REFEREED PAPER

SIMULATION MODELLING OF THE COST OF PRODUCING AND UTILISING FEEDS FOR RUMINANTS ON IRISH FARMS

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A static agro-economic simulation model, the Grange Feed Costing Model (GFCM), was developed to facilitate the rapid calculation of feed costs and to aid in explaining the interaction of variables influencing the cost of providing fifty three distinct feed crops to ruminants on Irish farms.

The GFCM was used to quantify the impact of changing biological, management and market variables on the cost of producing and utilising eight of the most common feed crops grown in Ireland. While grazed perennial ryegrass was found to be the cheapest feed, a wide range of feeds were shown to be cost competitive with grass silage as winter feed options.

Keywords: Crop cost, feed cost, GFCM, simulation model, winter feeds

1. Introduction

Irish agriculture is dominated by ruminant production systems with 95% of Irish farmers describing their farming systems as either 'mainly cattle' (beef and dairy), 'mainly sheep', or 'mixed crops and livestock' (DAF, 2008). Feed cost accounts for over 75% of total variable costs on these livestock farms (Connolly *et al.*, 2010) and can therefore have a significant impact on farm profitability. Ramsey *et al.* (2005) demonstrated a clear inverse relationship between feed cost and farm profitability on beef rearing farms in the USA, while McCall and Clark (1999) found similar results using data from dairy farms in the USA and New Zealand. Several other authors have highlighted the need for optimisation of feed sources as a means of improving farm profitability (Groen and Korver, 1989; O'Kiely *et al.*, 1997; Shalloo *et al.*, 2004).

Agricultural input and output commodity price peaks and troughs have impacted on livestock farm profitability in recent years. The considerable increases in the price of oil and oil-derived products (e.g. fuel, fertiliser, polythene and pesticides) during 2008 contributed to a significant fall in farm incomes. Similarly, the sizable drop in milk prices in 2008/2009 had a negative impact on dairy farm margins (Connolly *et al.*, 2010). As a result of the removal of agricultural commodity support structures in the EU, farmers are increasingly exposed to world commodity price fluctuations. In this context, low cost production systems are more likely to remain sustainable in the longer term. As feed cost constitutes such a large proportion of total variable costs, it is clear that prudent management of feed costs can significantly impact on the profitability and sustainability of ruminant production systems.

Selecting the most appropriate feeding programme has become a more complex task for Irish farmers in recent decades. New legislative environmental constraints such as 'The Nitrates Directive' (SI 378 – DAF, 2006), voluntary schemes such as the Rural Environmental Protection Scheme (REPS) and changes in the Common Agricultural Policy (CAP) have had implications for optimal farm systems (Crosson *et al*., 2006). New developments in agronomic and feeding technologies have resulted in increased production of whole-crop maize silage, whole-crop cereal silages, high moisture grains and grazed brassicas as alternative feeds (CSO, 2010). The wider choice of alternative, home-grown feeds, the changing regulatory environment and greater input cost variability have demanded a more fluid decision-making process of Irish farmers seeking to optimise nutrient supply to ruminant production systems. A number of authors (Walker, 2002; Newman *et al*., 2000) identified the need for a computerised tool to aid the understanding of such complex decision-making environments on farms.

Simulation modelling has been used for many years to aid in explaining, understanding and improving the performance of farm systems (Qureshi *et al*., 1999). Crosson *et al.* (2006) and Shalloo *et al.* (2004) developed systems models to analyse the economic impact of changes in the technical, environmental and policy environment on Irish beef and dairy farm systems, respectively. There have been numerous agronomic models developed to describe the impact of management and environmental variables on crop production (Dobos *et al*., 2004; McCown *et al*., 1996; Brisson *et al*., 2003). However, the number of models developed to simulate the economics of feed crop production and utilisation is low. O'Kiely *et al.* (1997) is one of very few published studies to have examined the costs of producing and utilising a range of feeds for ruminants while none have examined the impact of a range of fluctuating variables on feed cost.

To address the aforementioned set of complexities impacting on feed cost the Grange Feed Costing Model (GFCM) was developed. The objective was to develop a research tool which would consistently quantify the costs and values of changing feed cropping options and management practices in the production and utilisation of a comprehensive range of feed crops for ruminants on Irish farms. The GFCM was targeted for use by specialist advisory and agricultural systems researchers who could disseminate the results generated by the model to the ultimate beneficiary, the ruminant livestock farmer.

The modelling approach used permitted simulation of a much broader range of alternative feed crops and technologies employed by Irish farmers than previously studied by O'Kiely *et al.* (1997). Research by both McGee (2000) and O'Kiely *et al.* (1997) identified the problem of partial costing approaches to costing feed crops and the consequent "grossly misinforming conclusions" which could be derived from such approaches. Thus, developing a standardised 'full-costing' methodology across all feed crops within the model design was prioritised.

The objective of this paper is to describe the structure of the GFCM and to demonstrate its application by investigating the impact of biological, management and market changes on the cost of producing and utilising ruminant feed crops on Irish farms.

2. Model specifications and costing conventions

2.1 Model structure

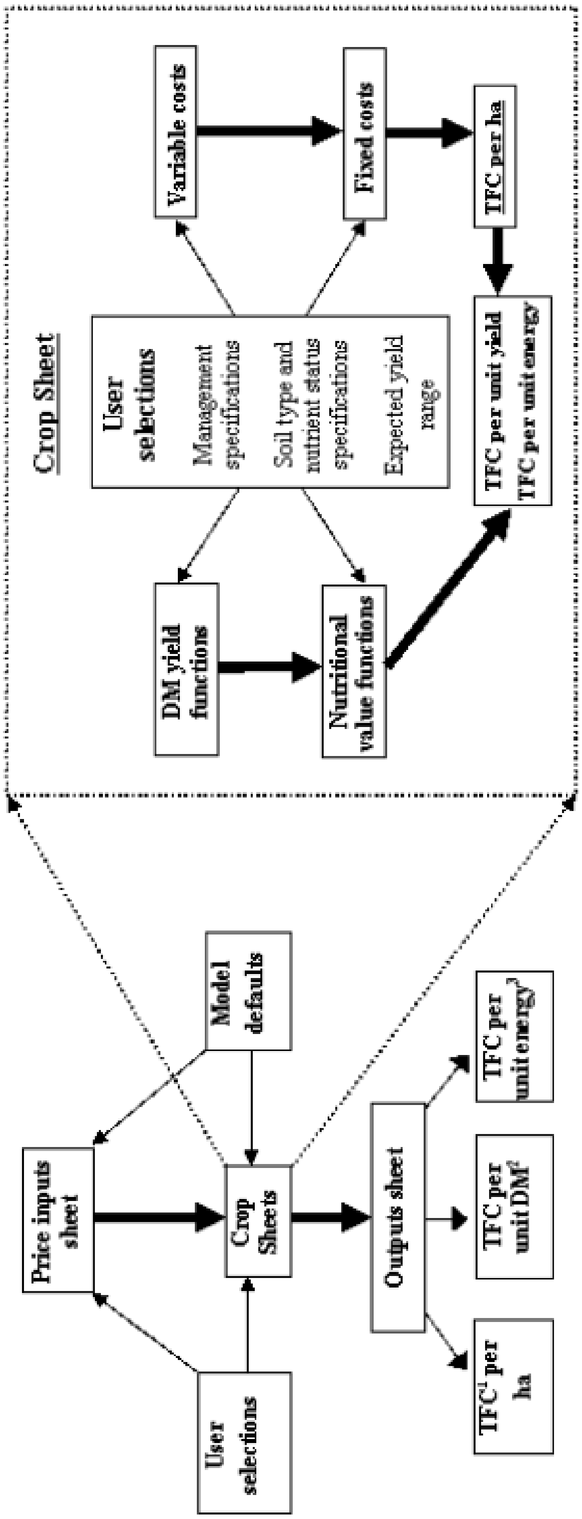
The GFCM is a static, spreadsheet-based, agro-economic simulation model for evaluation of the physical and financial performance of alternative feed crop production and utilisation options in Ireland. It employs a single-year, deterministic approach to modelling feed crop cost. Agronomic defaults in terms of sowing dates, field operations, and harvest and utilisation options are relevant to Irish conditions (Coulter and Lalor, 2008; O'Kiely, 2001; O'Mahony, 2009; O'Riordan *et al.*, 1998). Deterministic crop yields, based on specified biological and management factors, are calculated rather than simulating growth rates. The economics are based on annual input costs at prevailing 2009 prices (unless otherwise specified) and long term capital costs. Fifty three distinct feed crop production and utilisation options are modelled in the GFCM (Table 1) and are categorised as grass/legumes, cereals, brassicas and beet.

Table 1. GFCM feed crop production and utilisation options

Feed crop category	Feed crop	Sowing options	Grazing options	Silage *(whole-crop)* options	Other harvest options	Post harvest/ Conservation options
Grasses/ Legumes	Perennial ryegrass	User defined re-seeding interval	1[1]	4	2[2]	-
	Perennial ryegrass & white clover		1	-	-	-
	Perennial ryegrass & red clover		1[3]	4	-	-
Cereals	Wheat	Winter/ Spring	-	*(2)*	2[4]	4
	Barley		-	*(2)*	2	4
	Oats		-	*(2)*	2	4
	Triticale		-	*(2)*	2	4
	Maize	Mulch/ No Mulch	-	*(1)*	-	-
Brassicas	Kale	Multiple sowing date options	1	-	-	-
	Swedes		1	-	-	-
	Stubble turnips		1	-	-	-
	Fodder rape		1	-	-	-
Beet	Fodder beet	April sown	1	-	1[5]	-
	Sugar beet		0	-	1[5]	-

Grass may be rotationally grazed over a full grazing season or grazed before or after silage harvest; [2]Hay – early or late harvest; [3]Ryegrass/ red clover swards may be grazed following either the second or third silage harvest; [4]Small grain cereals may be harvested as HMG or 'dry' (> 80% DM) grain; [5]Beet tops may be grazed *in situ*.

Figure 1. Schematic of GFCM model structure



1.TFC = Total Feed Cost 2. DM grown or DM utilised (UDM) 3. Metabolisable Energy (ME) or net energy (NE)

In the GFCM and for the purposes of this paper "feed crop production" refers to all processes from land preparation, sowing and crop management through to the point of grazing or harvest. "Utilisation" refers to all processes from immediately prior to harvest through to the point of ingestion by an animal, including grazing or harvesting, processing, conservation, storage and feed-out. The model allows considerable usability and flexibility for the model -user as it was designed as a computer spreadsheet (MS Excel) incorporating drop-down menu options and clearly marked data input cells. It employs a comprehensive input price sheet which allows the user to model the impact of input price fluctuations across all of the feeds (Figure 1).

The GFCM contains individual "crop sheets" for each feed crop where a number of environmental and management variables must be specified by the user. Yield and nutritional value is computed by means of a series of inbuilt functions derived from long term experimental data measured under Irish conditions. Fixed and variable costs associated with the feed crop are detailed in tabular format in the crop sheet. Soil type and nutrient status affects feed crop fertiliser requirements and consequently feed cost. Management specifications such as stocking rate (for the grazed crops), sowing and harvest dates, and harvest and conservation technologies must also be defined by the model user in the crop sheets. The various management, biological and input price variables may be altered either simultaneously or sequentially by means of the data input cells in order to model the impact of different cropping scenarios on feed crop cost.

2.2 Feed crop yields

The model quantifies feed crop yield in a range of measures; dry matter grown per feed crop hectare (DM ha^{-1}), dry matter utilised per feed crop hectare (UDM ha^{-1}), digestible dry matter per feed crop hectare (DDM ha^{-1}), metabolisable energy per feed crop hectare (ME ha^{-1}), and net energy per feed crop hectare (NE ha^{-1}), which can be compared across all feed crops. Yield data were obtained from published Irish sources for feed crops grown in productive soils under good management (Butler, 2006; CSO, 2010; O'Kiely, 2001). In the absence of published data, yield data from Teagasc research farms were used to derive default values.

Nutritional value is expressed as follows;

1. Digestibility; dry matter digestibility (DMD) and organic matter digestibility (OMD for cereals); g kg DM-
2. Metabolisable energy; MJ kg DM^{-1}
3. Net energy; UFL kg DM^{-1} (Unité fourragère lait – Feed unit for milk production) and UFV kg DM^{-1} (Unité fourragère viande – Feed unit for meat production) (Jarrige, 1989).

2.3 Costing convention

The GFCM employs a full-costing approach in calculating the TFC (total feed cost) of each feed. TFC is equivalent to the 'economic cost' described by Kay and Edwards (1994) as the opportunity cost of the resources plus the 'accounting cost'. The accounting cost includes all production (land preparation, sowing and crop management) and utilisation (processing, storage, labour and feed-out) costs associated with the feed; in addition to non-cash costs such as depreciation of fixed assets (see Appendix A).

Labour is often included as an opportunity cost in the costing of feed crops but is treated as a cash cost in the TFC within the agricultural contractor charges which are applied for all feed crop production and utilisation operations (See Appendix A). The opportunity cost of the land is included as a 'land charge' (assumed as equivalent to the current annual market price for rental land) in the TFC to give the full economic cost of the feed.

TFC is expressed as Euro (€) per unit of feed crop yield; on net energy (NE), metabolisable energy (ME), dry matter grown/harvestable (DM), dry matter utilised – i.e. ingested by the animal - (UDM) and digestible dry matter (DDM) bases. The cost of balancing a feed crop for energy, protein, fibre or minerals in order to meet particular dietary requirements is not included in TFC. A facility is provided in the GFCM to benchmark home-produced feeds against the cost of purchased alternatives (including storage and feed-out losses and costs) such as rolled barley.

2.4 Model validation

In order to ensure that model outputs would provide a reasonable representation of reality a validation process was undertaken to assess the functionality of the model and the appropriateness of data sources used and assumptions made. In the absence of a broad and robust dataset of yields and input rates for feed crops grown on Irish farms, an assessment of "face validity" of the GFCM by "knowledgeable individuals" was conducted as described by Qureshi *et al.* (1999). Two separate group meetings of specialist agricultural advisors and crop and ruminant researchers were held to validate the GFCM development and functionality. Following thorough examination of the individual yield and nutritional value functions, input prices and scenario analysis it was deemed that the GFCM provided an appropriate model of the interactions influencing feed crop cost on Irish farms.

3. Model applications

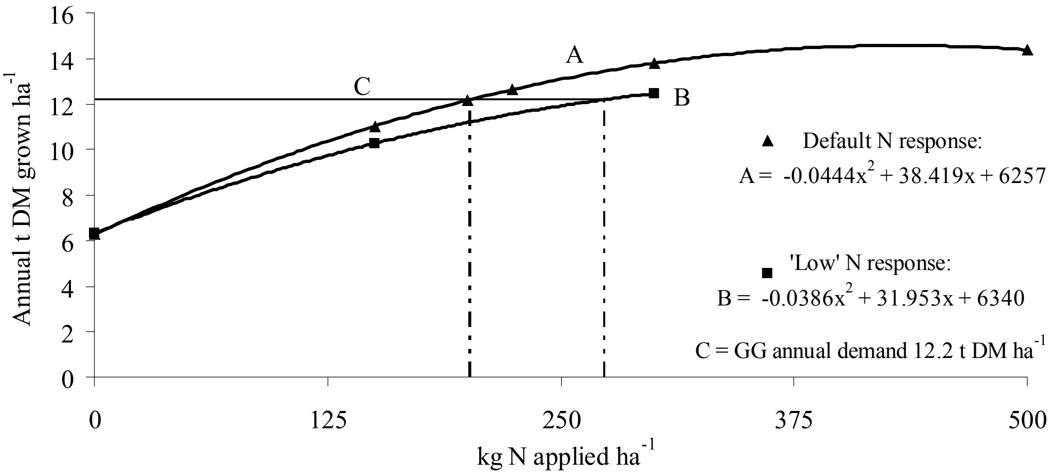
This section describes how the GFCM was used to analyse and compare feed crop production and utilisation scenarios and input price fluctuations. The following model applications demonstrate the capability of the model to simulate feed production and utilisation options and provide economic indicators to assist the user in evaluating the viability of these options.

3.1 Impact of biological factors: Nitrogen response of perennial ryegrass

A comparison of two annual nitrogen (N) response curves for a grazed perennial ryegrass sward was conducted using the GFCM to examine the impact of a non-management (biological) factor on the cost of producing a grazed grass crop (GG).

The N response curves for the default and 'low' N response rate scenarios are presented in Figure 2. The default N response curve is based on the work of Butler (2006) which used multi-year data from two Teagasc sites, Moorepark (in the south of Ireland, 52° 9' N, 8° 15' W) and Grange (in the east of Ireland, 53° 31'N, 6° 39'W).

Figure 2. Nitrogen response curves for grazed perennial ryegrass and annual DM demand for a beef cow plus calf to beef system used to model the economic implications of nitrogen response in the GFCM



A = Default annual perennial ryegrass nitrogen response curve; combined multi-year nitrogen response curve for Teagasc, Grange and Teagasc, Moorepark (Butler, 2006).
B = 'low' annual nitrogen response curve; nitrogen response for perennial ryegrass sward grazed at Tegasc Grange (O'Riordan, 1997).

The 'low' N response curve used in this analysis was derived from O'Riordan (1997), and is taken from a perennial ryegrass sward grazed on a 28 day rotation at Teagasc, Grange. The gley soil of the Ashbourne series prevailing at Grange contains 470 g N kg^{-1} organic matter in the upper 18 cm (An Foras Talúntais, 1983), while the acid brown earth soil at Moorepark contains 210 g N kg^{-1} organic matter in the upper 20 cm (O'Connell *et al.*, 2003). This difference in N content of soil organic matter contributes to the higher grass DM production observed at low or zero N application rates at Grange relative to Moorepark. At higher N application rates perennial ryegrass swards at Grange exhibit lower grass DM production relative to Moorepark.

To compare grazed grass production costs of both N response curves, a target annual yield of 12.2 t DM ha^{-1} was set. This yield is representative of the annual grazing season demand for a suckler beef farm stocked at 2.5 cow plus calf units ha^{-1} (Drennan and McGee, 2008). N was applied according to the requirements for this target yield specified by the specific N response curve. Phosphorous (P) and potassium (K) were applied in the form of inorganic compounds as per the recommended rates of Coulter and Lalor (2008).

3.1.1 Nitrogen response of perennial ryegrass: Results and discussion

The mean response over the grazing season at the default N response was 26.2 kg grass DM kg N^{-1} (Table 2). At the 'low' N response curve the mean response over the grazing season was 21.4 kg grass DM kg N^{-1}.

The additional 4.8 kg grass DM kg N^{-1} grown in the default scenario equated to a 23% greater response than that of the 'low' N response scenario. This resulted in a 10% difference in TFC due to the higher rate of N application required in the low N response scenario.

Table 2. Impact on fertiliser application and total feed cost (TFC) modelled using GFCM for two nitrogen response curves

	Mean nitrogen response	**Nitrogen applied**	**Yield**	**Fertiliser cost**		**TFC**	
	Kg DM kg N^{-1}	*Kg ha^{-1}*	*Kg DM ha^{-1}*	*€ ha^{-1}*	*€ t UDM^{-1}**	*€ t UDM^{-1}*	*€ GJ ME^{-1}***
Default N response	26.2	201	12,182	248	27.14	80	7.26
Low N response	21.4	273	12,182	320	35.02	88	7.98

* € per tonne of utilised dry matter
** € per gigajoule of metabolisable energy

As expected, this result indicates that increasing N application in order to increase the yield of grass DM per hectare under a low N response scenario will result in a greater feed cost relative to under a higher N response scenario. The real value of this model application is that a definitive quantification of this higher feed cost can be established. This information could be used by farmers to determine the N response at which point it becomes less expensive to purchase alternative feeds rather than to apply additional N fertiliser to a grass sward. Efficiency gains can also be realised by taking steps to improve the response of a grass sward to applied N. For example, reseeding with more productive grass varieties can increase the N response of a sward containing a low proportion of perennial ryegrass. In order to make most efficient use of N fertiliser, farmers should be cognisant of the N response status of the different soil types on their farms.

3.2 Impact of management factors: Grass silage and spring grazing

The impact of altering closing and harvest dates on DM yield, DMD, ME and consequently cost of a single harvest grass silage crop was modelled. The crop was assumed to be a 5 year old (mid-point of a 10 year re-seeding interval) perennial ryegrass sward. The crop was grown in a loam soil, in a field which was grazed during the previous year; hence it had an N requirement of 100 kg N ha^{-1} (Coulter and Lalor, 2008). P application was linked to expected DM yield and constrained by statutory limits (DAF 2006); i.e. 16 kg P ha^{-1} for crops yielding less than 5.5 t DM ha^{-1} and 20 kg P ha^{-1} for all greater yields. K was applied proportionately to expected DM yield.

There were three separate spring closing dates (i.e. the date of final sward defoliation prior to harvest) modelled, and a fourth scenario where there was no spring grazing, but where the sward was grazed to a residual of less than 4 cm in the previous November. The spring closing dates were 15-March, 31-March and 15-April. All inorganic fertiliser was assumed to be applied on the closing date or on 15-March for the ‘not spring grazed’ crop. Crop yields were modelled for a series of ten harvest dates for each of the four closing date scenarios. Yield and DMD values for the ‘not spring grazed’ crops were derived from five years of data for perennial ryegrass swards at Grange (O'Kiely, 2001). The harvest dates were at weekly intervals from 1-May to 3-July. The yields for each of the spring grazed crops were calculated using a co-efficient for the impact of spring grazing on subsequent grass silage yield derived from O'Riordan *et al*. (1998). Similarly, the DMD values at harvest for each of the spring grazed crops were predicted using a co-efficient derived from Humphreys and O'Kiely (2006) and O'Neill *et al*. (2000). Default DMD loss during conservation was 20 g kg^{-1}, while total DM losses during harvesting, conservation and feed-out amounted to 150 g kg DM^{-1} (O'Kiely *et al*., 1997). Average DM content at ensiling was 217g kg DM^{-1}. All silage crops were harvested using a precision chop harvester and stored in a walled concrete bunker silo.

Common (shared between multiple feed crops) annual fixed costs (i.e. fencing and roadways) were allocated to the grass silage crops in the same proportion as the land charge as described in Appendix A. The entire proportion of the fixed costs associated directly with the conservation of the crop (i.e. the silo and effluent tank) was allocated to the grass silage crop.

3.2.1 Grass silage and spring grazing: Results and discussion

Spring grazing of a grass silage sward in March had a modest impact on the UDM yield of grass silage from harvests after 22-May (Table 3). Although yield from these later harvests was slightly depressed by March grazing, DDM and ME yield was similar to the sward that was not spring grazed, due to higher digestibility of the harvested grass. Delaying closing date in the spring beyond late March had a more pronounced impact on silage yield, particularly for the earlier silage harvest dates.

Figure 3 shows how UDM yield of the ‘not spring grazed’ sward increases almost linearly from 2 t ha^{-1} on 1-May to 8 t ha^{-1} by 1-July. However as the DMD of the sward falls in an approximately inverse linearity to the DM yield, total ME yield peaks by mid-June. This decline in DMD and ME concentrations results in TFC per unit of ME beginning to rise again in the last week of June, despite the increasing DM yield.

Grazing of a silage sward after March depressed subsequent silage yields to the extent that it substantially increased the cost of the silage harvested before early June (Figure 4). However, grazing up until the 15-March resulted in a slightly lower TFC (on an ME basis) from harvests after 22-May relative to a ‘not spring grazed’ sward. This is because the increase in DMD at any given silage harvest date as a result of March grazing (Humphreys & O’Kiely, 2006) offsets the DM yield loss arising from such management. In addition to

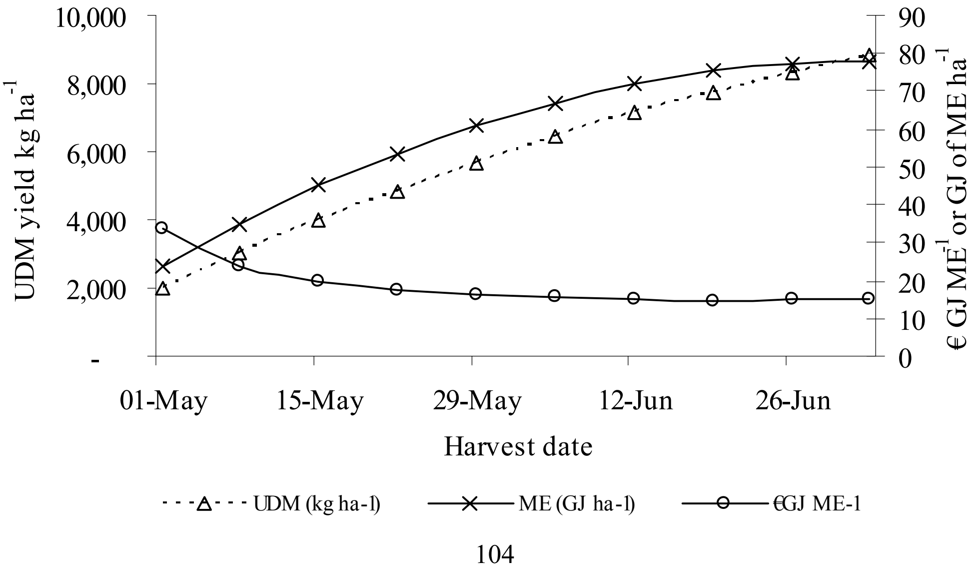
Table 3. Yields of grass silage dependant on spring grazing and silage harvest date for a range of closing and harvest dates as modelled using GFCM

	Closing date							
	Not spring grazed		**15 Mar**		**31 Mar**		**15 Apr**	
Harvest date			As proportion of 'not spring grazed' sward					
	Kg UDM ha^{-1}*	*Kg DDM** ha^{-1}*	*UDM ha^{-1}*	*DDM ha^{-1}*	*UDM ha^{-1}*	*DDM ha^{-1}*	*UDM ha^{-1}*	*DDM ha $^{-1}$*
01-May	2,015	1,600	0.75	0.76	0.55	0.56	0.38	0.39
08-May	3,024	2,372	0.78	0.79	0.60	0.61	0.42	0.43
15-May	3,970	3,066	0.81	0.82	0.65	0.66	0.47	0.48
22-May	4,854	3,674	0.85	0.86	0.70	0.71	0.52	0.53
29-May	5,675	4,194	0.89	0.90	0.75	0.76	0.58	0.59
05-Jun	6,434	4,621	0.93	0.94	0.80	0.81	0.64	0.65
12-Jun	7,131	4,953	0.98	0.98	0.83	0.84	0.67	0.68
19-Jun	7,765	5,189	1.00	1.00	0.87	0.87	0.70	0.71
26-Jun	8,336	5,329	1.01	1.01	0.89	0.89	0.72	0.72
03-Jul	8,845	5,372	1.00	1.00	0.92	0.92	0.74	0.74

* Utilised dry matter
** Digestible dry matter

examining the TFC, there is a need to take into account the farm silage requirement and the desired fill value (Jarrige, 1989) and DMD of silage for the chosen livestock system when deciding closing and harvest dates for grass silage swards. The effect on the cost of resultant additional grazing or grazing

Figure 3. Yield and total feed cost (TFC) of a single harvest grass silage crop (not spring grazed) for ten consecutive harvest dates as modelled by the GFCM

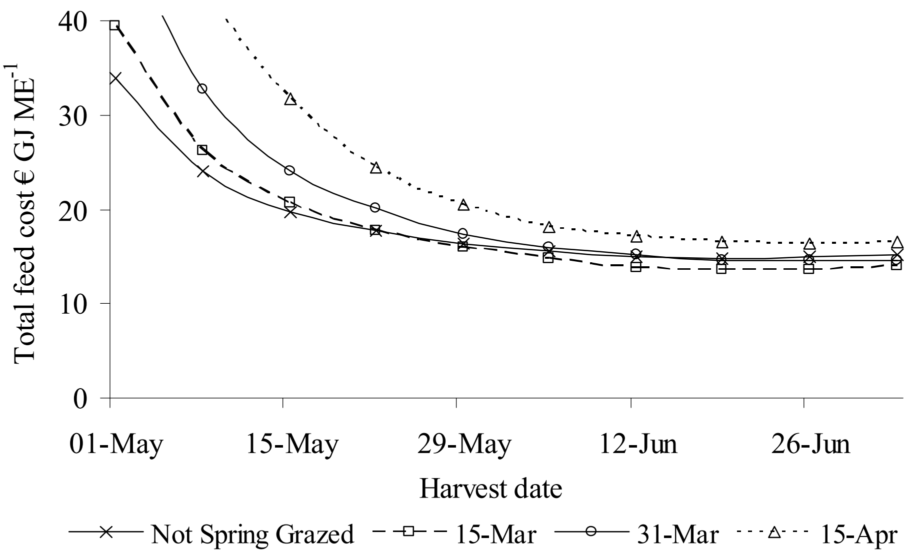


forgone and the balancing of feed supply and feed demand at a given time-point in the spring or summer will also impact on this management decision. Ongoing development of the GFCM will address this issue of costing a grass sward both grazed and conserved over the course of the farming year.

3.3 Impact of market factor: Fertiliser cost

The GFCM was used to calculate TFC for eight feed crops commonly fed

Figure 4. Impact of spring grazing and harvest date on total feed cost (TFC) of a single harvest grass silage crop(€ GJ ME^{-1}) for 10 consecutive harvest dates as modelled by the GFCM



on Irish cattle farms; grazed grass (GG), a single harvest grass silage crop (GS1), a double harvest grass silage crop (GS2), a single harvest baled grass silage crop (GSB), whole-crop maize silage (WCM), whole-crop fermented wheat silage (WCW), grazed kale (Kale) and harvested fodder beet (FBH). Input price sensitivity analysis was conducted using the GFCM to examine the impact of the increase in chemical fertiliser cost between 2007 and 2008 on the cost of producing and utilising each of the eight feed crops. Mean monthly fertiliser prices were used for each year (CSO 2010). All other input prices and yield values remained constant in this analysis.

Each feed crop was assumed to be grown in a loam soil with P and K indices of 3 (Coulter and Lalor, 2008). All harvested crops were assumed to be grown on land from which grass silage had been harvested the previous year (therefore index 2 for N; Coulter & Lalor, 2008). The kale crop was sown after grazed grass; i.e. in a field already fenced for grazing.

The full fertiliser requirement for each feed crop was provided by means of inorganic fertiliser application. Fertiliser was applied in a combination of compound and single nutrient inorganic fertiliser based on crop nutrient requirements (Coulter & Lalor, 2008) and constrained by statutory limits (DAF, 2006). Total fertiliser applied and the costs of this fertiliser (including spreading cost) are shown in Table 4.

Table 4. Quantities of fertiliser applied and their cost as modelled using GFCM for assessing the impact of market factors on total feed cost (TFC)

Feed crop	Macronutrients applied (kg ha^{-1})			Fertiliser cost[9] (€ ha^{-1})	
	N	**P**	**K**	**2007**	**2008**
GG[1]	201	10	15	175	248
GS1[2]	100	20	168	202	332
GS2[3]	185	30	205	317	513
GSB[4]	100	20	168	202	332
WCM[5]	140	40	190	274	445
WCW[6]	160	25	100	253	409
Kale[7]	80	30	170	218	363
FBH[8]	179	40	160	310	491

[1]Grazed perennial ryegrass; [2]Single harvest grass silage system; [3]Double harvest grass silage system; [4]Single harvest grass silage– baled; [5]Whole-crop maize silage; [6]Whole-crop winter wheat silage; [7]Grazed kale; [8]Fodder beet – harvested; [9]CSO (2009).

Table 5. Yield and quality data for eight feed crops modelled using the GFCM

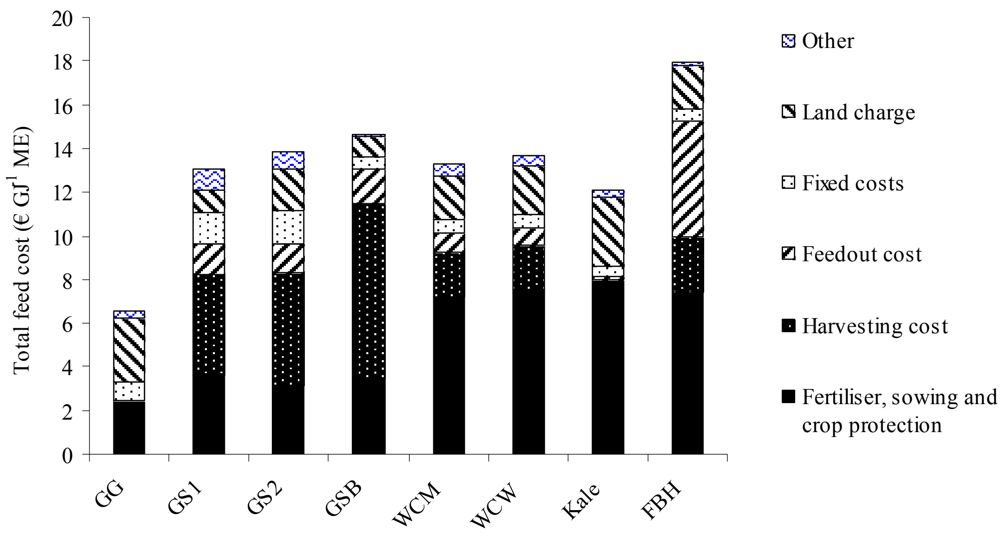
Feed crop	Harvest date	Crop yield (kg DM ha^{-1})	Utilised yield (kg DM ha^{-1})	DMD[1] at feed-out (g kg^{-1})	ME[2] at feed-out (GJ. kg DM^{-1})
GG[3]	Mar-Nov	12,182	9,137	780	11.00
GS1	12-Jun	6,934	5,918	700	10.15
GS2	22 May 24 Jul	11,996	10,240	722[4]	10.50
GSB	12-Jun	6,934	6,192	700	10.15
WCM	20-Oct	16,010	14,193	701	10.50
WCW	20-Aug	14,827	13,144	689	10.43
Kale	Nov-Jan	10,125	8,100	722	11.76
FBH	01-Nov	15,000[5]	14,400	851	12.40

[1]Dry matter digestibility; [2]Metabolisable energy; [3]Feed crop codes as per Table 4; [4]Weighted mean DMD of two harvests; [5]5,000 kg DM of beet tops and leaves by-product not included in yield

3.3.1 Fertiliser cost: Results and discussion

Table 5 shows the harvest dates and yields of the eight feed crops on DM and UDM bases. It also shows the DMD and ME concentrations of the feed crops at feed-out. These are the key default yield and nutritional values for these feed crops in the GFCM. Figure 5 shows the TFC of the eight crops using 2007 fertiliser prices. It also illustrates the breakdown of TFC into six key cost components to demonstrate the differing structure of total feed cost between the feed crops.

Figure 5. Total feed cost (TFC) categorised for eight feed crops[1] as modelled by the GFCM using 2007 fertiliser prices

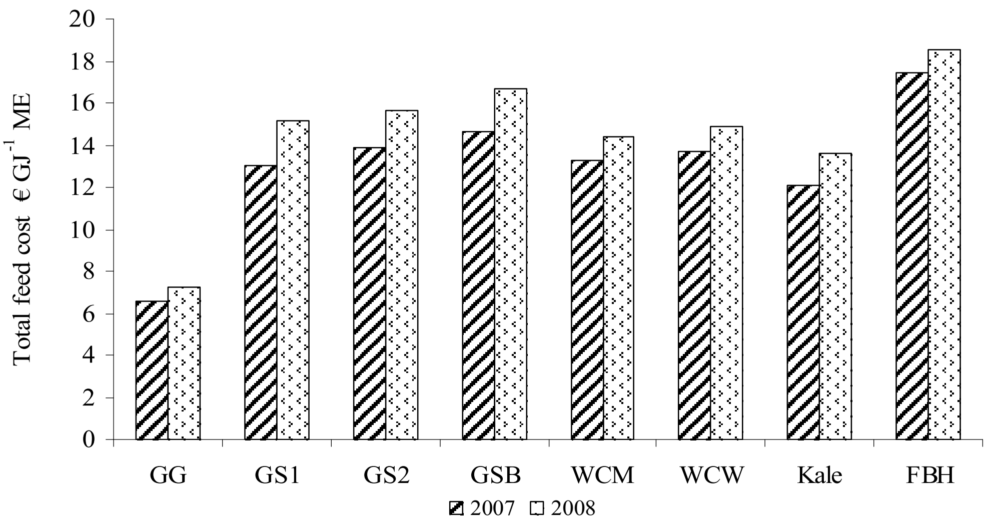


[1]Feed crop codes as per Table 4;
[2]Other costs include the cost of working capital and repair and maintenance costs of fixed assets;
[3]Annual land charge €300 ha^{-1}, or appropriate proportion of annual charge on a feed crop rotation interval time basis;
[4]For grass crops, crop establishment is included as a fixed cost depreciated over 10 and 14 years for the grazed and silage swards respectively;
[5]Feed-out work rates as per Forristal (1993).

On an ME cost basis the feed crops ranked (from lowest to highest) GG, Kale, GS1, WCM, WCW, GS2, GSB and FBH. The cost of the other seven feed crops relative to grazed grass emphasises its importance as the primary ruminant feed in Ireland during the months of March to November. In terms of cost relative to GS1, the most common winter feed for ruminants in Ireland, all winter feed crops with the exception of FBH could be produced and utilised at similar cost (on an ME basis) using 2007 fertiliser prices (Figure 5). While in these results kale ranks as the cheapest alternative to grazed grass, cognisance must be taken of the fact that environmental regulatory compliance costs such as a land charge for a "run-back area" (a grassland area of 1 ha accessible to each livestock unit grazed on the feed crop as required by EU legislation) may need to be included in TFC for brassica crops.

Fodder beet is the most expensive of the eight feed crops in this analysis at €18.52 GJ ME^{-1}. However a large proportion of this cost (29%) is accounted for by the labour and machinery intensive nature of the cleaning, chopping and feed-out operation for fodder beet. Figure 6 demonstrates the impact of the increase in fertiliser cost from 2007 to 2008.

Figure 6. Total feed cost (TFC) of eight feed crops calculated using 2007 and 2008 fertiliser prices as modelled by the GFCM



On an ME basis the increase in the cost of fertiliser between 2007 and 2008 resulted in an increased TFC of between 6% (FBH) and 17% (GS1). The greatest impact on TFC was observed in the feed crops where fertiliser cost comprised a greater proportion of TFC (i.e. the grass silages). Because of this, GS1 became more expensive relative to WCW, WCM and kale in 2008. P and K prices rose at a greater rate (+85% and +95%, respectively) than N prices (Calcium Ammonium Nitrate +57% and Urea +38%) between 2007 and 2008. Therefore the impact of the fertiliser price rise was greater for feed crops with greater P or K requirements. As the fertiliser requirement for the GG feed crop was mainly N, the impact of the fertiliser price rise was not as great as for some of the harvested feeds which had a proportionally greater P and K requirement. Determining the relative impact of such fertiliser price changes would be beneficial to a farmer deciding for example whether to replace a GS2 system with a WCW crop.

These results highlight the importance of making more efficient use of organic manures to meet crop nutrient requirements, particularly during periods of high inorganic fertiliser prices. In practice farmers tend to respond to high P and K prices by reducing application rates. Lalor *et al.*, (2010) found that inorganic P and K fertiliser usage in Ireland reduced by 29% and 25%, respectively between 2006 and 2008; a large proportion of this decrease can be attributed to the substantial price increases. Soil P and K levels are depleted over time when application rates are consistently below crop requirements and therefore this solution cannot continue indefinitely. More sustainable cost abatement options farmers could undertake include regular testing of soil nutrient status; using soil test results to match fertiliser application to the requirements for optimal yield, returning winter produced organic manures to fields from where winter feed was harvested, and as far as possible limiting the growing of harvested crops to fields where high levels of soil P and K prevail.

4. Conclusions

A computerised tool, the GCFM has been developed and applied to simulate the effects of market, management and biological factors on feed cost. The GFCM fulfils a recognised requirement of providing a standardised methodology to economically quantify the impacts of changing production and utilisation scenarios for a wide range of ruminant feed crops. The flexible structure of the GFCM permits analysis of changing input prices and changing feed crop production variables. The applications of the model outlined in this paper have quantified the considerable impact these highly variable factors can have on the economics of producing and utilising certain feeds. This GFCM could facilitate economic analysis of new feed crop research data relating to production or utilisation responses.

This study confirms and quantifies the substantial cost advantage of grazed grass relative to alternative feed crops in Ireland. In the default scenario TFC of feeds typically offered to ruminants outside of the grazing season ranged from 1.88 (kale) to 2.55 (fodder beet) times the cost of grazed grass on an ME basis (Figure 5). Yield is the primary factor influencing TFC. However, additional costs addressed in the GFCM, many which have not been widely quantified previously, including feed-out costs, storage and feed-out losses, and the cost of storage facilities for feeds can also have a considerable impact on TFC.

The analysis shows that there is a wide range of feed crops which can be cost competitive with grass silage as winter feeds for Irish ruminants. However, given that permanent pasture forms the majority of land used for ruminant production in Ireland, grass silage, as an integrated part of a grass-based production system, remains the primary winter feed option for cattle and sheep farmers. In addition, as yield is the key driver of TFC, if grass silage cannot be economically produced on a given farm due to site or soil factors, then it is unlikely that any of the alternatives could be economically produced on such a farm either. The significant seedbed preparation and feed crop establishment costs associated with annually sown feed crops tend to reduce their economic attractiveness when compared with perennial feed crops such as ryegrass. For livestock systems requiring high-energy diets (such as beef finishing or winter milk production) these alternative feed crops may play a valuable role as part of a grassland reseeding programme or in situations where a portion of the land area cannot be easily integrated into the grazing system; i.e. an 'out-farm' situated a long distance from the main farm unit. While this study examined the deterministic costs of the most common feed crops grown in Ireland, further development of the GFCM will allow valuable stochastic analysis of the effect of fluctuating yields and input prices on TFC.

The process of developing the GFCM highlighted the recognised requirement for more quantitative and qualitative data permitting more robust estimation of production functions for feed crops on commercial farms. Moreover, given the cost advantages of grazed pasture coupled with its role as the predominant ruminant feed crop in Ireland, there is a continued need for research focussed on improving grazed grass production and utilisation. These data are required to enhance understanding of DM production responses and utilisation rates, particularly in relation to factors such as weather, grazing strategy, soil-type, sward composition and age.

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APPENDIX A: METHODOLOGY OF TFC CALCULATION IN THE GFCM

Resource constraints

This appendix describes how the GFCM applies a cost to all of the resources employed in the production of feed crops as illustrated in Figure A. In addition to production cost and yield factors, a farmer must also consider the farm resource constraints when selecting the optimal feed crop production and utilisation option from a range of alternatives (O'Kiely et al., 1997). If any of the resources required to produce or utilise a certain feed crop are limiting, then the decision to select such feed crops is also limited.

A.1 Land

Land as a finite resource is one of the most limiting resource constraints. An opportunity cost of land is included in TFC by means of an annual land charge, or portion thereof, depending on the typical time interval between seedbed preparation for the feed crop being costed and seedbed preparation for the subsequent land use. Land charge for grass silage is apportioned to the feed based on the length of time between the date of final defoliation prior to harvest (closing date) and harvest date; calculated as:

[Equation 1]

$$A = \frac{H - C}{365} * LC$$

Where A = Land charge apportioned to the silage crop (€ ha^{-1}), H = harvest date, C = closing date (set as 1^{st} Jan for 'not spring grazed' crops), LC = Annual land charge (€ ha^{-1}).

A.2 Labour

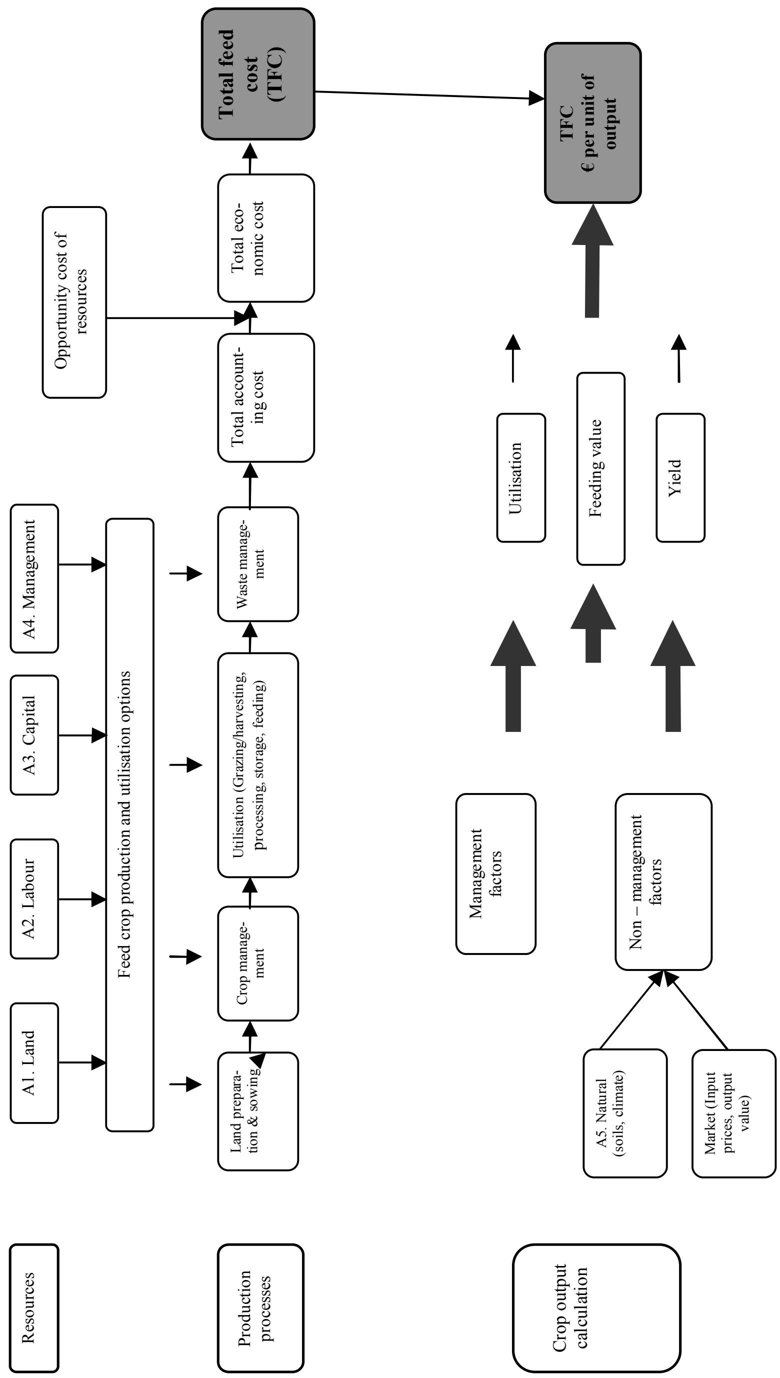
The labour, time and machinery costs involved in producing and utilising each feed are considered in the GFCM by assuming commercial agricultural contractor costs (Teagasc, 2008) and published work rates for all crop production and feed-out operations; e.g. tilling, sowing, fertilising, spraying, harvesting, processing and feed-out. This approach removes the requirement for complex machinery depreciation (which would depend on assumptions about the type and age of machinery) and labour opportunity cost functions within TFC. Labour for non-machinery related operations such as herding (moving of rotationally grazed animals and fences etc.) is costed per hour at average hourly agricultural wages for 2009 (CSO, 2010).

A.3 Capital

Fixed assets are also limiting factors in terms of feed crop selection. If a permanent facility or structure is required to produce, store or utilise the feed crop (such as a concrete silo or grain store) then a medium to long term investment decision must be made before deciding to produce the feed crop. This factor is integrated into TFC in the GFCM by including the cost of constructing and maintaining such fixed facilities as fencing, roadways, silos and grain stores. The required facilities for the particular feed crop, the associated construction/ installation cost and the age of the facilities must be specified by the user. Fixed assets are valued at their replacement cost based on the costings of the Irish Department of Agriculture and Food (DAF, 2007). Silos and buildings are depreciated over a specified period (typically 20 years), using the declining balance method. The age of the asset determines the depreciation and interest cost for the specified year. If use of a fixed asset is shared between two or more feed crops then the cost is also attributed to these feed crops in the same proportion as their usage (on a volume by time basis) of that asset. The cost of annual maintenance and repair of these fixed assets is charged at 1% of the construction cost per year within the variable cost fraction of TFC.

The interest cost on borrowed investment capital is accounted for in the GFCM by assigning an asset age, loan duration and interest rate to each asset. The total capital cost is the sum of interest payable and any depreciation costs arising. The user must specify the source of capital funding and the annual interest rate. In the GFCM default scenario annual interest on borrowing for construction of fixed assets is charged at 8%.

Figure A: Schematic of calculation of total feed cost (TFC) in the GFCM



Working capital is the capital required to finance the day-to-day operation of a farm business. Working capital is accounted for as an interest charge on savings foregone (O'Mahony, 2009) and calculated as follows:

$$WC = V * (P / 365) * 1/2$$

[Equation 2]

Where WC = Working capital cost (€ ha^{-1}), V = total variable costs (€ ha^{-1}) and P = length of the feed crop production period in days; i.e. the sowing to harvest time interval in the case of cereal crops, the closing date to feed-out interval in the case of grass silages and the grazing season duration in the case of grazed crops.

A.4 Management

Management input is the only resource not specifically accounted for as a financial cost in TFC. Some feed crops may require greatly differing crop management skills to others. Because of the difficulties of quantifying such a non-market variable as management input, this cost is not quantified in the TFC for the purposes of this paper. In order to allow consistent comparisons, a high standard of management is assumed in the default scenario across all feed crops in the GFCM.

A.5 Climate and soil

Local climate and soil factors can be major constraints on the range of feed crops that can be grown on a particular farm. Variability of feed crop yields, nutritional values and utilisation rates due to regional soil or climate factors is provided for within the model and these crop production variables may be changed to reflect location-specific values based on historical data.

Note: The Grange Feed Costing Model spreadsheet may be inspected on request to Eoghan Finneran (eoghan.finneran@teagasc.ie). Teagasc retains full intellectual property rights in the model.