Nethergill associates

Maximum Sustainable Output (MSO)

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Background

Through our own experience at Nethergill Farm and during some study work on upland farms in the north of England, in 2017, there emerged anecdotal evidence that as some farms downsized to withdraw from farming their losses reduced noticeably. Other farms which had downsized more modestly to adjust to the prevailing economy also reported an improvement in profitability.

This phenomenon seemed to fly in the face of logic and peoples' understanding of the underlying dynamics in business operations. MSO came out of attempts to explain (or disprove) what was being reported.

The Standard Model of the Firm

The standard model of the firm is based on some simple propositions:

- Revenues grow linearly with output.
- There will be a set of unavoidable fixed costs associated with enterprise establishment and management.
- There will be a set of costs (variable costs) that will grow linearly with output volumes.

Refinements to this model include cases where variable costs are non-linear but continuous. This model has been widely successful in industry and has been widely advocated by farming schools and colleges. The lessons of this model in farming are now deep-seated. **Many, if not most, farmers are convinced that expansion and intensification is the route to better commercial returns.**

Composite Sequential Variable Costs

The experiences of the farmers in the north of England, who had reduced their losses by downsizing, could be replicated by splitting variable costs into two components. The issue then was to establish why this should happen and what it meant.

Upland livestock farmers simply use grass to feed their stock and finish them for market. Grass availability is everything and is heavily influenced by the weather. The pursuit of volume and the incentive to maximise grass production in disadvantaged landscapes had led to widespread attempts at intensification. However, a great proportion of the grass occurred "naturally" and only the perceived "shortfalls" were being "forced". This led to the definition of the de-composed elements of variable costs, as follows:

- The first set of variable costs encountered in farming were those associated with working with *Nature*. These were defined as **productive variable costs** (PVCs).
- The subsequent set of variable costs encountered were those associated with substituting for *Nature*. These were defined as ***corrective variable costs*** (CVCs).

In farming the variable costs line is, therefore, bifurcated and comprises two sequential components.

The Concept of MSO

The immediate consequence of this re-definition of costs was to ask the question: what might be the significance of the inflexion point (between the PVCs and the CVCs)?

The inflexion point resides (in the case of farms forcing outputs) at the point where the natural grass available runs-out. For all-grass fed livestock this would be the point of maximum output on natural resources, that is the point of maximum sustainable output (MSO).

Front cover image by schneeknirschen from Pixabay

The MSO point, it was discovered, had other important attributes:

- It was the point of **maximum profitability.**
- It was a point where the pattern of prevailing bio-diversity was un-compromised by any artificial inputs. However, it must be noted that often the resulting pattern of biodiversity is disappointing for some farmers and conservationists. Being simply unadulterated is a perfectly tenable position because changing the situation in the hope of securing a specific pattern of biodiversity will require extra work and will not avoid the challenges of predicting the outcome.
- It was the point in a managed landscape, which is in state of dynamic equilibrium with *Nature*, where the work involved in maintaining the *status quo* was minimised.

Consequences for the Evolution of Unit Costs

On the standard model of the firm, unit costs of production reduce continuously as volumes increase. On the MSO model, unit costs reduce to the MSO point (at a faster rate than with the standard model) and then increase thereafter with volume increases. Historically, many farmers, believing in the standard model, have expanded in the expectation that unit costs can only fall, whereas in reality unit costs have been increasing faster than revenues beyond the MSO point. On the Nethergill Associates database (NAD) of over 230 farms (August 2023) the average for farms working above their MSO point is that every £1.00 of additional revenue it is costing £2.65.

Farming Above MSO

On the NAD, about 93% of the farms examined are working above their MSO point. For these farms, expansions in output result in increasing levels of unprofitability. To work at MSO these farms need to eliminate all their CVCs. This will, typically, involve a reduction in output of between 10 and 20%. The benefit come in improved profitability, which has been never less than 5% and comes with no apparent upside limits.

The biggest components of CVCs are fertilisers, food concentrates, and excessive vet & med expenses (caused by overstocking and over-cautious "insurance").

There is evidence that, in terms of dry matter production (measured in kg/Ha per annum), farms that have never ever used fertilisers can produce dry matter at the same rate as the best of the rest. MSO, although originally conceived for upland livestock farms, does have exactly the same relevance for arable, dairy and lowland livestock farming. All will have their profits maximised at their MSO point. Arable farms will benefit from some livestock content (where fencing provisions still exist) and working at MSO will cut-into problems associated with run-off into water courses and the accumulation of phosphates in the soil. Dairy farms comprise two very different components: a traditional farm (with livestock) and a factory (the milking parlour). Whilst the farm is capable of eliminating its CVCs, some concentrates are considered to be un-avoidable in dairy operations. However, what has become clear from our study work is that when specific milk production (defined as Litres/cow pa) increases, profitability decreases (at least when specific outputs are high).

Farming Below MSO

About 7% of the farms we have examined have been operating below its MSO point. There are three principal reasons for this:

1. A farm is in a process of transition.
2. A farm is working inefficiently with regard to its available natural resources.

3. A farm consciously chooses a "low-stress" regime to promote a programme of recovery for its bio-diversity.

Farms, not in transition, that are working below MSO have one question, in common, to answer: is it in the national interest not to use fully its available natural resources? Farms that work consciously at a "low-stress" level have an additional question to answer: what is the value to society in not exploiting fully its available natural resources?

We do not attempt to answer these questions. Property owners have the right to act (lawfully/morally) in accordance with their values and aspirations. However, our work has revealed two factors which need to be acknowledged:

- No farm working below MSO (even those registered as organic) has been free of all CVCs. These farms, too, have an inflexion point although this will not be its MSO point.
- The profits foregone in working below MSO have not been covered by the support payments available. If farms are to be compensated for "public goods" in the form of different patterns of bio-diversity the levels of support would have to increase substantially.

Measures of Business Performance

The Hierarchy of Profitability
The first objective of a business is to cover its variable costs. Failure to do so means that cash is lost on every transaction and the business is unlikely to be intrinsically viable. In the NAD, 18% of farms do not cover variable costs and make a positive 1st contribution on farm output revenues (pre-support income).

The second objective of a business is to cover all its variable and fixed costs. This would deliver a positive 2nd contribution. In the NAD, 80% of farms fail on this count and, as a consequence, are exposed to the forces of de-capitalisation.

After support payments are accounted for, the 2nd contribution becomes the 3rd contribution and this, if any, is the figure most farmers will recognise. In the NAD, 80% farms make a positive 3rd contribution – reversing completely the 2nd contribution picture and demonstrating the critical importance of support payments currently.

Return on Total Assets Employed (ROTA)
Farming is a capital-intensive endeavour and it is useful to ask the question: would it be more profitable to cash-in and invest funds in a building society?

In order to answer the question and make a valid comparison, farming performance measures have to be the equivalent of interest payments on capital. To do this, it must be recognised that money is a two-dimensional entity, having amount and term. The essential relationship is:

ROTA = Profit/Assets Employed
= (Profit/Sales) x (Sales/Assets Employed)
= Margin x Assets Turn

The margin is a measure related to the profit and loss account and reflects amount. Assets turn is a factor related to the balance sheet and reflects term. ROTA is, therefore, a composite measure of performance and has a place in business management practices on farms.

In our work we have set ROTA objective of 15%. This comprises 5%, reflecting building society rates, and 10% as compensation for business risk. Few farms are capable of exceeding 15% on pre-support revenues. Support payments transform this and a consequent move to MSO would add further improvement.

Farmers struggle with this concept but in cases where we have had 5 or 10 years of accounts we have tracked the movements in ROTA performance and invited farmers to explain what might have happened in particular years when the tracking was unusual. This has been successful, and those farmers have accepted ROTA as a valuable tool.

Energy Considerations

The Solar Constant

Every square metre of the planet, when in sunlight, has access to 1.36kW of power. This is not a function of latitude as the sun "sees" the planet as a disc. A farmer's mission is to capture this power and use it for maximum commercial advantage. The energy content (kWh) drives photosynthesis, plant growth, and the wider farming opportunity. It is this energy, and its' exploitation, that lies behind PVCs.

"Free-Issue" Resources

A farm, unlike an industrial enterprise, has access to important resources by courtesy of Nature. These resources are principally:

- Sunlight
- Soils
- Bio-diversity

The use of these resources should be maximised for the greatest commercial benefit.

Where these resources have been exhausted or are simply not available, the farming sector has developed a range of artificial substitutes. All these substitutes are invariably manufactured and consume significant amounts of industrial energy. These are the farm inputs that lie behind CVCs. Food is a fuel and fuels deliver energy. The energy content and value of food products (typically measured as calories) is low as food is often simply a bulk commodity. At this point it should be noted, in contrast, that the energy content of manufactured products is certainly not inexpensive. To understand this consequence requires an appreciation of physics and thermodynamics in particular.

The Four Laws of Thermodynamics

The four laws, which are inescapable, unavoidable, and inevitable, are (in a form framed for farming):

- **All systems in contact with each other will at some point reach a position of common equilibrium**. This is the managed landscape today, which is in a state of dynamic equilibrium with *Nature*. The equilibrium is dynamic in the sense that it needs constant maintenance. This is

not a fatal flaw by any means as the only true state of stable equilibrium for any landscape is the unaltered primal wilderness.

- **To change a system (the managed landscape) from one state to another requires work**. It does not come free. A landscape will change if it is completely neglected but this is not free as *Nature* provides the energy to accomplish the work.
- **When any system changes there is an increase in general disorder**. Even when part of a system is ordered (farmed productively) there is a greater amount of disorder created in the external environment. This is the "arrow-of-time" phenomenon that lies behind all decay and is known to science as *entropy*. Work, and consequently energy, that is put into a landscape can never be fully recovered and such changes to a landscape will be irreversible (or not fully-reversible). This has fundamental implications when re-wilding programmes are undertaken.
- **There are no pathways back to any set of original conditions.** Nature acts randomly with a mechanism that is non-linear and exhibits positive-feedback (that change is amplified by prior changes). This is chaos. However, order does come from chaos (known as the phenomenon of resonance) but it is unpredictable and entirely dependent on starting conditions. This is why re-wilding (without intervention) inevitably produces an unexpected dominant species of plants and animals (the resonant effect). Note that re-wilding, with intervention, may change outcomes but only with components that involve the consumption of industrial energy.

Farmers as Energy Producers

As food producers, farmers are in the energy business and, it could be said, are probably the most important energy producers in the economy.

The critical appreciation of this reality lies in the recognition that when one form of energy is converted into another, such as natural gas into electricity, useful energy is lost and is irrecoverable. To put this in terms of livestock farming, there is nothing more effective than putting adapted native breeds on pasture, with an all-grass feed on a year-round basis outside. Anything else, in this case, involves compromises (non-native breeds) or industrial inputs (fertilisers and concentrates) or extra costs (silage, shelter, etc.).

Natural Capital

The Problems with Qualitative Measures

Many people see landscapes in entirely qualitative terms. "The Lake District is sublime"; "the Brecon Beacons are rugged"; "coastal perspectives are more attractive than inland landscapes", etc. This makes comparisons either intractable or even invalid. When it comes to setting objectives for necessary patterns of bio-diversity, despite the philanthropy, a full agreement is most unlikely. The dilemma is encapsulated in the question: how many worms equal a lapwing?

The Challenges of Quantification

Currently, there is no generally accepted quantifiable-measure for natural capital. However, valuations of businesses are often made on the basis that income streams also have an equivalent capital value. As Nature, by providing assets in the form of natural resources, allows farm businesses to produce income it is reasonable to suggest that capitalising this income stream will be a measure of natural capital.

The conversion of an income stream into an equivalent capital value is dependent on two factors; the horizon over which the income stream is projected and the rate at which the income stream is discounted from year to year. If the appropriate horizon for farming is regarded as medium term, on the grounds that economic conditions change over similar horizons, and if the appropriate rating of risk in farming is regarded as very high, on the grounds that weather events intervene significantly and that farming is heavily dependent upon subsidies, then an horizon of 15 years and a discount rate of 33% would seem to be a good starting point. On these assumptions, the income stream in farming that is entirely attributable to the use of natural resources would be converted into an equivalent capital value by a factor of 4x.

Primary Natural Capital

Farm income, in the form of revenues before subsidies, incurs costs associated with exploiting natural resources and "free-issue" energy from sunlight. These costs are the PVCs and are unavoidable. The primary net income stream for a farm, and its' consequent natural capital value is, therefore, set out by the key relationships:

- Primary Net Income (PNI) = Farm Income (before subsidies) – PVCs
- Primary Natural Capital (PNC) = 4 x PNI

Capital Value Attenuation

The primary natural capital (PNC) of a farm business is quickly degraded by the use of CVCs, which reduces the income stream, and by fixed costs, which impose an additional administrative burden on the resultant net income. These attenuations are often severe. Whilst CVCs may be eliminated, by working at MSO, the administrative burden can never be totally eliminated.

Dealing with Accounting Conventions

One of the benefits that come from a proper quantification of natural capital is that the values could and should be taken into standard accounting conventions.

To do this, it must first be accepted that Nature, as a provider of natural resources, needs to be recognised as a legitimate "stakeholder" in a farm business. All accepted stakeholders in a business must rank alongside shareholders or subscribers of capital. In accounting terms, these stakeholders are treated as liabilities on the business balance sheet. However, Nature, unlike a traditional investor, does not demand a dividend payment; instead, it provides a bonus through the availability of its' natural resources and the access to its' "free-issue" energy. Therefore, it should appear as a negative liability on a business balance sheet.

All liabilities are offset by values on the assets side of the balance sheet and the negative balancing entry on the assets side will be the natural capital assets value. This appears to be counter-intuitive at first but is "proved" by the realisations that:

- Natural capital should help with generating income (as in its absence there would be no income) and the greater its value the more beneficial this should be.
- With a negative natural capital assets value, the net assets employed in a business is reduced. This makes it easier to deliver a particular ROTA objective.
- If natural capital is destroyed, by bad farming practices or the use of CVCs, then meeting a specific ROTA objective becomes more difficult. This is as it should be if we value the environment.

Treating natural capital in this way would make it clear at all times that Nature is a key partner in farming and that adulterating Nature has a detrimental effect on commercial returns.

Strategic Implications

Downsizing to MSO

From NAD data, 93% of farms would appear to be working above its MSO point and to work at MSO farm outputs would fall by, typically, 15%. Conversely, the 7% of farms that appear to be working below MSO have the opportunity to expand output. However, in this second group there are farm businesses which choose to work below MSO so as to make its contribution to "wildlife recovery" initiatives. Expansions from this group will be small under present circumstances.
A reduction in farm outputs cause alarm bells to ring on the grounds of national food security issues.

However, an MSO programme will now have been pursued for up to four years on some farms. Other farms, that used the covid pandemic period to move quickly, have moved to MSO in one year. Evidence from these farms show that in going to MSO, there is a natural recovery in soil fertility and that the MSO-point increases in time. There is reason to believe that output levels at MSO will improve to previous levels (if not beyond) over a period of two to four years. Whilst the loss of output in moving to MSO would be temporary, the permanent benefits would be improved farm profitability and a more sustainable farming regime.

Furthermore, as CVCs are reduced (or eliminated) the land set aside to produce animal feed substitutes (other than grass) would be released for alternative arable production or conversion into pasture. This could release up to 40% of arable land resources for new commercial endeavour.

Implications for Net-Zero Policies

Farming is cited as a major source of CO_2 emissions and it expected to play its part in reducing this greenhouse-gas. However, all living species emit CO_2. Without this CO_2 plant life would not survive in its current abundance on sunlight alone. The CO_2 problem has to be seen in industrial terms (otherwise the climate change problem will mutate into an overpopulation problem). If farms work at MSO, all its' free-issue energy will have been used and no inputs with an industrial energy content will have been consumed. Essentially, a farm at MSO is at both a natural balance with Nature and an energy balance, too. Such farms could claim to be at net-zero. This would leave all grass-fed livestock numbers untouched as a consequence.

The Design of Support Schemes

Farming, short of price rises of over 100% across the board, is dependent on support payments from government. The challenge for government is how to distribute this support fairly and constructively. Whatever mechanisms are deployed for the distribution of support there is a good argument to say that the objectives of future support programmes should be to incentivise farms to operate at MSO.

Glossary of Terms: MSO Theory

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Term	Explanation
Farm Output	The revenue from the sale of farm produce, without support.
Fixed Costs	The permanent costs of establishment in running a farm business. These costs will not change with different output values.
Variable Costs	The cost inputs that are volume dependent. In MSO theory, these costs de-compose into two sequential groups. These are the productive variable costs (PVCs) and the corrective variable costs (CVCs). See below.
PVCs	PVCs (productive variable costs) are those exclusively associated with working with Nature and the natural resources on the farm. These costs would include grass management, ploughing and harvesting. PVCs are linked to "free-issue" resources. See below.
CVCs	CVCs (corrective variable costs) are those associated with substituting for *Nature* or natural resources. Typically, these cost items will be one of two types: 1. Items that incorporate an industrial energy content. 2. Items that correct for some disadvantages linked to latitude, elevation, or rainfall. These costs would include concentrates, fertilisers, and silage production.
Free-issue	*Nature*, in providing farms with sunlight, rainfall, and fertile soils, is delivering valuable resources essentially free, although it will take work to exploit these advantages (in the form of PVCs). These resources are therefore available on a "free-issue" basis and will not appear as costs in any set of accounts.
Profitability	In general, profits are the surpluses in revenues after costs have been deducted. This is far too general to be useful so profitability has been sub-divided into three different levels of *Contribution*. See below
1st Contribution	Farm Output less total Variable costs: It is the contribution to other subsequent costs, such as, fixed costs, farm drawings, capital expenditures, and taxation. When the 1st Contribution is negative, a business loses cash on every transaction and is intrinsically un-viable without subsidy.
2nd Contribution	1st Contribution less total Fixed Costs: It is the contribution available to cover the remaining costs in the business. When the 2nd Contribution is negative, a business is de-capitalising and will only survive if capital injections are made from time to time.
3rd Contribution	This is unique to farming: 2nd Contribution plus subsidies, support, and grants. (This is the measure of profits recognised in statutory accounts).
Break-even	Revenues and costs in a business increase with output volumes, but in different ways. Revenues increase generally as volumes increase. Total costs, which comprise fixed costs and variable costs, also increase with volumes but only as variable costs occur. At low volumes of output total costs will exceed total revenues but there will be a point, in a viable business, where revenues equal costs. This is the break-even point. Beyond this point revenues will exceed costs, at least to some future point. See below.
Break-back	CVCs, if present in a business, will be incurred after the resources related to PVCs have been exhausted. These CVCs will, invariably, increase at a faster rate than revenues. (The reasons for this are discussed under MSO and Thermodynamics, later). As CVCs increase there will be a point when total costs overtake total revenues again. This is the break-back point. Beyond this point all profits have been eliminated and losses increase indefinitely.

MSO	MSO: (maximum sustainable output). This is the farm output generated when all the natural resources available on the farm have been consumed and no other artificial inputs have been used. For most farms this will be at the inflexion point between the PVCs and the onset of the CVCs. The exceptions to this are the low output farms where not all their natural resources available have been consumed.
Thermodynamics	Farms produce food and foods are a fuel. Fuels are forms of energy and the science of energy is founded in thermodynamics. There are four laws in thermodynamics which constrain all aspects of energy production and usage. These are set out below, phrased for farming but using the illogical but common referencing convention from science.
Law 0	All landscapes in contact with *Nature* will, at some point, reach a position of common equilibrium with *Nature*. This is the managed landscape.
Law 1	To transform the managed landscape from one state to another cannot be done without putting in work. Change does not come free.
Law 2	All changes produce increasing levels of disorder and these changes will never be fully reversible. That is the energy content of farm inputs (concentrates, fertilisers, etc,) can never be fully recovered in farm produce (as food calories).
Law 3	There are no pathways back to any set of original conditions. Change, such as a "re-wilding" programme, can only produce a new future and not some return to a previous world.
Solar Constant	The sun sees our planet as a disc and solar radiation, as sunlight, is the same on any part of that disc. Consequently, there is available at any time, when in sunlight, 1.36kW/square metre of "free-issue" energy available to landowners and farmers. The mission of farming is to turn this energy into valuable food products. The wavelength of sunlight (the visible spectrum) makes it "transparent" to the atmosphere and it has no heating effect. However, on striking the surface of the planet the wavelength of the radiation is changed (to infra-red) and it is this energy that then warms the atmosphere to an ambient 15°C.
Natural Capital	All resources, including natural resources, can be regarded as capital items. Many discussions around the concept of natural capital are in the context of offsetting qualitative values against hard-nosed financial capitalism. However, natural capital can be quantified. It can be defined as the net present value of the income stream attributable to the use of natural resources in producing food products. The relevant income stream for a farm can be defined simply as farm output less PVCs. The resulting value is the natural capital value of the farm resources. If the environment is adulterated by inappropriate farming practices this is equivalent to decapitalising the business. Profitability inevitably declines in these circumstances.
Unit Costs	Unit costs are simply the total cost of production divided by the volume of output. The usual measure is £/unit of output. However, unit costs change as the profiles of costs and outputs change. On the standard model of the firm unit costs decrease, at reducing rates, as outputs grow. On the MSO model this decrease only happens up to the MSO point and will increase thereafter. The absolute value of unit costs at any time can be misleading on its own; it is the direction of change that is more important. Marginal cost analyses fall into this trap. If unit costs are measured as total cost divided by the value of output (£cost/£value of unit sales) then profits are made when the measure is less than 1 and losses are made when it is greater than 1.

Saddle Points	In *Nature* it is usual for some aspects to move in one direction whilst other aspects will move in an opposite direction. This trade-off situation results in a search for a point at which an acceptable compromise can be found. When one factor, such as farm profits, are maximised it would be important to confirm that, say, any environmental damage would be avoided, or that energy consumption is minimised. When these conditions are all met it is said that the system (farming in the managed landscape) is at a saddle-point as the shape of the equations resembles the surface of a saddle which goes down around the back of a horse and upwards to provide support for a rider. Where the shape tops-out for the horse and bottoms-out for the rider is the "mathematical" saddle-point. MSO is a saddle-point where profitability is maximised, energy consumption is minimised, and Nature is optimised (in the sense that it is uncompromised but different from that of other landscapes).