The economic impacts of grassland reseeding in Northern Ireland

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Contributed Paper prepared for presentation at the 96th Annual Conference of the Agricultural Economics Society, K U Leuven, Belgium

4 – 6 April 2022

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Abstract

In this paper, a Cost-Benefit Analysis (CBA) was carried out to investigate the profitability of investment undertaking on grassland reseeding using a simulation of different scenarios on reseeding rates. We employed the Net Present Value (NPV) and the Annualised Net Present Value (ANPV) evaluation criterion to determine the possible returns from grassland reseeding on a dairy farm. Furthermore, the assumptions made in the CBA are improved using econometric analysis.

Both fixed and random effects regression models were applied to improve the assumptions. The results show that the effects of increasing reseeding rates will increase profit on a dairy farm. In grassland production, the profit is a result of increasing silage yield. Dairy profit is mainly a result of substitution between concentrate feed and silage. The correlation between silage yield and the reseeding rate is also positive. A 1% increase in reseeding rate could increase silage yield by 225kg. The correlation between milk yield and the reseeding rate is also positive. A 1% increase in reseeding rate could increase milk yield by 55.8 litres. This study also estimated the least-cost substitution between concentrates and silage feed occurs when the MRS is at 20.5%.

Keywords [Grassland reseeding; Cost-Benefit Analysis (CBA); a fixed-effect model on milk yield regression; and random-effect model on silage production regression.]

JEL code (Agricultural & Natural Resource Economics) www.aeaweb.org/jel/guide/jel.php?class=Q)

I. Introduction

Grass biomass production is a crucial agricultural activity for dairy farms in Northern Ireland (NI). Permanent and temporary grasslands play a central role in sustaining livestock production systems and the effectiveness of grassland reseeding activity is essential in improving livestock farming.

Farmers are quite uncertain about the profitability of increasing the grassland reseeding rate. Its high investment cost increases the level of investment risk. The length of production lifespan of the grassland reseeding cycle also needs long time-series data set for validation in the econometrics analysis.

In the last few years, grassland reseeding has been on a declining trend in the Republic of Ireland (RoI) (Creighton et al, 2011), an agri-food system structurally similar to NI. Shalloo et al. (2011) show that about 23% of dairy farmers had not been reseeding for 3 consecutive years in the ROI. Teagasc (2014) suggested that a decline in reseeding activity in the RoI could be due to the associated high investment cost per ha, which is considered a burden. However, the adoption of increasing reseeding remains crucial.

Farm economic performance is generally reduced by the presence of old permanent pastures mainly because of reduced grass yields when compared to newly reseeded grasslands. Evidence from a recent NI study (AFBI, 2017) suggests that the beef and dairy sectors could have the opportunity to increase grass production and utilisation by increasing the percentage of grassland reseeding.

The objective of this study is to evaluate the profitability of different rates of reseeding across intensively managed grasslands in Northern Ireland. This study provides estimates of the profitability of grassland reseeding for a dairy farm in NI. As it will be shown, the profit of reseeding is generally derived by substituting concentrate feed with silage and grazing as well as increasing grassland yield.

The study also estimates the Marginal Rate of substitution (MRS) between concentrate feed and silage in milk production using econometric analysis. We also investigate the relationship between milk yield[1] and grassland reseeding rate[2] and MRS.

II. Methods and assumptions

Financial analysis

A Cost-Benefit Analysis (CBA) was applied to derive the profitability of reseeding at various intensities on a dairy farm over 15 years. The total NPV per ha can be calculated as follows:

$$NPV = \sum_{t=1}^{T} \frac{(B_t - C_t)}{(1+r)^t}$$

where NPV is the total net present value of a farm per ha, B_t is the financial benefit of a farm at a given time t, C_t is the costs of reseeding, and r is the discount rate. The green book provides a discount rate of 3.5% for public projects (HM Treasury, 2020). Since this reseeding project is based on private farming investment, a discount rate of 5% per annum is assumed, and this method aggregates the discounted net present profit for future values. A NPV was calculated for both dairy farms as well as those producing grass at different reseeding rates[i]. This allows for the profitability of grass and dairy production systems to be evaluated separately.

The NPV per ha from grass production depends on the depreciation of grass yield and the cost of growing grass for silage. After reseeding, a linear grass yield depreciation and average grass yield methods are assumed to compute the subsequent years' grass yield over time. The starting

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[1] Milk yield is also defined as the total milk production per cow.

[2] Reseeding rate (%) is defined as the percentage of reseeded land (in ha) to the total land area (i.e. improved and permanent pasturelands).

grass yields could increase with the frequency of reseeding rates. A farmer's reseeding strategy is assumed to be undertaken in places where the actual grass yield is lower than an expected amount.

Since each reseeding scenario is an independent project with a different life span, we also applied another evaluation technique using the present annualised worth method (Remer & Nieto, 1995) to estimate the profitability of reseeding on grasslands. The present annualised worth can be calculated using the formula:

$$ANPV = NPV(\frac{r(1+r)^n}{(1+r)^n - 1})$$

where $ANPV$ is annualised present worth of a farm per ha. This method has an advantage because it provides an easy way to evaluate projects with different reseeding life cycles within the project lifetime. It also provides a uniform annual worth criterion to calculate profitability.

The effect of grassland reseeding on the NPV and ANPV were modelled using four scenarios at different reseeding rates (S0: (0%) no reseeding, S1: 10% reseeding (reseeding in every 10 years): S2: 14.3% (reseeding in every 7 years) and S3: 20% (reseeding in every 5 years). The baseline scenario is no reseeding. And a reseeding rate of 10% is typical practice in NI.

Assumptions of financial analysis

Grass production

Here, grass production is considered to be an enterprise and managed separately from the dairy farm. The enterprise maximises its profit by producing silage. The key assumptions used in the CBA of grass production are presented in Table 1. The total reseeding investment cost was assumed to be £609 per ha. This total reseeding investment cost includes the machinery and manpower costs. The total reseeding cost consists of ploughing (£75), power harrowing and sowing (£75), seeds (£168), lime (£120), fertiliser (£101), and spray (£70) (DAERA, 2020). The cost of lime is £120 per ha over 4 years (DAERA, 2020). The cost of reseeding and liming are considered fixed costs because they are investments on the farm.

Table 1. Scenarios and assumptions for grass production

	0%	10%	14.3%	20%
Reseeding	**S0**	**S1**	**S2**	**S3**
Land area (ha)	40	40	40	40
Reseeded land (ha)	0.00	4.00	5.71	8.00
Reseeding rate (%)	0	10.0	14.3	20.0
Reseeding cost (£/ha)	0	61	87	122
Cost of liming (£/ha)	0	30	30	30
Additives for silage (£ per ha)	1.63	1.63	1.63	1.63
Fertiliser for Silage (£ per ton)	300	300	300	300
Starting DM Grass Yield (t per ha)	10.0	12.25	13.21	14.50
Grass utilisation rate (%)	85	85	85	85
Grass yield depreciation rate (%)	2.0	2.0	2.0	2.0
Value of silage DM (£/t)	65	65	65	65

The total grassland area was assumed to be 40 ha. In grassland production, the whole land was allocated for silage production. The costs of growing silage include intermediate inputs such as fertiliser, fuel, additives, and labour. Revenue is simply the value of grass production per ha. The selling price of DM grass was assumed to be £65 per ton (Witzel & Finger, 2016) and would be increasing at the rate of 1.8% per year after the year 2020.

The maximum grass yield potential that could be achieved in NI was 15t DM/ha from silage grasslands (AFBI, 2017). Under S0, the starting grass yield was assumed to be 10.0 t Dry Matter (DM)/ha whereas under S3 the starting grass yield was 14.5 t DM/ha. The grass utilisation rate is assumed to be 85% (Shalloo et al, 2011, pp116) and remains the same for all scenarios.

The grass yield depends on the frequency of reseeding. In S1, reseeding occurs every 10 years and so 10% of the farmland was reseeded annually and the whole grassland area would be reseeded in 10 years. In all scenarios, it is assumed that grass yield depreciates in subsequent years after reseeding at the rate of 2% per year. The rate of depreciation of grass yield depends on farming grassland management and the fertility of the land. Thus, it is assumed that the management of grassland would be the same for all scenarios.

The gain from reseeding could be completely lost if the grass yield depreciation rate is high (>10%). The change in the price of grass over time might compensate a part of lost grass yield by deprecation. Grass price was assumed to increase at the rate of 1.8% per year. In this case, the net effect of the depreciation over inflation is only 0.2%.

Dairy farm

Key assumptions used in the financial analysis of a standard dairy farm are shown in Table 2. The source of price information is the Farm Business Survey (DAERA, 2020). The change in the price of milk and livestock over time is derived from the literature (DAERA, 2020; Davis et al, 2017). Milk price is assumed to increase at the rate of 2% per year after 2020 (Davis et al, 2017). All these assumptions do not depend on the frequency of reseeding and they are the same for all scenarios.

Table 2. Assumptions used livestock prices in the dairy production model, the same for all scenarios (£).

Description	Cost
Milk price (pence/L) in 2020	27.0
Milk price increases (%)	1.8
Mortality of calf (%)	4
Stocking rate (LU)	2.7
Heifer replacement rate %	25
Calf price	115
Heifer price	1,300
Culled cow price	650
Bull variable cost per bull	146
Concentrate cost per ton	260
Silage cost per ton	19.55
Grazing cost per cow	44
Sundries cost per cow	150

Source: FBS (DEARA, 2020)

In dairy production, variable costs for dairy farmers also include feed cost, livestock purchase for replacement, and sundries expenses (Vet medical and Sundries). All input costs are assumed to increase at the rate of 2% per year including concentrates. For dairy farm financial analysis, the number of cows is assumed to be 100 cows for all scenarios. All other key assumptions used for dairy profit estimation are shown in Table 3.

Table 3. Scenarios and assumptions for dairy profit analysis

Description	**Frequency of reseeding**			
	0%	10%	14.3%	20%
	S0-D	**S1-D**	**S2-D**	**S3-D**
No of cows	100	100	100	100
No of cow calving (%)	87	87	87	87
Milk yield (litre/cow)	7,500	8,058	8,297	8,616
No of calf sold (head)	84	84	84	84
Grazing land (ha)	20	20	20	20
Silage land (ha)	20	20	20	20
Fertiliser cost for Grazing (£ per ton)	250	250	250	250
Fertiliser for Silage (£ per ton)	300	300	300	300
Concentrate usage (tons)	175.4	191.0	195.1	205.4
Silage in take (ton)	852.9	929.0	949.0	999.0
Heifer replacement rate %	25	25	25	25
Bull number (10% of Cows)	10	10	10	10
Fixed cost £ per ha	787	787	787	787
Cow depreciation cost (£ per cow per year)	13	13	13	13
Length of grazing season	230	238	240	245

In dairy production, the grassland is divided into grazing and silage. Under all scenarios, the total grassland was equally allocated between grazing and silage (each 20ha). Unlike the grass production model, dairy farmers face two types of costs in the grass production system, the cost of growing grass for grazing and silage. In both cases, the costs of growing grass include intermediate inputs such as fertiliser, fuel, and labour. The cost of growing grass for silage would be slightly higher than grazing due to the additional cost of additives. The fertiliser cost per ton varies between silage and grazing because they are different types of fertilisers. Also, more fertiliser per ha is applied on silage land.

Grass production is a part of the dairy farm. In the dairy CBA, grass production was used as an input for cost-effective milk production. In the dairy production system, cows are often offered a 'basic diet' (silage plus concentrates) to support the energy requirements of the cow for maintenance at a given milk yield. Additional concentrates may be offered to individual cows to support more milk yields above those supported by the basic diet.

Grass production and dairy production are linked using connecting variables such as grass yield and costs of growing grass for grazing and silage land. Higher levels of reseeding rates are assumed to affect the length of grazing season by increasing grass yield.

Silage production is assumed to increase with the level of reseeding. Only 20-25% of the total silage consumption was produced at the farm level. Additional silage was purchased to meet the total demand. Silage usage was assumed to be 9 tons of DM per cow per year for baseline scenarios.

Reducing concentrates, increasing silage feed, and grazing to produce milk are naturally quite important issues in grass-based systems (Kennedy et al, 2002, Shalloo et al, 2011). In S1-D concentrate feed usage was calculated about 191.0 tons when silage intake was 929.0 tons. In S3-D, concentrate feed usage was calculated at 205.4 tons when silage feed consumption was 999.0 tons. The proportion of concentrates feed to silage was 0.205.

In dairy production, fixed costs are calculated based on the size of the farm (DAERA, 2020 pp. 95). These expenses include fuel electricity, labour repair, machinery operation, phone, and insurance. FBS microdata suggests an equal lump sum fixed cost (£787 per ha), which is assumed to be unaffected by the level of reseeding.

Econometric model

In the finical analysis and CBA, we have identified a few limitations. These limitations were related to the assumptions made in this paper (e.g. the substitution between concentrate and silage as well as the relationship between milk yield and reseeding rate are not validated econometrically). The purpose of the econometric work is to calculate the marginal rate of substitution between silage and concentrate feed using the actual data set. The econometric work improves the accuracy of the assumptions in the financial analyses.

The econometric model was based on a silage and milk production function approach. This approach is relevant to investigate the impacts of productive inputs on efficiency by focusing on silage productions, milk yield, and substitution of concentrates by silage.

Heady, (1951); Heady and Dillon, (1961) indicated the quadratic production function is one of the popular forms used in silage and dairy production analysis. It has also greater flexibility than the Cobb-Douglas and linear functions because it assumes no constant elasticities of response, allowing the substitutions to change with greater inputs (Nathan 1971). The function also allows diminishing return following a negative marginal product in the quadratic term.

The substitution rate between concentrate and silage is also constant if we apply the Cobb Douglas and linear production functions. But for quadratic production function, the substitution rates vary within farms and over time. That is why we selected the quadratic function.
Panel data allows to take into account for variables we cannot observe across farms such as the difference in grass management practices. Applying Fixed Effect (FE) and Random Effect (RE) models account for farms heterogeneity.

A RE model is usually related to the variation of the coefficient of inputs over time and the scale issue. There are also two error terms in the model. The first error term is between-farms and the second one is within-farms. When the variance across the panels is large the RE model is a better fit. The advantage of the RE model is that it can include time-invariant variables (I.e. farm characteristics). It is appropriate to model to measure farms heterogeneity in silage production.

To determine whether the model is a FE or a RE model, we used a Hausman- specification test for model determination (Hausman, 1978). What matters is the level of correlation between the covariates and the unit effect and the extent of unit variation in the independent variable relative to the independent variable.

A FE production function is usually used for panel data analysis when we are interested in the impact of inputs that vary over time (Kumbhakar and Heshmati, 1995). The FE model estimates assume that the productivity of inputs and inputs coefficients are time-invariant but vary across farms (Ahmad and Bravo-Ureta, 1996). An important assumption of the FE model is those time-invariant characteristics are uncorrelated to farm inputs. FE can remove the effect of those time-invariant characteristics so that we can estimate the net effect of the inputs on the output. This is the main reason for the choice of the FE method.

Since silage and milk production decisions are made differently and silage is also an input into milk production, we will face an endogeneity problem. To solve the endogeneity problem, it is important to determine both technologies simultaneously (Wooldridge, 2002). A two-step estimation method is often used to solve endogeneity problems in most empirical studies (Ahmad and Bravo-Ureta, 1996). Thus, a two-step estimation procedure was employed to get a consistent estimation of input coefficients of milk and silage production technologies (Kumbhakar and Heshmati, 1995).

In the first step1, a Random-Effect (RF) silage production function in quadratic form can be estimated using the following equation:

$$S_{it} = \mu_i + \theta_1 Z_{1it} + \theta_2 Z_{1it}^2 + \theta_3 Z_{2it} + \theta_4 Z_{2it}^2 + \theta_5 Z_{3it} + \theta_6 Z_{3it}^2 + \theta_7 Z_{4it} + \theta_8 Z_{4it}^2 + u_{it} + e_{1it} \quad (1)$$

Where:

S = Silage production

Z_{1it} = Fuel

Z_{2it}= Labour in silage,

Z_{3it} = Grasslands area,

Z_{4it} = Fertiliser,

u_{1it} = between error term

e_{1it} = within error term

t= time and

i=farms

In step 2, a FE milk yield regression in quadratic form could be used to estimate the substitution between concentrate and silage in milk production. It is also hypothesised that both milk production technologies are fixed over time but farm level FEs can vary.
A FE milk yield function can be written in quadratic form as follows:

$$Y_{it} = \alpha_i + \beta_1 X_{1it} + \beta_2 X_{1it}^2 + \beta_3 X_{2it} + \beta_4 X_{2it}^2 + \beta_5 X_{3it} + \beta_6 X_{3it}^2 + \beta_7 X_{4it} + \beta_8 X_{5it} + \beta_9 X_{1it} * X_{2it} + e_{2it} \quad (2)$$

Where:
Y = Milk Yield
X_1 = Silage usage (ton)
X_2 = Concentrate feed (ton),
X_3 = Labour milk (hr per week),
X_4 = Sundries and Vet (£),
X_5 = Grazing land (ha),
X_1 * X_2= Silage use * concentrate interaction,
e_{2it}= the error term.

Milk yield is a function of a quadratic form of silage, concentrate use, and labour. But the veterinary sundries and grazing land inputs are in linear form. There is also an interaction term between silage and concentrate usage.

Silage production plus the purchased silage would be the total silage input into milk production. Total utilised silage in milk production would be determined by taking 85% of silage production and purchased silage. To solve the endogeneity problem, in the second stage of regression, we used the predicted amount instead of the actual silage production.
The marginal products of silage and concentrates can be determined by differentiating the milk yield function, or equation (2) w.r.t. silage and concentrates as:

$$\frac{dy}{dX_1} = \beta_1 + 2\beta_2 X_1 + \beta_{12} X_2 \quad (3)$$

$$\frac{dy}{dX_2} = \beta_3 + 2\beta_4 X_2 + \beta_{12} X_1 \quad (4)$$

Marginal product measures the change in a unit of milk yield per a unit of change in respective inputs. The marginal rate of substitution (MRS) of concentrate feed by silage is given by,

$$\frac{dX_2}{dX_1} = \frac{\beta_1 + 2\beta_2 X_1 + \beta_{12} X_2}{\beta_3 + 2\beta_4 X_2 + \beta_{12} X_1} = MRS \qquad (5)$$

The MRS of concentrate feed by silage measures the change in a unit of concentrates per a unit of change in silage inputs.

Data

The panel database used for this study was collected from DAERA's Farm Business Survey (FBS) that was conducted between 2011and 2018. A total of 125 dairy farms were collected for 8 years. However, data on grassland reseeding was only available for 5 years between 2014 and 2018. Thus, reseeding rate variable was included in the econometric analysis for a reduced sample.

III. Results

Table 4 below presents the results of the CBA on the NPV per ha of a dairy farm and grassland production alone. The results show that reseeding has a positive effect on NPV per ha. In grass production, over 15 years of the project lifetime, increasing the frequency of reseeding rate from not reseeding to reseeding every ten years (10%) could increase the total NPV by £893 per ha whereas increasing the reseeding from no reseeding to reseeding every five years (20%) also increases NPV profit by £1,748 per ha.

Table 4. Total NPV per ha (profitability) of the farm (40 ha farm)

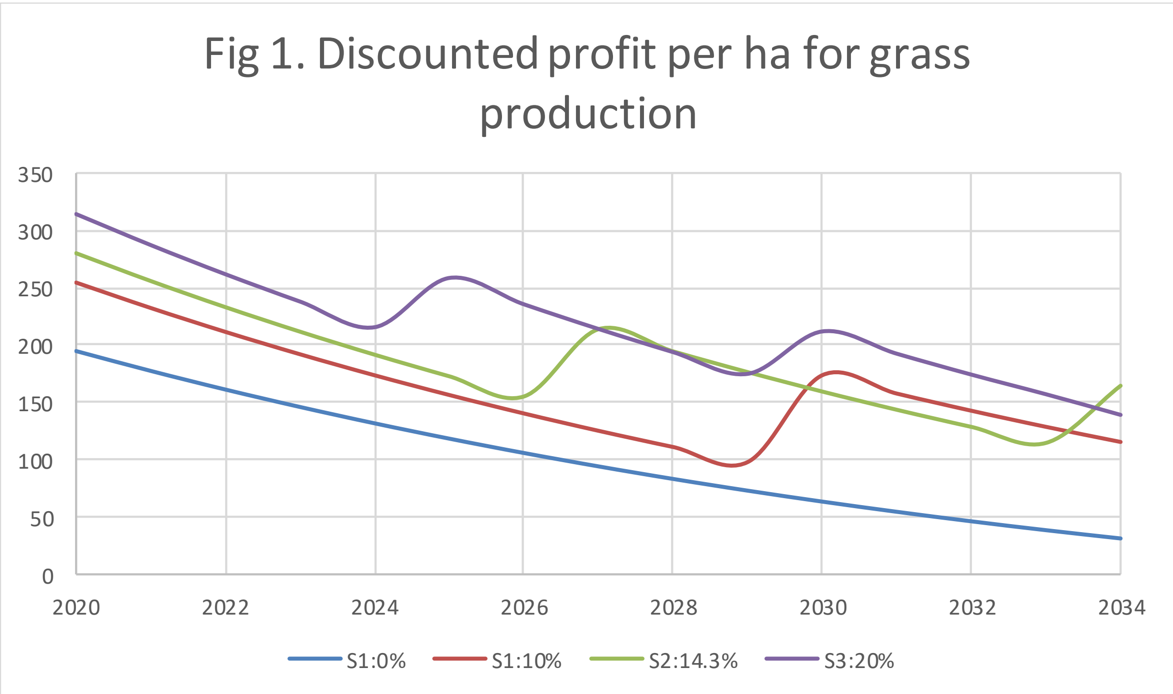
	NPV per ha from grass production				NPV per ha from Dairy production			
Project	**Frequency of Reseeding**				**Frequency of Reseeding**			
Year	0%	10%	14.3%	20%	0%	10%	14.3%	20%
	S0	S1	S2	S3	S0-D	S1-D	S2-D	S3-D
2020	195	254	280	314	363	559	666	766
2021	177	232	256	287	116	332	429	550
2022	161	211	233	262	128	339	433	549
2023	146	192	212	238	140	346	435	547
2024	132	174	192	216	151	352	438	546
2025	118	156	173	258	162	358	440	595
2026	106	140	155	236	172	363	442	592
2027	94	125	214	214	182	368	496	589
2028	83	111	194	194	191	373	496	585
2029	73	98	176	175	199	377	496	581
2030	63	174	159	212	207	429	495	623
2031	55	158	144	192	215	431	495	618
2032	46	143	129	174	222	433	494	613
2033	38	129	115	157	229	435	493	607
2034	31	115	164	139	235	504	604	670
Total NPV/ha (2020-2034)	1,519	2,413	2,795	3,268	2,913	5,998	7,352	9,030
Present annualised worth	146	232	269	315	281	578	708	870
Change in Total NPV £ per ha Compared to S0/ S0-D		893	1,276	1,748		3,085	4,439	6,117
Change in Annual worth Compared to S0/ S0-D		86	123	168		297	428	589

In dairy production, increasing the frequency of reseeding rate from no reseeding to reseeding every ten years (10%) could increase the total NPV per ha by £3,085 per ha whereas increasing the reseeding from no reseeding to reseeding every five years (20%) also increases profit by £6,117 per ha.

Using reseeding, the grass production alone shows an ANPV of around £146-£315 per ha while the profit from dairy production alone is £281-£870 per ha based on the assumptions outlined above.

Grassland Production

Fig 1 shows that profitability of reseeding can vary markedly year-on-year under different levels of reseeding rates. The blue line represents no reseeding scenario and it is a downward slope sightline. For other reseeding plans, the yearly profit cycle between reseeding shows peaks and troughs in the profitability of grass production. Peaks in profit coincide with when grasslands are reseeded while falls in the net profitability over time are primarily due to the depreciation of grass yields over time.



Since profitability is measured annually, it is possible for higher levels of reseeding to appear less profitable for some given years at the time of reseeding within the project lifetime. This is true when comparing S1 with S2. In this case, there are years where S1 profits are higher than S2 (i.e. in years 2030-2033). Also, there are years where S2 performs higher than S3 (in 2027-2029). This highlights the importance of timing on the reseeding events to maximise profit. However, all reseeding plans are more profitable than no reseeding.

Dairy Production

Table 5 shows that dairy production makes a profit per ha per year of around £207- £623 in 2030 based on the assumptions outlined above in Table 3. Over 15 years of project life, annualised profit increment from S0-D to S1-D is £222 per ha while from S0-D to S3-D is £416. As assumed by the model, increasing the levels of reseeding increases grass feed usage at the expense of concentrate feeds.

Table 5. The effect of level of reseeding on the performance of dairy production

Frequency of Reseeding rate (%)	0%	10%	14.3%	20%
	S0-D	S1-D	S2-D	S3-D
Dairy production in 2030				
Revenue				
Milk Sales (£)	229,514	246,840	254,165	263,933
Calf sales (£)	12,982	12,982	12,982	12,982
Culled Cow Sales (£)	21,839	21,839	21,839	21,839
Costs				
Concentrate cost	69,692	71,989	74,567	75,549
Grazing cost	4.489	4.489	4.489	4.489
Silage cost purchased	18,759	18,937	19,379	19,771
Cost of growing grass for grazing	7,716	7,716	7,716	7,716
Cost of growing grass for silage	8,725	8,887	8,895	8,977
Sundries and Vet (£) (AL+VET)	16,360	16,623	17,059	17,439
Total feed cost	109,581	112,397	115,471	117,037
Heifer Replacement cost	39,617	39,617	39,617	39,617
Labour cost	15,999	15,999	15,999	15,999
Fixed cost	54,240	54,240	54,240	54,240
Discounted profit				
Profit £ per ha (2030)	207	429	495	623
Change in annualised worth (2020-2034)		222	288	416

Comparing the different reseeding scenarios may show a better picture of feed substitution. Under S0-D or (0%) reseeding, the proportion of the value of feed costs comprised of 60%, 27%, and 13% of concentrate, silage, and grazed grass, respectively, compared to 63%, 26%, and 11% in S3-D (20%), where the reseeding rate is the highest, respectively. For S1-D and S2_D, the proportion of the value of feed costs contains 62%, 26%, and 12% of concentrate, silage, and grazed grass, respectively. Thus, in the S3-D scenario, more concentrate was substituted by grass-based feeds as the two feeding strategies were not the same in proportion to the reseeding plans.

Econometrics model results

Table 6 presents the summary results of descriptive statistics of data on silage and milk production and relevant inputs that are included in the regression models. The production data is based on 909 observations (where 125 farms make a decision repeatedly for 8 years i.e., 2011-2018). Because the whole database is unbalanced, the balanced data contains only 84 farms (which is N=672 obs.) In the balance data set, all 84 farms appear in all 8 years.

The estimation of the silage production function is based on the balanced data set. There are four inputs in silage production: fuel, labour, improved grassland, and fertiliser. Fuel consumption is only for silage production and it is measured in pound steering. It is calculated by taking 9% of the total fuel consumed on the farm. In silage production, labour is measured in hr. per week worked and includes both family and hired labour. Fertiliser is the total quantity of N, P and K applied in the silage grassland. Based on the balanced data set, the average silage production was 762 tons.

The estimation of milk yield production function is based on unbalanced data set, N=909. In milk production technology: five inputs included: silage used, concentrate feed, No. of cows, labour in dairy, and cost of sundries. The average recorded milk yield was 6,506 litres. Total utilised silage was assumed to be 85% of the sum of silage production and purchased feed. This assumption is the same as in the CBA. The average utilised silage is 720 tons. However, the average total silage use including the unused or wasted silage is 847 tons.

The total labour in milk production includes both family, relatives, and hired labour worked per week in hrs. The average grazing land is 50 ha and improved grassland is 20 ha. The total land is 70 ha on average. The total land also includes owned land, taken in and let outlands. But, in the CBA, we have assumed 20 ha each for both improved silage grassland and grazing land.

Reseeding rate variable is based on only five years of data between 2014 and 2018. The average reseeding rate is only 0.83% if zero rates (no reseeding) are included. This indicates the adoption of reseeding is very low. In addition, the percentage of farmers who have been reseeding their grassland at least once in 2014-2018 was 31.5%. Excluding no reseeding, the average reseeding rate is about 7.6% of the total land.

Lastly, the average MRS based using pooled data is 9.6% whereas based on the data only between 2013 and 2018 is 10.1%. This indicates a little bit more substitution of concentrates were used in recent years relative to old years in 2011- 2013.

Table 6 Descriptive statistics for factors affecting silage and milk production

Variables description	Average	Std. error	Minimum	Maximum
Silage production (N=672)				
Silage production (ton)	762	697	5	4,200
Fuel in silage (£)	703	687	51	5,546
Labour in silage (hr)	26	36	5	316
Improved Grassland(ha)	20	18	0	112
Fertiliser (ton)	48	42	3	329
Milk Yield (N=909)				
Milk yield (I per cow)	6,506	1,594	1,736	12,240
Cow (number)	106	82	14	560
Utilized Silage (ton)	720	464	100	3,692
Concentrate feed (ton)	270	340	3	2,834
Labour milk (hr)	106	50	15	308
Sundries and Vet Med (£)	14,671	19,363	618	214,103
Grazing (ha)	50	31	0	192
Concentrate*Silage use	298,807	625,539	1,247	5,907,504
Reseeding (N=542)				
Reseeding rate (%) including zero rates	0.83	3.05	0.00	33.47
Reseeding rate (%) without zeros	7.6	5.8	1.1	33.5
Total Grassland	73	44	19	281.1
Reseeding uptake rate (%)	31.5	46.6		
MRS (%) (N=542)	9.6	12.3	0.2	98.0
MRS (%) (N=909)	10.1	13.8	0	100

Table 7 shows the results of a random-effect silage production function in quadratic form. The regression is based on 672 obs., which is the balanced data set. The Hausman specification test indicates that the regression is a random-effect model because chi^2 is significant at a 1% level (see at the bottom of the table). Also, the Wald Chi^2 test shows the regression is a good fit at a 1% significant level. All factors included in the regression are significant except the linear component of labour.

Table 7. Estimation results in a random-effects regression on silage production in quadratic form (N=672)

Variables	Parameter	Coef.	Std. error	t
Z_1 – Fuel in silage(£)	θ_1	0.8987	0.0984	9.14***
Z_1^2- Sq. of Fuel in silage	θ_2	-0.0001	2.08E-05	-6.05***
Z_2 – Labour in silage (£)	θ_3	2.7890	2.2277	1.25
Z_2^2- Sq. of Labour in silage	θ_4	-0.0143	0.0076	-1.88*
Z_3 – Improved grassland	θ_5	18.5483	3.8918	4.77***
Z_3^2- Sq. of improved grassland	θ_6	-0.1289	0.0438	-2.94***
Z_4 – Fertiliser	θ_7	-5.0999	1.8054	-2.82***
Z_4^2- Sq. of fertiliser	θ_8	0.0199	0.0069	2.87***
Constant term	μ	98.3406	54.2056	1.81

R^2 within= 0.3778
R^2-between=0.7249
R^2-overall =0.3633 Hausman chi^2 test:
Wald chi2(8) = 378.2*** $Chi^2(7)$=20.47***

Table 8 below presents the results of coefficients of a FE milk production function in quadratic form. The regression is based on pooled data set. The Hausman specification test indicates that the regression is a FE model because chi^2 was not significant at the 10% level. Rho parameter indicates only 1.3% of the variance is due to the difference across the panels, indicating the FE model is better. The F-test indicates the model is a good fit.

All coefficients are significant including the constant term. The negative coefficients in the quadratic terms explain the impact of diminishing marginal returns. The grazing variable controls the effect of grazing on the milk yield and the coefficient is negative. This may be because some farms have large farm areas but the excess land is not productive unless they have relatively high stocking rates.

Table 8. Estimation results in a fixed-effects regression on milk yield in quadratic form (N=909)

Variables	**Parameter**	**Coef.**	**Std. error**	**t**
X_1 – Utilized Silage (ton)	β_1	-0.7522	0.3247	-2.32**
X_1^2- Sq. of Utilized Silage	β_2	0.0004	0.0002	2.20**
X_2 – Concentrate feed (ton)	β_3	8.2549	0.5397	15.29***
X_2^2- Sq. of Concentrate	β_4	-0.0017	0.0002	-9.62***
X_4 – Labour in milk (hr)	β_5	10.7442	3.5601	3.02***
X_4^2- Sq. of Labour in milk	β_6	-0.0410	0.0125	-3.28***
X_5 – Sundries and Vet (£)	β_7	0.0091	0.0046	1.99**
X_6 – Grazing land (ha)	β_8	-10.6023	1.5142	-7.00***
X_1*X_2= Silage*Concentrate	β_9	-0.0016	0.0004	-4.02***
Constant term	α	5128.2560	215.6155	23.78***

R^2 within =0.4813

R^2-between=0.5736

R^2-overall =0.4824

F(9,892) = 92.00***

Rho=0.013

Hausman chi^2 test:

$Chi^2(7)$=7.359

Chi2 was not significant

The reduced form of the estimated milk yield, i.e. equation (6) shows only those variables that are significant at the 1% (***), 5% (**), and 10% (*) levels of probability. A constant term can be estimated by substituting the average values of excluded variables, labour, vet. Sundries, and grazing land. Thus, milk production can be written as a function of silage usage, concentrate feed, and their interaction as:

$$Y = 5{,}313 - 0.7522X_1 + 0.0004X_1^2 + 8.2549X_2 - 0.0017X_2^2 - 0.0016X_1 * X_2 \qquad (6)$$

This expression shows the change in milk production for the unit change in the intake of silage and concentrate. Diminishing marginal returns indicate each additional unit of concentrates adds a smaller increase in milk yield. After some optimal level of capacity utilisation, the addition of this input will inevitably yield a decreased amount of incremental returns.

Equation 7 is an isoquant or milk production frontier in terms of silage and concentrate for the specific levels of output. This curve shows all the combinations of silage and concentrates that yield the same level of output. It can be obtained by solving a quadratic equation in the form of silage input while other variables kept constant:

$$X_2 = \frac{(0.0016X_1 - 8.2549) \pm sq\ root((8.2549 - 0.0016X_1)^2 - 4(-0.0017) * (5313 - 0.7522X_1 + 0.0004X_1^2 - Y))}{2(-0.0017)} \qquad (7)$$

The MRS of concentrate by silage is given by equation 8,

$$\frac{dX_2}{dX_1} = \frac{-0.7522 + 0.0008X_1 - 0.0016X_2}{8.2549 - 0.0034X_2 - 0.0016X_1} = MRS \qquad (8)$$

Equation 8 refers to MRS measures concentrates feed replaced by a unit addition of silage. The equation helps us to estimate the least-cost combination of feeds. Also, we used the MRS variable to estimate milk yield as well as silage yield for each reseeding rates.

Table 9 presents the estimated results of two-step Heckman selection model on silage yield based on reseeding rate as a selection dependent variable. Here, we are interested to estimate silage yield based on increasing reseeding rate. Silage yield (kg/ha) is defined as the predicted silage production per total grassland. The selection equation is based on reseeding rate on education, lime application and fuel. And, this regression was based on N=542 obs. Therefore, this analysis also indicates that long time-series data is needed for better estimation.

In this regression, the relationship between silage yield and the reseeding rate is positive. A 1% increase in reseeding rate could increase silage yield by 225 kg. In the selection model education of the farmer is not affecting the decision for reseeding rate. But the application of limwas related to the reseeding rate.

Table 9 Estimation results of two-step Heckman selection model for relationship between silage yield and reseeding rate (N=542)

Variables	**Coef.**	**Std. error**	**t**
Silage yield = Dep var.			
Reseeding rate (%)	0.2251	0.0684	3.29***
Fertiliser	-0.1149	0.0212	-5.41***
Fuel	0.0065	0.0017	3.73***
Constant term	11.1218	5.3914	2.06**
Reseeding rate			
Education	0.0242	0.0206	1.17
Lime application	0.0001	0.0001	1.69*
Fertiliser	-0.0016	0.0031	-0.53
Fuel	-0.0003	0.0002	-1.36
Constant term	-1.1156	0.1407	-7.93***
Wald chi2(3) = 43.25			

Thus, the relationship between silage yield and reseeding rate (%) is given by:

$$Silage\ Yield\ (kg)\ = 10{,}000 + 225 * Ressedg\ rate(\%);\ R^2 = 0.58\ ; \qquad (9)$$

Table 10 presents estimated results of a Fixed-Effect Linear Regression (FELR) model on milk yield based on reseeding rate and MRS. Here, milk yield is the same as before, the total milk production per cow. In this case, we are interested to investigate the impact of reseeding rate and MRS on milk yield. The FETR model results show that there is a positive linear relationship between reseeding rate and milk yield. A 1% increase in reseeding rate could increase milk yield by 55.8 litres.

The relationship between milk yield and substitution rate is negative. Because substitution of concentrates by silage can reduce milk yield. A 1% increase in substitution rate could reduce milk yield by 30.5 litres. It is important to note that increasing reseeding rate will compensate for the reduced amount by substitution.

Table10 Estimation results a fixed-effect linear model the relationship between milk yield and reseeding rate (N=542)

Variables	**Coef.**	**Std. error**	**t**
Milk yield = Dep var.			
Reseeding rate (%)	55.8	17.86	3.12
Total Silage use (ton)	0.3	0.19	1.47
Concentrate usage (ton)	4.5	0.40	11.27
MRS (%)	-30.5	7.11	-4.29
Grassland land	-9.6	1.93	-4.99
Constant term	6,167.1	119.37	51.66
R^2 within=0.4254			
R^2-between=0.9316			
R^2-overall =0.4284	Hausman chi² test: Chi²(7)=2.41 Not significant		
F(5,532) = 78.77***			

The relationship between milk yield and reseeding rate (%) is given by:

$$Milk\,Yield\ (l\ per\ cow) = 7{,}500 + 55.8 * Ressedg\ rate(\%)\ ;\ R^2 = 0.93 \qquad (10)$$

Based on equations (6 and10), we have revised the milk yield and silage yield assumptions for different reseeding rates in the CBA. Table 11 shows the various combination of milk yield, silage use, concentrates feed under different scenarios used in the CBA after the results of econometric analysis. A least-cost combination of silage and concentrates was calculated using the results of econometrics analysis. The ideal combination of silage and concentrates occurs when MRS is 20.5%. At this point, the concentrates to silage percentage will be 20.5%.

Table 11 Combination of silage, concentrate levels, and MRS for two levels of milk production.

Reseeding rate (%)	**Milk yield (l per cow)**	**Silage use in ton**	**Concentrate in ton**	**MRS (%)**
0	7,500	852,900	175,462	20.5
10	8,058	929,000	191,081	20.5
14.3	8,297	949,000	195,185	20.5
20	8,616	999,000	205,447	20.5

V. Conclusion and recommendation

The economic analysis of different reseeding rates was evaluated based on NPV per ha and ANPV per ha. The CBA results show that grassland reseeding has a positive effect on profit. However, the margin per ha from grass production alone is low compared to returns from other agricultural activities such as growing high-value crops in NI.

The profit of producing potatoes was £1,643 per ha per year and for sugar beet £1,260 per ha per year (Alexander & Moran, 2013). In our CBA, the annualised profit for growing grass while reseeding every five years was only £351. However, this study demonstrates that there is a possibility of increasing profit from grasslands by increasing the reseeding rates. The CBA and together with the econometrics analysis show that the effect of increasing the level of reseeding can increase profits on the dairy farm.

The profitability of grass production depends on the depreciation of grasslands. It can reduce grass yield and profit after reseeding. Reseeding also increases grass yield and it can be considered as the second driver of change in profit. The annualised profit per ha from reseeding under grass production was lower than dairy production. This may be because of two reasons. First, the price of grass is relatively low as compared to many kinds of cereals. Second, the investment cost of reseeding is very high (i.e. £609 per ha).

Reseeding rates depend on long-term planning to maximise revenues. Under ideal conditions of our model, higher reseeding rate can be seen as more profitable at the time of reseeding since profits depend crucially on when the land was reseeded.

To get an accurate relationship between concentrate feed use (kg) and silage (kg), it needs to be estimated using econometrics, particularly when reseeding rate changes over time. The increase in milk yield and silage yield as a result of increasing the levels of reseeding rate also requires validation using econometrics analysis. These shortcomings of CBA can be improved by applying long time panel data using econometric analysis.

The econometric analysis shows the relationship between silage yield and the reseeding rate is linear and positive. We find that a 1% increase in reseeding rate can increase silage yield by 225 kg. The impact of reseeding rate on milk yield is also positive. A 1% increase in reseeding rate can increase milk yield by 55.8 litres kg. Furthermore, the substitution of concentrates by grass-based feed could reduce milk yield unless it is compensated by increasing reseeding rate. This study also found that the least-cost substitution occurs when MRS is at 20.5%.

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