A Comparison of Grassland Management Systems for Beef Cattle Using Self-Contained Farmlets: Effects of Contrasting Nitrogen Inputs and Management Strategies on the Farm Economy

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Abstract

The financial implications of manipulating nitrogen (N) inputs and management strategies for beef production systems were assessed. One-hectare grassland farmlets were grazed to a target sward height by beef steers; herbage surplus to grazing requirements was cut for silage. Three systems were compared: 'CN', conventional mineral N application to a grass monoculture and broadcast slurry; 'TN', tactical mineral N application at fortnightly intervals to a grass monoculture with slurry injection and the early housing of cattle; 'GC', a mixed grass/white clover sward with no mineral N addition and slurry injection. Comparisons were made on two contrasting soil types: a freely-draining sandy loam (site 1) and a poorly drained clay (site 2). Financial budgets for 1999-2000 show that estimated gross profit margins (gross outputs minus variable costs), after deducting contractor's charges for sward preparation and fertiliser spreading, were highest for treatment CN at both sites [Ξ](€1552, €1356 and €1461 ha^{-1} for site 1 and €1562, €1281 and €1287 ha^{-1} for site 2, for treatments CN, TN and GC, respectively). Treatment TN was penalised by increased costs associated with an extended housed period and the need to purchase additional silage for winter feeding which cost €242 ha^{-1} at site 1 and €250 ha^{-1} at site 2. Savings in N fertiliser for TN in comparison with CN (€44 ha^{-1} at site 1 and €39 ha^{-1} at site 2) were more than offset by the increased costs of fortnightly fertiliser applications (€54 ha^{-1} at site 1 and €46 ha^{-1} at site 2). Treatment GC benefited from zero costs for the purchase and spreading of mineral N fertiliser but was penalised by increased variation in forage DM production which resulted in a shortfall in winter fodder requirements with a replacement cost of €250 at site 1 and €435 at site 2. The best overall economic performance after the allocation of all possible relevant costs (variable, fixed and capital) in terms of the relative net profit margin, was for GC at site

1 and for CN at site 2 (-€1358, -€2399 and -€1304 ha^{-1} at site 1 and -€1122, -€2810 and -€1380 ha^{-1} at site 2, for CN, TN and GC, respectively). The opportunity costs of reducing N surpluses at the gross profit margin level (after contractor's charges) for treatments TN and GC over treatment CN were calculated at €2.29 kg^{-1} N surplus for TN and €0.67 kg^{-1} N surplus for GC at site 1, with corresponding values of €4.91 and €1.57 at site 2.

Keywords: Farmlets; Systems; Beef cattle; Nitrogen; Slurry; Animal production; Economics; UK

1. Introduction

Agriculture in the UK is recognised as a major source of pollution of both water and the atmosphere. In particular, intensively managed grassland supporting specialised animal production systems such as dairy farming are of concern, with nitrogen (N) being lost to the atmosphere in gaseous forms such as nitrous oxide and ammonia (NH_3) and to ground waters as nitrate (Jarvis et al., 1995). The land spreading of cattle manures has been identified as the single largest source of NH_3 emission, accounting for 45 kt of the 226 kt NH_3-N arising annually from agricultural sources in the UK (Misselbrook et al., 2000). As well as environmental concerns, this loss represents a considerable financial penalty for livestock farmers, with the total N lost each year as NH_3 alone from all agricultural sources being equivalent to €93 million as fertiliser.

Recent research has identified various management strategies to abate losses and make better use of N supplied as inorganic fertilizer or organic manure in farming systems. These include the tactical (diagnostic) application of N (Scholefield et al., 1995), which aims to match mineral N addition to crop requirements whilst accounting for soil mineral N content, exploitation of N fixation by legumes, the early housing of cattle to avoid the

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[Ξ] All £ to € conversions carried out at the agrimonetary exchange rate on 25/02/2002 of £1 = €1.63559.

accumulation of soil inorganic N and reduce the risk of leaching in autumn (Wilkins, 1993), and the use of shallow injectors or band spreaders for slurry application (Huijsmans et al., 1997). These options, when considered alone or in combination, have a significant impact on the flows and excesses of N in animal production systems (Jarvis et al., 1996) but also impact on the overall farm economy.

A whole systems approach was used to evaluate the effects of combinations of management strategies designed to reduce N losses on N budgets, and herbage and animal production in South West England. Animal and herbage production and N budgets for each treatment were reported by Laws et al. (2000). In the present paper, the financial implications for the whole farm economy of adopting a reduced N input approach are examined.

2. Materials and methods

2.1. Site and sward details, management strategies and treatments

Sites and swards, management strategies and treatments were described in detail by Laws et al. (2000). In summary, a series of 1 ha grassland farmlets were established on two soil types with contrasting drainage status, at two sites situated within 4 km of the Institute of Grassland and Environmental Research (IGER), North Wyke in South West England, UK (latitude 50.46 N, longitude 30.54 W). The soils were a freely draining, coarse, sandy loam (site 1) and a poorly drained clayey shale (site 2). Each farmlet was managed to incorporate all the components of grassland management *viz*. grazing, cutting, mineral fertiliser and slurry application, and supported 4 autumn-born, Limousin x Friesian steers (221 kg mean liveweight at turnout). The area available for grazing was adjusted to maintain the height of the sward above 75 mm when measured with a sward stick (Bircham, 1981), using an

electrified fence to sub-divide the farmlets. Herbage surplus to grazing requirements was cut for silage on three occasions each year. Slurry was returned to the farmlets with amounts based on standard values for excreta production during the housed period (MAFF, 1994).

There were three treatments:

'CN', conventional N fertiliser management in which 280 kg N ha^{-1} was applied as ammonium nitrate each year, at set times and in set amounts as prescribed by current recommendations (MAFF, 1994); 'TN', the tactical application of N fertiliser in order to achieve NO_3^--N losses which comply with the EC Nitrate Directive (CEC, 1991), and 'GC', a mixed grass/white clover sward with no mineral N addition.

Key features of the treatments are shown in Table 1.

2.2. Financial and physical data.

Various measurements and estimates used in the financial calculations are shown in Table 2. Measured values are reported for all the factors associated with the grazing period. As facilities for housing were not available, productivity during the housed period was based on calculations and production optima using standard tables and research findings as follows. Daily growth rate was assumed to be 0.95 kg $head^{-1}$ and the animals were finished for slaughter at 515 kg liveweight (Nix, 1999). The duration of the housed period was calculated for each treatment group using these estimates and measured values for liveweight at the time of housing. The animals were assumed to be offered a diet of grass silage plus a cereal supplement to satisfy a daily intake of 8.0 kg DM per head (Wilkinson, 1984). For treatments CN and GC, rolled barley was offered at a rate of 3 kg $head^{-1}$ day^{-1} for the first 90 days of the housed period, increasing to 4.5 kg $head^{-1}$ day^{-1} thereafter (Wilkinson and Tayler, 1973). For treatment TN, the animals were assumed to be fed a silage-only diet for the period up to the

housing of the cattle on treatment CN, at which time barley was included in their diet as described above. For all treatments, the silage portion of the diet, calculated to meet the remainder of the diet, was increased by 25% to allow for wastage during feeding (Lazenby, 1988).

Calculations of the amount of slurry requiring storage and spreading for each treatment were based on the number of animals, the duration of the housed period and an assumed 27 litres of faeces and urine excreted per head per day (MAFF, 1994). Prices, costs and valuations used in the calculation of gross outputs, variable and fixed costs and gross, operating and net profit margins are as per Nix (1999).

3. Results and discussion

Results were broadly similar for both sites and so the results obtained on the freely draining soil type at site 1 are highlighted in this section. Differences between sites are indicated where appropriate.

3.1 Gross Outputs

The gross outputs of value of liveweight gain at pasture and when housed, beef special premium payments (www.maff.gov.uk) and surplus silage values are shown in Table 3. The liveweight of the cattle at turnout to pasture in spring was similar for all treatments (Table 2). Consequently, the liveweight gain required to achieve the target liveweight at slaughter (515 kg head^{-1}) and the associated financial output was similar for all treatments. The Beef Special Premium subsidy was included in full although this is dependent upon the overall stocking rate on the farm and will vary according to regional limits. Treatment CN

only realised a small surplus of silage in excess of winter feeding requirements. Therefore, the total financial gross outputs were similar for all the treatments (€2448 ha^{-1}, €2440 ha^{-1} and €2439 ha^{-1} for treatments CN, TN and GC, respectively). However, differences between treatments were evident in the apportionment of the liveweight gain to the grazing and housing periods and, consequently, in the relative impact each treatment had on the variable and fixed costs associated with being housed.

3.2 Direct/variable costs

The variable costs - before contractor's charges for fieldwork - (Table 3) were lowest for treatment CN at both sites (site 1: €765 ha^{-1}, €900 ha^{-1} and €886 ha^{-1} for CN, TN and GC, respectively; site 2: €700 ha^{-1}, €919 ha^{-1} and €1044 ha^{-1} for CN, TN and GC, respectively). Treatments TN and GC suffered a financial penalty for having reduced herbage production compared with treatment CN, with the additional silage for winter feeding costing €242 ha^{-1} and €250 ha^{-1} for TN and GC, respectively (€214 ha^{-1} and €435 ha^{-1}, respectively, at site 2).

In contrast, treatment GC benefited from zero costs for the purchase and spreading of N fertiliser. Treatment TN realised savings in N fertiliser of €44 ha^{-1} compared with CN, but additional N fertiliser applications on the TN treatment increased application variable costs by €54 ha^{-1} at site 1 with similar increases being evident at site 2. This treatment also incurred extra variable costs associated with the extended housing period. Contractor's charges for sward preparation were €25 ha^{-1} greater at site 2 than site 1 reflecting the increased cultivation required on the heavier soil type (€67 ha^{-1} at site 1 and €92 ha^{-1} at site 2). The total variable costs (after contractor's charges) were €898 ha^{-1}, €1084 ha^{-1} and €978 ha^{-1} for treatments CN, TN and GC, respectively at site 1 (€854 ha^{-1}, €1120 ha^{-1} and €1158 ha^{-1}, respectively, at site 2).

3.3 Gross profit margins

Because no two farms are alike in the cost and availability of resources at their disposal, gross profit margins (gross outputs minus variable costs) were calculated both before and after consideration of contractor's charges for fertiliser applications and sward preparation; the resultant margins were called the gross (profit) margin before contractor's charges (GMBC) and the gross (profit) margin after contractor's charges (GMAC). Determination of the GMBC provides the best general guide to the economics of the three treatments and is most relevant to those farm business which could draw on spare labour and appropriate mechanisation resources.

Values for GMBC were highest for treatment CN at both sites (€1683 ha^{-1}, €1541 ha^{-1} and €1552 ha^{-1} for CN, TN and GC, respectively, at site 1; €1716 ha^{-1}, €1482 ha^{-1} and €1402 ha^{-1} for CN, TN and GC, respectively, at site 2). GMAC presents a modified picture of which treatment is most economically viable, and should be considered by the farm business which is reliant upon contractor support or which feels that contractors' prices represent a realistic approximation of the additional cost of carrying out these operations on their farms. Table 3 shows that, after consideration of contractor's charges, the CN treatment retained it's relative advantage at both sites with a treatment ranking, from highest to lowest, of CN>GC>TN with values of €1552 ha^{-1}, €1356 ha^{-1} and €1461 ha^{-1} for CN, TN and GC, respectively, at site 1, and €1562 ha^{-1}, €1281 ha^{-1} and €1287 ha^{-1} for CN, TN and GC, respectively, at site 2.

In order to validate the GMBCs, comparisons were made with predicted values for the 1999/2000 marketing year reported by Nix (1999) for 18-month beef production systems, of €1881 per forage ha for high performance and €1464 per forage ha for average performance based upon beef prices per live kg of €1.64 and €1.59, respectively. Treatment CN achieved

values comparable with the high performance level at both sites, whereas values at both sites for treatment TN and at site 1 for GC were higher than the predicted values for average performance.

3.4 Indirect/Fixed Costs

The indirect/fixed costs represent those costs that are difficult to allocate to individual enterprises, cannot easily be changed in the short term and which do not vary in direct proportion to the scale of the enterprise. Those relating to mechanisation, labour, buildings and capital are shown in Table 4. Although it is difficult to generalise over the implications for these costs for specific farm businesses, these recognise that the treatments vary in respect to their relative requirements for fixed resources.

Slurry application costs were greater for treatments TN and GC (shallow injection) than for CN (surface broadcast) with increased costs over CN of €39 ha^{-1} for TN and €26 ha^{-1} for GC (€51 ha^{-1} for TN and €28 ha^{-1} for GC at site 2). The additional costs of silage harvesting for treatment TN were more significant, with increases over CN of €121 ha^{-1} at site 1 and €147 ha^{-1} at site 2. However, differences in the amount of silage made for these two treatments were small being 0.3 t DM more for CN than TN at site 1 and 0.8 t DM less for CN than TN at site 2 (Table 2). Silage harvesting costs were least on treatment GC reflecting the much reduced yield on this treatment. However, savings in the cost of storing less silage on this treatment were more than offset by the cost of purchasing additional silage to satisfy winter feed requirements. Total mechanisation fixed costs showed an advantage in favour of GC at both sites with savings of €16 ha^{-1} and €177 ha^{-1} over CN and TN, respectively, at site 1, (€54 ha^{-1} and €252 ha^{-1} over CN and TN, respectively, at site 2).

The TN treatment had a significantly higher labour demand than the other treatments with increased costs associated with the extended housed period and the time taken to test for soil mineral N contents. The winter housing work related to time spent feeding, scraping slurry and bedding down the livestock. Based on a labour cost of €9.32 $hour^{-1}$, the TN treatment generated excess costs over CN of €623 ha^{-1} at site 1 and €1065 ha^{-1} at site 2. Labour costs for GC were broadly comparable with CN, being €69 ha^{-1} less at site 1 and €93 ha^{-1} more at site 2.

The longer winter housing period for treatment TN also had fixed cost implications relating to the additional storage requirements for silage and slurry. However, because the storage facilities were depreciated over a 25-year estimated working life, annual differences between treatments were small. Total building costs were €224 ha^{-1}, €226 ha^{-1} and €201 ha^{-1} for CN, TN and GC, respectively, at site 1 (€216 ha^{-1}, €237 ha^{-1} and €185 ha^{-1} for CN, TN and GC, respectively, at site 2).

The indirect/fixed costs have been included in the relative operating and net profit margin budgets for each treatment to represent the full cost implications for each treatment but with the strict proviso that, in interpreting these data, such costs should not be considered as universally applicable. Individual business circumstances should be taken into account. Many businesses would probably not need to invest additional capital and would simply utilise existing capital resources (already acquired and therefore representing a “sunk” cost) more fully. Also, it is unlikely that businesses would employ additional labour, preferring, if necessary, to work a little harder or longer to make a system work. Having trimmed labour back in many instances during the current recession in UK agriculture, those systems that offer the least demand for this constrained resource might well be preferred. Under these circumstances, the GC system might be favoured.

3.5 Capital costs

There are two categories of capital costs shown in Table 4. The first relates to the working capital required to fund the level of production achieved by each treatment at 50 % of the annualised average treatment variable costs. The second relates to the average fixed capital invested in the infrastructure (buildings, silage & slurry storage) required to support each treatment (@ 50% of the total infrastructure cost). All capital was charged at an interest rate of 12% annual percentage rate per annum.

For working capital, treatment TN showed a relative cost disadvantage (€183 ha^{-1}, €242 ha^{-1} and €183 ha^{-1} for CN, TN and GC, respectively), whereas, for the fixed capital required for silage and slurry storage, there was an advantage in favour of treatment GC (€337 ha^{-1}, €340 ha^{-1} and €303 ha^{-1} for CN, TN and GC, respectively). Total annualised capital costs showed a relative advantage to treatment GC and were ranked in order from highest to lowest TN>CN>GC at both sites.

3.6 Relative operating profit margins and net profit margins

The Relative Operating Profit Margin (GMAC minus the fixed costs before capital costs (interest), Table 4), was broadly similar for treatments CN and GC but considerably lower for treatment TN (-€837 ha^{-1} for CN, -€1819 ha^{-1} for TN and -€818 ha^{-1} for GC at site 1; -€630 ha^{-1} for CN, -€2193 ha^{-1} for TN and -€913 ha^{-1} for GC at site 2).

The Relative Net Profit Margin (Relative Operating Profit Margin minus the Total Capital Costs), showed that the GC treatment gave the most favourable relative economic performance at site 1, with a Relative Net Profit Margin of €-1304 ha^{-1} compared with €-1358 ha^{-1} for treatment CN and €-2399 ha^{-1} for TN. At site 2, treatment CN was most

favourable whilst treatment TN again exhibited the lowest Relative Net Profit Margin with values of

€-1122 for CN, €-2810 for TN and €-1380 for GC.

The negative values for the relative net profit margins for all treatments show that lowland beef production is currently unprofitable when costs are based on current cost accounting procedures if starting such an enterprise on a 'green field' site. Under these circumstances relatively small variations in system performance are extremely important to individual producers and more complex systems that require additional investments of capital (especially fixed capital) are unlikely to be adopted. Thus the GC system would tend to be favoured. When one also considers the possibilities for quality production of beef and the ease with which organic conversion (together with its associated conversion payments and product price premia) could be achieved from the GC system, then the benefits of adopting this system become more compelling. Against this is the increased variation in forage DM production and hence requirements for additional silage to be purchased for GC, making this system more susceptible to seasonal risks.

3.7 Sensitivity analysis

The two main economic factors that affected the gross margin calculations were the values budgeted for the liveweight gain (€1.59 kg^{-1}) and the cost budgeted for N fertiliser (€143 t^{-1}). A sensitivity analysis was carried out to examine the associations between the value/cost of these determinants and profitability.

Values for the price of beef ranging from €1.31 kg^{-1} to €2.04 kg^{-1} were used together with N fertiliser prices ranging from €131 t^{-1} to €188 t^{-1}. Results (Figure 1) illustrate how sensitive the financial performance was to beef price but that changes to fertiliser price had

relatively little effect. Changes in the beef price showed an advantage to the GC system because of the enhanced animal performance at pasture, particularly at site 1, compared with the other two systems. At a fertiliser price of €147 t^{-1}, (a price close to the budgeted price of €143 t^{-1}), GMAC ranged from €1210, €1014 and €1122 ha^{-1} for CN, TN and GC, respectively, at a beef price of €1.31 kg^{-1} liveweight to €2082, €1886 and €1994 ha^{-1} for CN, TN and GC, respectively, at €2.04 kg^{-1} liveweight. Thus the gross profit margins altered by €872 ha^{-1} for all treatments, indicating that the budgets are sensitive to the beef price changes over the anticipated range.

Analysis of the sensitivity to N fertiliser price also provided evidence of the differences between the treatments. At €1.55 kg^{-1} liveweight, a value close to the budgeted value (€1.59kg^{-1}), gross profit margins ranged from €1513, €1313 and €1413 ha^{-1} for CN, TN and GC, respectively, at a fertiliser price of €131 t^{-1} to €1467, €1284 and €1413 ha^{-1} for CN, TN and GC, respectively, at a fertiliser price of €188 t^{-1}. Thus the GC treatment was unaffected by fertiliser N price changes (as none was used) whereas the GMAC for treatment CN altered by €46 and for treatment TN by €29. Overall, however, the budgets were not very sensitive to fertiliser price changes over the anticipated range.

3.8 Environmental costs

The environmental costs associated with the three treatments are more difficult to define. Nitrogen inputs and management factors have a profound effect on the amount of herbage grown and harvested and on N utilization. Laws et al. (2000) reported surpluses of N at site 1 of 239 kg ha^{-1}, 153 kg ha^{-1} and 104 kg ha^{-1} for treatments CN, TN and GC, respectively, being significantly ($P<0.001$) greater on CN than the other treatments. Similar values were obtained at site 2 for CN and TN but with a much reduced surplus for GC (232

kg ha^{-1}, 175 kg ha^{-1} and 58 kg ha^{-1} for CN, TN and GC, respectively). When the surplus N was related to animal production, the GC treatment was again most favourable with significantly less surplus N per 100 kg liveweight gain (41, 32 and 15 kg surplus N per 100 kg liveweight gain for treatments CN, TN and GC, respectively, at site 1, with corresponding values of 47, 73 and 13 kg surplus N per 100 kg liveweight gain at site 2).

These estimates can be related to the opportunity costs of achieving a reduction in surplus N by adopting each of the less profitable treatments (as represented by GMAC), rather than the CN treatment. There was a significant surplus N reduction cost advantage in favour of site 1 compared with site 2, with costs of €2.29 kg^{-1} and €0.67 kg^{-1} for TN and GC, respectively, at site 1 and corresponding costs of €4.91 kg^{-1} and €1.57 kg^{-1} at site 2. Although specific to the package of measures implemented for each treatment, these estimates provide a basis for detailed consideration of the effects of management changes on N budgets and the environment.

4. Conclusions

Manipulations made to the management strategies of livestock production systems had implications for the physical and financial outputs and the variable, fixed and capital costs of each system. Treatment CN benefited from being self sufficient for winter fodder and from the lower costs of conventional slurry broadcasting compared with shallow injection. It consequently exhibited the highest gross profit margins.

Although successful in reducing N surpluses, treatment TN was penalised by the early removal of cattle from pasture. It thus carried higher labour costs and a greater dependence on fixed resources, and consequently showed the lowest financial performance across all categories of margin (gross, operating and net).

Under treatment GC, although forage DM production was reduced, particularly at site 2 where less clover was present in the sward, there was a reduced reliance on resources and reduced N fertilisation costs. Thus this treatment demonstrated that reductions in N surplus can be achieved at relatively low cost.

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Table 1. Treatment descriptions

Conventional N (CN)	Sward:	Grass monoculture
	Mineral N:	280 kg N ha^{-1} applied from March to August, at set times and in set amounts, according to current recommendations for beef production (MAFF, 1994).
	Slurry:	Surface broadcast in spring and post silage cuts.
	Grazing :	April to October.
	Cutting:	3 times.
Tactical N (TN)	Sward:	Grass monoculture
	Mineral N:	Fortnightly from March to August, based on measurements of soil mineral N to maintain NO_3^--N in leachate at <11.3 ppm.
	Slurry:	Injected in spring and post silage cuts.
	Grazing :	April to August.
	Cutting:	3 times (twice after the cattle were housed).
Grass/clover (GC)	Sward:	Grass/white clover.
	Mineral N:	Zero.
	Slurry:	Injected in spring and autumn (including a nitrification inhibitor in autumn only).
	Grazing :	April to October.
	Cutting:	3 times.

Table 2. Some treatment characteristics based on various measurements, assumptions and current best estimates. Data are reported on a 'per ha' basis for the grazing period and 'per group' for the housed period, and are means over 3 years for each treatment .

	site 1			site 2		
	CN	TN	GC	CN	TN	GC
Mean liveweight at turnout to pasture (kg head^{-1})	218	220	219	224	225	221
Grazing period:						
Duration (d)	180	115	178	172	102	175
Liveweight gain (kg)	576	446	591	612	343	602
Silage offtake (t DM)	5.25	4.95	3.36	4.84	5.64	2.04
Housed period:						
Duration (d) *	162	193	156	146	215	154
Liveweight gain (kg)	616	732	596	552	820	584
Total DM requirement (t) [§]	7.09	8.13	6.88	6.49	8.87	6.79
Concentrate fed (t DM) [†]	1.91	1.53	1.82	1.67	1.78	1.79
Silage required (t DM) [§§]	5.19	6.59	5.06	4.82	7.09	5.00
Surplus (+)/deficit (-) in silage (t	+0.06	-1.64	-1.70	+0.02	-1.45	-2.96
DM) Slurry generated (m^3) [‡]	17.5	20.8	16.9	15.7	23.2	16.6

Abbreviations as for Table 1. * Based on a finished liveweight of 515 kg (Nix, 1999) and a daily growth rate of 0.95 kg head^{-1} during the housed period (Wilkinson and Tayler, 1973). [†] Assuming a daily allowance of rolled barley @ 3kg head^{-1} for the first 90 days of housing increasing to 4.5 kg head^{-1} thereafter @ 85% DM content (Wilkinson and Tayler, 1973). [§] Assuming a daily DM intake of 8.0 kg head^{-1} day^{-1} (Wilkinson, 1984). [§§] Increased by 25 % to allow for losses and wastage (Lazenby, 1998). [‡] Based on 27 litres of faeces and urine excreted head^{-1} day^{-1} (MAFF, 1994).

All £ to € conversions in tables 3 and 4 carried out at the agrimonetary exchange rate on 25/02/2002 of £1 = €1.63559 or €1 = £0.6114.

Table 3.Gross outputs, variable costs and gross profit margins for Conventional N, Tactical N and Grass/clover treatments at both sites (€ ha^{-1}).

	Site 1				Site 2			
	CN	TN	GC		CN	TN	GC	Valuations and costs used in gross profit margin calculations.
GROSS OUTPUTS:								
Liveweight gain (grazing)	908	718	942		976	546	960	LWG at pasture @ €1.59 kg^{-1}.
Liveweight gain (housed)	981	1169	945		885	1304	934	LWG when housed @ €0.1.59 kg^{-1}.
Headage payment	551	551	551		551	551	551	Beef special premium subsidy @ €137.91/head.
Surplus silage sold	8	0	0		3	0	0	Surplus silage sold @ €36.8 t^{-1} fresh material.
TOTAL GROSS OUTPUT	**2448**	**2440**	**2439**		**2416**	**2401**	**2445**	
DIRECT/VARIABLE COSTS:								
Additional winter silage purchased	0	242	250		0	214	435	Additional winter silage purchased @ €36.8 t^{-1} fresh material.
Silage supplement at grass	18	0	20		5	0	3	Silage fed at grass @ €36.8 t^{-1} fresh material.
Concentrates when housed	311	252	296		273	293	293	Rolled barley @ €131 t^{-1}.
Bedding	74	88	72		67	98	70	Straw @ 3.5 kg/head/day @ €33 t^{-1}.
Veterinary/medicines	144	144	144		144	144	144	Veterinary and medicinal costs @ €36/head.
Nitrification inhibitor	0	0	16		0	0	16	Nitrification inhibitor (10 litres ha^{-1} @ €3.27 $litre^{-1}$ on 0.5 ha).
Nitrogen fertiliser	118	74	0		118	79	0	Ammonium nitrate (34.5% N) @ €143 t^{-1}.
Maintenance phosphate	13	13	13		10	10	10	P_2O_5 @ 29p kg^{-1} nutrient based on 0:24:24 @ €180 t^{-1}.
Maintenance potash	10	10	10		5	5	5	K_2O @ 23p kg^{-1} nutrient based on 0:24:24 @ €180 t^{-1}.
Maintenance lime	31	31	31		31	31	31	Lime @ €31.49 t^{-1} delivered and spread @ 5 t ha^{-1} once every 5 years
Sward establishment:								Sward establishment costs (annualised over 5 years):
Grass seed	25	25	11		25	25	11	Grass seed (26 kg ha^{-1} for CN and TN, 12 kg ha^{-1} for GC) @ €4.58 kg^{-1}
Clover seed	0	0	8		0	0	8	Clover seed (4 kg ha^{-1}) @ €9.81 kg^{-1}
Herbicide/Pesticide	13	13	7		13	13	7	Draza slug pellets @ 5kg ha^{-1} @ €7.31 kg^{-1}
Seedbed fertiliser – grass	11	11	0		11	11	0	250 kg ha^{-1} 10:24:24 @ €213 t^{-1} for CN and TN
Seedbed fertiliser – grass/clover	0	0	10		0	0	10	250 kg ha^{-1} 0:24:24 @ €180 t^{-1} for GC
VARIABLE COSTS *	**765**	**900**	**886**		**700**	**919**	**1044**	
Contractor's charges:								Contractor's charges (annualised over 5 years):
N fertiliser application	51	105	0		51	96	0	Routine N fertiliser application @ €13/ ha^{-1}
P and K application	13	13	13		13	13	13	P and K application @ €13/ha
Ploughing	13	13	13		13	13	13	Ploughing @ €65 ha^{-1}
Flat rolling	7	7	7		7	7	7	Flat rolling @ €34 ha^{-1}
Power harrowing	21	21	21		21	21	21	Power harrowing @ €52 ha^{-1}
Ring rolling	13	13	13		23	23	23	Ring rolling @ €22 ha^{-1}
Spring tine harrowing	8	8	8		23	23	23	Spring tine harrowing @ €38 ha^{-1}
Grass broadcasting	5	5	5		5	5	5	Grass broadcasting @ €26 ha^{-1}
Clover drilling	0	0	7		0	0	7	Clover drilling @ €35 ha^{-1}
Spraying	0	0	3		0	0	3	Spraying @ €19.6 ha^{-1}
TOTAL ALL VARIABLE COSTS †	**898**	**1084**	**978**		**854**	**1120**	**1158**	
GROSS PROFIT MARGIN *	**1683**	**1541**	**1552**		**1716**	**1482**	**1402**	
GROSS PROFIT MARGIN †	**1552**	**1356**	**1461**		**1562**	**1281**	**1287**	

Abbreviations as for Table 1. *, before contractor's charges; †, after contractor's charges. Valuations and costs are according to Nix, (2000).

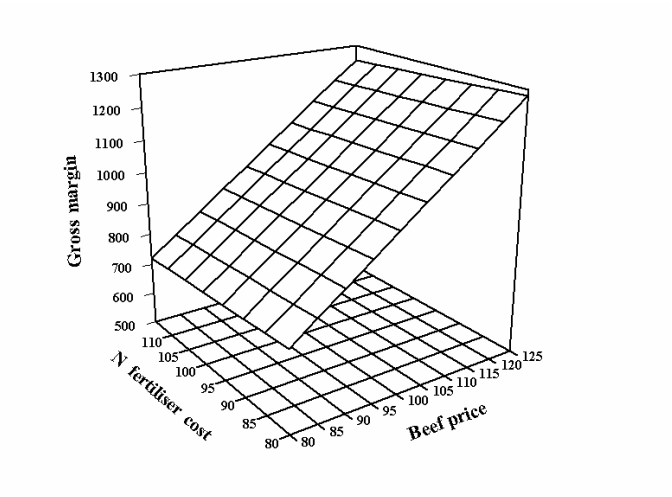
Table 4. Fixed and capital costs with the relative operating profit margins and the relative net profit margins for Conventional N, Tactical N and Grass/clover treatments for both sites (€ ha^{-1}).

	Site 1				Site 2			
	CN	TN	GC		CN	TN	GC	
ALLOCATED INDIRECT/FIXED COSTS:								
Mechanisation:								*Mechanisation (based on contractor's charges):*
Slurry applications	33	72	59		29	80	57	Surface spreading @ €1.17 m^{-3}; injection @ €3.47 m^{-3}.
Silage harvesting	244	365	201		244	391	162	Cutting, carting and ensiling costs @ €180 ha^{-1}.
TOTAL	**276**	**437**	**260**		**273**	**471**	**219**	
Labour:								*Labour:*
Feeding	756	900	728		680	1003	718	Feeding time @ 30 minutes $group^{-1}$ d^{-1} @ €9.32 hr^{-1}.
Slurry scraping/bedding down	1133	1349	1091		1021	1503	1076	Slurry scraping/bedding down time @ 45 minutes $group^{-1}$ d^{-1} @ €9.32 hr^{-1}.
Soil sampling and testing	0	262	0		0	262	0	Soil mineral N testing time @ 2 hrs per fortnight over 28 weeks @ €9.32 hr^{-1}.
TOTAL	**1887**	**2511**	**1819**		**1701**	**2766**	**1794**	
Buildings:								*Buildings (depreciation straight line over building life):*
Winter housing	136	136	136		136	136	136	Building cost at €846/head over 25 years.
Slurry storage	28	31	26		25	36	26	Slurry generated during housing @ €39 m^{-3} storage cost.
Silage storage	62	59	39		56	65	23	Silage storage @ 25% DM @ €73.6 t^{-1}.
TOTAL	**224**	**226**	**201**		**216**	**237**	**185**	
TOTAL FIXED COSTS	**2390**	**3175**	**2280**		**2190**	**3474**	**2200**	
RELATIVE OPERATING PROFIT MARGIN	**-837**	**-1819**	**-818**		**-630**	**-2193**	**-913**	Gross profit margins after contractor's charges minus the total fixed costs.
CAPITAL COSTS:								
Working capital	183	242	183		170	262	190	
Fixed capital	337	340	303		324	355	278	
TOTAL CAPITAL COSTS	**520**	**581**	**486**		**494**	**617**	**468**	
RELATIVE NET PROFIT MARGIN	**-1358**	**-2399**	**-1304**		**-1122**	**-2810**	**-1380**	Relative Operating Profit Margin minus the total capital costs.

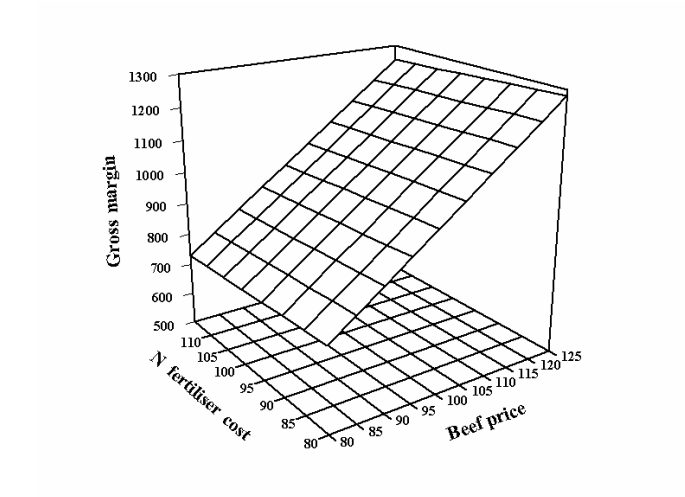
Abbreviations as for Table 1.

Figure 1. Sensitivity analysis: Associations between beef price (p kg^{-1}), fertiliser cost (£ t^{-1}) and gross margin after contractor's charges (£ ha^{-1}) for treatments CN, TN and GC at both sites. Abbreviations as in Table 1.

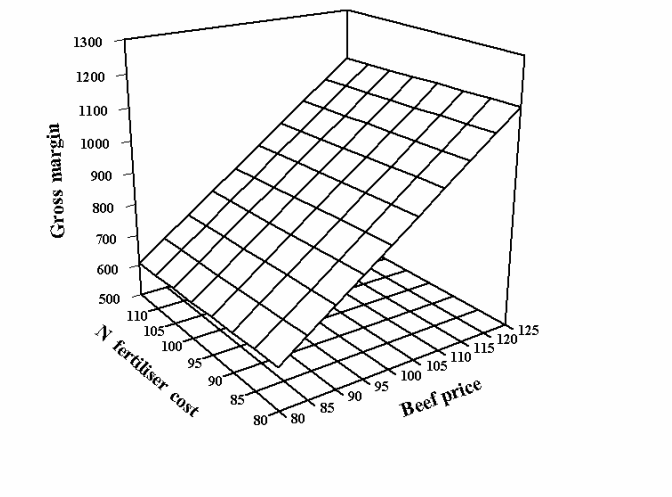
a) CN, site 1



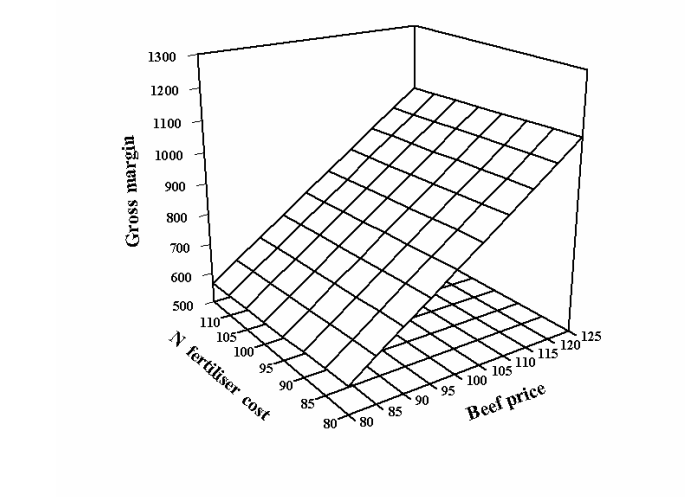
b) CN, site 2



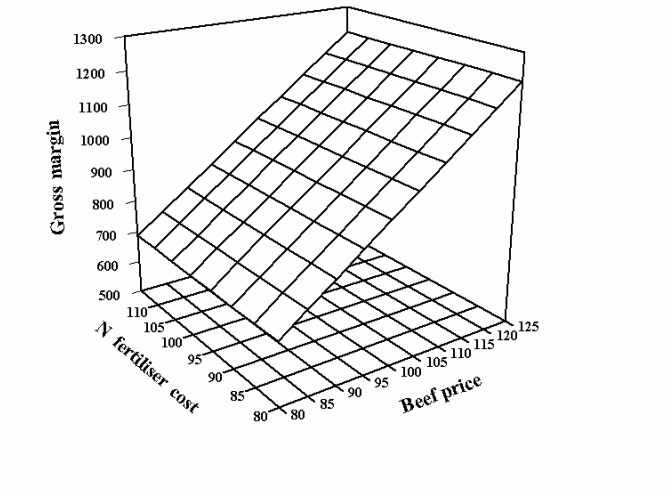
c) TN, site 1



d) TN, site 2



e) GC, site 1



f) GC, site 2