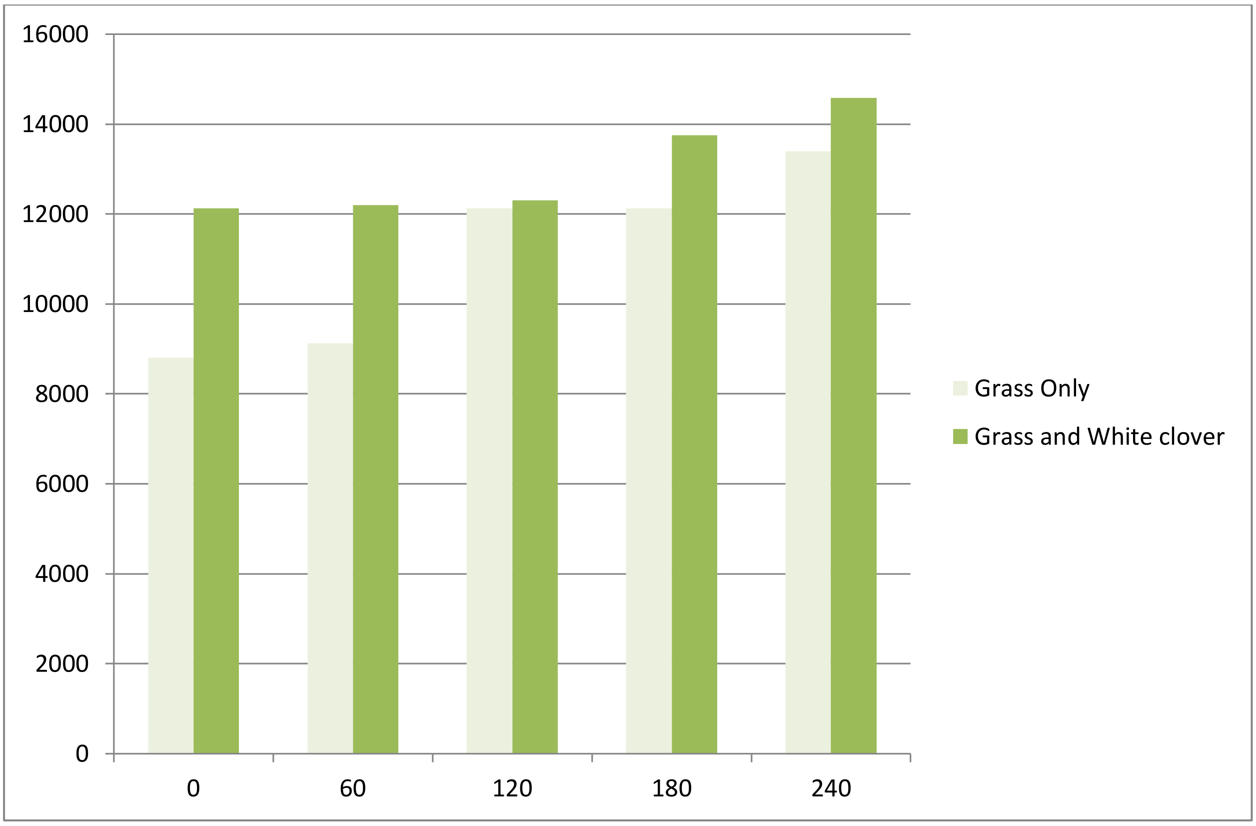
6.3.iii. Clover

Generally the intensive UK pasture based industry relies on nitrogen fertilised perennial ryegrass swards to provide feed for livestock, with little reliance on clovers as a quality feed source or to fix nitrogen.

However, clovers and other legumes are valuable forages as they produce large amounts of high-quality forage without the need for N fertiliser. Clover through the symbiotic rhizobia bacteria found in root nodules can fix large amounts of N from the air. (White Clover 170 kg/N ha, University of Arkansas). This supports the growth of other forages, reducing or can eliminate the need for N fertiliser in fields having good clover stands. However, the rhizobia bacteria only fix enough N for it and the clover plant host. The fixed N does not leach freely into the soil and is not immediately available to the companion grass. To make use of this fixed N, you must understand where the N is fixed and stored in the plant and how to make it available to other forages in the pasture.

Although the N is fixed by rhizobia bacteria in the root nodules, it is not stored there. Most of the N is found in the top growth of the plant with a smaller amount in the crown, roots and nodules. Estimates for perennial legumes show that about 75-80 percent of the plant's N content is in the top growth. This is only released through grazing, mowing or death of the plant. Clover will not fix nitrogen if there is sufficient N available.

Research carried out by Teagasc at Moorepark has revealed that herbage production in rye grass and clover mixed plots with a range of N application rates out-yielded the grass-only plots by an average of 2t DM/ha. As expected at the low N input, production increased by over 3 t DM/ha but at the higher rates of N application production was further enhanced by 1.1t DM ha. Rather surprisingly, when application rates were increased from 0 through to 120 kg N/ ha, production was increased from 8.8 t DM/ha to 12.1 t DM/ha in the grass only plots whilst production on the grass clover mix plots was only increased slightly from 12.1t DM/ha to 12.2 t DM/ha.



Graph 2. T/DM produced under varying applications of N. *Teagasc*

In 2011 and 2012, Teagasc extended their trial work to include milk yield and milk solid production off the trial plots. It was discovered that milk production on the grass clover swards increased from mid June onwards when sward clover content was increasing and the digestibility of the grass declining.

	2011 (Apr-Oct)		2012 (Apr-Oct)	
	Grass Only	Grass & Clover	Grass Only	Grass & Clover
Milk Yield (kg/cow/day)	19	19.8	17	18.6
Milk Solids Yield (kg/cow/day)	1.52	1.47	1.41	1.53
Herbage Production (t DM/hec/yr)	13.5	13.6	13.6	14.7

Table 9. Daily milk yields and milk solid production from cows grazing grass only and grass-clover swards. (*Teagasc)*

These experiments and similar ones conducted by Dairy NZ and Beef and Lamb NZ concluded that including white clover in grass swards can increase herbage and animal production whilst reducing costs of production through reducing N fertiliser requirements.

Photograph 2. Grass clover sward, *Glenapp 2014.*

6.3.ii. Red clover.

Red clover is a well established legume that provides a high protein forage. The plant is usually grown in a mixed grass clover sward but can yield 15 tonnes DM /ha as a pure stand.

As with white clover, the benefits of growing red clover include the conversion of atmospheric nitrogen into a plant usable form, therefore potentially reducing N fertiliser use. It can also be ensiled as high quality silage with tremendous aftermath for livestock.

Red clover can contain phyto-oestrogens which can reduce ovulation rates in sheep. Providing breeding ewes are removed from grazing red clover 6 weeks before and 6 weeks after tupping then the risk of reduced fertility is negligible.

6.4. Drainage.

Over 33% of livestock production in the UK and Ireland is carried out on so-called heavy soils. The problem with these soils is low permeability; i.e water is slow to pass down through the soil profile. *(Teasasc, Soil Management)* This results in soils becoming easily compacted when wet, drainage issues, grass production, and utilisation being impaired and therefore profits being reduced.

The purpose of land drainage is to lower the water-table to provide suitable conditions for grass growth through deeper rooting and increasing nutrient availability. The deeper rooting and increased sward productivity will improve the carrying capacity of the soil and reduces the damage caused by grazing and machinery.

The huge variety in soil types and issues means that every drainage challenge is unique and should be approached as such - just because a solution worked at one location does not mean it will work at another. Underlying the feasibility of all drainage work must be the economic returns to the farming business.

When planning any drainage programme, the potential of the land to be drained needs to be assessed first. It is essential to determine whether the costs incurred will result in an economic return through additional yield and utilisation of the grass or other crops grown.

Through effective land drainage, there is enormous potential for developing our land resources. Drainage problems tend to be as a result of three major factors: high excess rainfall, soil compaction and a complex geological history.

The first step is a detailed investigation into the causes of poor drainage. Knowledge of previous schemes in the area and their effectiveness, will often guide the investigations.

A number of test pits (at least 2.5m deep) should be excavated within the area to be drained. As the pits are dug the soil type should be established. The pits should be left for a rest period of at least 6 hours and then checked with the rate and depth of water seepage into the pit observed. The depth and type of the drain to be installed will depend on the interpretation of the characteristics revealed by the test pits. If drainage pipes need to be installed, it is most effective to position them below the impenetrable layer.

Photographs 3 and 4. James O'Loughlin of Teagasc with Test Pits prior to the Glenapp Estate Open Day in 2014.

Drainage is costly; therefore it is imperative that the correct drainage solution is chosen – it must improve the levels of grass production and utilisation – and once installed it must have regular maintenance.

Drainage System	Drain Spacing (m)	Depth (m)	cost/ m (£)	Cost/ha (£)
Collector Perforated drains	20	0.75	6.25	3125

Table 10. An example cost of a drainage system

	Milk Price (£/litre)			Beef Price (£/kg)		
Increase in Grass growth	**0.22**	**0.28**	**0.34**	**4.00**	**4.25**	**4.5**
10%	-28%	12%	13%	-631%	-119%	-59%
20%	82%	33%	27%	-322%	-46%	-13%
30%	192%	50%	42%	-45%	22%	30%

Table 11. Profitability increase on land drainage project, costing £3,125/ha, for milk and beef production.

From Table 11 we can see that that with poor product prices and increases in grass growth < 10%, drainage projects cannot be financially justified in either milk or beef production. However, as grass production uplifts improve and product prices increase margins, significant investment into drainage projects can be easily justified.

6.5 Earthworms

Earthworms are an excellent indicator of soil health because they do not like soil that is too acid, alkaline, dry, wet, hot or cold. High densities are found in fertile, well aerated and well drained productive soils.

Earthworms have been called 'ecosystem engineers'. Much like human engineers, earthworms change the structure of their environments. Different types of earthworms can make both horizontal and vertical burrows, some of which can be very deep in soils. Earthworms have numerous advantages to soil health.

6.5.i. Improved nutrient availability

Worms feed on plant debris (dead roots, leaves, grasses, manure) and soil. Their digestive system concentrates the organic and mineral constituents in the food they eat, so their casts are richer in available nutrients than the soil around them. Nitrogen in the casts is readily available to plants. Worm bodies decompose rapidly, further contributing to the nitrogen content of soil.

In New Zealand, research shows that worm casts release four times more phosphorus than does surface soil. Worms often leave their nutrient-rich casts in their tunnels, providing a favourable environment for plant root growth. The tunnels also allow roots to penetrate deeper into the soil, where they can reach extra moisture and nutrients. Earthworm tunnelling can help incorporate surface applied lime and fertiliser into the soil.

6.5.ii. Improved drainage

Soils with earthworms drain up to 10 times faster than soils without earthworms

The extensive channelling and burrowing by earthworms loosens and aerates the soil and improves soil drainage. Soils with earthworms drain up to 10 times faster than soils without earthworms. In zero-till soils, where worm populations are high, water infiltration can be up to 6 times greater than in cultivated soils. Earthworm tunnels also act, under the influence of rain, irrigation and gravity, as passageways for lime and other material.

6.5.iii. Improved soil structure

Earthworm casts cement soil particles together in water-stable aggregates. These are able to store moisture without dispersing. Research has shown that earthworms which leave their casts on the soil surface rebuild topsoil. In favourable conditions they can bring up about 50 t/ha annually, enough to form a layer 5 mm deep. One trial found worms built an 18-cm thick topsoil in 30 years.

6.5.iv. Improved productivity.

Research into earthworms in New Zealand and Tasmania found earthworms introduced to worm-free perennial pastures produced an initial increase of 70–80% in pasture growth, with a long-term 25% increase: this raised stock carrying capacity. Researchers also found that the most productive pastures in the worm trials had up to 7 million worms per hectare, weighing 2.4 tonnes. There was a close correlation between pasture productivity and total worm weight, with some 170 kg of worms for every tonne of annual dry matter production.

Due to the earthworms' positive effect on soil health it is not surprising that research has been conducted to introduce worms to soil with low densities. The most successful that I witnessed was achieved by cutting pasture sods from areas with high worm populations and transferring them to worm-free areas. The new colonies established themselves within 2 years provided there was plenty of organic matter and soil and climatic conditions are favourable. However, as yet this practice is uneconomical.

It is however surprising how quickly they build up in favourable conditions. The favourable conditions that worm require are:

pH

Earthworms do not like acid soils with pH less than 4.5. The addition of lime raises pH and also adds calcium. Earthworms need a continuous supply of calcium, so are absent in soils low in this element. (South Australian research found that earthworm numbers doubled when pH rose from 4.1 to 6.7)

Increase organic matter

Earthworms feed on soil and dead or decaying plant remains, including straw, leaf litter and dead roots. They are the principal agents in mixing dead surface litter with the soil, making the litter more accessible to decomposition by soil microorganisms. Animal dung is also an attractive food for many species of earthworms.

The following farming practices provide food for earthworms:

Permanent pasture*:* Permanent pasture provides organic matter as leaves and roots die and decay. Unutilised pasture and manure from grazing animals are also good sources of organic matter in pasture.

Green manure crops: Green manure crops are fodder crops turned into the soil to provide organic matter to benefit the following crop. The crops are grazed or slashed, sometimes pulverised, and then left on the surface or turned into the soil.

Crop stubble: Stubble is an important source of organic matter. Burning stubble destroys surface organic matter, and this affects worm numbers. It is best to leave stubble to rot down, and sow following crops into the stubble using aerial sowing, direct drill or (at least) minimum tillage. All these techniques mean less cultivation, and this also encourages earthworms.

Rotations: Rotating pasture with crops helps build up organic matter levels and earthworm numbers.

- Reduce use of some fertilisers and fungicides.
- Highly acidifying fertilisers such as ammonium sulphate and some fungicides reduce worm numbers.
- Keep soil moist.
- Worms can lose 20% of their body weight each day in mucus and castings, so they need moisture to stay alive. Groundcover such as pasture or stubble reduces moisture evaporation. Decaying organic matter (humus) holds moisture in the soil. In dry times some species burrow deep into the soil and are inactive until rain 'reactivates' them.
- Improve drainage.
- Worms need reasonably aerated soil, so you may need to drain or mound soil in wetter areas to prevent water-logging.
- Reduce soil compaction.
- It is difficult for earthworms to move through heavily compacted soil, so keep vehicle and animal traffic to a minimum in wet conditions.
- Reduce cultivation.
- Ploughing soil reduces earthworm numbers. Researchers have found that after four years, zero-tilled paddocks had twice as many worms as cultivated soils. However, shallow cultivation may not affect worm numbers.
- Protect from climatic extremes

Earthworms are intolerant of drought and frost, and do not like dry sandy soils. They are active only when the soil is moist, and are inactive when it is dry. Organic matter cover helps reduce the effect of climatic extremes, and retains soil moisture.

6.6. Effective hectares.

The effective hectarage of a grazing platform constitutes the total farm area minus the areas occupied by roads, buildings, wasteland, and rough grazing expressed in terms of its pasture equivalent. Therefore maximising the effective hectares on a grazing platform can significantly increase output and capital appreciation.

Many pastures in the UK have poor growth areas within them - such as rock outcrops, stone piles, derelict buildings etc. These can be recycled into effective infrastructure (e.g. livestock tracks), whilst removing them from a pasture increases the potential output of that area.

Photograph 5. Increasing effective hecs at Manuka, Chile, where land improvements are allowing 7 new dairy farms to be established per annum.

6.7. Precision farming

Precision farming is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops.

These concepts are being continually developed in the cereals sectors to drive efficient use of inputs, machinery and labour. However, much of the technology is transferable to the grass based sectors.

During the course of my study I saw precision testing and applications of FYM and fertilisers during application, varied seed rate trials and inter row fertiliser application. Currently many of these technologies are either not available commercially or are prohibitively expensive in grass based scenarios.

However, GPS soil testing and variable rate application of lime, P and K on variable soils can provide a solution which can increase production and reduce costs.

Auto steer on machinery comes at a variety of different levels and can also be useful and cost effective for the application of inputs plus controlled traffic systems to reduce machinery compaction.

There are now a multitude of software solutions to enable grass based livestock farmers fingertip access for pasture planning, budgeting and comparisons. Many of these are an excellent tool to assist in improving grass utilisation and target improvement areas.

6.8. Acidification of slurry.

In Denmark, I witnessed the addition of concentrated sulphuric acid (96% H_2SO_4) for the acidification of slurry to stop the volatilisation of ammonia and the loss of N. The total reduction in gaseous losses of ammonia from the buildings, storage and the field equals 29 kg N/ha.

The use of acidification ensures that the majority of nitrogen in the slurry is retained in the form of ammonium (NH_4^+), instead of ammonia (NH_3), which can volatilise. Lowering the pH is very effective for this, since at a pH of 6.0 ammonia losses are minimal.

Odour nuisances from livestock buildings and slurry after application can also be expected to decline. In addition, there are expectations of improved well-being and health of livestock and a better working environment in livestock buildings.

It is being used increasingly in Denmark for environmental approval of livestock housing.

Photograph 6. Acidification of slurry in Denmark, 2013.

7.0. Step 2: Grow livestock.

"We begin by growing as much grass as we can, ***then we turn most of that grass into milk".*** *Colin Armour, CEO Armer Holdings.*

Colin Armour is a dairy farmer, but it doesn't matter if it's milk, beef, lamb or venison that's the end product. The key is to turn as much as possible of the grass that we grow into animal protein. To do that we need a cost effective animal management programme which means reducing animal wastage and maximising herd/flock growth.

There are 4 main factors that influence livestock performance:

- Intakes
- Nutritional value of feed
- Animal Health and
- Animal Genetics

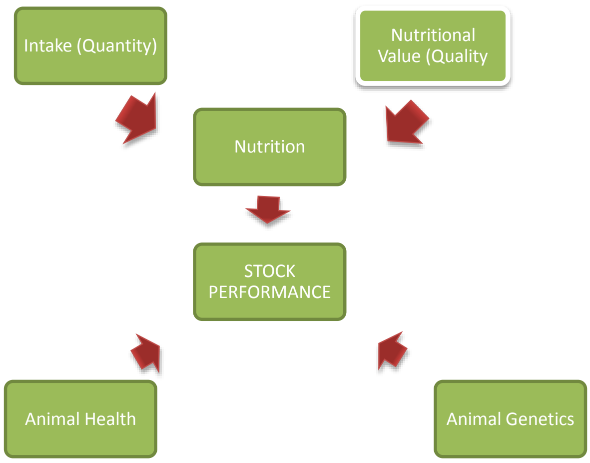


Diagram 3. Factors affecting stock performance.

7.1. Intake and nutritional value.

Pasture intake and nutritive value have a major effect on liveweight gain, milk and fibre production, as well as livestock health and reproductive performance.

The potential feed intake of animals is determined by physiological state (e.g. pregnancy, lactation, sex) and genetics, whilst the animals' health and the feed offered determine whether the potential is reached.

Intake is primarily influenced by the amount of pasture offered and the quality of that pasture.

7.1.i. Quantity

Grazing animals generally select a diet of higher quality than the average of the pasture offered. The preference of animals for particular components, and their accessibility in the pasture, governs selection.

However, the more that is offered, the more that they can potentially harvest. This has to be balanced by the need to keep pasture quality high, ensure good regrowth and maintain economic stocking rates.

The perceived maximum amount of pasture DM that livestock can consume can be increased through:

- **Premowing**
  Premowing pasture effectively increases the DM of the pasture on offer allowing the livestock to consume more. This also has the added advantage of rejuvenating a pasture and minimising pasture rejection through previous faecal contamination.
- **Frequent moves**
  Either by subdividing fences or moving to a new area, it stimulates the animals' appetite and can increase intakes by up to 3.5%.

7.1.i. Quality

The quality or palatability of a pasture can be described as the readiness with which animals consume it. Therefore intake is also influenced by pasture quality.

This is because herbage of low nutritive value moves more slowly through the animal's digestive tract which physically restricts their intake. Pastures that have a high nutritive value contain more useful energy per unit of DM. An animal will also eat more when pasture quality is high. Animals therefore have a higher intake on high quality pasture, and the energy is used more efficiently, getting closer to the potential intake and performance.

Knowing the relationships between a pasture and its nutritive value gives an understanding of the importance of botanical (plant species) and structural (stem versus leaf, dead versus green) makeup, and how to use this information to assess the nutritive value of a pasture. Nutritive value has a direct effect on feed intake, but other factors such as legume content and the amount of stem and dead matter also affect intake because livestock will consume the more attractive parts of a pasture.

7.2. Animal health.

Animal health often refers to disease status but it is of primal importance that an animal is in the correct physiological position to display the full potential of its genetics.

The Livestock Improvement Company (LIC) has developed a “Six Week Challenge”. In block calving herds, the 6 week in-calf rate measures performance during the all-important first two rounds of mating.

They have identified it as the best measure of overall herd reproductive performance. A herd or flock’s submission rate and conception rates are key drivers of that success at mating time. In fact, it comes down to one simple equation: Submission rate x Conception rate = In-calf rate.

In grass based livestock it is essential for sustainability that they have offspring once a year. Getting livestock pregnant quickly so they parturate quickly is a foundation principle of seasonal farming.

For cattle, it’s like a race against time. With 282 days of the year spent being pregnant, they only have 83 days between calving and mating. Earlier calving leads to earlier recovery, cycling, and more chances to conceive - which means more cows in-calf earlier and less herd wastage.

Genetics certainly play a critical role in cow fertility, but it is the year round herd management practices which have the biggest impact. It takes a whole-farm approach to effectively manage a herd’s reproductive performance and increase a 6 week in-calf rate.

The 6-weeks challenge helps farmers to apply a whole-farm, 365 day approach to managing herd reproductive performance, and focus on the eight key management areas that affect herd reproductive performance:

7.2.i. Calving pattern

Understanding the current calving pattern and where cows calve in it, is critical to evaluating where the herd is currently positioned in terms of its reproductive performance.

Tightening up the calving pattern brings other advantages such as peak workloads allowing labour focus, equally-aged batches of calves for management, and a larger number of heifers born at the start of calving; to supply future replacements which therefore have longer to reach target weights.

7.2.ii. Heifer management.

Young stock must achieve target weight for age. Target weights for your young stock should be relative to the weight that they will grow to as mature cows. They need to achieve 30% of mature live-weight at six months of age, 40% at nine months, 60% of mature liveweight at 15 months, and 90% of mature liveweight at 22 months.

(Heifers) need to achieve 30% of mature live-weight at six months of age

Dairy NZ research has shown that not only does achieving targets minimise the incidence of non-cycling heifers at mating, it increases production at all future lactations plus reduces herd wastage. This is especially true in the first lactation where heifers’ energy balance can be improved and they will achieve better conception rates.

This research showed that for every additional kg a heifer at 22 months of age gained, if she was within her target weight of 80-90% of her mature liveweight, she will produce an additional 0.25 kg/MS (3.1 litres at 8% MS) in her first lactation.

Photograph 7. 4000 R2 Heifers at Tower Peak in New Zealand. 99.6% achieve target bulling weights/annum.

7.2.iii. Body condition and nutrition

A cow's body condition score (BCS) provides a reasonably accurate measure of her energy reserves, and BCS targets at key stages of lactation have been identified to optimise production systems.

BCS have quantified the recognised effects on dry matter intake, milk production, reproduction, and cow health and welfare. In addition, there was evidence that BCS in early lactation can affect the sex of future calves and the productive and reproductive capacity of heifers yet to be born.

Irrespective of the system of farming cow genetics, or the country where the research was undertaken, productivity was optimised when mature cows calved between BCS 5.0 and 6.0, NZ Body Condition Score, UK equivalent 3) and when first and second calvers were 0.5 BCS units fatter than mature cows.

However, the productivity benefit declined with increasing BCS and the risk of metabolic health disorders at calving was greater, such that increasing BCS beyond 5.0 in mature cows and 5.5 in first and second calvers cannot be justified economically or from an animal welfare perspective.

It is important to realise that the recommended calving BCS targets are a compromise between wanting cows with sufficient energy reserves for milk production, while not being so fat as to compromise cow health.

It should be remembered that even with exceptional feeding, cows rarely gain more than 0.5 BCS units in a month. Cows do not gain BCS in the month before calving because so much energy is required for pregnancy (approximately 60% of the energy needed for pregnancy is required in the last month before calving, equating to approximately 4-5 kg DM/cow/day.)

The average loss of BCS in early lactation should not be more than 1.0 BCS unit, because greater average losses indicate that too many cows have lost 1.5 or more BCS units.

BCS Targets

Mature cows
Calve at a BCS of 5.0, with: - not more than 15% of herd less than BCS 5.0, and not more than 15% of herd greater than BCS 5.5.
In farm systems using low levels of supplementary feed (<500 kg DM/cow), mature cows should be BCS 4.0 at least 100 days before calving.

Second calvers (rising three-year-olds)
Should calve at a BCS of 5.5 and have a BCS of 5.0 by 60 days before calving.

First calvers (rising two-year-old heifers)
Should calve at BCS of 5.5 and have this achieved 60 days pre calving.

7.2.iv. Heat detection

Accurate heat detection is critical to the success of AI. Pre- breeding heat detection should be used to identify non cycling cows.

7.2.v. Dealing with non-cyclers

There are various programmes and techniques designed to deal with these. Undoubtedly, all are short term measures and once a herd is established with the correct management and genetics these cease to be an issue.

However, non cycling cows must be examined and treated pre the start of the breeding season. Protocols and procedures should be set up with a vet.

7.2.vi. Artificial breeding practices

If you are using DIY AI it is best practice to take a refresher course every 2/3 years.

7.2.vii. Bull management

Bulls should be checked annually - physiologically and semen tested. One bull is required per 40 cows not in calf.

7.2.viii. Cow health

7.2.viii.1 Minerals

Ruminants require minerals for normal function. The amount available to the animal is influenced by many factors. These include the levels in pasture, the diet selected, the rate of pasture intake, the amount of soil eaten, the efficiency of absorption from the digestive tract, and interactions with other minerals in the digestive tract.

Minerals that are present in very small amounts are known as "trace" elements. Common trace element deficiencies in UK livestock include selenium, cobalt, copper (often related to high molybdenum and sulphur levels), and iodine.

Vitamin levels in fresh herbage are generally adequate for grazing livestock in the UK. Rumen microbes synthesise vitamin B12 using cobalt in the diet; thus low cobalt availability can lead to vitamin B12 deficiency.

If mineral deficiencies are suspected, pastures should be tested and expert advice sought.

7.2.viii.2. Parasites

Internal parasites have two effects on the growth of young animals. Firstly, the presence of parasite larvae on the pasture eaten causes the animal to mount an immune response that uses energy and protein. Secondly, parasitised animals have a depressed appetite, increased maintenance energy and protein requirements, and impaired protein and mineral nutrition.

Nutritional options to manage parasite burdens include providing high quality pasture or using tannin-containing plants (e.g. chicory). Management techniques that reduce the level of parasite larvae on the pasture, and use of anthelmintics are commonly key parts of parasite management programmes.

Care must be taken with parasite management programmes as anthelmintic resistance is and will become an increasing challenge within the livestock sector unless farmers act responsibly now.

7.2.viii.3. Disease.

As with parasites, disease has two effects on the performance of livestock.

Firstly, the presence of a disease challenge can cause the animal to mount an immune response that uses energy and protein.

Secondly, diseased animals have a depressed appetite, increased maintenance energy and protein requirements, and impaired protein and mineral nutrition.

There are a wide range of diseases in grazing livestock and a comprehensive health plan should be formulated and reviewed with a veterinary. The plan needs to analyse risk to plan isolation, control or eradication procedures.

Whilst the LIC programme is obviously designed for dairy cattle, the procedures and gains through achieving targets are equally relevant to other grass based livestock.

7.3. Animal genetics.

As the industry has increasingly focused on output - whether it be litres of milk or growth rates generally - fertility has declined, increasing herd wastage and decreasing the possibilities of herd/flock growth.

Breeding goals in UK grass based livestock systems show significantly more variation than in any other country I visited. This is due to numerous reasons including the high levels of mixed farmed units, wide range of breeds, the value placed on aesthetic traits for the show ring and high levels of non farming income being invested in breeding stock.

Today's livestock farmers are fortunate to have additional tools to aid selection of stock that our grandfathers did not have. These do not replace good stockmanship but they undoubtedly can increase the rate of improvement of a herd/flock and improve the consistency of stock selection.

To improve the sustainability of a herd/flock, we must consider how we can improve its feed efficiency. Grass based livestock is very far behind pig and poultry sectors. Recent US research into grass based livestock has shown a 25% variation in animal to animal performance (*Dr Sinclair Mayne).*

Grass based livestock is very far behind pig and poultry sectors in feed efficiency

An example of this is two cows with the same output weighing 500 and 600 kg. The cow that weighs 600 kg will eat 340 kg additional feed/annum to maintain her body (*Dairy NZ).*

It is interesting to compare the potential species output/kg of DM grass consumed. In the model below I have used a 500 kg dairy cow producing 500 kg MS vs a 600 kg beef cow producing a calf at 620 kg calf at a year old and a 70 kg ewe producing 40 kg twins.

Livestock	kg DM/year	Produces	Product	Output £/kg	Total £	Depreciation	£/kg DM
500kg Dairy Cow	4750	500 Kg/MS + Calf	kg MS	4.13	2112.5	225	0.40
600 kg Beef Cow	5090	365	kg beef	3.70	1350.5	91.67	0.25
70 kg Ewe	500	36.8	kg Lamb	3.60	132.48	16.25	0.23

Table 12. Comparative species potential efficiency on grass based systems. *C.Russell 2014.*

This shows the relative inefficiency of red meat production when compared against milk production from grass. Thankfully rapid progress on feed efficiency is being made globally and this is happening commercially through three channels.

7.3.i. Estimated breeding values (EBVs)

Estimated Breeding Values are a modern genetic evaluation programme for livestock farmers comparing and predicting the genetic merit of individual animals on the basis of their potential breeding worth.

These values are provided internationally by numerous suppliers and can be used by livestock farmers to assist in selection decisions and purchase of breeding stock. EBVs are now accepted by the majority of the developed world's livestock producers as an essential tool in the breeding and marketing of breeding stock and increasingly for store and fat animals.

The EBVs are based on all available pedigree and performance records provided by breeders across the globe. These allow the best means for comparison of the relative genetic merit of animals across a breed for those traits included in the analysis. It is essential that EBVs are not used in isolation for any selection or purchase decision. Visual assessment by experienced stockpersons is still necessary for those characteristics not adequately described by EBVs. (eg structural soundness and locomotion)

Accuracy remains an issue in countries which have not wholeheartedly adopted the use of EBVs. Unfortunately, the information calculated can only be as good as what is available. Breeders who manipulate captured data are limiting the potential progression of their herd/flock, damaging other breeders' livestock and should be expelled from whatever breed society they belong to.

Genetic gain is powerful and … the additional returns on investment are far greater than the extra production costs.

Genetics are exceptionally powerful and it is essential that breeding goals are selected carefully to deliver the expected outcome for the location. For example, on extensive hard hill sheep farms, a breeding goal may be to have 1.4 lambs weaned at 30kg plus. For that we need to select for high fertility and fast growth rate. However, on lowland flocks the focus is on weaning weights and meat yield.

Genetic gain is powerful and the gains made in year one are built on year upon year, so the additional returns on investment are far greater than the extra production costs. The right sires in a farming system have the ability to boost the profitability considerably.

However these benefits of genetic gain don't just benefit the farmer. They flow along the entire value chain – from producer to consumer.

It is quite staggering that in the relatively short time since 1990 New Zealand sheep numbers have halved to 20.4 million breeding ewes *(Beef and Lamb NZ 2013)*. Improved genetics, combining with better feeding and on-farm management, have ensured that exports of sheep meat are only seven per cent less than at that time.

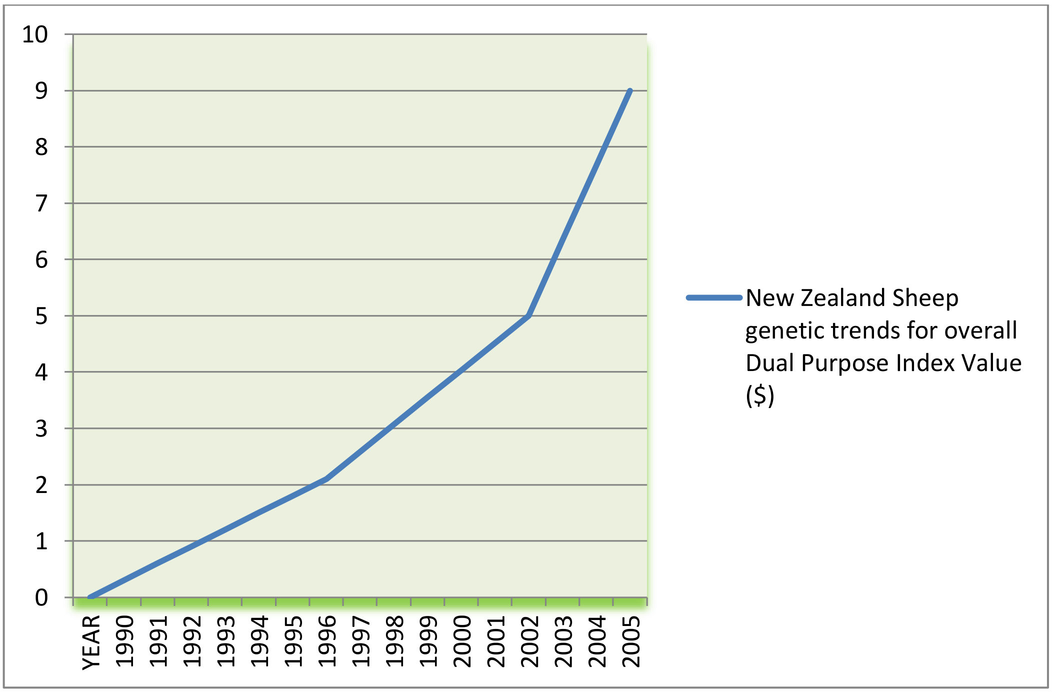
This impressive level of productivity improvement would not have been achieved without the investment into research and science.

7.3.ii. Central progeny testing.

With central progeny testing individual male animals are brought to a central location where genetic merit can be established by comparing the performance of the animals under the same conditions.

The test compares the terminally bred animals using a growth index (calculated from weaning and carcass weight breeding values) and a meat value index (derived using VIAscan predictions of the meat in the loin, leg and shoulder).

This data produces breeding values more suited to the current yield-based grading systems and genetic connections between breeds and breed groups have enabled across-flock and across-breed analysis to be run. This allows direct comparisons on individuals in different breeds.



Graph 3. New Zealand sheep genetic trends for overall dual purpose index value ($) (*Beef and Lamb NZ)*

Graph 3 of the New Zealand national genetic trends for overall dual purpose indexes show two significant points of increase in genetic gain. In 1996 Sheep Improvement Limited (SIL) was established which provides EBVs for the New Zealand sheep flock. This had an immediate impact by increasing indices by an average of just under $0.5/annum. In 2002 Central Progeny Test was established and again immediately impacted on the rate of improvement. It is impossible to say how much of the increase in index value from 2002 onwards is directly due to the Central Progeny Test and how much is due to other initiatives undertaken in this period.

However, it can be concluded that the Central Progeny Test has stimulated a lot of interest in sire referencing and progeny testing which indirectly benefits genetic improvement in industry.

Photograph 8. Hereford bulls at the Central Progeny Test Station of Kiyu, Central du Prueba, Uruguay.

7.3.iii. Genomics.

Genomic selection is actively available within the plant breeding and dairy industries. It is achieved by selecting individuals based on the profile of their DNA rather than waiting to access performance data of their offspring.

The real advantage of genomic selection is that it allows farmers to access the most advanced genetics years earlier by shortening the generation interval and reducing costs. It is this ongoing increase in the rate of genetic gain that makes genomic selection the most significant development in dairy genetics since artificial insemination began more than 50 years ago.

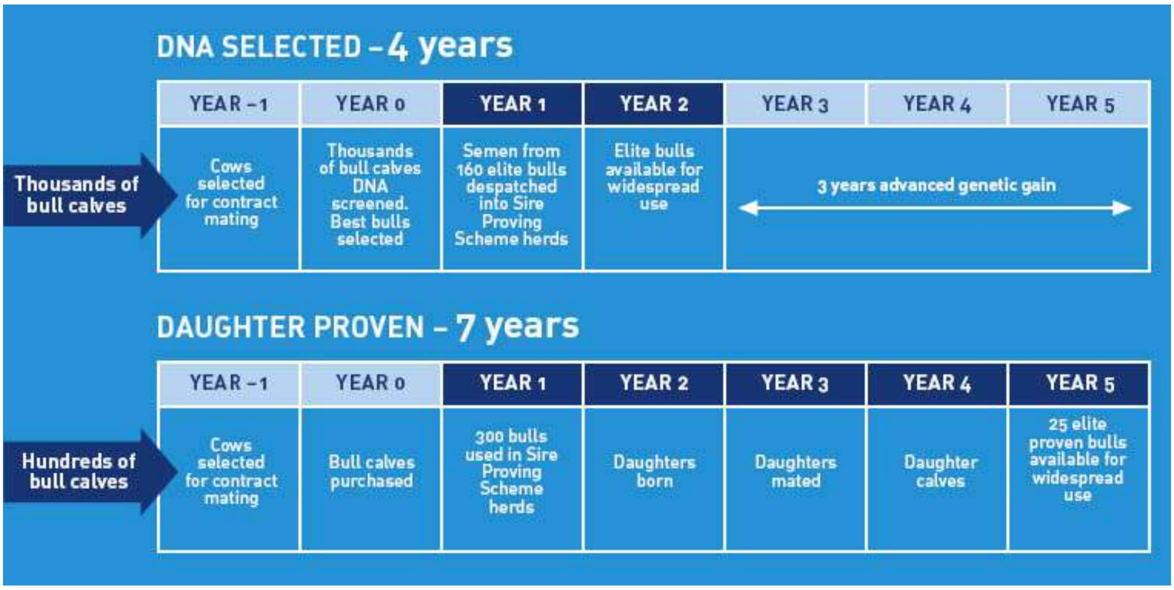


Diagram 4. Diagram depicting the time difference to produce elite bulls through genomic and daughter proven selection. (*LIC, NZ)*

As can be seen from Diagram 4, the process results in a generation interval that's shorter by up to three years.

7.3.iv. Cross breeding

Cross breeding has been utilised in the pig and poultry industries over past *decades* with huge impact. An ever increasing diluted version has become the norm within commercial sucker herds and sheep flocks in the UK.

The two primary reasons for cross breeding are:

1. to introduce favourable genes from another breed that strongly demonstrates specific traits of interest.

   To deliver this, the breed that is being introduced must be of superior genetic merit for this trait and the trait must be heritable.

2. to capitalise on what is known as hybrid vigour or heterosis.

This is the phenomenon which occurs when the animals being crossed are particularly different in a particular gene, resulting in synergies that means the offspring will perform better for certain traits than what would be expected from the average of its parents. However, this alone will not guarantee the success of a cross breeding programme. Particular attention must be paid to additive genetic differences which will have particular relevance in the first cross. In the vast majority of cases the overall success of a cross breeding programme will result from this additive genetic difference for a variety of different traits that sires and dams transmit to their offspring to produce a long term genetic gain.

Estimates into the benefits of hybrid vigour vary considerably depending on the trait being examined and the genetic difference between the breeds being crossbred. Rather surprisingly hybrid vigour will generally be higher in traits with lower heritability (e.g. health, fertility and ability to maintain body condition). For example in New Zealand the 50:50 (Friesian:Jersey) Kiwi X dairy cow survives 227 days longer than the average of its parents. The sheer scale of this improvement is highlighted by the fact that the current rate of genetic gain for longevity is 9.5 days per year and therefore to get that level of impact through selection alone will take 24 years with cows bred pure.

This has been backed up by numerous studies in the northern hemisphere, including performance data generated through Moorepark's large on-farm study on over 10,000 matings. The study demonstrated that the crossbred animals in this case, by introducing Norwegian Red, are capable of production levels equal to or greater than their Holstein Friesian herd mates on a low cost system (production + 10%). It also showed impressive increases in fertility and survival levels (6 week in calf rates +10%) .

Economic analysis using the data generated in the Moorepark on-farm trial highlighted a substantial profit benefit per lactation with the crossbred cows.

	Breed Group				
	Holstein Friesian (HF)	Jersey (J)	JxHF	Norwegian Red (NR)	NRXHF
Annual Milk Yield (kg)	543916	480087	510032	542073	555302
No. Of Cows	96.3	113.8	96.7	98.6	95.9
Land Area	40	40	40	40	40
Stocking Rate (LU/hec)	2.28	2.7	2.34	2.38	3.32
Milk Price (c/l)	30.68	38.12	35.47	30.52	30.52
Labour Cost (Euros)	27760	32811	28463	29005	28230
Concentrate cost (Euros)	5953	7037	6442	6564	6389
Livestock Sales (Euros)	28675	22296	21674	26097	26401
Replacement Costs (Euros)	38904	45982	26935	27447	26715
Total Costs (Euros)	149852	167089	137786	139708	137268
Milk Price 27 c/l					
Milk returns	158675	172816	171790	157226	161223
Profit / Kg Milk Solids (Euros)	0.92	0.65	1.29	1.09	1.23
Profit/ha (Euros)	938	711	1392	1090	1259
Profit/farm (Euros)	37499	28423	55678	43615	50356

Table 13. Physical and financial components of cross bred trial on 40 ha farm. *Teagasc.*

The difference in performance over the three year trial significantly equated to over €18,000 with Jersey X Holstein Friesian (a 48% lift in profit/€180/cow) and €12,000 for the Norwegian Red X Holstein Friesian herds (a 34% lift in profit/ €130/cow) on the 40 ha farms with a base milk price of 27 c/l.

The analysis was extremely detailed taking into account variations in production, mature weights, replacement rates, cull cow values, male calf values, vet and med, rearing costs and labour.

The improved profitability is primarily attributable to improvements in milk solid production and large differences in reproductive efficiency and longevity observed in cross bred herds. The performance of the Norwegian Red X Holstein Friesian is generally what would be expected if Holstein Friesian cows had similar fertility and longevity as the Jersey x Holstein Friesian.

Photograph 9. Luing cattle (75% Beef Shorthorn, 25% Highland) Glenapp 2014

Whilst production gains in beef and sheep trials are not as transparent, similar lift in profitability has been observed in beef cattle and in sheep.

8.0. Step 3:Grow productivity.

*“**Create demand on grass growth but never supply.** Arthur Bryon.*

When soil fertility has been optimised, and aggressive grazing animals - bred for purpose that harvest the pasture and deliver efficiently produced proteins - are on site, it is time to grow productivity. Attempting to further increase productivity of grassland swards without optimal fertility or the correct livestock will reduce the sustainability of the enterprise.

Livestock adds value to grass by turning it into human edible protein. It is entirely possible to grow over 14t DM for every hectare of rotational grassland and utilise 85% of it, but in the UK the average is about a third of that. By carefully stocking the farms and developing a grazing plan we can substantially increase the % utilised.

Good grazing management is based on keeping the ryegrass plant leafy and actively growing whilst matching grass supply to livestock needs. This delivers many benefits including:

- Optimal use of grass and increased livestock output per hectare (ha)
- Swards dominated by sown species and fewer weed grasses
- Improved self-sufficiency/reduced reliance on bought in supplementary feed
- Better use of fertilisers and manures
- Lower farm carbon footprint
- Improved animal health

Good grazing systems match livestock needs to grass growth. As grass growth and stock needs vary, measuring grass and adjusting the grazing area and/or stock numbers and supplementary feed throughout the season is essential for efficient grazing management. The two basic grazing systems used are continuous or rotational grazing.

8.1. Continuous grazing

Continuous grazing is where the livestock have access to a large area for most of the grazing season. Swards are monitored and when growth exceeds the target guidelines a percentage of the area is shut up for winter feed production either as conservation or a forage crop. Whilst continuous grazing or letting the animals have access to as big an area as possible can have advantages, such as reducing mis-mothering at lambing time, it does limit production of pasture and livestock.

Pasture production is limited through *“the continual removal of the plants’ solar panels”. (John Bailey 2014).* For optimal grass production the ryegrass plant should be allow to regrow to 3 leaves with regrowth starting after 24 hours from grazing. Grass that is continually overgrazed will develop root thatch impeding its ability to uptake nutrients, legumes’ nitrogen fixing ability will be reduced, whilst the soil will be drained of fertility. The animals graze in a parasite bath and it is completely unsuited to the inclusion of chicory or red clover in the sward.

8.2. Rotational grazing

Rotational grazing is not a new concept. Nature and evolution spent several million years getting this model correct.

Photograph 10. The migration, Tanzania.

The principle is to set up a grazing platform so that it can model the migratory potential offered by scaleless nature. This unlocks the potential stocking capacity with a paddock layout that allows flexible rotation lengths to manage livestock at the non or reduced growth periods and to maximum utilisation in the high DM production periods.

To do this generally fields are split into a number of paddocks using electric fences, and stock graze them in turn for anything between 0.5 to 7 days depending upon the species of livestock and system adopted. The speed of rotation (the speed of movement through the paddocks) is based on monitoring sward growth.

Paddocks are grazed when the sward reaches the pre-graze target measurement - ideally 3000kgDM/ha, but between the two and three leaf stage: at the three-leaf stage, if short of feed, and at the two-leaf stage if there is plenty of feed. Livestock are removed when the sward is grazed down to post graze target measurement (1500 kgDM/ha).

The paddock is then allowed to rest and re-grow. The time this takes varies depending on the time of year and speed of re-growth and can range from 14 days in spring to over 100 days in winter. Paddocks are taken out of the grazing area when growth exceeds livestock needs and utilised for winter feed production (conservation or fodder crops.)

Research by Teagsac and Dairy NZ has shown that 12-hour shifts can increase grass production by 34 %, 24 hours shifts by 22 %, and 48 hour shifts by 14 %, over continuous grazing (conventional set stocking).

By maximising grass production, then getting the livestock to utilise as much of that grass as possible, livestock farmers can make a staggering difference to their annual income.

Farm Type	Grass Grown (t DM/Ha)	Utilisa-tion (%)	Grass Utilsed (t/ha)	Conver-sion (kg)	kg of	Total kg	£/kg	Total (£)	increa se (%)
Dairy	14	50	7	67	Milk Solids	469	4.5	2110.50	
Dairy	14	85	11.9	67	Milk Solids	797.3	4.5	3587.85	70%
Beef	14	50	7	37.5	Beef	262.5	3.5	918.75	
Beef	14	85	11.9	37.5	Beef	446.25	3.5	1561.875	70%
Sheep	14	50	7	53	Lamb	371	3.8	1409.80	
Sheep	14	85	11.9	53	Lamb	630.7	3.8	2396.66	70%

Table 14. The effect of increasing pasture utilisation on income

Table 14 shows that by increasing pasture utilisation by 35% - from 50 to 85% - it is possible to increase farm income by 70%. This obviously has a major impact on profitability as the costs to grow this grass are already being incurred.

Twelve hour shifts also show a lift in animal productivity over 24 hour shifts. INIA research in Uruguay discovered that 3.5 % of a beef animal's live weight can be allocated and harvested on 12 hour breaks (equals 7% in 24 hours), whilst only 6 % on 24 hours.

Dr Arthur Bryant's research in 1974 showed that increasing the rotation length by delaying grazing by 5 days or half a leaf stage could increase DM production by 1tDM/ha - or 5%/annum - whilst ME density was reduced by just 0.3 MJ (ME/kg DM) or 2.5%.

8.2.i. Cell grazing/ Technograzing.

Cell grazing is effectively intensive rotational grazing with livestock grazing small paddock (0.1 ha) cells for 0.5 to 1 day at maximum, with high stocking densities to match the grass available. It promotes more even grazing and reduces the number of livestock tracks and preferred resting areas. It can be particularly useful with fattening cattle and is used extremely effectively to fatten dairy bulls at pasture in New Zealand.

Where cells are used in winter, in conjunction with deferred grazing the system has been named "All Winter Grazing"

8.2.ii. Leader-follower (forward creep) grazing.

Leader-follower livestock grazing is a form of rotational grazing where a number of paddocks are grazed in turn with older or less productive stock following younger or more productive stock. This allows the productive livestock to graze the best quality grass ahead of the older stock. It is always essential to monitor the follower group to check their performance is not being compromised.

9.0. Step 4: Growing the business.

It makes economic sense to fund improvements immediately to increase the fertility of the land rather than relying on an under-performing farm to progressively fund a series of “drip-drip” improvement projects.

Colin and Dale Armour, in less than 23 years, have moved from being farm labourers; to share milkers running 150 cows; to farm investors owning and running 11 farms with 10,000 cows in the North Island of New Zealand. They are also equity partners in Dairy Holding Limited in the South Islands which own and operate 56 farms with 55,000 cows.

the key to growing a business is “to do it with someone else’s money”.

They believe that the key to growing a business is “to do it with someone else’s money”. They are strong believers in the motivation of being in debt and consider a well-run farm will generate sufficient funds to service a mortgage, make capital repayments and provide a surplus for further expansion.

This high gearing allows them to establish farms with minimal direct investment which then quickly begins generating additional capital for expansion.

I was fortunate to meet some exceptional pasture based businessmen early in my Nuffield Farming travels. It became obvious to me that where they really differed from Mr and Mrs Average Farmer was the clarity of their joint vision and their business governance.

It has to be observed and I am convinced that it is no coincidence that many of the large business top operators had been through a huge financial or personal challenge at some point in the past. However, this had galvanised and focused them for the future.

9.1. G.R.O.W. The vision.

“*The empires of the future are empires of the mind.*” Winston Churchill.

9.1.i. Goals

An inspiring vision with up to 40 strategic possibilities is required to be written down in a “long list”.

9.1.ii. Reality

An internal and external “hard” SWOT analysis should be carried out to understand where we are now. True strengths, weaknesses, opportunities and threats that can make a real difference to your business can be quantified.

9.1.iii. Options

From our long list we want to examine the price and the payoff of the strategic possibilities and check them against our goals to make sure they still fit.

"Turning a weakness into a strength that doesn't have an impact on the profitability of the business is simply housekeeping" (Bob Lee, Barfil Management Centre)

9.1.iv. Way forward

From the options, we develop a short list of what we will do, by when and through which strategic process. It is vital to assign a project leader and review progress to ensure deliverability by the required date.

9.2. Governance

"20% of the growth of a business is based on operational performance and 80% on strategic decisions. However, you can't realise the potential of having an excellent strategy if you have not got operational performance nailed." Dennis Brosnan, ex CEO Kerry Holdings.

Governance is often seen as the domain of large corporate businesses. However, good governance can bring significant advantages to all sizes of businesses. Governance is "The system by which businesses are directed and controlled" (*Sir Adrian Cadbury).* The simplest interpretation is how the owners' vision and values are transferred and delivered within their business environment.

At the very core of good governance is better decision making. This ensures that the business delivers what the owners want. This is because the key actions leading to good governance have been addressed and they are:

1. Clarity and agreement by the owners of the values, purpose and objectives of the business.
2. Agreement on the objectives and specific actions of strategic plans for the next 3 to 5 years.
3. Agreement on annual business objectives, targets and operational plans
4. Clarity of organisational leadership with clear roles and responsibilities, and with proper delegation of the authority to fulfil that role.
5. Transparent and timely systems of accountability, reporting and benchmarking that are used to improve the performance of the business.

When good governance is adopted extra value is created because it shifts the focus of the business to wealth creation and business resilience. It speeds up decisions and actions aligned to a common purpose with the result that it delivers the goals faster. It creates an opportunity for strategic possibilities to be identified and actions agreed. It provides an opportunity for people at all levels of the business to be held accountable and given proper recognition for successful performance.

Within a family business, it creates a "safe place" for complex family business issues to be discussed and resolved; thereby separating family relationships from business relationships, and can greatly facilitate the succession process.

There is enjoyment and satisfaction from the involvement in a well-run, transparent business that delivers as desired.

The Institute of directors has identified 4 pillars that make up governance in a business:

Institute of Directors' Pillar		Governance Practices.
1	Determining purpose	i.)The practice of acting with a purpose in mind
2	Effective governance culture	ii.) The practice of holding effective governance meetings
		iii.) The practice of working with other people
		iv.) The practice of making right decisions
		v.) The practice of reflecting and learning
3	Holding account	vi.)The practice of knowing what is going on and knowing what to do about it
4	Effective compliance	vii.) The practice of managing risks effectively.

Table 15: The Seven Governance Practices.

What is very clear from looking at businesses with exceptional governance and at Table 16 below, is that good governance creates value for a business when most of the time is spent looking forward rather than back to past performance.

Richard Westlake of Westlake Governance developed the "FICKS" model (Table 16) of how effective boards should spend their time on an annual basis. This model serves any governance group well when setting up a new governance structure.

Function- FICKS		% of Board Annual Time
F	Future focus	30
I	Issues and risk	30
C	Compliance	15
K	KPI monitoring	15
S	Skills and succession	10

Table 16. FICKS model.

In farming we need to think about governance in a way that relates to a very wide range of business stages. The diagram on next page shows that governance is about standing back from the day to day operation and management of a business and taking a forward looking view of the business.

Quite simply governance is the job of the owners of the business. In the diagram they are the ones riding the bike deciding what the purpose of the business is, where the business is going and what route and challenges it will face.

They must assess the operational and management wheels to ask if they are strong enough for the challenges they see.

The owners must objectively assess the frame (business structure) and gearing (financial) to ensure they are suitable. Concurrently they must be judging their progress towards their destination and against others to see if they can get there faster.

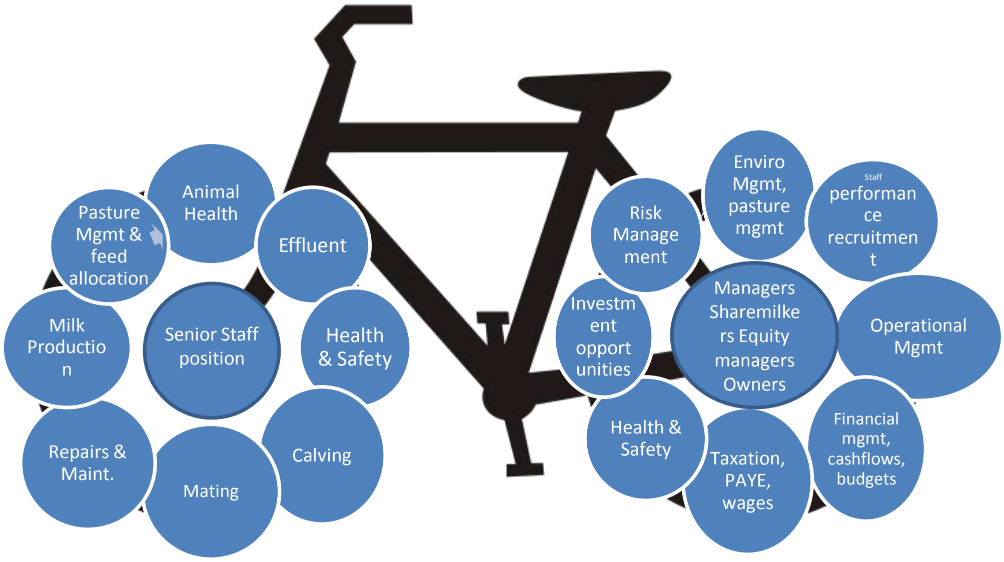


Diagram 5. Operation and management wheels of a business
Adrian Van Bysterveldt, 2014

Finally, the diagram should remind us that, as in business, there are two ways to control a bike; leaning the whole bike or turning the handlebars. A business is controlled through the culture that is promoted and established, combined with any formal governance structures in use.

A business is controlled through the culture that is promoted and established, combined with any formal governance structures in use.

The six steps to set up governance in any business are:

1. Write a clear written statement of the purpose and objectives of your business.
2. Share this with family and other stakeholders.
3. Build plans to steer the business towards achieving the agreed purpose and objectives of the business.
4. Have clear roles and responsibilities with proper delegation of authority.
5. Monitor and benchmark business performance.
6. Seek advice from trusted sources.

9.3. Expansion

As farmers look forward with a reformed Common Agricultural Policy, the abolition of quotas and increasing efficiencies with global transport networks, expansion is often deemed as the "silver bullet".

Nobody wants to admit that they are average. Nonetheless, the fact remains that 50% of UK farmers are performing at worse than average – that is what the metric 'average' means. The greatest opportunity for most, therefore, lies in improving current operating performance and not in expansion - expansion of a poorly-performing business could be disastrous. Once operating performance is good, expansion becomes a viable option. However, there must be 'skill before scale'.

Farming businesses will need to be resilient to withstand the environment of the future. The storage and delayed selling of commodities in the EU and the US, in the past created stable prices. With the removal of these storage vehicles, prices have fluctuated by up to 100% over the last four years alone. In addition to this, energy price and supplement price volatility has led to large swings in the price of inputs. For example, the average price of corn in the US prior to 2006 was US$130/t. This increased to over US$200/t during 2007-08 and was between US$300-400/t in 2012. Here in UK, concentrate prices have increased by more than 100% over the last decade.

This level of volatility will continue in the future and the farm business must be able to weather the bad years while taking advantage of the good years.

"Failing to plan is planning to fail", Professor John Roche.

Resilience is the ability of a system to absorb and manage change. For a farm, this means:

1. It should be profitable every year and not just when prices are high.
2. It should provide an enjoyable family lifestyle, with sufficient time off for all people in the business.
3. It should be environmentally benign.
4. It should create opportunities for further training, diversification, expansion, etc.

However, only when operating performance is good does expansion becomes a viable option.

There are obvious routes to expansion through purchasing or renting additional land. The most successful livestock unit that had previously expanded that I visited never spread the debt of expansion over existing holdings to justify an investment. The expansion project had to stand on its own with current assets being used only as collateral.

We have all heard "but you only get the opportunity to buy the farm next door once in your lifetime" and up until my travels I would have agreed with that. However I have now witnessed the reality that the first time you purchase a "model farm" or "the final piece of a jigsaw" without the ability for that investment to stand up by itself, it puts considerable pressure on the whole business.

For a variety of reasons the opportunity of outright purchases or rental agreements by the existing operating business may not be the correct course of action. Expansion through contract farming opportunities or equity partnerships can be attractive.

9.3.i. Contract farming.

A contract farming agreement (CFA) is a joint venture between a landowner or occupier and a contractor. Each party provides different capital inputs, sharing the cost of variable inputs and the surplus.

For the land owner, the immediate benefit is a reduction in capital employed on the farm, as most of the machinery becomes surplus and is sold, reducing cost of production significantly. These agreements allow a farmer to reduce his physical input while still living on the farm and running the business. Some may want to release capital to pursue other business or investment ideas.

In the UK, CFAs are more flexible than traditional tenancies whereby allowing the landowner to continue trading as a farmer and allowing income and inheritance tax advantages.

The contractors can benefit from economies of scale by taking on more acres, receiving a guaranteed payment per acre with an incentive to do a good job to maximise the surplus and their overall payment.

It is important to get the terms right and agree a ratio that works across a range of performance results. This usually develops into two tiers for sharing the divisible surplus. Contract farming agreements can work well for both parties, but only if they are fair and transparent.

9.3.ii. Equity partnerships.

An equity partner is a partner in a **partnership** who is a part-owner of the **business**, and is entitled to a proportion of the distributable **profits** of the partnership.

I saw many successful examples of this in livestock farming. The most successful had a clear vision, an exit strategy and demanded time and a range of expertise from the partners. For example, individual directors would be in charge of development, operation, accounting and future strategy and would report back to frequent board meetings. Most had equal voting rights across the equity partners irrespective of their percentage ownership. This encouraged an affinity and loyalty to the business.

I did visit two equally successful examples with "silent" equity partners who contributed capital only but demanded a return. In these examples the operational partner was employed as an overseer and giving a performance-driven incentive salary. However, I also witnessed larger equity partnerships that had invested overseas in different cultures. Here operational difficulties were significant.

The larger investments with numerous equity partners distanced the owners from the business and diluted their impact and vision. Whilst knowledge gained in one country did not translate to another and cultures clashed. However, both modern sources of expansion were excellent in the right circumstances.

Expansion comes with obvious management challenges which start simply with the challenge of dealing with more of everything. However, the biggest challenge is people.

10.0. Step 5: Growing people.

Managing a team effectively and efficiently to deliver the business's vision is one of the most important and difficult steps.

Training can be just as important for the owner/manager as it can be for the rest of the team especially during a development phase of the business.

Livestock farming cannot happen without people looking after the livestock. A good business should provide a safe and stimulating environment, with sufficient time off for all people in the business and should create opportunities for further training.

Thankfully, we are all different but it is important as a manager to understand what motivates your team and respond to that. Not everyone wants to be or needs to be a leader, but the ones that do are a key to the success of sustainable livestock farming.

As technology has entered livestock farming, less and less people are required to look after the livestock and farms have become increasingly specialised. This brings issues, especially in more remote areas where much of the grazing land in the UK is situated.

1. Community shrinkage inevitably reduces services within the area, potential employment positions for other family members, and the community spirit.
2. The repetitive nature of the work increases.
3. There are less people in the community available for seasonal/large labour input days (eg shearing) and this results in long hard hours for the remaining team.
4. Less progression opportunities within the business.

These, along with the perception that agriculture is not an attractive career to work in, need to be understood and addressed to attract key staff members.

It was interesting in New Zealand and South America to see individual farmers and in some cases farming groups coming together to support or purchase what they saw as priority local services, namely the schools, shops and pubs. Farmers in these regions recognised that without these services their positions on the farms would become less attractive to prospective team members and therefore actively managed the situation to maintain them. In some cases this helped to provide employment for employees' family members, increasing their affiliation to the area and the business.

Regular team meetings are essential to share and reinforce the business vision. Individual team members must have transparent appraisals that objectively review performance and set future targets. This helps to develop an open culture within the business and an understanding of everyone's motivation.

Some team members will thrive on empowerment, which is the process of giving greater responsibility to make decisions. Empowering members of an organisation is a tremendous motivational tool because they feel that they are contributing, through their own initiative, to improving performance and achieving better results.

Managers need to understand who the key team members are and cultivate future ones. It is my understanding now that we as livestock farmers need to modernise our motivational and affiliation techniques.

We should not be afraid of sharing business success with our key personnel through additional training, bonus targets, share profit or share ownership. With the correct people and correct structure this only drives success.

Mid morning Beer and Birthday Cake to celebrate Charlie Gillespie's (Glenapp's head tractorman) 60th birthday with part of Team Glenapp

11.0. Step 6: LEAN

In 1913 Henry Ford married consistently interchangeable parts with standard work and moving conveyance to create what he called flow production. This was a truly revolutionary break from the shop practices of the American system that consisted of general-purpose machines grouped by process in car manufacturing.

The problem with Ford's system was not the flow. He was able to turn the inventories of the entire company over every three days. Rather it was his inability to provide variety. The Model T was limited to one colour and one specification so that all Model T chassis were essentially identical up through the end of production in 1926.

Within 19 years the world wanted variety and Ford seemed to lose his way. Other automakers responded to the need for many models, each with many options, but with production systems whose design and fabrication steps regressed toward process areas with much longer throughput times.

After the Second World War Toyota revisited Ford's original thinking and realised a series of simple innovations would make it possible to provide both continuity in process flow and a wide variety in product offerings.

This system shifted the focus of the manufacturing engineer from individual machines and their utilisation, to the flow of the product through the total process, and LEAN process systems were born.

Toyota through developing these principles is currently positioned to become the largest automaker in the world in terms of overall sales. Its dominant success in everything from rising sales and market shares in every global market, not to mention a clear lead in hybrid technology, stands as the strongest proof of the power of LEAN enterprise.

Lean concepts are already established within parts of the UK agricultural industry with many processors such as Arla and retailers such as Tesco utilising Lean management in their production systems.

However, livestock farming businesses can benefit from Lean processes also. Initially businesses need to identify how value is created in the business. Then they must minimise or eliminate any activity that doesn't add value, whilst sustaining a focus on continuously achieving clearly identified targets.

Undoubtedly successful/sustainable farm businesses already set production and profit targets annually to challenge the business as a whole. However, it is altogether less common for them to continuously challenge every area of production activity, year on year.

Many livestock farmers believe that, with the impacts of unpredictable weather on production, variability in the biological processes involved in production and the relatively low level of control that they have over input and output prices, they have to accept underperformance against planned targets as a fact of life.

However, continuous performance monitoring actually helps anticipate changes, so allowing managers to make decisions that will mitigate at least some of the impact of external shocks.

Livestock North West have funded a project at Clive Hall in Winsford, Cheshire, which ran for three years from April 2010. The project focused on the physical management of dairy processes ensuring that a set of tasks and communications around them were agreed with systematic and timely actions being carried out and that they resulted in the planned outcomes.

This in turn prevented escalating costs, such as those associated with breakdowns in animal health. The results showed that the Lean management framework was effective at delivering unit cost savings.

These were achieved primarily through more effective use of inputs and waste being squeezed out of the system. This delivered cost reductions of 5% and an increase in net margin from 6ppl to 9ppl between the 2011/12 and 2012/13 financial years.

This is no more complex than the standard 'Plan, Do, Check and Act' cycle (pictured in Diagram 6). However it ensures that this way of working is sustained within a production cycle and then repeated over successive production cycles.

The PDCA cycle is the principle that drives Continuous Improvement. It is the heartbeat of problem detection and resolution as it provides a framework for developing, testing and reviewing ideas.

Diagram 6. Plan Do Check Act cycle, *DairyCo and RADA*

Dr Carson of Reatheath College who carried out the research at Clive Hall suggested that there are eight characteristics that can be found in a lean operation.

1. A lean farm business sets an annual financial budget driven by a comprehensive and realistic production plan. Both top level financial and production targets are set on a monthly basis. These plans are familiar to the entire production team and monthly performance against targets is discussed every month.

2. The production plan is developed under the leadership of the manager responsible for production outcomes but it also involves the entire production team. On larger farms, individuals responsible for clearly-identified processes, such as milking, fertility or forage management, would be expected to contribute to the production planning and budget-setting process for their area. Key performance indicators (KPIs) for production management are set at this stage on a daily, weekly, monthly and annual basis as appropriate. These KPIs 'belong' to the production team.

3. The entire production team has been trained in the use of value stream maps (see Appendix 2) and is encouraged to map each process to find improvements and plan their implementation. These maps are clearly visible where the staff congregate for breaks and are working documents to aid planning and decision making; they are not production blueprints. Staff is always encouraged to contribute to discussions and grow their skills in decision making.

4. Value stream maps identify the flow of value through processes; process maps help define each process and summarise performance data. Additionally, standard operating procedures – or protocols – are agreed with the production team to define best practice for each process in light of current technical knowledge. A staff training schedule needs to be developed to ensure that process performance is less likely to be impaired by human error. Copies of these protocols need to be succinct, clear, accessible and visible to the workforce at all times.

5. All staff is responsible for monitoring and recording performance data for the processes they operate and can report on current performance to the appropriate level of management.

6. All staff is aware of the need to ensure that the farm is kept to a high standard of order and compliant with statutory and contractual obligations and all are responsible to make it happen. This not only increases labour efficiency, as no time is wasted – for example, in finding or mending tools, materials or protocols – but it also raises staff awareness of the importance of health and safety legislation, animal welfare and environmental responsibility. The same rules apply to all staff no matter how senior or junior in the business.

7. The manager is responsible for ensuring staff adheres to protocols and review process performance with the agreed regularity; he or she should encourage staff to seek to improve performance on a continuous basis. He/she does this by 'walking the farm' and observing staff. It is very important that the manager's standard checks are known to the production team – the manager is not policing the workforce but is another pair of eyes, supporting the team in achieving their planned KPIs.

8. Senior management facilitates structured continuous improvement activities – which are short term and accessible to the staff. When outside support is required he/she ensures that the right support is provided.

This process of change is referred as the 'road to lean'. This is the point at which the entire workforce engages with lean management, because that becomes the culture of the business and they are happy to be part of it. However, the DairyCo dairy lean pilot programme showed that to fully install these eight characteristics took a minimum of three years.

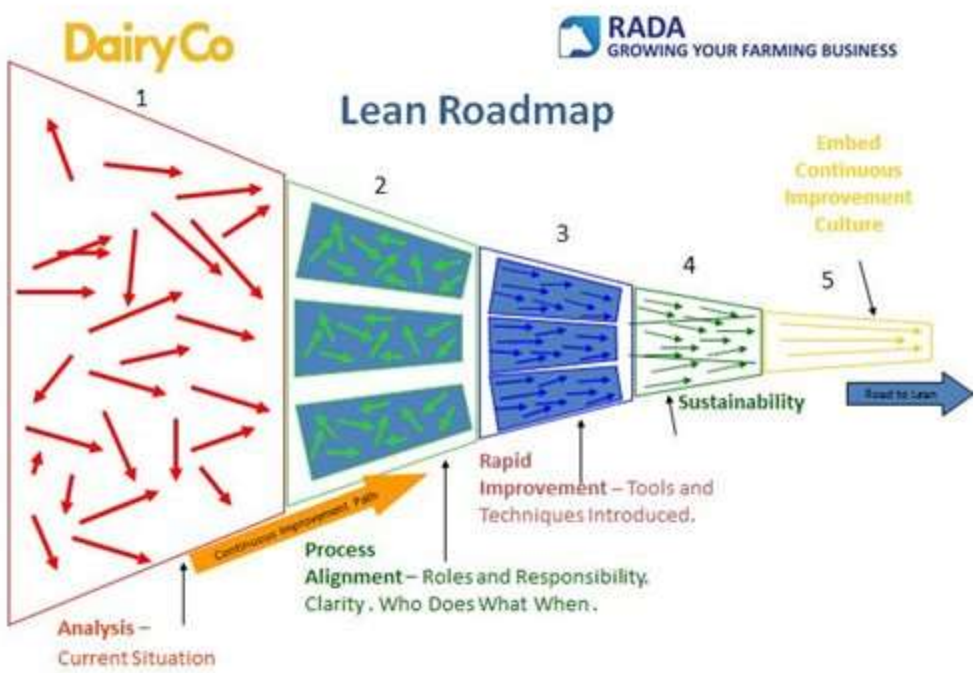


Diagram 8. Lean roadmap.*DairyCo and RADA*

Unfortunately, success was not guaranteed and the greatest success factor was the willingness of the business owners, managers and their staff to go through a process of cultural change led by the farm's senior management.

To be truly sustainable, lean management needs to be about the whole farming team (family, paid labour and external support) adopting and working towards improvements and a common goal all the time.

12.0. Conclusions

1. **The three P's; profits, people and planet.**

   True business success and sustainability is achieved through managing the triple bottom line - a process by which businesses manage their financial, social and environmental risks, obligations and opportunities.

2. **Skill before Scale.**

   Technical efficiency must be achieved prior to expansion.

3. **K.I.S.S**

   Keep It Simple Stupid. A lack of focus can easily erode enterprise margin. When technical efficiency has been achieved replication is often more rewarding than seeking to capture the final 5%.

4. **Profitability, Sustainability and Success are a choice and change is inevitable.**

5. **Change before you have to.**

   To survive the imminent changes, livestock farmers need to plan a strategy to maximise the efficiency of their business.

   Successful and sustainable pasture based livestock farmers of the future will need to adapt and engage with an evolving political arena. They will need to align their production to their consumer's demands, reduce their impact on the environment, whilst optimising the production and utilisation of grass. They will need to improve the feed efficiency of their livestock and effectively and efficiently grow the people within their business, whilst continually strengthening their enterprise to cope with increasing volatility.

13.0. Recommendations

13.1. Recommendations for farmers

1. Good governance and a clear vision are essential ingredients of a successful and sustainable business. Priority management time must be given to deliver clear strategies, which are reviewed and challenged continuously.
2. Do not underestimate the lift in performance that buy-in from your team will deliver. Time spent understanding your team members' goals and aligning them to business targets will benefit all.
3. Drive grass production through improving soil health and sward composition whilst eliminating barriers to growth as soon as possible.
4. Invest in suitable top quality genetics utilising all the tools available.
5. Ensure animals fulfill their genetic potential by achieving target weights. Clear procedures to optimize nutrition, intakes and animal must be considered.
6. Benchmark your business against a comparative top performer. Understand and erode the differences.
7. Rotationally graze pasture-based livestock. It improves profitability and animal health.
8. Proactively engage with the government with solution based proposals that will grow agriculture's contribution to the economy through GDP and job creation.
9. Work with government and conservationists to provide proposals that show agriculture's true role in conservation and how to reduce government spending long-term.

13.2. Recommendations for government

10. Continuously review designations to ensure their prescribed management is delivering the intended vision.
11. Target future potential funding streams towards sustainable projects with a particular emphasis on soil health. This will increase livestock farming's sustainability and grow agriculture's contribution to the economy through GDP and secure jobs.

13.3. Recommendations for the dissemination of information

12. Rather ironically, after completing my Nuffield Farming Report, information for dissemination should be no more than two pages with links provided for additional information. Web based presentations are excellent.

14.0. After my study tour.

During the course of my Nuffield Farming Scholarship we have become one of two Scottish DairyCo Monitor Farms. This has been a fantastic way for us to further explore my findings and get many of the industry experts that I was lucky enough to meet on my travels, to Glenapp, and share their knowledge and vision with the wider community.

This continual feed-back and community inclusion has allowed us to fast track many projects:

- To date we have fully committed to improving the soil health. We have GPS soil-tested and vary-rate applied lime, P and K to attain ideal soil pH, P and K status.
- Started a programme that will improve access, drainage and water which will help us increase the amount of grass we can utilise on the beef, sheep and dairy platforms.
- Overhauled our youngstock rearing programme with monthly weighing and continuous monitoring.
- Improved our physical and financial accounting processes to provide real time actual information vs budgets in a transparent format.
- Set up a training programme for team members to facilitate their growth and develop an open culture for discussion and alignment of goals.
- Installed a variety of renewable energy sources to mitigate our exposure to energy prices.

Within Quality Meat Scotland we have become the South West Grass Monitoring Station. This new programme is designed to reveal grass growths and quality across the country to stimulate debate and a quest for information on grass from the wider grass-based livestock community.

Through other industry roles I have fed back my recommendations relating to the dissemination of information. INYA, the research institute in Uruguay, now has a policy where all written releases for external dispatch must be no more than two pages long. They record all their field days and presentations and stream them live onto the web.

The uptake of knowledge through this has been fantastic with increasing numbers of farmers and staff seeking their new releases.

15.0. Executive summary

With the imminent Common Agricultural Policy reform, the abolition of milk quotas, an independence debate, increasing efficiencies with global transport networks, further reductions on EU import tariffs and a disengaged consumer, the UK business environment for pasture based livestock farming is changing.

Grassland accounts for two thirds of the agricultural land in the UK and supports £10 billion worth of ruminant products per year, which represents 60% of the UK agricultural output. An estimated 35% of the total cost of ruminant production is the cost of feed and 75% of the feed requirements are presently obtained from grass and forage.

Global demand for meat and milk products continues to increase and yet UK livestock enterprises have generally failed to capture the increased revenue at bottom line.

The primary goal of my report was to determine the attributes of successful and sustainable grass based farmers and their relevance to UK agriculture.

Eighty four visits or interviews in England, Ireland, Denmark, New Zealand, Uruguay, Chile, Brazil and Scotland covered a mixture of pasture based livestock enterprises (beef, sheep, dairy, deer, goats), diversified pasture enterprises, research institutes, manufacturers and non farming companies.

I examined the economic and environmental position of the businesses and how political and social factors contributed to the businesses' success and sustainability. It is hoped that my findings should prove useful not only to farmers but any other stakeholder in a pasture based system.

Far from being stereotypical capitalists, my research revealed that successful pasture based livestock farmers are genuinely interested in sustainable techniques. However the word "sustainable" was globally hotly contested with wide ranging debate over its overuse, its significance and even its definition.

True business success and sustainability is achieved through managing the triple bottom line - a process by which companies manage their financial, social and environmental risks, obligations and opportunities. The three P's: profits, people and planet.

There remains a strong tendency for farmers during an evolution of their business environment to consolidate or strive to increase in size and increase livestock numbers whilst maintaining current management systems to maintain profitability. Ultimately, this perpetuates the issue. The dangers of emotion based decisions cannot be overlooked.

Successful and sustainable pasture based livestock farmers of the future will need to adapt and engage with an evolving political arena. They will need to align their production to their consumers' demands, and reduce their impact on the environment whilst optimising the production and utilisation of grass. They will need to improve the feed efficiency of their livestock and effectively and efficiently grow the people within their business whilst continually strengthening their business to cope with increasing volatility.

Profitability, Sustainability and Success are a choice and change is inevitable.

16.0. Thanks and Acknowledgments.

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continued on next page

In Memoriam: David Dewar

In 1999 I was interviewed and subsequently employed by Glenapp Estate Company Limited. David Dewar, the Estate Factor, was on the interview panel.

David and I worked side by side until his “retirement” in 2003 when he was appointed to the Glenapp Estate Board and our work continued to involve the Estate. Throughout this time our relationship evolved from employer to mentor to sounding board to friend. He constantly challenged me to improve and inspired a hunger for knowledge that has culminated in this Nuffield Farming Scholarship.

David died suddenly on the Estate on the 14th of December 2013 prior to my sharing my Nuffield Farming experiences. He is sadly missed by all who knew him but his enthusiasm for life infected many.

David and Kate Dewar

See Appendices on next page.

17.0. Appendices 1 and 2

Appendix 1: The return on capital of lime, C. Russell 2014.

	Product			Kg to grow 14t DM grass			Loss due to inefficiency caused by pH				Lime requirement to pH 6.5	Lime requirement to pH 6.5	Return on Capital %, NPK efficiency only	% of Optimal Grass Growth as restricted by pH	Loss in Grass growth on 14t DM/hec (t DM)	Substitution cost due to loss in production caused by ph	Substitution cost due to loss in production caused by ph	ROC % with Purchased feed substitution at	Substitution cost due to loss in production caused by ph
	N	P	K																
Product	Urea	DAP	MOP																
%	46	45	60									£/t							
£/t	265	320	290	N	P	K	N	P	K	Total		30.00							
															£/t purchased	£/t purchased	£/t purchased	£/t purchased	£/t purchased
Ph	Inefficiency *			280	78.4	268.8	£/hec	£/hec	£/hec	£/hec	t/hec	£/hec				121	224	121	224
5.1	51%	64%	43%	143	50	116	82.27	35.68	55.87	173.81	14	420	41%	88%	1.69	77.73	251.77	60%	101%
5.2	44%	61%	38%	123	48	102	70.97	34.01	49.37	154.35	13	390	40%	89%	1.54	71.01	230.02	58%	99%
5.3	38%	58%	38%	106	45	102	61.30	32.34	49.37	143.00	12	360	40%	90%	1.40	64.30	208.27	58%	98%
5.4	31%	55%	28%	87	43	75	50.00	30.66	36.38	117.05	11	330	35%	91%	1.25	57.58	186.52	53%	92%
5.5	23%	52%	23%	64	41	62	37.10	28.99	29.88	95.97	10	300	32%	92%	1.11	50.87	164.77	49%	87%
5.6	21%	51%	21%	59	40	56	33.87	28.43	27.28	89.59	9	270	33%	93%	0.96	43.95	142.36	49%	86%
5.7	18%	50%	18%	50	39	48	29.03	27.88	23.39	80.30	8	240	33%	94%	0.81	37.03	119.95	49%	83%
5.8	16%	50%	16%	45	39	43	25.81	27.88	20.79	74.47	7	210	35%	95%	0.65	30.11	97.54	50%	82%
5.9	14%	49%	14%	39	38	38	22.58	27.32	18.19	68.09	6	180	38%	96%	0.50	23.20	75.14	51%	80%
6	11%	48%	0%	31	38	0	17.74	26.76	0.00	44.50	5	150	30%	97%	0.35	16.28	52.73	41%	65%
6.1	9%	38%	0%	25	30	0	14.52	21.19	0.00	35.70	4	120	30%	98%	0.28	13.02	42.18	41%	65%
6.2	7%	28%	0%	20	22	0	11.29	15.61	0.00	26.90	3	90	30%	98%	0.21	9.77	31.64	41%	65%
6.3	5%	20%	0%	14	16	0	8.07	11.15	0.00	19.22	2	60	32%	99%	0.14	6.51	21.09	43%	67%
6.4	3%	10%	0%	8	8	0	4.84	5.58	0.00	10.41	1	30	35%	99%	0.07	3.26	10.55	46%	70%
6.5	0%	0%	0%	0	0	0	0.00	0.00	0.00	0.00	0	0	0%	100%	0.00	0.00	0.00	0%	0%

Appendix 2: An example of a value stream