



**A Nuffield Farming Scholarships Trust
Report**

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**Forage and grazing techniques
for sustainable pasture-based
dairying and livestock farming**

Robert Thornhill

July 2014

NUFFIELD UK

NUFFIELD FARMING SCHOLARSHIPS TRUST (UK)

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A Nuffield (UK) Farming Scholarships Trust Report



Date of report: July 2014

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

Title	Forages and grazing techniques for sustainable pasture based dairying and livestock farming
Scholar	Robert Thornhill
Sponsor	The Trehane Trust
Objectives of Study Tour	<ul style="list-style-type: none">• To find alternative forages that could prove better than straight ryegrass• To increase the resilience of pasture to climatic variables• Investigate whether mixed swards can improve animal and soil health
Countries Visited	UK USA Netherlands France New Zealand
Findings	<ul style="list-style-type: none">• Appropriate rest period of pasture is key to animal performance and soil health• Diverse swards provide greater flexibility and resilience for grazing management especially in dry conditions• Multi-species pastures can offer additional nutritional benefits for livestock

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DISCLAIMER

The opinions expressed in this report are my own and not necessarily those of the Nuffield Farming Scholarships Trust, or of my sponsor, or of any other sponsoring body.

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1. About me

Although the son of a farmer, my early years were not spent running around the farm. We didn't live on the farm, in fact there was no house on the farm, and until the age of 10 most of my father's time was spent managing the family poultry business. My grandfather was a poultry farmer who had the first registered egg packing station in Derbyshire, and was a pioneer of the inclusion of limestone grit into poultry rations. My father started the dairy herd in the 1950s with a handful of Guernsey cows and built it up into a modern farm with a herd of pedigree Holstein Friesians alongside what was by then a substantial poultry processing operation.



Me, Robert Thornhill

I was in my early teens before I chose farming as a career in preference to joining the Royal Air Force. After A-levels and a year working at home I went to Myerscough Agricultural College in Lancashire. As part of my three year HND course in general agriculture I spent some time working in France and New Zealand before returning home to join the family farm.

My forward thinking parents quickly realised that to allow their business to continue to flourish they had to allow the next generation to take on the management responsibilities at an early age, and I was made a partner in the business at the age of 26. I spent several years fine tuning the system, but as I began to concentrate more on grazing I also became increasingly disillusioned with the direction of Holstein breeding and its suitability for what I was trying to achieve. I had developed an aversion to purchasing the feedstuffs required to allow the breed to fully express its yield potential, and, after having seen the simplicity of the New Zealand system, was becoming increasingly uncomfortable about year-round calving. So it was a natural progression when, in the year 2000, I took the decision to breed only in spring using New Zealand Jerseys to cross breed with our pedigree Holsteins.

Two years later our closed herd had become a spring calving crossbred herd and, with a network of cow tracks and electric fencing established, I soon realised that grazing cows was my passion. I have pursued this with great enthusiasm ever since and am now looking to make the modifications to the system that I feel are necessary, which inexorably led me to apply for a Nuffield Farming Scholarship.



2. Introduction

The reason that prompted me to undertake a Nuffield Farming Scholarship was really a growing disquiet about the direction in which pasture based dairy farming was going. I have an inquisitive mind and am known for asking questions. I am often regarded as, and have sometimes been called, sceptical. I have to know how things work in order to understand them to the best of my ability. However, recently I became aware that my questioning was within fixed parameters. I realised that although I was examining and analysing almost every detail and procedure, it was only within what is now known as conventional farming that I was addressing these questions.

I am the archetypal student of modern agriculture. Schooled in modern science, alumnus of agricultural college, member of pasture discussion group and avid reader of modern farming literature, I feel I have been indoctrinated into a system controlled mainly by vested interests other than my own. I am the progeny of industrialised farming where one is only regarded as being progressive by adopting all new technology.

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I'm not suggesting that farmers should abandon new technology as it can offer great benefits to modern agriculture. Physical items, such as plastic water pipe and electric fencing, have been of huge benefit to graziers in managing their pasture. Information technology, now widely used in all aspects of life, can also offer great benefits to farmers. Personal computers, smart phones and GPS have been adopted by agriculture and are proving to be ever more useful. We use an electronic rising plate meter every week to measure grass quantity over the whole farm, and a computer programme to speed up the process of calculating growth rates and quantities per paddock to enable us to plan our grazing.

But I believe we need to start taking a more biological approach to farming

All farmers are in fact solar farmers

But I believe we need to start taking a more biological approach to farming. Today it appears that much of modern farming has forgotten what the basics of agriculture really are. All farmers are in fact solar farmers. Their job is to capture solar energy and convert it into a biological product that can be redeemed for cash. Even animal confinement systems are solar farming by proxy as they purchase inputs that are grown outside.

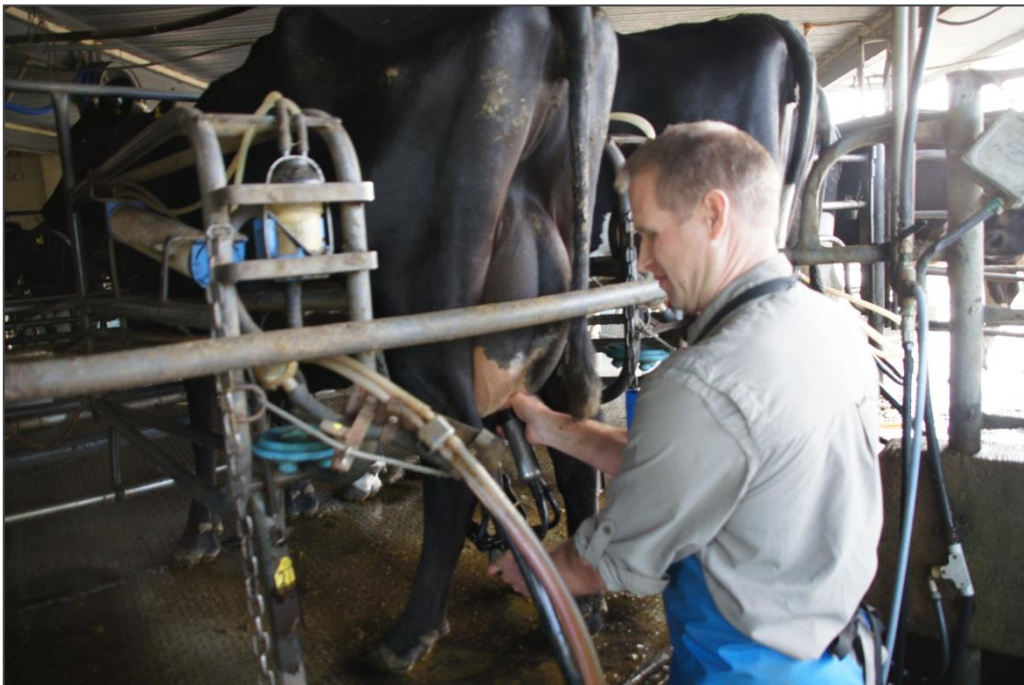
Although my study is about forage crops and techniques for successfully harvesting them by grazing dairy cattle, my visits and research continually brought me back to the unequivocal importance of soil, too often nowadays

regarded as merely a structural medium to support plants. It is a living entity, a whole subterranean ecosystem of which we have become increasingly oblivious as an industry. The benefits of a fertile and biologically active soil are quite profound and, to ensure a long lasting viable agriculture, its health must be nurtured and guarded.



This report is not intended to be a scientific study, or an academic paper. It is a collection of my current thoughts and findings, with some recommendations, on the topic. It will illustrate the journey I am on in my quest for improvements, and hopefully stimulate the reader to question all things. It is not a manual with step-by-step instructions to implement procedures. You will find no blueprint here, there is no such thing. Any attempt to provide such would be misleading. The things I have discovered during my research are not new, in fact quite the opposite, but many of them are new to me mainly because of my start in agriculture that I have already explained.

My visits and research continually brought me back to the unequivocal importance of soil, too often nowadays regarded as merely a structural medium to support plants



Me milking cows in New Zealand, in the same parlour where I had done the job 23 years previously.



3. Countries visited

My destinations may not be a collection of the most exotic places on earth but were a result of following the trail of breadcrumbs left by my research. I certainly had no need for translators on my travels (I speak a little French and the Dutch speak excellent English) and although there were no huge cultural divides to bridge, sometimes it's the subtle ones that catch you unawares!

USA : July 2013

I've visited farms in seven different States and travelled through several others. I started in the Midwest, studying the grazing used on large beef ranches in a country that raises most of its beef in intensive feedlots. I wanted to see what their pastures were like and how they managed their dry summers, to see if I could learn anything that could be implemented at home.

The image of the US dairy industry is one of predominantly huge intensive dairies, but in reality this is not the case, with over half the milk produced still coming from small family farms. In a country that seems to have embraced genetically modified organisms and is comfortable with the use of performance-enhancing hormones, I sought out the farmers who chose to fully utilise grazed grass. I met up with Sarah and the boys in New York City for five days of urban fun before I moved on to wide open spaces again.

Canada : July 2013

I flew to Saskatchewan, known as the "land of living skies", a reference to the huge vistas the wide open landscape affords, and as big a contrast to NYC as could be imagined. I had met Neil Dennis in the UK and wanted to see first-hand how he used his livestock to improve a degraded soil, while still achieving good animal performance.

The Netherlands and France : September 2013

Here I met dairy farmers using a different approach to grazing their dairy herds in a comparable climate to home.

New Zealand : December 2013

No dairy grazing study would be complete without a trip to the country that has based its entire milk production industry on the effective use of grazed grass. With dairying being the biggest industry in NZ, it is no surprise that there is a huge amount of research still being conducted on all things related to grazing.



4. Some thought provocation

“Agriculture is the heart of all human endeavour”: Alan Savory, 2013

Events in nature are a result of the interaction of a series of highly complex processes, no matter how simple the apparent outcome appears to us, and to assume we can understand it using a handful of metrics is merely an attempt to simplify what we do not fully comprehend. Our sole reliance on science to provide us with answers to what goes on in the world, I believe, can sometimes be a hindrance by creating tunnel vision. We constantly need to be reassured with the verification of peer reviewed findings before accepting something as true, and while I still fit securely within this category, I am now trying to take a more empirical approach to my farming, and also to life in general. I often smile when, referring to scientific data, I hear people say *“we used to think that, now we know this”*. Just imagine what we could find out tomorrow! When discussing possibilities, and people respond by saying there is no scientific data to support a theory, while this may be true, I like to suggest that today’s science was yesterday’s witchcraft.

For example, mainstream agriculture has confined farming by cycles of the moon to a distant and mythical past, yet we know the moon has a profound influence on the single greatest mass on the planet, the oceans. So is it really inconceivable to consider the moon cannot have an influence of some description upon what is happening on the land? Certainly biodynamic farmers believe this is the case. Prior to written calendars and weather forecasts farmers had their own assessment of timing and relation that was clearly effective enough to sustain the human race prior to the Industrial Revolution.

These ramblings are not intended to denigrate modern scientific thinking, but simply to prompt further questioning. Proven science can help explain what we formerly didn’t understand, or can confirm what we previously thought was true. An illustration of this would be the example of a recent scientific finding that reiterates the importance of soil organic matter. In 1996 a US soil scientist isolated compound

from soil now known as glomalin. This glycoprotein is now regarded as one of the most important parts of organic matter and is described as the superglue that binds organic matter to soil particles. It is also estimated that it accounts for up to 27% of carbon in the soil. We now believe that glomalin is an essential part of organic matter and that high levels in the soil are a good thing; but this merely confirms what good farmers and gardeners have known all along, that a cohesive soil structure which is also friable between the fingers is most beneficial for plant growth.

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which is also friable
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beneficial for plant growth.*

But there are still scientists today who believe we have discovered all we need to know about plant growth, and discount the importance of soil organic matter for example, illustrating this with the ability to grow plants hydroponically. While it cannot be disputed that food can be grown effectively through the use of hydroponics, and that this method may be the only way in extreme conditions of the world, I would suggest that mostly it is not just possible, but preferable, to grow food in soil both in terms of health (people and planet) and economics.

“We don’t know what we don’t know”



5. Open-minded development

As I outlined in my introduction, I had a traditional upbringing in terms of education, both in science and in agriculture. My curious nature however did not until recently allow me to cross the divide into “alternative” farming - as it is often viewed. I find it interesting that modern agriculture is described as conventional and we now have a sector called organic, when in actual fact organic farming is the conventional system, while conventional farming (sometimes termed chemical farming) has only been around for perhaps just over a century since the advent of early fertilisers and agrochemicals.

During my study I met with organic farmers, biodynamic farmers, holistic managers and advisers, regenerative farmers, permaculture practitioners and educators, as well as the whole spectrum of farmers, advisers and scientists involved in conventional agriculture. There is a great wealth of knowledge and expertise in all these sectors, but I believe the integration of some of these principles and practices into mainstream agriculture could have even greater benefits than their total adoption in a minority of situations.

“Disregard the majority opinion. It is probably wrong.” Max Gunther

5a. Beware of pseudo science

Despite what I have said so far, I am still a great believer in science and the clarification that its results can offer. Scientific papers can be difficult to interpret for those without a scientific education, but it is important to delve beyond the conclusion into the methods and results, to gain full confidence by trying to omit any subjectivity that could be implied.

The problem today is we seem to be bombarded with more and more “pseudoscience”, and sometimes this can be quite difficult for the layman to separate from real science when it is supported with plausible arguments that appeal to our sentiments. Pseudoscience seems to have evolved out of the post-modernist view that, if you believe it, it must be true. Add to this the political correctness that encourages the suspension of criticism of other views and opinions, and you have an environment where anyone can dress up an idea with semi-scientific jargon and we are expected to believe it.

There is perhaps no better example of this than in the realms of biological and organic farming.

Stories abound of sterilised soils due to modern farming practices, the advocacy of “natural methods” of production, and miracle cures in the form of lotions and potions that are available to remediate past damage and set your farm on the road to natural Utopia.

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I can only advise caution with regard to some of these products and, while I cannot state whether they will be effective or not in a particular situation, would suggest trying one of two things while remaining vigilantly open-minded. Firstly I would talk to someone whom you trust who has had positive experiences with them, whose farm and livestock appear to be in good stead and who is making money. Secondly I would conduct my own on-farm trial to try and gauge the level of efficacy and therefore ascertain the cost benefit.

If you have an on-farm problem it can sometimes be difficult to find impartial advice, and although I am a great advocate for remaining open-minded to all things, I also appreciate the difficulty in trying something different or unproven when you have to foot the bill. Where I really struggle with all of this is that, although science is very critical of biological farming and frequently cites a lack of evidence to support the theories of such proponents, the fact remains that my finely calibrated “farming eye” gauged all the farms visited, yet found some of the best were the biological ones. I cannot explain why this might be the case and my critical nature doesn’t allow the use of rose tinted spectacles, but it could just be possible that we are actually waiting for some scientists to catch up and *prove* what is obvious to some.

The absence of evidence is not evidence of absence.

5b. Who Is milking who?

“Beware the cost of efficiency does not exceed the cost of inefficiency”. *Unknown*

The above is a question I often ask myself, and I also ask of other people. Farmers are made to feel modern if they belong to a large club of support industries that provide supplementary feedstuffs, fertilisers, sprays and a plethora of synthesised imports. When you go to an agricultural show or field day, take a look at all the exhibitors and try and determine where the true wealth is. Look at those with the largest trade stands, or offering the most expensive refreshments and freebies, and then decide who is making the most money in dairy farming.

Is it the farmers milking the cows, or is it the companies milking the farmers? This is not to suggest by any means that all imports are superfluous, but we must remind ourselves what is truly necessary in providing the finished product, together with profit for the farmer.

Keep it simple:

sun→ biology→ cash

5c. Artificial fertilisers

It has been estimated that almost half the world’s population is fed as a direct consequence of nitrogen fertilisers. The manufacture of these often includes the Haber Bosch process which uses natural gas both as a source of hydrogen and energy. Given that it is universally accepted that fossil fuels are a finite resource, regardless of when shortages will restrict the use of fertiliser manufacture either by reduced availability or prohibitive cost, it seems the provision of a large proportion of the world’s food supply can be regarded as being in a somewhat precarious position. Can we really convince ourselves that this is a sustainable situation? And it’s not just nitrogen. Phosphorus is a finite resource that cannot be substituted or replaced. It is an essential nutrient for plant growth,



and in fact all life, and leaves farms in the form of crops and livestock (and via soil erosion). The main source is phosphate rock and while estimates of reserves differ wildly, I believe future generations are going to have to develop phosphate recycling systems to close the loop.

I have no wish for this report to be interpreted as the rhetoric of a “fertophobe”. There are many who, in the name of environmentalism, denounce the use of artificial fertilisers, claiming it causes widespread denigration of soil organic life and the poisoning of our food. In certain situations this may well be true, but it is also a gross oversimplification. *“Don’t blame the tool for poor workmanship”*. Artificial fertilisers can actually be used to help increase organic matter in soils by stimulating extra growth above what would be naturally possible, and allowing this to be incorporated into the soil either mechanically or through animals. In his book “Out of the earth”, Louis Bromfield makes reference to his accelerated soil improvement on Malabar Farm as a result of using fertiliser.

Phosphorus is a finite resource that cannot be substituted or replaced. It is an essential nutrient for plant growth, and in fact all life, and leaves farms in the form of crops and livestock (and via soil erosion).

I met with a scientist at Lincoln University in New Zealand who, during the course of our conversation, stated *“all grass is N deficient”*. He quoted various figures illustrating the responses of pasture growth to the application of nitrogen with and without irrigation. I do find his quote somewhat curious though, and can’t help but feel it’s a little like saying all humans are malnourished. There are many examples of people who have maximised their food intake and the results are obvious but, in accordance with my thoughts on *“maximum is rarely an optimum”*, these are not the athletes amongst us.

I found another scientist who wrote that, in his opinion, *“all soils are nitrogen deficient”*. Clearly these people are much more knowledgeable than I am and would be able to robustly justify these comments. But to me they simply illustrate von Liebig’s Law of the Minimum and there are few examples where real world economics could justify such high levels of nitrogen, even when the responses could still be measured.



6. Definition of sustainability

I have some reservations about including the word “sustainable” in my title as it seems to have been hijacked in recent times. It has become a buzz word, overused and misused, a marketing tag and a ubiquitous environmental stamp, used whether applicable or not in its true meaning. One of the Concise Oxford Dictionary meanings is “keep going continuously”. I would suggest when you see this word you need to ask whether this definition is applicable in the circumstance. Since the first line of sustainability has to be profit then I believe we need to take note of this.



Irrigation on Canterbury Plains, NZ

6a. Definition of profit

For the purpose of this report I’m going to assume profit means surplus cash, as opposed to any tax implicated definition. It is up to the individual to determine what is a reasonably expectable profit, and for them also to decide the best mechanism to achieve this. I believe this is an important point with regard to sustainability, as regardless of how noble a land carer’s intentions may be, a business without profit cannot perpetuate, ergo, profit is the first line of sustainability. But profit is not the only motivator for many people and nor should it be. Wealth can be measured in non-financial terms and depends on an individual’s goals and aspirations for their business and personal life.

... regardless of how noble a land carer’s intentions may be, a business without profit cannot perpetuate; ergo, profit is the first line of sustainability.

Milk production is often analysed on a financial basis by the cost of production measured in pence per litre. However, if we focus too closely on this we can indeed reduce overall production. For example, if I wanted to produce milk at the very lowest cost, I would take one cow, a milking stool



and pail, and graze my cow on the roadside verge. Not only would this give me the lowest cost of production per litre, but also one of the highest yields per cow from pasture. This is because the cow would graze the “cream” of the grass because she wouldn’t be expected to graze down hard. In this situation the cow would be managed on the very lowest stocking density with no consideration for future pasture recovery and quality. This would be some of the most efficient milk production on a per litre basis perhaps, but would not generate nearly enough cash for a modern lifestyle.

*There is no single figure
that tells the whole story
of a farm, either
financially or physically.*

For many farms land area is often a limiting factor, so profit per acre/hectare may be a more useful measurement, but if a business is of a sufficient scale to meet the demands of the owners and operators, then comparative analysis of costs against gross farm income may produce the best indicator of efficiency. There is no single figure that tells the whole story of the farm, either financially or physically.

6b. A maximum is rarely an optimum

I believe chasing maximum yields in any agricultural sector is dangerous. Focusing too heavily on productivity often distracts from profitability, highlighting the idiom “turnover is vanity, profit is sanity”. The strongest proponents of maximising production are not only farmers, but those with vested interests supporting this mechanism, whose businesses revolve around this and consequently who profit greatest from it.

If seeking maximum production is a priority, it must always be borne in mind that while it is not possible to have profit without production, it is possible to have production without profit. It is imperative to know what the costs of production are and to be in full control of these costs. While the goal is to reduce costs as much as possible while maintaining an acceptable level of production, there are limits to how far this can be taken. Sometimes changes to the system itself can provide greater results.

*while it is not possible to
have profit without produc-
tion, it is possible to have
production without profit*

6c. Do you want to super-size that?

We live in a world where we now want everything to be “maxed out”. Everything has to be bigger, more powerful, faster, and we expect the latest models and versions to provide these benefits. In my opinion “a maximum is rarely an optimum”.

Suppose we apply these principles to the selection of a motorcar. If we want the fastest, we would select a Formula One racing car. Clearly this would allow us to reach our destination in the shortest possible time (while also collecting the maximum number of speeding tickets!) but if it was to the shops, where would we put the shopping? Or how will carry passengers if we wanted to? If we were looking for maximum load carrying capacity, surely we should select a 100 tonne mining dump



truck. Clearly this would fulfil the specific role best, but it is not practical, and this is where compromise and balance comes in.

6d. Regular or large?

We should consider the same sort of compromising attitude when selecting grasses for grazing. When reviewing grass performance by plant breeders and commercial seed sellers, grasses are ranked in a league table of performance. But this league table is a measurement of total dry matter production and rarely takes into consideration nutritive value. The dry matter yield in trial plots is also arrived at under completely unrealistic conditions. These grasses are fertilised with artificial nitrogen at rates up to 365 kg per hectare and grown on unconsolidated plots. This bears little resemblance to most real world farming situations. It merely tells us how fast the Formula One car can go.

Obviously in a race this will be the correct selection to make, as with the highest yielding grass under a high nitrate application system with sufficient regular rainfall. When conditions favour the highly tuned tool, it will always win hands down. Enter a variable environment, the challenges increase and the chance of maximum performance is reduced. The Formula One car wouldn't be much good when faced with speed bumps or pot holes.

6e. It's all about balance

As with all things in farming, I believe it's all about balance. The farmer's role is to determine which inputs are really necessary to reach the chosen goals of the business. Too few inputs, leaving the nomadic verge-side cow aside, have the danger to reduce production in relation to fixed costs, therefore negatively affecting profit. It is also balance that I believe is lacking in the approach taken to managing many modern pastures used for dairy cows.

Gavin Fisher introduced me to a new concept which he described as "farming the pendulum". He explained that balance in nature is never constant and that if we try and achieve this we will be fighting nature rather than working with her. For example, if adverse weather conditions result in grazing animals poaching the sward and exposing bare soil, this will be colonised by new plants, thus altering the balance. This is not necessarily a problem, just a change.

The farmer's role is to determine which inputs are really necessary to reach the chosen goals of the business. Too few inputs ... have the danger to reduce production in relation to fixed costs, therefore negatively affecting profit.

The predator/prey relationship in nature would be similar, where an abundance of prey allows for the proliferation of predators to the point where there is insufficient prey to support this population. The resulting deficit of prey (food) has a negative impact on the population of the predators, allowing an opportunity for the prey to multiply once more, and so the cycle continues. Long-term balance is achieved through short-term fluctuations.



6f. Boom or bust

If we choose to plan for a good year every year and put all our eggs in one basket with a single species, and conditions favour this decision, and productivity and quality is maximised, can this one-year, or several good years, be enough to carry the business over a bust period of less favourable conditions? In some situations it is possible to reduce some of the risks that can affect production.

For example, on the Canterbury Plains in the South Island of New Zealand, irrigation is used to plug the gaps in natural rainfall. As moisture deficiency can be one of the main limiting factors of growing grass, when also combined with fertiliser, irrigation allows farmers to control a major risk to forage production and so maximise their production. In this situation the use of a Formula One type of forage can pay dividends.

6g. The multi-tool syndrome

Multi-tools of any description are often said to do many jobs adequately, but none exceptionally. The right tool for the job will always out-compete any multi-tool. The best quality screwdriver is of little use if all you need is a saw. The same goes for agricultural crops, so if conditions for that particular variety are ideal, then productivity can be maximised. But in the farming environment we cannot guarantee to be able to supply the exact amounts of sunlight, moisture and nutrients that can be provided in a laboratory or testing environment. This is where the multi-tool may be more useful for commercial farmers.



The multi tool syndrome!



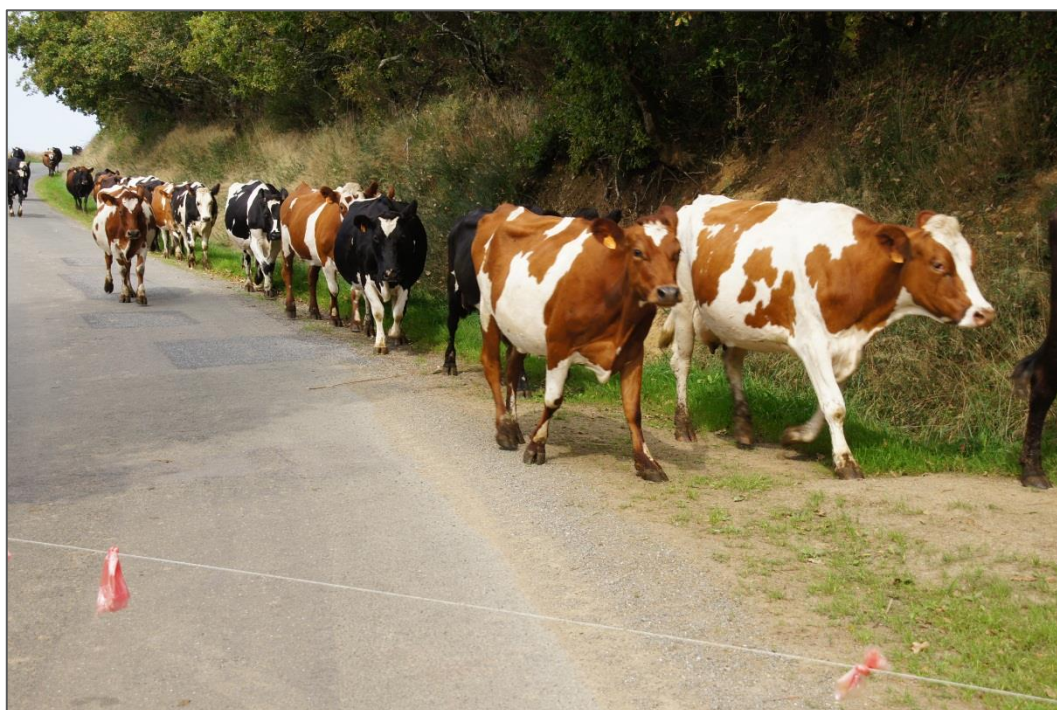
7. Sustainability recognised

One of the farms I visited in France was the home of Erwan and Laurence Le Roux in Brittany. In 2011 they were awarded “Les trophées de l’agriculture durable” for being the most sustainable farm in France in recognition of their innovative and environmentally responsible approach to agriculture.

The farm has been certified organic since 2009 but Erwan and Laurence, as part of their spring calving pasture based system, started milking once-a-day some years before this. Erwan comes from a farm advisory background and takes a very analytical view of everything he does. He applied this approach to analysing his cow performance records and, through careful animal selection, is now achieving the same yields on once-a-day as he did when milking twice-a-day. Erwan and Laurence target lifestyle and efficiency which must be reached within an environmentally safe system.

Like any other farm, this one also has its challenges, frequently enduring hot dry summers which affect the variable soil types in different ways. Erwan identified water management and soil biology as the main limiting factors to his farm’s production. He measures the water capacity of the soil, and when this falls to a predetermined level, Erwan alters his grazing management and begins to graze taller pasture, while also leaving higher residuals.

The farm used to be operated on perennial ryegrass and white clover pastures, but these have been replaced with diverse swards to improve summer production and soil health. Tall fescue, timothy, meadow grass, hybrid clover, chicory and plantain are now used to make up the dairy pastures. Lucerne and cocksfoot are present in the young stock pastures and Erwan uses a host of mixed annuals for his silage production, as well as for green manure prior to direct drilling crops.



Erwan and Laurence Le Roux’s cows



8. No “one size fits all”

All farms are different and need managing accordingly. Altitude, aspect, topography, soil type and rainfall are all individual, and experience is the only true qualification for elite management. As Confucius wrote, “*the best fertiliser of any farm is the footsteps of the owner*”. What he meant was the best farmer is one who knows every foot of their farm and understands its behaviour in terms of health and production in response to different weather and management.

It must be borne in mind that all selections for agriculture must be able to withstand as many potential variables as might be encountered. Some will say you should never plan for a bad year as that is all you will ever get, but it’s about contingency preparation as well. This is where the “multi-tool principle” is applicable. I believe that “*hope for the best, plan for the worst*” is one of the most useful strategies in any part of life.

During my travels I wanted to see how good graziers of cattle operated in very dry climates. This resulted in my visiting several beef farmers in North America who are pushing the boundaries of what was thought possible in terms of grassland management in their areas. What quickly became apparent to me while on these cattle ranches was the vital importance of rest (the interval between grazings), and also of the diversity of plant species in the sward.

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.....

Long rest periods however provide another challenge, which is forage quality.

The rest period between grazing is decided by growth rate, which is ultimately dictated by the amount and timing of precipitation, combined with stocking rate i.e. feed demand. This allows the plant to recover fully, not just above ground in terms of leaf area, but below ground in terms of root mass. The longer that pasture is left to rest, the higher the leaves grow and the deeper the roots penetrate in search of moisture and nutrients. Long rest periods however provide another challenge, which is forage quality.

In these arid conditions, diverse swards play a dual role. Firstly they provide a variety of different nutritional statuses, and secondly they introduce a resilience to the sward enabling it to cope with the differing conditions of climate. Shallow rooted plants are the first to dry out but also the first to capitalise on rainfall, while deeper rooting plants will keep growing longer and, with higher underground reserves, are more likely to survive extended dry periods. It should be noted that in most cases above-ground growth is mirrored underground, with equal amounts of roots as foliar growth.

By having many different plant species to graze, a farmer is providing his stock with wider nutritional qualities than he would by just using a single species. The different species also mature at different



times which helps to provide these wider advantages. A single species crop has a very narrow window of opportunity for optimum harvesting quality. The theory of having a very diverse mixture of plants in a grazing sward is that each plant's optimum harvesting window will be different at any particular time, thereby providing an element of digestibility for a longer period. Obviously this can forsake maximum yield in certain situations, but this is countered by the "all eggs in one basket" avoidance of singular failure under extreme challenges.

The common evidence from all these ranchers and farmers was both the improved health of the plants and subsequently the livestock. The individual species of plants did not appear to succumb to the diseases and pest attacks that were prevalent in nearby single species crops. Clearly there are mechanisms at work in a mixed crop situation that provide significant advantages to the plant's health.

In every walk of life there are polar opposites of opinion, and in the United States I found this was no different when it came to people's attitudes towards food. This is a nation that really epitomises large-scale industrialised food production together with genetically modified crops and performance enhancing hormones in animals. Yet everywhere I went it was evident that there was a small but strong demand for GMO-free, hormone-free, organic and local produce. I visited several "no grain" dairies supplying unpasteurised milk from cows that are fed no grain supplements, just hay or silage during the winter months, and as much grazed grass as possible during the summer.

What I did find with these farms however was that, in some cases, their grassland management was less important than the fact that their cows were fed no grain - as demanded by their customers - and that the revenue gained from retailing offset any inefficiencies in potential pasture production. Many of them were seeking a greater diversity of species within their pastures and some were experimenting with tall grazing.

8a. Mixed pastures

"Chaos is not dangerous until it starts to look orderly."

The Zurich Axioms

Throughout my travels I found many examples of diverse swards with good evidence to support the reasons for their use. I found the single most interesting farm on my travels in the North island of New Zealand. My appointment was for a visit to a highly recommended organic farm, but I wasn't prepared for what I was going to find there.

Gavin and Sheryn Fisher farm near Te Aroha, at the base of the Kaimai mountain range in the North East of the Waikato region, and as I turned up their road I realised I had found something quite different. On the opposite side of the road was the ubiquitous post and wire boundary fencing familiar in many parts of New Zealand, whereas on the opposite side I couldn't even see into the Fisher's farm due to the hedges of New Zealand flax and trees.

I found the single most interesting farm on my travels in the North island of New Zealand. I wasn't prepared for what I was going to find there.



A typical paddock on Gavin Fisher's farm.

As I began talking to Gavin in their house I soon realised that this was not a typical organic farm, but a very special biological farm. There is no doubt that this is not a unique farm, either in New Zealand or anywhere else in the world, or an easy one, with an annual rainfall of 1400mm while being prone to dry summers, but it was one of the farms I visited where everything seemed to be working in perfect harmony. So much of what I had been considering, or had read about, was being successfully implemented here, and the results were impressive.



Healthy cows on Gavin and Sheryn's farm

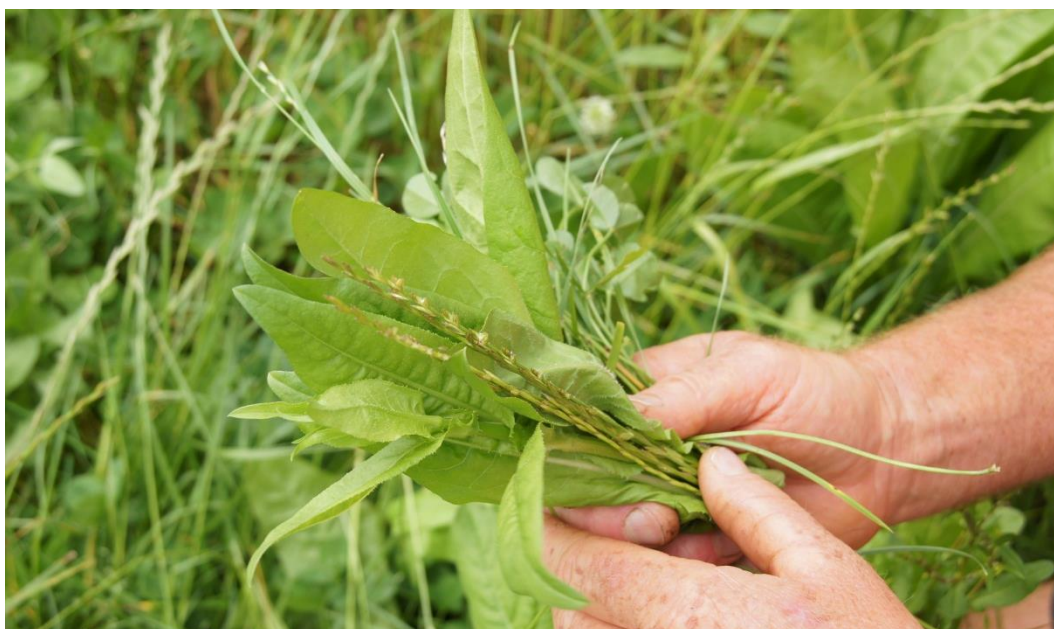


Before taking me out into the paddocks to show me what it meant in practice Gavin explained to me why he and Sheryn had decided to adopt this method of farming. Gavin's family have been on the farm for several generations, which is more unusual in New Zealand than in England, but after taking two years away from the farm, Gavin returned to find things had changed. His father was now using bloat drench and was also experiencing metabolic disorders in the cows. Gavin deduced that it was the introduction of nitrogen fertiliser and new grasses that was contributing to these negative changes and so decided to adopt a more natural method of farming.

He started to farm more biologically for several years and found that he was saving money. In 1999 the farm became certified organic in order to add value at the farm gate and, because of how the farm was operating, this was a simple and logical step. Although below regional average in terms of scale, the farm is stocked at 2.8 cows per hectare, with production around 900 kilograms of milk solids (butterfat and protein combined) per hectare, showing comparable performance with conventional farms. Factor into this the savings of no reseeding of pastures, no antibiotic use, no dry cow therapy, no grain feed and even no teat dip (*"it kills good bacteria as well as bad"*), and minimal animal health costs, it is clear to see why this is a financially viable unit. Add on to this the organic milk price premium and it means that Gavin and Sheryn produce just under double the profit of the Waikato average. Gavin describes himself as a "production ecologist", explaining that by farming for ecology, production follows.

I think one of the reasons I got so much out of this particular visit was, not just because it is exceptionally well managed, but because it took place quite late in my Nuffield Farming travels and I had become much more open-minded to the more alternative methods of agriculture. As I outlined in my Introduction chapter I had a very conventional education in terms of science and agriculture.

The first thing that struck me on the Fisher's farm was the shelter afforded by all the trees. As part of his big picture of biodiversity, Gavin has planted trees and hedges along many sides of most of the paddocks. The second thing that struck me as I entered the first paddock was the number of broadleaved plants in his grazing sward, in fact I would almost describe it as an absence of grass.



A typical sample from Gavin's paddock



8a.i Mimicking nature

Let's be honest, nature has had more practice at all things natural than has mankind: growing plants and animals together, adapting to changing environments, simply perpetuating life, indeed being truly "sustainable". So there are not so much clues in nature rather than blatant evidence. There are no monocultures to be found in nature, they just don't exist, they're not natural. Nature will not tolerate bare ground, is constantly evolving and is never static. All these states are man-made when referring to nature and require considerable amounts of energy to maintain. This is not working *with* nature. If you're not with it, you're against it, and that sounds like hard work.

There are no monocultures to be found in nature, they just don't exist, they're not natural. Nature will not tolerate bare ground, is constantly evolving and is never static.

8a.ii Recalibrating the eye

One of the biggest challenges, I believe, in accepting diverse swards and the appearance that results from the different grazing techniques, is going to be recalibrating the eye from what we are used to seeing. We have been accustomed to seeing visual perfection in all parts of agriculture. While in Pennsylvania, U.S., I saw farms straight out of a child's storybook. Visitors on a bus tour commented on how beautiful these farms appeared, with their hoop-topped barns, cylindrical silos, white picket fences, perfectly uniform maize crops and manicured roadside lawns, even horses working in the fields. It is picture perfect farming

By contrast, grazing mixed swards can sometimes appear scruffy, as indeed can the pre-graze appearance of this varied crop. Intensive graziers of perennial ryegrass swards use specific pre-graze and post-graze numerical targets. Due to the monoculture status of the swards, uniformity is common at all stages. It is easy for the managers to assess when the pasture is ready to graze, and also when the cattle are ready to be removed, by visually assessing the sward before grazing or the stubble that is left behind. Mixed swards will not appear like this and therefore require a modification to the way we view them.

One of the biggest challenges, I believe, in accepting diverse swards and the appearance that results from the different grazing techniques, is going to be recalibrating the eye from what we are used to seeing.

Clearly a mixed sward is anything that contains more than one species, but when I refer to a diverse pasture, I am talking about a mixture of many different grasses and plants. Some of the non-grass plants may be regarded as weeds by farmers, but the commercial varieties available today have significantly different qualities to the indigenous plants people are used to seeing. Plantain is a good example of this.



8a.iii Not just the small

I am fascinated by the level of interest large and mainstream farmers have in increasing the number of plant species within their pastures. This was also confirmed on my trip to New Zealand where grass-based dairying is the norm, despite ryegrass being most common throughout the country, except in the North where fescues are also common. I found chicory and plantain being grown on many farms, sometimes with grass and sometimes as pure stands, and not just on small farms.

At the end of my trip I just managed to squeeze in a short visit to one of the largest farms in New Zealand. I was given a contact at lunchtime and was kindly accommodated with a brief appointment the same afternoon with Nikki Watt. Nikki and Andrew are operations managers for Cloverdale Dairies near Ashburton in Canterbury. This 2002/2003 conversion comprises over 1300ha in total, milking 3000 cows through two 80-bail rotary parlours with 16 staff (20 during calving). This is a low input, spray irrigated system, with 85-90% of the diet derived from pasture. On the ryegrass pastures the rotation length is set using leaf phase, targeting grazing at 2.25-2.5 leaves.

Cloverdale has been successful in introducing a more biological approach to their farming practice, including mixed swards of chicory, plantain, ryegrass and dandelion for mineral and medicinal values, together with the use of humates and foliar sprays. This has enabled the business to reduce nitrogen use from 300kg/ha to 90kg/ha, impressive considering they are harvesting 17 to 17.5tDM/ha/year. They have almost eliminated grass staggers and bloat. Nikki and Andrew have won several awards over the past few years for their business skills, with the latest one in 2012, which included one for the farm with the lowest environmental footprint.

Nikki has a BAgSc (Hons) and, as well as her role in the business, and being a mother of four and a part-time consultant, is taking a scientific approach to experimenting with fertilisers on the farm. She has been working with Massey University as well as conducting her own trials on different granular nitrogen fertilisers versus foliar versus liquid, and is measuring leachates to test the efficacy of the biological system.

8a.iv Environmental benefits

There is increasing scientific evidence suggesting a reduction in the leaching of nitrogen and carbon with mixed swards. Much of this may be attributed to a greater quantity of biomass above ground, but also to the presence of legumes.

There is increasing scientific evidence suggesting a reduction in the leaching of nitrogen and carbon with mixed swards

Trial work has shown a decrease in the volume of leachates through species-rich swards which in turn reduces the amount of leaching of organic carbon, and both organic and inorganic nitrogen, compared to a monoculture of ryegrass¹. (See References on last page of this report) It seems it is not necessarily a mixture of plant species *per se* that is responsible for these environmental benefits, but perhaps certain species present, for example red clover². There seems to be



much discussion within scientific communities about the long-term environmental benefits of diverse pastures on a large scale³. (See References on last page of report)

One of the main causes of nitrogen losses in a pasture-based dairy system is via urinary nitrogen deposits. The reason for this is because the majority of urinary nitrogen is in the form of urea which is mineralised into ammonium and nitrate which are easily leached through the soil. This is also estimated to account for approximately 60% of nitrous oxide emissions from pasture. The fact that many forages usually provide a level of protein that exceeds a dairy cow's requirement means that the level of excreted nitrogen is even higher.

While visiting DairyNZ in Hamilton, New Zealand, I saw trial work in progress aimed at trying to identify the specific mechanisms or species within a mixed sward that reduce nitrate leaching, following a previous trial showing the feeding of mixed swards can halve urinary N excretion compared to standard pasture without negative impacts on milk production⁴. DairyNZ is a levy funded research and advisory organisation for New Zealand dairy farmers and it was very interesting to see research being conducted in this area. They were growing pure stands of chicory and plantain and these were going to be fed to cows that were to be monitored for dietary intake, milk yield and excretory products.

A recent study conducted by Massey University also showed grazing a diverse pasture reduced the level of excretory nitrogen compared to the standard perennial ryegrass and white clover mix⁵. In this case the diverse pasture contained chicory, plantain, prairie grass and either lucerne or red clover mixed with standard pasture.

Reducing nutrient leaching from agricultural land is of prime importance. Nitrate losses, and the requirement to reduce these, has been part of European Union legislation for many years now. In New Zealand this has recently moved much higher up the agenda for dairy farming and is now seen as one of the biggest issues. Although it is absolutely essential that all agricultural practices protect the environment, I feel most farmers see this only as pressure from

What many fail to recognise is that a loss of any nutrients from the system is in fact a symptom of inefficiency that has detrimental economic effects to a business. These losses are wasted resources

environmentalists, and in some cases an attack on traditional farming practices. What many fail to recognise is that a loss of *any* nutrients from the system is in fact a symptom of inefficiency that has detrimental economic effects to a business. These losses are wasted resources that should be retained and utilised for production on farm.

8a.v Drought resistance

At the time of writing, drought resistance may not be the most pertinent of subjects in the UK, although there are parts of the country where this may be of more interest. As New Zealand is the country most closely associated with pasture produced milk, perhaps it comes as no surprise that there is a significant amount of scientific research still done in that area, and this includes multi-species swards. Parts of the country that are inherently dry provide an opportunity to conduct farm scale experiments that simulate drought conditions that



may occur in other parts of the country. There is data to show that herbal leys can be considered a serious option for dryland areas, or areas that may be susceptible to drought⁶.

The proportion of species can alter through the season, e.g. the amount of chicory and lucerne can increase during the summer and autumn, where plantain remains more constant. Summer and autumn performance from these mixed swards can be superior to standard pasture, but overall on an annual basis it would seem the two are similar in terms of total dry matter production, as the ryegrass and clover sward performs better in winter and spring. Annual milk production would seem to be the same⁷, illustrating the fact that these diverse swards could be a useful tool when used over part of the farm. Further research that documents comparative performance against standard pastures under irrigated systems does not preclude the use of mixed swards in more humid regions⁸.

8a.vi Species selection

When choosing species to put into a diverse sward, the dilemma is what to use. Some people suggest finding local indigenous species as these are proven by nature to survive in the local environment. Places to find these may be on roadside verges, old railway line embankments or even cemeteries. However, although these have been finely tuned to the local environment, over time they may not provide the best production for agricultural needs.

While emulating nature is right, it must be appreciated that we are seeking production beyond what is naturally found, so the selection of grazing forages must be made carefully and should probably include modern productive varieties of naturally occurring plants. Many agricultural seed merchants can provide off-the-shelf mixes of diverse swards for a variety of uses, and will also provide mixes for individual requirements.

In Appendices I and 2, I have listed a selection of grasses, herbs and clovers as an illustration of the variety available in case some may have been overlooked or forgotten.



9. Herbs and weeds

Weed control in multi-species pastures will require a different approach, as selective broadleaved herbicides that are effective in pure grass crops cannot be utilised as they would kill many of the desirable broadleaved plants. It must be decided which plants are in fact weeds as some of the species selected for inclusion in mixed swards can be viewed as weeds by some people in certain situations. This brings me to the definition of a weed in this context.

It is often said that weeds are just plants in the wrong place, or “one man’s weeds are another man’s flowers”. It fascinates me how we interpret weeds. For example, an arable farmer may sow a crop this season, which he tends closely, and after harvest he ploughs it up and plants a different crop. The next season, remaining seed from the previous crop emerges and is then termed a volunteer weed and is targeted as such to be eliminated from the new

... the definition of a true weed (in this context) should really be a plant that a cow will not graze at any stage, or a plant that would be injurious to her if consumed.

crop. This is the perfect example of a plant in the wrong place. A weed may therefore be described as a plant that is despised by a farmer. In this context, however, the definition of a true weed should really be a plant that a cow will not graze at any stage, or a plant that would be injurious to her if consumed. The term “herb” will be used to describe all non-grass plants accepted in a sward, whether introduced or not.

Herbs/weeds are said by some to be able to tell us about the state of our soils. The German scientist Ehrenfried E. Pfeiffer wrote a book entitled “Weeds and What They Tell Us” in the 1950s and Newman Turner made considerable reference to the same subject in his book “Fertility Pastures” around the same time. This is not a subject I have researched extensively and is now understandably dominated by the organic farming movement, but clearly there has to be some sound scientific basis for this reasoning for the simple fact that the occurrence of these plants is never uniform over any single farm, let alone region or country.

Herbs can provide additional nutritional benefits when consumed by stock, especially in the form of minerals, and this is one of the main reasons for some farmers including these plants in their pastures. In Appendix III I have listed the results of a recent study showing the nutrient composition of commonly occurring pasture “weeds”. It is interesting to note the results for dandelion as this plant was mentioned on more than one occasion in New Zealand as being a desirable species. Personally I can see no problem in maintaining the population of dandelion in the sward!



10. Annual crops

A huge range of annual crops is available to a farmer, including grasses, cereals, brassicas and root crops, that can be harvested and used for winter feed or in times of grazing deficit. Seeing that my interest here is in grazing crops, I shall not be covering mechanical harvesting, although many of these crops can in fact be grazed at earlier stages of growth. On my travels I saw the grazing of sorghum, forage maize and kale. I discussed the merits of grazing root crops, such as turnips and fodder beet. The latter can be a costly crop to grow in terms of inputs, but when coupled with the very high yields of dry matter that it can produce, this makes it a very cost-effective option for the filling of a late season feed gap.

I have concerns about the impact on soils that grazing these crops can have during wet seasons. I'm sure there are farms with favourable soil types where this winter feeding has been used as a successful option for many years, but I know this has not always been the case. This is an example of no "one size fits all" and in this context must be viewed within the parameters of sustainability.

The main emphasis of this report revolves around perennial crops as I believe they are a step ahead of annuals in terms of sustainability. However annuals can play an important part and in Wisconsin I came across one example. Cheyenne and Katy Christianson operate an organic dairy herd supplying milk to the farmer-owned cooperative Organic Valley. They have been organic since 1996 but in 1999 Cheyenne decided to stop feeding grain. He will admit that one of his primary focuses is experimentation on his farm, especially with the grazing. He's grazing taller pasture than is usually deemed acceptable for dairying, and his swards are also quite diverse. Cheyenne makes use of annuals such as oats by drilling them in early August, so that they are ready to graze in October.

On farms where the perennial grass becomes dormant in dry seasons, pasture cropping may provide a useful option. The system was pioneered by Colin Seis in Australia and is the practice of direct drilling an annual crop into a permanent pasture to give a temporary boost to production, or a second crop for harvesting, while leaving the original intact.

He's grazing taller pasture than is usually deemed acceptable for dairying, and his swards are also quite diverse. (He) makes use of annuals such as oats by direct drilling them in early August, so that they are ready to graze in October.



11. Trees

The role that trees play on a farm, and the decisions regarding what sort of trees and where to plant them, was another recurring subject that came up on my travels. I found serious consideration being given to the benefits provided by trees rather than regarding them as something that just happened to be there and acknowledged for its aesthetic properties. Many farmers were regarding trees as a way to add a third dimension to their farm by tapping far deeper into the soil than traditional herbage can reach, and providing growth above ground that was higher than that of other crops.

I found serious consideration being given to the benefits provided by trees rather than regarding them as something that just happened to be there and acknowledged for its aesthetic properties.

11a. Advantages

On the Fishers' farm in New Zealand, Gavin explained that when selecting which trees to plant they had to fulfil a multitude of requirements. They had to be deciduous in order for them to let the weak winter sun through and prevent the farm becoming too cold, and the autumn leaf fall also allowed nutrient recycling from the deeper soil that other plant roots cannot access. The position for tree planting was very carefully thought out as they all had to provide both shade and shelter, they had to be accessible to allow for browsing by the cattle for forage and medicine, and they had to provide habitat for wildlife. Using a variety of species helps to fulfil these roles, including willow, poplar, paulownia, feijoa and olive. Fruit and nut trees also provide a cash crop at the same time as providing shade and shelter.

I think the benefits that trees can offer as part of the whole system are often overlooked by many farmers. Just as some arable farmers in the past have seen hedges as taking up space that could be growing cereals, or getting in the way of operating large machinery, rather than realising the benefits in terms of protection from soil erosion and habitat for pollinators, I believe livestock farmers often viewed trees in a similar light. It's not uncommon to hear complaints about dairy cows camping under a tree and increasing the rate of mastitis. The problem is more likely to be that there is an absence of other trees with which to provide shade or shelter, together with the fact that the grazing management does not include regular rotation, therefore allowing periods of extended lying in the same place.

11b. Edible silvopasture

Silvopasture is a form of agroforestry where trees are introduced into a grazing system to produce timber while at the same time providing shelter for the livestock. Edible silvopasture is where a tree crop is planted into pasture for the specific purpose of grazing with livestock.

In the US I met Jim Elizondo who is a pioneer of no till high density tree planting for forage. On his ranches in Mexico Jim will plant 80,000 seeds per hectare from the leucaena tree at 5 cm intervals into a Bermuda grass pasture. Allowing for germination losses this means that surviving plants will occur every 10 cm. Plantings are in rows 1.7 m apart, and one row every 30 m is fenced off and allowed to grow into a hedge for shelter. The planting is expected to last between 30 and 50 years.



The leucaena tree is a leguminous subtropical tree capable of rapid growth of high-protein (24%) highly digestible feed which is estimated to contribute approximately 330 kg of nitrogen per hectare per year. Not only does this benefit the tree but it also has a beneficial effect on the Bermuda grass pasture. For his beef animals, Jim claims it is the highest producing pasture, per hectare per kilogram of beef produced, in the world, allowing average daily life weight gains of almost 1 kg per animal per day at a stocking rate of around 7½ steers per hectare.

For his beef animals, Jim claims it is the highest producing pasture, per hectare per kg of beef produced, in the world

When grazed with Jim's tropically-adapted dairy cows in a high stocking density rotation, forage production doubled and milk production rose by around 40%, without any fertiliser and with less irrigation, compared to his Bermuda grass-only pastures. He uses the leader-follower grazing system, milk cows first followed by dry cows. It is important with this species of tree to introduce it slowly into the grazing rotation to allow the rumen to adjust - as with any significant change in forage type - and to ensure it remains in the diet. The rotation length is 35 days in summer and up to 65 days in winter. If cattle are given intermittent access to it they will never adjust, especially because it contains the detrimental mimosine chemical. With the right rumen bacteria this is degraded into a non-toxic compound and is not a problem.

When grazed with Jim's tropically-adapted dairy cows in a high stocking density rotation, forage production doubled and milk production rose by around 40%, without any fertiliser and with less irrigation, compared to his Bermuda grass-only pastures.

The diffuse shading from the young leucaena trees has a beneficial effect on the Bermuda grass, helping to keep the fibre content lower and the protein higher. Too much shade would result in a reduction in the sugar content and therefore energy. The more mature trees provide shade in the hot weather, reducing the rate of moisture evaporation and, in turn, the irrigation requirement, but they can also provide shelter against the cold.

The main limitation with edible silvopasture is the establishment time required for the crop. Even in Mexico it can take between six and twelve months for the crop to reach around 2m tall and ready for grazing and, in order to provide sufficient grazing, suitable areas would have to be set aside for the beginning of production on a staggered basis.

There will be very clear benefits to this system as long as a farm can justify having significant areas of land out of production during establishment. The crop needs to be set back periodically using a rotary topper to prevent the stems becoming too thick and therefore too difficult for the cattle to bend over and reach the leaves.



Leucaena silvopasture 3 months after direct drilling into Bermuda grass

11c. Species selection

The subtropical leucaena tree is clearly not suitable for use in the UK. Jim suggests that black walnut may be suitable for more temperate climates. If so, I am wondering whether hazelnut and beech nut may also be suitable. Poplar and willow are fast growing and may also be suitable, although I would caution against exclusive grazing of the latter due to its content of salicin, a precursor to aspirin.

Edible silvopasture does not seem to appear in the UK, perhaps because of our ability to consistently grow grass. While tree fodder may have been used in the past on the small scale - even gorse and holly have been used for winter feed - modern machinery now allows the easy harvesting of grass and cereals for storage and use during winter.

It is clear that cattle will choose to eat the leaves of most trees when given the opportunity, as illustrated by the browse lines that give trees their noticeable flat bottomed appearance. In terms of contributing to forage for dairy cattle in the UK, I believe in the majority of cases access to field boundary trees for occasional browsing and any benefits this may bring may be the most suitable application.



12. Grazing management principles

It may be of interest to those not involved with grazing cattle that there are several different methods of management, with variations within each system, and proponents who argue strongly for and against. The effective utilisation of pasture with cattle, whether for meat or milk, requires careful planning and precise implementation of procedures set out to achieve specific objectives. It is more than simply allowing cattle access to some grass, although I believe this approach to grazing is all too common in beef and dairy systems.

The challenge with managing grassland is twofold. Firstly grass growth is not constant in terms of quantity and its provision of quality. Secondly the demand of the herd i.e. nutritional requirement, alters throughout the season due to factors such as growth rate, stage of lactation and stage of gestation. The marrying of these two situations for optimum performance is the challenge for the pastoral farmer or grazier.

The effective utilisation of pasture with cattle, whether for meat or milk, requires careful planning and precise implementation of procedures set out to achieve specific objectives. It is more than simply allowing cattle access to some grass.

The principle of any grazing system should be the optimisation of the resource of land in order to meet the pre-set targets of the business. For true long-term sustainability these targets should be derived from within the parameters of the “triple bottom line”, fulfilling not just financial but also social and environmental criteria. In some cases people now believe this approach should be superseded to include a fourth element of culture, the so-called “quadruple bottom line”, or QBL which is now implemented by the New Zealand government in consideration of the Maori people.

There are many good publications available on grazing management that cover this subject in great detail, far beyond what I am able to do here, and I have listed those with which I am more familiar in the Further Reading chapter. Some become quite complicated and mathematical, but all the principles are aimed at the same end result of producing the best efficiency from the land.

When supplying a generic product, the lowest cost of production per unit of comparable quality will always leave the largest margin. This is similar to what Porcius Cato (born 234 BC) is believed to have meant when he wrote “*to feed with moderation*” in reference to raising certain profit from land. “The cheapest food for stock is grass” (Robert H Elliot, *the Clifton Park System of Farming, 1907*) is not a new theory and still holds true today, being the underlying principle behind the New Zealand dairy industry. This clearly only applies to grazed grass, not the zero grazing/cut-and-carry mechanically harvested operations. The grazier must be constantly aware of employing mechanisation and its associated costs for reasons other than complete necessity, and not be persuaded by those with vested interests in the supply of such equipment that the aesthetic grooming of pasture increases utilisation efficiency and produces higher profit.



12a. Definitions

This is a list of some of the more common terms used to describe grazing methods, together with my interpretation of them:

12a.i Set stocking

This is where stock are allowed to graze freely over a given area of land for an indeterminate period of time. The livestock would usually have been moved to a fresh area based on a visual assessment of the pasture, i.e. when it is too short to effectively graze any further and the animals have in effect “eaten up”. On this system, grazing can continue on the same area for days, weeks or even months. Over extended periods of time this is one of the strategies that produces the lowest yields of pasture as the grass never gets time to rest and therefore grow its foliage and roots to a significant quantity.

There are methods that attempt to create a certain element of rotational grazing within a set stocking system by applying fertilisers or manure to a section of the land, usually one third of the area, to discourage grazing and allow further growth. I have no experience of this but am dubious of its efficacy.

12a.ii Rotational grazing

This is a commonly used term to describe grazing management, but its loose meaning can be applied to many different forms. Rotational set stocking is where the above practice is carried on over several separate areas. Rotational grazing can be used with high levels of supplementation where the grazed grass forms only a portion of the diet and the animals are moved on a regular basis. The term is also often applied to paddock grazing.

One of the main underlying principles of maximising pasture productivity under a managed grazing system is the rest period, that is to say the interval between grazings. This can either be a fixed time or a variable period. Fixed interval rotational grazing is a simplistic method which would normally use supplements to counter changes in both quality and quantity within the paddock. A more efficient rotational grazing system takes into account the growth rate of pasture and the herd's feed requirement to determine the intervals between grazings. With this approach supplements are used in times of deficit, with crop conservation in times of surplus. In a closed system this conserved surplus can be used as the supplement. Stocking rate, pasture species, soil fertility and moisture availability all exert an influence on the rate of pasture growth, therefore making each farm completely individual in terms of pasture performance.

12a.iii Paddock grazing

The mainstay of New Zealand dairy systems, this is probably one of the best researched and documented grazing techniques. It employs a relatively fast rotation, typically 20 to 25 days in the growing season, with cows being presented with a fresh ungrazed area usually every 12 or 24 hours. On a dairy farm this is not inconvenient as the cows are taken from the pasture to the shed for milking and so can easily be returned to a different area. Further flexibility is provided by the use of portable electric fencing to provide precise allocations.

Estimates of grass quantity should be taken on a regular basis to maximise the potential of this system. This can be done by a trained eye, or more commonly using a mechanical



device such as a rising plate meter that measures the height of compressed pasture. The application of a specific mathematical formula to this reading provides an estimate of dry matter in the paddock and this can be matched to the feed demand of the herd. When done weekly, this measurement provides a picture of change over the whole farm and is a useful tool to warn of impending surplus or deficit. Post grazing sward heights, or residuals, are monitored and targets set for these to ensure the best quality regrowth for the following grazing.

12a.iv Techno grazing™

This is a variation on a theme, and while perhaps not widely known, was one I was keen to investigate after seeing some of the equipment in use in France. TechnoGrazing uses specifically designed portable equipment to create small cells within larger paddocks and the stock are moved frequently to maximise pasture utilisation. The system is the brainchild of Harry Weir, an ingenious man who uses design to solve problems and seek potential improvements that he sees.

I have been using good quality portable electric fencing for many years, but on Harry's farm, and others I've visited using his system, I saw it used to another level. Light weight electric fencing and portable water troughs allow the quick and easy movement of livestock, especially when using the quad mounted system that allows one person to set up and take down an electric fence at running speed without getting off the quad. I was particularly impressed with the man and his system when he gave me a demonstration of his StockRod, that allows an electric line to be cast like using a fishing rod, which he used to quickly segregate an animal that I chose at random.



Me on Harry Weir's quad



Technograzing. Note diverse pasture and residuals

12a.v Three leaf system

The three leaf system of grazing was developed in Australia and is a type of rotational grazing for ryegrass swards and is based on the principle that the plant only ever has three healthy leaves at one time. On the emergence of a fourth leaf, the first leaf at the bottom of the plant begins to die off, reducing average nutrient quality and the ability to hit the desired residuals which in turn affects the quality of regrowth. The loss of this leaf is also a wasted opportunity that could have been ingested and turned into milk.

Rather than measuring pasture height, leaf emergence is monitored and this dictates the optimum time for grazing. The principles of the system are sound and often observed in a paddock grazing system wherever possible, but in my experience, especially during the rapid growth of spring, it can be difficult to manage. I believe this system is best suited to a very high stocking rate where grazed pasture is used alongside supplementation for higher yielding cows.

12a.vi Rational Grazing

This is a concept devised by André Voisin and one which I had not come across until reading his book “Grass Productivity”. He goes into extraordinary detail to describe the elements that make up this system, using equations to illustrate livestock units, “cow-days” stocking density and rest period among others.

He created his four “Laws of rational grazing” and discusses the interconnectivity of these. This book is highly recommended but it must be appreciated that it was written in the 1950s in French, and the English translation, although excellent, does not lend itself to be the easiest of reads. Therefore I shall attempt to paraphrase the four laws that Voisin devised.



1. There must be sufficient interval between grazings to allow the accumulation of root reserves to enable rapid regrowth.
2. Animals must not remain in the same paddock long enough to graze regrowth.
3. Quality grass should be of a sufficient length (22 cm) to maximise intakes.
4. Maximum milk yields result from daily allocations, but never staying for more than three days in the same paddock.

These principles are not dissimilar to those employed under the paddock grazing system. Indeed Voisin states that the period of stay in a paddock is not constant throughout the season, but varied according to growth rate.

12a.vii MIG or UHSD/mob grazing

Management Intensive Grazing (MIG) or Ultra High Stock Density Grazing, increasingly known as mob grazing, is a method of pasture management devised by Alan Savory for use with beef cattle in arid regions of the world, as part of his Holistic Management principle. You may be wondering why I have included this in a paper about grazing dairy cattle. While in the Midwestern USA, I visited cattle ranches in order to see the application of this system, as I was curious about whether it lived up to the claims of soil improvement, and also to see whether there were any parts of the system that could be applied to dairying. I also spent three days on a Regenerative Ranching Course where one of the educators was Johann Zeitsman, who is credited with being the first man to successfully implement UHSD grazing to achieve environmental improvement together with good animal performance and profit. His approach to cattle breeding is profoundly sensible.

Neil Dennis in Saskatchewan, Canada, is perhaps one of the world's leading practitioners of mob grazing. He custom rears almost 850 animals over 12 months of age which arrive on his 475ha (1175 acre) farm weighing, approximately 300kg. Neil started rotational grazing in 1989 but, after continual poor performance, was persuaded by his wife Barbara to attend a Holistic Management course in 1998. As Neil puts it, he spent the next four years "trying to prove it wouldn't work", but after failing to do so he attended another Holistic Management course in 2006 and that's when things really began to take off.

Neil and Barbara are the fourth generation on the farm, but due to traditional cropping practices the levels of soil organic matter had fallen from about 12% to below 4%, resulting in a significant reduction of productivity from the land. The principle behind using mob grazing to increase soil organic matter is based on animal impact i.e. trampling. Neil uses a very high stocking density and moves his cattle from anything up to 4-8 times per day, a job made easier than it sounds by the use of solar powered automatic gate releases. He says that for every 1 pound of pasture eaten, 2.6 pounds are trodden in, meaning he is using almost 75% of what is grown as fertiliser for the soil. One of Neil's sayings is "earthworms can't jump" so the intense trampling effect of the cattle results in vegetation contacting the soil.

This will seem to many a very wasteful system, but soil fertility is improving, with organic matter levels now around 10%, and as a result the farm is able to carry more stock. The only imported nutrient that Neil uses is purchased hay for supplementary feeding. I just want to clarify the difference between stock density and stocking rate, as the former is not



something most farmers would calculate. Stocking rate is the number of animals per unit area of land per year, whereas stock density is the number of animals (or units of liveweight) per unit area of land during the period of occupation, or to be more precise, during simultaneous grazing.

Based on the fact that Neil moves his cattle several times a day (they get a larger area at night), this means his 850 cattle could be on just one acre for one hour. This results in highly competitive grazing of the very tall multi-species pastures, which does not allow for selective browsing but, because of the competition, the cows eat a good cross-section of what is available. As a result daily live weight gains are good and the diversity within the diet means their free choice mineral consumption is low.

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I've visited several farms that were attempting to implement a version of this grazing method in a dairy system. The problem with this "tall grazing" as it is sometimes referred to is that, when using predominantly grass, the extended rotation results in a reduction in digestibility that is unable to realise sufficient milk yields. However, I believe this sort of management for non-milking dairy stock could offer serious benefits in certain situations.



Neil Dennis



Stock density on Neil Dennis's farm

12a. viii Holistic planned grazing

As previously mentioned, this is a system that is part of Alan Savory's Holistic Management (HM) approach for land care. It is a regenerative form of farming to help areas that have suffered from over- and under-grazing. Savory believes animal impact and appropriate rest periods between grazing is a key to the health of grasslands, particularly in extremely brittle (dry) environments like Africa, where the system was conceived.

It is important to be aware that excessive rest can be just as detrimental as insufficient rest. He talks about the dangers of excessive rest periods in arid environments. This can cause oxidation of plant material increasing the risk of fire, and also tussock-like growth with bare ground in between, often associated with overgrazing. He claims, however, that it is undergrazing that produces these conditions, with increased exposure of soil between the tussock lumps. With the right rest

period and the correct animal impact levels, he says, significant improvements in deteriorated grazing lands can be made, reducing and reversing desertification in many cases.

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Although this seems a far cry from the green and pleasant lands of England, Savory assures me that the underlying principles of HM can be applied to any situation, as he believes the fundamentals are the same albeit on an accelerated scale. I am yet to be convinced of how relevant the grazing principles are, although the general principle of HM can be applied to any business or life situation.

12a.ix Grazing diverse swards

While the techniques already discussed can all be applied to a diverse sward, certain principles are required to maintain the desired populations of the different species. Under real conditions the proportions of different plants within the sward will not remain constant, and as Gavin Fisher pointed out, this should not necessarily be the target.

In a meeting with the holistic educator John King in Christchurch, New Zealand, John explained the key to maintaining a level of diversity which I hadn't formally grasped, and which also reflected what Gavin Fisher believed. He told me that, under set grazing patterns or rotations, the swards will evolve so that eventually they contain a reduced variety of species. It is therefore essential to vary the intervals between grazings.

Multi-species swards need special management to ensure the persistence of diversity. A fixed grazing rotation length will result in the favouring of species that suit that particular period of rest. So if a farm is used to managing perennial ryegrass swards, with or without white clover, the rotation length will normally be between 20 and 25 days under good growing conditions. On the whole this will coincide with leaf emergence intervals resulting in a pre-graze stage of around three leaves. If this regime is continued for a mixed sward that contains ryegrass, then that species will be favoured and is likely to become dominant over time.

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I have heard it suggested that any perennial plant should be left to fulfil its whole life-cycle (i.e. allowed to reproduce and drop seed) every few years, for the health and vitality of the parent plant, as well as allowing it to propagate. Clearly a mixed species crop will have plants maturing and seeding at different times so if this was to be undertaken, a sufficient time period must be allowed for all plants to reproduce and maintain the chosen diversity.

Given that seed mixtures for herbal leys are generally more expensive than grass mixtures this could be considered as a cost-effective reseeding practice. Time out of production would probably not be dissimilar from a cultivated reseed, although the timing would be different, and there would have to be an ability to utilise the mature crop effectively, either by grazing or cutting, in order for it to be an economic proposition.

Gavin Fisher was successfully utilising a similar principle on his Waikato farm. He does not have a policy of cultivation and reseeding but relies heavily on the fact that his long rotation



means that some plants will be dropping their seed at certain times of the year. He also fences off a quarter of some paddocks during times of surplus growth instead of mechanically harvesting it, and this is reintroduced as growth rates slow down, by which time it is comparatively mature and may be dropping seed.



Diverse pasture on Gavin Fisher's farm

It should also be noted that the application of high levels of artificial nitrogen fertiliser, while being detrimental to the persistence of nitrogen-fixing legumes, can also have an effect in reducing the diversity of species⁹. Although this is not to suggest that artificial nitrogen cannot be used to boost growth, it should perhaps be considered best used - in an attempt to elongate the growing period - at the beginning and end of the season when the legumes are not active.

12a.x Overgrazing

Although I believe this should not be a planned grazing technique, I just want to offer what I think is an accurate explanation of overgrazing, a description often used but, in my opinion, not fully understood. Overgrazing is a frequently used term applied to the deteriorated appearance of a landscape. What must be understood is that only a plant can be overgrazed, not land, and that overgrazing is a result of the presence of animals for too great a period of time, rather than merely too many animals as is often thought. To illustrate this, imagine one cow in a paddock with a small watering point for 365 days. At the end of the year there would be a bare path to the water point. Now think of 365 cows in the same paddock for one day. The impact left by this number of cows would probably not be evident after a couple of weeks during the growing season. This is the same number of "cow days", but with a hugely different impact on the pasture, and therefore the landscape.



13. The right tool for the job

I'm talking here about cows.

If your main business objective is to turn grass into cash via the sale of milk, you're going to need the right sort of cow. There is a reason why dairy cattle that are good grazers are smaller than their confined counterparts. Grazing cows have substantially larger rumens than total mixed ration (TMR) fed cattle, and their lower body weight requires less maintenance feed. If you select for the most efficient grazing cows, either milk or beef, they will be smaller than cows bred for production from grain-based diets. It is important to note however that you shouldn't just breed for small cows thinking they will be more efficient.

André Voisin was an astute observer, and was critical of experiments in his time that conducted trials using mechanical cutting to simulate grazing. He discusses that a different result in terms of pasture performance often occurs under these conditions, and that animal performance can differ when presented with pre-cut material as opposed to self-harvested food. He conducted many of his own experiments to show how pasture responded differently when grazed with cows, and studied the interaction of the two. He describes grazing as *"the meeting of cow and grass"*, and states the importance of monitoring the two as interdependent. He states *"when we think of the cow, we will not forget the demands of the grass. When we examine the grass, we will always bear in mind the demands of the cow."*

*"when we think of the cow,
we will not forget the
demands of the grass."*

*When we examine the grass,
we will always bear in mind
the demands of the cow."*

Surely this should always be considered by graziers.



14. Soil

**“Carbon is the currency for most transactions within and between living things.
Nowhere is this more evident than in the soil.” Christine Jones**

This report is not about soil, and as a subject in its own right there is far too much to go into here but, as I have already mentioned, because my findings consistently come back to the importance of soil, it cannot go unmentioned.

The first thing to fully appreciate in agriculture is that everything is linked. Managing any single aspect of agriculture has a resulting domino-like effect on the rest of the system, and soil is no different. Animals, plants and soil are all linked as one process working together, and to separate any one in isolation without consideration for the others will be to the long-term detriment of the business.

I’m clearly far from expert on this subject, and when faced with something about which I don’t have a good understanding I always break things down to the basics and analyse these first. Much of my previous education about soil, and most of current agriculture, is concerned with the chemical components of soil and how they can best be balanced with chemical fertilisers.

The chemical portion of the soil is of course essential but is one third of an equal triangle, of which physical and biological components make up the other two. (See Dr. Clapperton’s diagram on the next page). Each of these is of equal importance and so must be addressed whenever we look at soil. Like agriculture as a whole, these three are interconnected so that an effect on one will have an influence on the others.

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I have already referred to some of science’s views in relation to “new-age hocus-pocus biological systems” and the view that chemistry is unparalleled in its explanation of all things. Although I believe the chemistry is irrefutable it is, as I have already mentioned, only part of the equation, in fact only one third in this situation. For example the importance of the presence of air in soil is often overlooked.

For those who still dismiss the importance of the physical and biological aspects and their influence on the chemical side, I’d like to draw a parallel between soil and silage. Silage-making simply involves the cutting of fresh grass and the exclusion of air through compression of the grass, and protection from the atmosphere using a plastic film. These principles apply to both baled and pit silage.

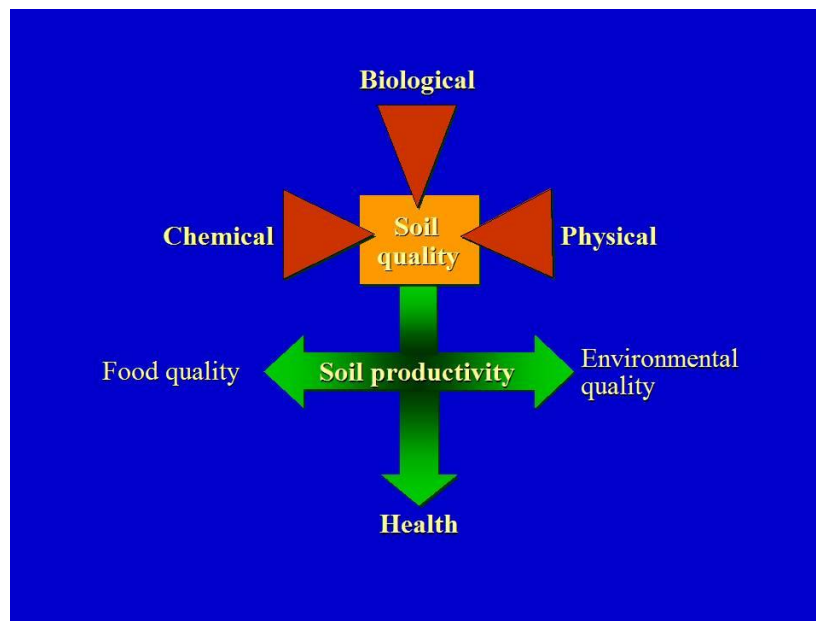


Diagram by Dr Jill Clapperton

When I mow my lawn I cut fresh grass and store it in a heap, just like making a silage stack. The material is the same (fresh grass), but the physical state is not, i.e. it is not compressed and covered with an impervious material. My loose heap (physical) of lawn clippings means there is air present and aerobic bacteria (biological) work to decompose the grass into compost, which clearly has considerably different (chemical) properties to silage.

When one point of the triangle (physical/biological/chemical) is altered with grass, it alters the other two. Why should it be different with soil? If the soil is compacted then there will be an effect on the biology, and subsequently the chemistry, in the soil.

In the UK so much emphasis is, and has been for some time, placed on simple soil analyses that provide very little data, yet are used to make fertiliser recommendations of huge financial significance. Results of available phosphate, potash and magnesium, together with a pH reading, are what are commonly provided and are the foundation for fertiliser applications, usually in line with the standard DEFRA RB209 fertiliser handbook.

There are many more detailed soil analyses available from a host of organisations that include a huge amount of information including trace elements, measurements of organic matter and indicators of microbial activity. A good analysis with correct interpretation can paint an altogether different picture from the standard four-result method. Most of these will measure not just available nutrients but also *total* nutrients with the aim of trying to make these more available on a longer-term basis rather than just to keep on applying available plant nutrients from a bag. As usual there is no universal agreement on which is the best method of analysis and interpretation, or the way to remedy imbalances, but there is always more than one way to achieve the same end.



15. Can it feed the world?

Whenever I mention adopting a more biological style of farming the question above is the one I get asked most often. Operators of large-scale farms believe, and are led to believe, that they are the most efficient farms. Modern machinery allows operations to be carried out by a single person over huge areas of land, but efficiency must also be measured in productivity per hectare in terms of crop/stock yield as well as labour efficiency.

It is possible for small farms to out-yield large farms when they can employ techniques that are impractical or less cost-effective on very large scales, such as composting or the management of multiple species of animals and crops on the same area of land. The higher requirement for labour on these farms is often viewed as reduced efficiency, but labour units are extremely versatile, unlike specialised machinery.

The higher requirement for labour on these farms is often viewed as reduced efficiency, but labour units are extremely versatile, unlike specialised machinery.

My Nuffield Farming Scholarship started with a two-day regenerative agriculture course, listening to the controversial alternative farmer, author and speaker from Virginia, USA, Joel Salatin of Polyface Farm. To be truthful there are very few people that I could listen to for two days straight, but the charismatic Joel kept me riveted for the entire time. He explained how, in his opinion, global agriculture had “*become accomplished at hitting the bullseye of the wrong target*”. His different approach to traditional agriculture started me on my Nuffield journey with an enthusiasm to scrutinise all orthodox practices surrounding my topic.

global agriculture had “become accomplished at hitting the bullseye of the wrong target”.

Joel explained how his parents came to the rundown farm in 1961, and how the family has been working to improve the fertility of the land ever since. Stating that “*everything we do is to stimulate the ingestion of green material*”, all the livestock at Polyface are pasture fed: beef cattle, pigs, broilers, turkeys, laying hens and rabbits. Often criticised, and sometimes ridiculed, Joel

claims everything he does is open to scrutiny, and as such Polyface is probably one of the few farms in the world that has a 24-hour 365-day open visiting policy. Anyone can turn up at any time of day without a prior appointment and wander round the whole farm, so I decided to do just that while I was in the States. It was evident that the multiple species clearly permit high output, yet to the casual observer this appeared to be a quite unremarkable farm.

Productive output per unit area of land of any farm, like profitability, is linked much more closely to the skill of the management than the land. I believe there are greater

I believe there are greater differences in the levels of efficiency within systems, both livestock and cropping, organic and conventional, than between the actual systems.



differences in the levels of efficiency within systems, both livestock and cropping, organic and conventional, than between the actual systems. The evidence I have seen does **not** lead me to believe that farms adopting more biological methods will have such reduced output that, if adopted worldwide, would require much greater areas of land.

"It's important to ask questions, but it's even more important to question the answers."

Gavin Fisher



My own cows on mixed sward



16. Conclusions

- A planned approach to grazing is essential to make the most of any pasture
- The rest period between grazings determines the health of the pasture
- Increasing the number of plant species in the sward brings health benefits to stock and soil
- Diverse pastures may help dairy farms reduce their environmental footprint
- A balanced soil is the foundation of all production

17. Recommendations

- All dairy farmers utilising grazed grass should use some sort of planned grazing with a system to evaluate pasture growth
- Portable electric fencing should be employed where necessary to provide the control and flexibility of the grazing plan
- Wherever possible cattle should not remain on the same grazing area for more than 24 hours, and never for more than 4 days, in order to prevent the grazing of regrowth which will reduce pasture performance
- Consider using diverse swards over parts of the farm to reduce the “all eggs in one basket” trap and improve soil conditions



18. Postscript

It's so common to hear people who've had a Nuffield Farming Scholarship saying it was "a life changing experience" that it has become something of a cliché nowadays. Although no one could expect such varied overseas visits to leave any person unchanged, before starting out I admit was wondering if I could end up being one of the untransformed. I was unprepared for how wrong that assumption could have been.

A Nuffield Farming Scholarship is always going to be a huge learning experience, and my travels were no exception. Of course the learning is never confined only within the parameters of the chosen subject. Like any research topic, branching out from the original core is inevitable, and invaluable.

The biggest change of all however has been in me, and I'm sure all Nuffield Farming Scholars would agree it was the same for them. The situations you put yourself in as part of your study ensure you have to dig deep in every respect, but the person that emerges from the other side will carry those positive changes for life.

I have begun implementing on my own farm some of the things I have learned, in order to monitor them first-hand. I enjoy sharing my experiences whenever asked to speak about my Nuffield study tour, and I hope to be able to help as many people as possible improve their business efficiency through more effective use of grazed forages.

The secondary benefit of my Scholarship is the realisation that, like those before me, I find my business can remain successful after I have been absent for significant periods of time. Looking forward I am hoping to start a second dairy unit, and I have also been approached about some advisory work, which is something I am very interested in being involved with in the future.

Robert Thornhill



19. Executive summary

The sustainability of any business includes the ability to make a profit in order to continue to operate. As grazed grass is proven to be the cheapest feed for livestock, its inclusion as a cost-effective input for efficient dairy businesses should not be overlooked in a country such as the UK, which has a climate predisposed to the effective growth of grass. In the UK, ryegrasses have become the mainstay of pasture production both for grazing and cutting. The ability of perennial ryegrass to recover from animal trampling and machinery traffic is one of its greatest attributes and, together with its good rate of response to artificial nitrogen, makes it the recommended choice for the dairy industry. Although the continued supply of artificial fertilisers manufactured from finite resources is not going to be an immediate problem, the cost of these products will always remain high.

I wanted to investigate whether the disproportionate interest in, and use of, ryegrasses was fully justified, and whether there were alternative forages that could offer additional benefits for grazing dairy cattle in the UK that would contribute to all the elements that make up sustainability.

In order to find out how farmers successfully implemented the grazing of cattle in conditions that would be considered inappropriate by many people in the UK, my visits to the USA, Canada, the Netherlands, France, New Zealand plus within the UK itself, provided environments both comparable to home and also extremely dissimilar. I experienced the grazing of pastures containing multiple species of plants to see whether some of their promoted benefits could deliver real improvements to livestock and soil, and therefore ultimately profit. I was curious to find out whether these diverse pastures could help lengthen the grazing season or offer extra resilience to climatic extremes, and to discover what different skills were required to manage them.

Whatever forage is offered, planned grazing, with a particular emphasis on the rest period of the pasture between grazings, is of paramount importance in order to obtain the best animal performance. This provides the tools necessary for the grazing manager to make the most cost-effective decisions. The importance of having a balanced soil in terms of its biological, physical and chemical properties is also often overlooked and underutilised and it offers significant potential to mitigate adverse environmental impacts while, at the same time improving financial efficiencies.

Multi-species pastures can offer additional nutritional benefits above grass-only swards, especially in terms of mineral supply. Their rooting systems are very beneficial to soil structure and health and they have been shown to produce more dry matter than do grass/clover swards in dry conditions.



20. Acknowledgements

I cannot attempt to list all the people who have been of help to me since being awarded my Nuffield Farming Scholarship, but whether mentioned or not, they have all made a contribution to this report and have profoundly influenced my thoughts and knowledge.

I would like to thank **The Trehane Trust** for having confidence in me and providing the opportunity of a lifetime, and also **John Stones**, former Nuffield Director, for his patience and perseverance at the time of my application.

Special thanks also go to **Neil and Barbara Dennis** and **Gavin Fisher**.

Sincere thanks go to my team, **Darren Spibey** and **Sam Rogers**, who did an excellent job of maintaining high performance on the farm in my absence.

Most of all I would like to thank the **whole of my family** who have been so supportive and encouraging, none more so than **my wife Sarah**, without whom my Nuffield Study would not have been possible.

See subsequent pages for Appendices and References



21. Appendix 1: grasses

GRASSES

The following is by no means an exhaustive list of grazing forages. I am including this section merely to illustrate the range of better known grasses and broadleaved plants available as seeds in the UK for agriculture. No attempt is made to list grasses more suitable for amenity use, or naturally occurring plants not commercially available. If certain varieties of species are mentioned, this is mainly because they significantly differ from either natural or more common varieties.

Perennial Grasses

Perennial Ryegrass (*Lolium Perenne*)

This is probably the best-known and most widely used grass in the world today for grazing dairy cattle. It is fast-growing and high in energy, and also extremely responsive to nitrogen applications. There is no single species of grass that has received more attention from plant breeders in Europe in recent years, and the livestock industry in general, than perennial ryegrass (PRG).

There is a bewildering array of seeds of many different varieties of this species available to the livestock farmer, each claiming particular benefits for their intended application. Varieties are available for specific management purposes, whether mainly for grazing or cutting, or a combination of both. These varieties can be either for short term or long term leys, depending on their anticipated productive lifespan, and can be early or late flowering.

Another great attribute of PRG is its durability in being able to withstand considerable abuse under real farming conditions. Its ability to proliferate tillers enables it to recover exceptionally well after being trampled with livestock or driven over by heavy machinery in sub-optimal conditions.

Cocksfoot or Orchard Grass (*Dactylis Glomerata*)

Cocksfoot is a very productive grass capable of good growth in dry conditions and can tolerate low soil fertility. It has an erect growth habit and if under-grazed, or not mown, can develop a tufty growth pattern. It is palatable to stock in the young stages of growth but can quickly produce coarse leaves and become stemmy and therefore ignored by animals. More recent varieties have improved the leaves of this grass, making it a more attractive proposition for livestock and farmers.

Timothy (*Phleum Pratense*)

Timothy is a highly productive grass, also capable of good growth during summer. Like cocksfoot, it has relatively few tillers, but is later flowering than most grasses. It is slower to establish than cocksfoot and ryegrass, and will not tolerate intense grazing as well as they do.



Meadow fescue (*Festuca pratensis*)

Although slow to establish, meadow fescue can be a productive grass once it gets going, although it can be outcompeted by ryegrasses. It can grow well in July and August when ryegrasses are at their lowest production, and also in winter, and is reputed to be one of the more nutritious grasses.

Tall fescue (*Festuca elatior*)

Tall fescue is a taller growing and deeper rooting grass than meadow fescue, with few tillers. It also has broader leaves and a long growing season and is relatively tolerant of dry summers.

SHORT PERENNIAL GRASSES

Grasses such as smooth and rough stalked meadow grass, hard fescue, crested dog's tail, creeping red fescue and meadow foxtail are some of the lesser known perennial grasses to be found in older pastures today. While they may not all be considered short in terms of their mature height, they are able to provide some bottom fill to the sward that most of the fast-growing upright grasses do not. Although white clover is very good at filling the bottom of the sward, it may not have the stock carrying capacity that these fine leaved grasses have, especially if one were seeking more overwintering capacity.

Annual Grasses

Italian ryegrass (*Lolium multiflorum*)

This is a very high yielding annual grass that will last up to 2 years and is capable of producing very heavy crops. It has a very open growth habit due to the low number of tillers and produces a very tall plant better suited to cutting. Grazing can be effective during the leafy stage, but is better done during dry weather to avoid soil damage due to the lack of ground cover.

Westerwolds ryegrass (*Lolium multiflorum westerwoldicum*)

This annual ryegrass is very fast to establish and quickly produces large amounts of forage. This copious above ground growth is matched by an extensive root system, allowing good uptake of nutrients as well as the potential for improving soil organic matter and structure .

Westerwolds is the only grass to produce a stem and the seed head from the spring sowing. This is an advantage if it is intended to make hay, but for grazing this requires careful management and frequent and aggressive grazing. A lack of tillering produces the same challenges as with Italian Ryegrass.

Hybrid Grasses

Hybrid ryegrass

Perhaps one of the most useful grasses to the modern farmer, the main commercially available varieties of hybrid ryegrass were developed in Wales by IGER (Institute of



Grassland and Environmental Research) by crossing perennial and Italian ryegrass. This produces a grass which is longer lasting than Italian ryegrass but also has more tillers, therefore producing a denser crop with better ground coverage, more suited to grazing.

Festulolium

This is a cross between fescue and lolium (Italian or perennial ryegrass). Although this is a naturally occurring hybrid, plant breeders have been making significant improvements in recent years. The aim is to combine the winter hardiness and cold season growth of the fescue with the high yield and digestibility of ryegrass. IBERS (Institute of Biological, Environmental and Rural Sciences), formerly IGER, has recently developed a new variety with Italian parentage that displays exceptionally deeper rooting abilities. This could provide not only drought tolerance, but also the ability to improve drainage and reduce risk of flooding due to the deep soil penetration of roots.

See next page for Appendix 2 : clovers and herbs



22. Appendix 2: clovers and herbs

CLOVERS and HERBS

This is a subject that really interests me as a companion to grass. From the perspective of grazing sward, it is usually only white clover that is given mainstream consideration as a desired component. Red clover and lucerne are usually regarded as best suited for leys destined for cutting. Some of the following plants may be regarded by some as indigenous residents, by which I mean not deemed desirable or undesirable, while others may be viewed as weeds (*see Chapter 9, page 22, on weeds and attitudes to*).

White Clover (*Trifolium repens*)

White clover is perhaps the best-known accompaniment to grass for grazing, either in naturally occurring strains or in the large-leaved modern varieties which are capable of making significant contributions to sward in terms of both quantity and quality, as well as fixing high levels of atmospheric nitrogen for the benefit of the companion grasses. White clover is good at filling open gaps in a sward due to its ability to spread laterally, and can offer good summer growth. Like all legumes however, high levels of artificial nitrogen application will suppress growth.

Red clover (*Trifolium pratense*)

Red clover is usually used in cutting situations, either on its own or more usually with other companion plants. It is a short lived perennial that can produce large amounts of forage but its persistence is not high. It is susceptible to sclerotinia and stem nematodes, especially when grown as a pure stand, but IBERS are currently developing varieties that are resistant to these. It is also used as a green manure crop. It can also contain high levels of oestrogen, so caution should be exercised when feeding to breeding livestock.

Alsike clover (*Trifolium hybridum*)

Despite its scientific name, alsike clover is not a hybrid, but was named when it was thought to be a cross between red and white clover.

Persian clover (*Trifolium respusinatum*)

This is an annual clover that works well with grass.

Sweet clover (*Melilotus spp*)

This deeper-rooting biennial is named after the characteristic sweet smell of its flowers. Despite this, the plant is bitter tasting and is often used as a green manure crop. There are different species of this European native, commonly yellow and white, and under the right conditions this can become invasive.

Birdsfoot trefoil (*Lotus corniculatus*)



Although this is a member of the pea family, its appearance is similar to some clovers. Its common name is derived from the appearance of the arrangement of the seedpods

Sanfoin (*Onobrychis*)

Sanfoin is a drought-resistant legume that doesn't cause bloat and contains natural anthelmintics.

Lucerne/alfalfa (*Medicago satvia*)

There are many different varieties available, mostly suited to cutting for hay, but some more suited to grazing are available.

Chicory

There are several different commercial cultivars available, each offering something different from the wild variety. This deeper rooting high-protein forage plant is high in minerals and drought hardy.

Ribwort plantain (*Plantago lanceolata*)

Modern cultivars have improved growth and palatability for this light-land loving perennial herb that is deeper rooting and a good source of minerals.

Yarrow (*Achillea millefolium*)

Often regarded as a weed due to its invasiveness, yarrow can help produce diversity and supply trace elements in a mixed sward.

Sheep's parsley (*Petroselinum crispum*)

This is another plant able to supply diversity and trace elements to a sward. Slightly ironic to include it in a study for cattle, but valuable nonetheless.

Small burnet (*Sanguisorba minor*)

Has good forage value and trace elements and useful in adding diversity to sward.

Common vetch (*Vicia satvia*)

This legume is often grown with cereals in a mixture with cereals but can be grown on its own or in a mixed pasture.

See Appendix 3 on next page



23. Appendix 3

TABLE 1: The macronutrient composition (% of dry matter) of pasture and weed species from organic dairy pastures. Figures in bold indicate significantly higher analyses than for either perennial ryegrass or white clover.

	N	P	K	S	Ca	Mg	Na
Perennial ryegrass	3.77	0.370	3.80	0.347	0.42	0.173	0.182
White clover	4.56	0.347	2.83	0.213	1.19	0.237	0.205
Chicory	4.35	0.663	3.80	0.627	1.18	0.393	0.591
Narrow-leaved plantain	3.37	0.480	1.97	0.530	1.77	0.253	0.618
Broad-leaved dock	4.50	0.430	4.10	0.287	0.80	0.520	0.026
Californian thistle	2.80	0.357	2.93	0.570	1.87	0.307	0.047
Dandelion	3.60	0.570	3.43	0.393	0.96	0.353	0.420
Hairy buttercup	2.93	0.457	3.03	0.323	1.16	0.250	0.433
Yorkshire fog	2.70	0.400	3.20	0.260	0.36	0.173	0.175
LSD P (<0.05)	0.84	0.071	1.06	0.148	0.473	0.074	0.161

TABLE 2: The micronutrient composition (mg/kg) of pasture and weed species from organic dairy pastures. Figures in bold indicate significantly higher analyses than for either perennial ryegrass or white clover.

	Fe	Mn	Cu	Zn	B	Co	Se	Mo
Perennial ryegrass	151	99	7.9	22.0	19.0	0.193	0.023	0.640
White clover	109	55	8.6	22.0	28.7	0.173	0.073	0.223
Chicory	167	161	18.6	57.7	38.3	0.273	0.043	0.420
Narrow-leaved plantain 0.270	182	109	15.1	37.7	23.3	0.360	0.053	0.270
Broad-leaved dock	95	283	7.6	30.7	23.0	0.560	0.047	0.420
Californian thistle	139	120	17.0	41.7	29.3	0.330	0.033	0.210
Dandelion	115	93	14.2	37.0	35.0	0.180	0.043	0.373
Hairy buttercup 0.497	117	150	18.4	41.7	27.7	0.253	0.043	0.497
Yorkshire fog	116	142	5.7	19.3	16.0	0.163	0.027	1.243
LSD (P<0.05)	67	70	2.8	12.0	5.4	0.105	0.075	0.261

(continued on next page)



TABLE 3: The levels of acid detergent fibre (ADF), ash and total crude protein (all expressed as g/kg of dry matter) of pasture and weed species from organic dairy pastures. Figures in bold are significantly higher than in either perennial ryegrass or white clover.

	ADF	Ash	Protein
Perennial ryegrass	281	117	232
White clover	228	129	270
Chicory	261	147	307
Narrow-leaved plantain	256	119	283
Broad-leaved dock	245	151	305
Californian thistle	247	128	292
Dandelion	262	130	287
Hairy buttercup	233	123	278
Yorkshire fog	261	116	295
LSD (P<0.05)	18	20	33

K.C. Harrington et al,
Mineral composition and nutritive value of some common pasture weeds.

See next page, References, for further explanation of various footnotes placed throughout this report.



24. References

(as referred to throughout the report)

1. Gerlinde B. De Deyn *et al*, Vegetation composition promotes carbon and nitrogen storage in model grassland communities of contrasting soil fertility
2. Gerlinde B. De Deyn *et al*, Additional carbon sequestration benefits of grassland diversity restoration
3. D. U. Hooper *et al*, Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs 75:3–35.
4. S.L. Woodward *et al*, Can diverse pasture mixtures reduce nitrogen losses?
5. Edith N. Khaembah, The potential of diverse pastures to reduce nitrogen leaching on New Zealand dairy farms
6. M.J. Daly *et al*, A comparison of multi-species pasture with ryegrass–white clover pasture under dryland conditions
7. S.L. Woodward, *et al*, Are diverse species mixtures better pastures for dairy farming?
8. F. Nobilly *et al*, Productivity of rotationally grazed simple and diverse pasture mixtures under irrigation in Canterbury
9. Yan Hautier *et al*, Eutrophication weakens stabilizing effects of diversity in natural grasslands

25. Further reading

Grass productivity, André Voisin

Milk Production from Pasture, C.W. Holmes *et al*

Fertility Pastures, Newman Turner

Holistic Management, Alan Savory

Holistic Management Handbook, Jodie Butterfield *et al*