Horizon 2020 Programme
Research and Innovation Action

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement ***No 773649****.*

Efficient Carbon, Nitrogen and Phosphorus cycling in the European Agri-food System and related up- and down-stream processes to mitigate emissions

Start date of project: 2018-09-01

Duration: 48 months

D4.3. Protocols for the collection of technical and economic data, technical and economic efficiency of the pilot farms (ex-ante).

Deliverable details	
Deliverable number	D4.3
Revision number	Circular Agronomics-D4.3-E-0222-cost assessment
Author(s)	Kees de Roest, Stefano Pignedoli, Fiona Thorne
Due date	28/02/2022 (updated 30/04/2023)
Delivered date	28/02/2022
Reviewed by	Victor Riau
Dissemination level	Public
Contact person EC	Violeta Kuzmickaite

Contributing partners	
1.	FCSR
2.	Teagasc

TABLE OF CONTENTS

Executive summary

Sustainable circular management of Carbon (C), Nitrogen (N) and Phosphorus (P) is a major challenge for agriculture and will be facilitated if the economic returns are of interest for farmers. An analysis of the cost effectiveness and the benefits of single innovative technologies has been carried out.
A higher C sequestration can be obtained when a no-tillage system is applied to wheat grain cultivation. Compared to conventional tillage and minimum tillage a no-tillage system applied to the cultivation of winter wheat presents respectively 22% and 9.7% lower crop costs.
Fertirrigation of microfiltrated digestate obtained by solid-liquid separation and microfiltration may reduce ammonia emissions by almost 90%. The cost per kg of lost ammonia emissions of this innovative technique has been estimated at 6.75 €/kg NH_3-N.
An excess of N-fertilisation of wheat may lead to a high run-off of N to the groundwater. Going beyond 90 kg of N per hectare the gross margin over fertilization costs tends to decline, unlike the fact that at higher levels of N-fertilisation the protein content and price of wheat is increasing.
Precision feeding of milking cows leads to a significant reduction of feed costs, that is able to compensate for the investment in this technology: the total cost of precision feeding is 13% lower than feeding with a conventional system and, as milk yield is similar in both systems, farm net income is even 21% higher.
Digestate, dried with solar energy, can be used an alternative for mineral fertilizers and contributes to the reduction of the use of fossil energy needed for the production of fertilisers. The application of solid digestate obtained from solar drying is significantly lower (-63%) than the costs of mineral fertilization. However, the reduced yield capacity of dried digestate by 8% leads to small reduction of farm net income.
An over use of concentrate feed may cause a waste of minerals. With an increase of the use of concentrate at a certain level the profit margin per kg milk declines. International dairy farm data show even an inverse relationship between concentrate feed use and profit margin. However, data of small to very small dairy farms in this study did not allow to draw clear conclusions.

1. Introduction

At the outset of the work carried out for this deliverable, protocols for economic data collection were identified. The protocols identified the following:

Step 1: Criteria for inclusion/exclusion of case studies in the cost/benefit assessment;

Not all demonstrated technologies could be subjected to a cost benefit analysis, as two selection criteria have been applied:

1. The technologies need to be applied at farm scale. This implies that those foreseen in WP3 are not taken into consideration.
2. The experiments need to be carried out at the minimum at hectare base and not on plot scale, as these latter data are difficult to extrapolate to a farm scale.

The following technologies and experiments then have been subject of a cost benefit analysis:

1. Precision farming and conservation tillage with and without cover crops in Emilia-Romagna
2. Energetic valorization of manure, solid-liquid separation and microfiltration of digestate for fertigation in drip line in Emilia-Romagna
3. Genotype differences in mechanisms contributing to N-efficiency of plants in Brandenburg.
4. Feeding strategies and precision feeding tools focused on the reduction of GHG emissions on dairy farms in Catalonia.
5. Production of bioenergy and high-quality fertilizer from manure by means of solar energy in Catalonia
6. Feeding strategies directed towards feed autonomy on dairy farms in Austria.

Step 2: Identification of *cost and benefit variables* necessary for the analysis (in task 4.3.1.) of the economics of case study technologies.

The protocols for data collection for the cost/benefit assessment focused on the quantification of investment costs of the technologies, changes in labour, feed, energy and other operational costs and of benefits related to changes in crop yields, prices and returns. The protocols established for the collection of the afore mentioned variables, were established through bi-lateral communication with case study leaders. For each of the technologies a tailor made set of technical efficiency and economic data have been collected. The emphasis of the data collection has been put on changes in the technical performances of the crops and animals, as the improvement of the technical efficiency due the implementation of the technologies contributes to reduce or compensate for the investment costs. As the results are presented in a farm context, these can be used as business models for farms who are interested to invest in these technologies.

2. Precision farming and conservation tillage with an without cover crops in Emilia-Romagna

Three different types of tillage are compared: conventional tillage, minimum tillage and no-tillage for winter wheat grain cultivation. The objective of this process is to reduce CO_2 emissions by means of a higher C sequestration of the soil.

The costs of individual operations were calculated, including depreciation, maintenance and repair costs, fuel consumption, fertilisers, agropharmaceuticals, seeds and labour costs.

For the agricultural machinery we have collected the value when new on which a 9 % depreciation rate and a 3,5 % for maintenance and repairs were assumed. Working hours per hectare were estimated on the basis of working speed and individual operating characteristics (working width, load capacity, etc.).

Fuel consumption was estimated using the equation of Grisso et al., (2004):

$$Q = (0.22\ R + 0.096)\ (1-(-0.0045\ R\ Nred + 0.00877\ Nred))\ Ppdp$$

where:

Q = quantity of diesel consumed in l/h

R = ratio between power at the equivalent power take-off (pdp) and power at rated speed at the power take-off

Nred = reduction in percentage (%) of the delivery control valve: a reduction of 20% with respect to the maximum delivery has been assumed.

Ppdp = engine power in kW measured at the power take-off, an efficiency at the power take-off of 95% has been assumed, considering that from tests carried out on tractor engines at standstill the difference between the engine power and the power at the power take-off, all other parameters being equal, is generally around 5%.

Further assumptions considered in the analysis included the use of subsidised diesel at 0.75 €/liter and a labour cost of 15 €/hour (both for Italy).

Tables 1 to 3 provide an overview of the diesel fuel consumption for conventional tillage, minimum tillage and no tillage respectively.

Table 1. Conventional tillage

Conventional tillage	Diesel fuel consumption l/ha
Urea fertilization 60 kg/ha	0,8
Ploughing 35 cm	52,7
Hoeing	30,1
Sowing wheat 190 kg/ha	5,7
Ammonium nitrate fertilisation 286 kg/ha	0,8
Weeding	1,0
Urea fertilization 238 kg/ha	0,8
Weeding	1,0

Wheat harvesting	22,8
Transport wheat 30 km	14,2
Total	**130**
Without transport	**116**

Table 2. Minimum tillage

Minimum tillage	Diesel fuel consumption l/ha
Urea distribution 60 kg/ha	0,8
Harrowing two steps	46,9
Hoeing	23,2
Sowing wheat 190 kg/ha	5,7
Ammonium nitrate fertilisation 286 kg/ha	0,8
Weeding	1,0
Urea fertilization 238 kg/ha	0,8
Weeding	1,0
Wheat harvesting	22,8
Transport wheat 30 km	14,2
Total	**117**
Without transport	**103**

Table 3. No tillage

No tillage	Diesel fuel consumption l/ha
Urea distribution 60 kg/ha	1,2
Weeding	1,0
Sod seeding wheat 220 kg/ha	25,6
Ammonium nitrate fertilisation 286 kg/ha	1,2
Weeding	1,0
Urea fertilization 238 kg/ha	1,2
Weeding	1,0
Wheat harvesting	22,8
Transport wheat 30 km	14,2
Total	**69**
Without transport	**55**

In the following tables, 4, 5 and 6, the results for the different field operations are shown.

The tables show detailed cost data for individual operations including fertilisers and pesticides costs, while transport costs were not included as they were not necessary for the comparison.

Table 4. Conventional tillage costs

Conventional tillage	€/ha
Urea fertilization 60 kg/ha	€ 31,66
Ploughing 35 cm	€ 135,60
Hoeing	€ 76,65
Sowing wheat 190 kg/ha	€ 121,79
Ammonium nitrate fertilisation 286 kg/ha	€ 104,16
Weeding	€ 52,24
Urea fertilization 238 kg/ha	€ 113,54
Weeding	€ 43,20
Wheat harvesting	€ 215,00
Total €/ha	**€ 893,83**
Yield 13% U. t/ha	**5,76**
€/t	**€ 155,18**

The cost of conventional tillage is 893,83 €/ha, coupled with a wheat yield of 5,76 t/ha, results in 155,18 € per tonne. The highest costs are due to fertilization, harvesting and ploughing.

Table 5. Minimum tillage costs

Minimum tillage	€/ha
Urea distribution 60 kg/ha	€ 31,66
Harrowing two steps	€ 48,89
Hoeing	€ 58,96
Sowing wheat 190 kg/ha	€ 121,79
Ammonium nitrate fertilisation 286 kg/ha	€ 104,16
Weeding	€ 52,24
Urea fertilization 238 kg/ha	€ 113,54
Weeding	€ 43,20
Wheat harvesting	€ 215,00
Total €/ha	**€ 789,43**
Yield 13% U. t/ha	**5,91**
€/t	**€ 133,58**

The cost of minimum tillage is 789,43 €/ha, coupled with a wheat yield of 5.91 t/ha, results in 133,58 € per tonne. The highest costs are due to fertilization, harvesting and sowing.

Table 6. No tillage costs

No tillage	€/ha
Urea distribution 60 kg/ha	€ 33,69
Weeding	€ 26,67
Sod seeding wheat 220 kg/ha	€ 195,55
Ammonium nitrate fertilisation 286 kg/ha	€ 106,19
Weeding	€ 52,24
Urea fertilization 238 kg/ha	€ 115,57

Weeding	€ 43,20
Wheat harvesting	€ 215,00
Total €/ha	**€ 788,09**
Yield 13% U. t/ha	**6,54**
€/t	**€ 120,50**

In case of the no tillage system the weeding costs are similar to the conventional and minimum tillage systems, because the comparison between the three systems started when the no tillage system was already three years in place. At the very start the weeding costs of no tillage of wheat are high, but after three years tend tend to decline to levels that are comparable to the other two systems. Pest management costs are included in the overall weeding costs.

The cost of no tillage is 788,09 €/ha coupled with a wheat yield of 6,54 t/ha, results in 120,50 € per tonne. The highest costs are due to fertilization, harvesting and sod seeding.

The highest costs were found in the conventional tillage operations; lower costs were found in the other two techniques both on a per hectare and production yield basis.

The costs of minimum tillage per hectare are similar to the costs of no tillage, while the high yield of minimum tillage gives the lowest costs per ton of product for this technique. To compliment the cost/benefit analysis on a per hectare and per tonne basis, presented in Tables 4,5 and 6, an additional analysis was carried out to provide results on a farm basis, for the region examined, n Emilia-Romagna in Italy. Aggregated data for the region was obtained from the EU's Farm Accountancy Data Network (FADN) for specialized cereal, oilseed and protein farms. A number of assumptions are provided here firstly to provide a background to the whole farm costs benefit analysis results:

- The whole farm CBA was calculated on a total cost basis, as provided in tables 4 through to 6; rather than just direct costs, , hence there is no need for overhead cost allocations based on FADN data;
- Price per tonne of wheat sold in 2019, was based on CLAL data, at €218 per tonne for the year 2019;
- Average area for specialized cereal, oilseed and protein farms (COP) for the region, based on FADN data, for cereals was 20.3ha and UAA 27.5 ha;

Based on the above data and assumptions, the results for the whole farm analysis, is presented in Figure 1 below. The results indicate for the average size specialized COP farm, in the Emilia Romagna region of Italy, that the farm based net margin for the no tillage scenario was €2,815 per hectare higher than the minimum tillage scenario and €5,598 per farm higher than the conventional tillage scenario.

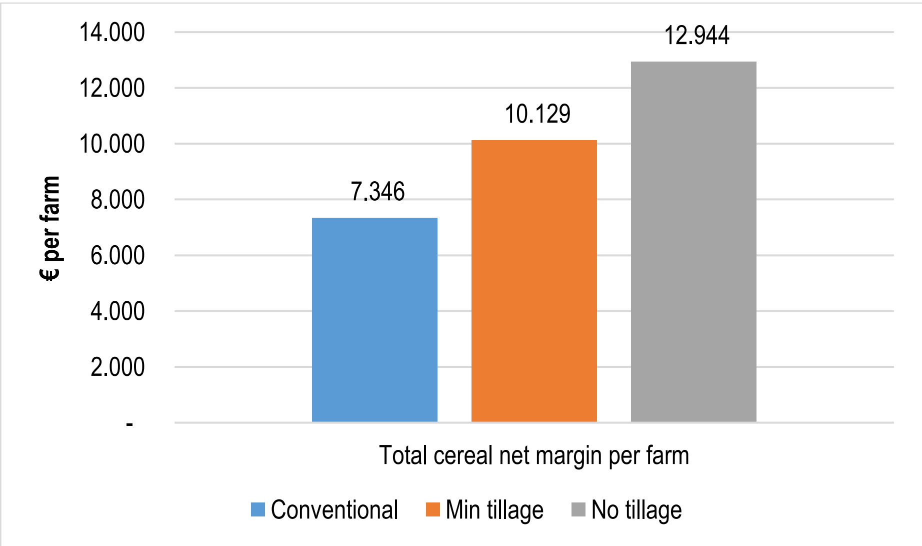

Figure 1. Farm scale cereal enterprise market based net margin, €uro per farm basis.

3. Energetic valorization of manure, solid-liquid separation and microfiltration of digestate liquor for fertirigation in drip line in Emilia Romagna.

Two different types of fertilisations are compared: direct spreading of raw digestate of maize for silage in the field and fertirigation of microfiltrated digestate obtained by solid-liquid separation and subsequent microfiltration

The costs of the individual operations were calculated, including depreciation, maintenance and repair costs, fuel consumption, fertilisers, agropharmaceuticals, seeds and labour.

The methodology for calculating field work operations is similar to those described above in the Emilia-Romagna Region wheat case.

For hose-reel irrigation a cost of 0,20 €/m³ has been estimated (BAU), while the cost of fertigation including the costs of solid-liquid separator and the microfiltration system has been estimated at 1,05 €/m³ (NEW) of which 0,26 €/m³ is due to the system of positioning and removing of drip lines and 0,79 €/m³ to the separation and microfiltration system.

Table 7. Raw digestate distribution, per hectare costs (BAU).

Operation	€/ha	
Digestate fertilization with slurry spreaders 45 t/ha	€	81,76
Ploughing 45-50 cm	€	154,95
Urea fertilization 330 kg/ha	€	155,04
Harrowing	€	43,53
Maize sowing 75 cm	€	338,14
Weeding	€	107,28
Urea fertilization 360 kg/ha	€	168,84
Irrigation 40 mm	€	81,91
Irrigation 40 mm	€	81,91
Maize harvesting	€	592,00
Total €/ha	**€**	**1.805,36**

Table 8. Fertirrigation with microfiltered digestate, per hectare costs (NEW).

Operation	€/ha	
Digestate fertilization with slurry spreaders 45 t/ha	€	81,76
Ploughing 45-50 cm	€	154,95
Harrowing	€	43,53
Maize sowing 75 cm	€	338,14
Weeding	€	106,13
Urea fertilization 140 kg/ha	€	67,18
Fertirrigation with micro-filtered digestate, 52 hours 105,3 mm and 27 hours 54,7 mm	€	594,09
Transport n. 4 trips microfiltrate digestate 3 km	€	122,31
Maize harvesting	€	592,00
Total €/ha	**€**	**2.100,09**

Table 9. Unit product cost

Raw digestate distibution (BAU)	
€ 1.805,36	€/ha
€ 68,40	Maize (33% DM yield) t/ha
€ 26,39	€/t
Microfiltered Digestate to Fertigation (NEW)	
€ 2.100,09	€/ha
€ 65,70	Maize (33% DM yield) t/ha
€ 31,96	€/t

The results *(table 9)* indicate higher costs of microfiltered digestate fertirigation with a lower product yield. In order to achieve satisfactory economic results, it would be important to increase yields. It should however be noted that the advantages of this microfiltrate digestate fertirigation, are the considerable reductions in ammonia emissions.

In order to try to estimate the costs of reducing ammonia losses achieved with the new system, it is necessary to estimate the ammonia losses of the two systems. In the conventional system (BAU), losses of 50 kg NH_3-N/ha were quantified, while in the new system the losses were only 6,4 kg NH_3-N/ha (-87%)

By dividing the difference in cost of the two systems (294,74 €/ha) by the kg of ammonia avoided (43,6 kg NH_3-N/ha), we obtain the cost per kg of lost ammonia emissions of 6,75 €/ kg NH_3-N. If no extra yield can compensate for these higher costs, policy measures may provide incentives to this technique as society would benefit by the significant reduction of the emissions of ammonia.

Following the procedure outlined earlier in section 2, an additional whole farm cost/benefit assessment was carried out for the region to compliment the cost analysis on a per hectare and per tonne basis, presented in Table 9, for the Emilia-Romagna in Italy. Aggregated data for the region from FADN for specialized milk farms was used. A number of assumptions are provided here firstly to provide a background to the whole farm costs and benefits analysis results for this specific case study:

- The whole farm costs analysis (CA) was calculated on a total cost basis, as provided in table 9; rather than just direct costs, , hence there is no need for overhead cost allocations based on FADN data;
- Average area for specialized milk farms for the region, based on FADN data, was 48.2 hectares of UAA, forage area 39.2has, of which it was arbitrarily assumed that half of the forage area was silage maize.
- An average value of maize silage for use on dairy farms was assumed, at €46.50 per tonne, which was used in the CBA.

Based on the above data and assumptions, the results for the whole farm analysis, are presented in Figure 2 below. The results indicate for the average size specialized milk farm, in the Emilia Romagna region of Italy, that the farm based net margin for the BAU case was €26,947 and the NEW scenario was 418,712., indicating that the higher costs and lower yield potential of the NEW scenario results in a lower economic benefit compared to the BAU scenario. Overall, on specialist milk farms in the region, the net impact of the NEW scenario would result in a decrease in returns of €8,235 per farm, which is equivalent to 10 percent of total family farm income in 2019, which was €84,791.

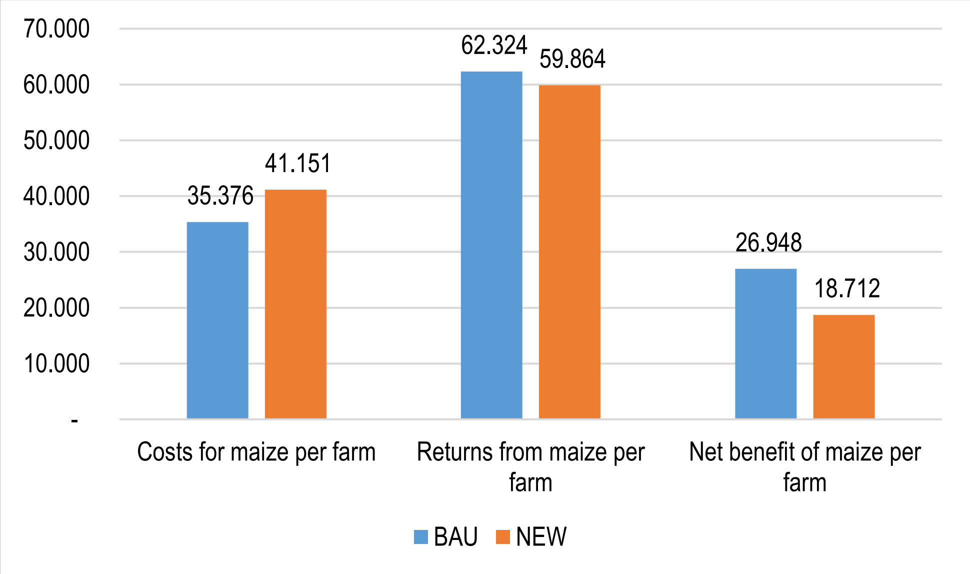

Figure 2. Farm scale costs of production (and benefit) associated with maize silage on specialist milk farms in Emilia-Romagna, €uro per farm basis.

4. Genotype differences in mechanisms contributing to N-efficiency of plants in Brandenburg

The tests consisted of different levels of fertilisation or no fertilisation with or without irrigation of wheat. Three different wheat varieties with different protein contents were compared: Elixer, Hyvento, Kerubino. Considering a different remuneration price of the product according to the protein content, the differences between gross margin and the fertilisation costs were calculated.

Table 10 shows the selling prices of wheat flour according to protein content in Germany .The differences on prices have been collected using the German market data published on: https://www.agrarmarkt-aktuell.de/Trends-Analysen/Weizenpreise-Entwicklung_si1417080527.html.

Table 10. Wheat grain prices in Germany

	%protein	Min €	Avg €	Max €
E-Weizen is usually at a minimum of 14.5 % Protein	14,5	159,00	228,50	298,00
A-Weizen is at 13,5 % Protein	13,5	146,00	215,50	285,00
B-Weizen is at 11,5 % Protein	11,5	140,00	210,00	280,00
Below this is feed - "animal feed wheat"	9,5	130,00	204,00	278,00

*) the first three varieties are of bread quality

On the basis of the average price data, we constructed a regression line *(Figure 3)*, which guarantees a good fit to estimate the prices according to the real protein content of the trials with the first three varieties.

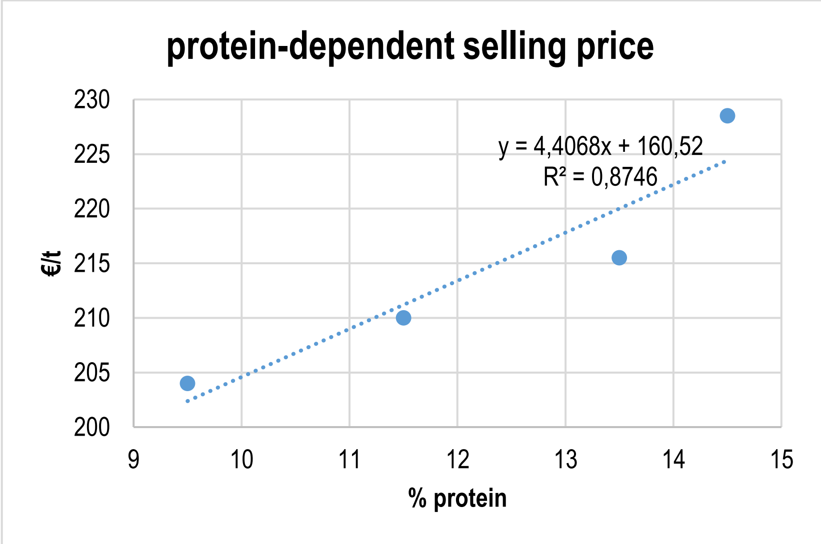

Figure 3. Protein-dependent sales price of wheat.

The tests consisted of four levels of fertilisation or no fertilisation with or without irrigation in particular: 0, 90, 135, 180, 225 kg/N per hectare. As fertilizer we considered the YaraBela CAN (27% N) which is a quality granular calcium ammonium nitrate-based nitrogen fertiliser for use on any crop. YaraBela CAN contains nitrogen as nitrate and ammonium. The fertilizer price is 350 €/t.

For the cost of the fertilisation a reference price list of a contractor in Germany has been taken *(table 11)*. The calculation shown in the table below yields a cost of 0.061 €/kg of fertiliser distributed.

Table 11. German contractors costs of fertilizer distribution

Costs of distribution		
Tractor 4WD 66-80 PS	26,6	€/h
labour cost	15	€/h
Tractor	41,6	€/h
Pneum fertiliser spreader	10	€/ha
Speed	7	km/h
working width	12	m
Fertilizer	330	kg/ha
Labour capacity	46,2	kg/minute
Hopper capacity	450	kg
time emptying	10	minutes
loading+manoeuvring etc.	10	minutes
work time	0,24	h/ha
cost	€ 20,04	€/ha
cost	**€ 0,061**	**€/kg fertilizer**

In order to assess the effect of the benefits of fertilisation, the cost of fertilisation in both the irrigated and non-irrigated case was subtracted from the gross turnover of the three wheat varieties.

The values refer to gross margins over fertilizer costs and in fact relate only to the costs of fertilization. All other costs, that have not been calculated, must be subtracted from this gross margin as they are considered to be equal in all trials.

The results are also shown in *figures 4 and 5.*

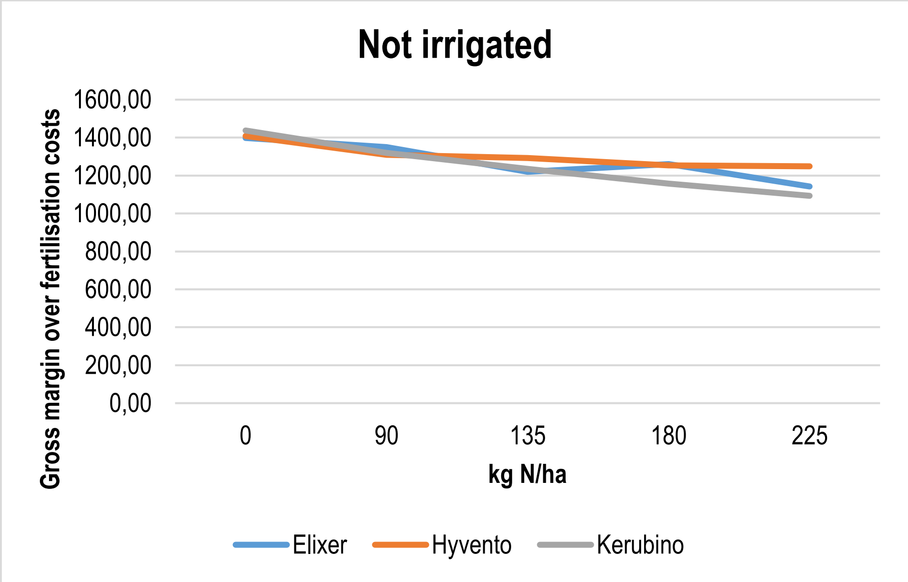

Figure 4. Not irrigated

In the non-irrigated trials no economic advantage of fertilisation has been observed, despite the increase in protein content (dependent on the amount of fertiliser distributed). The costs of fertilisation outweigh the benefits of increased remuneration due to the higher protein content.

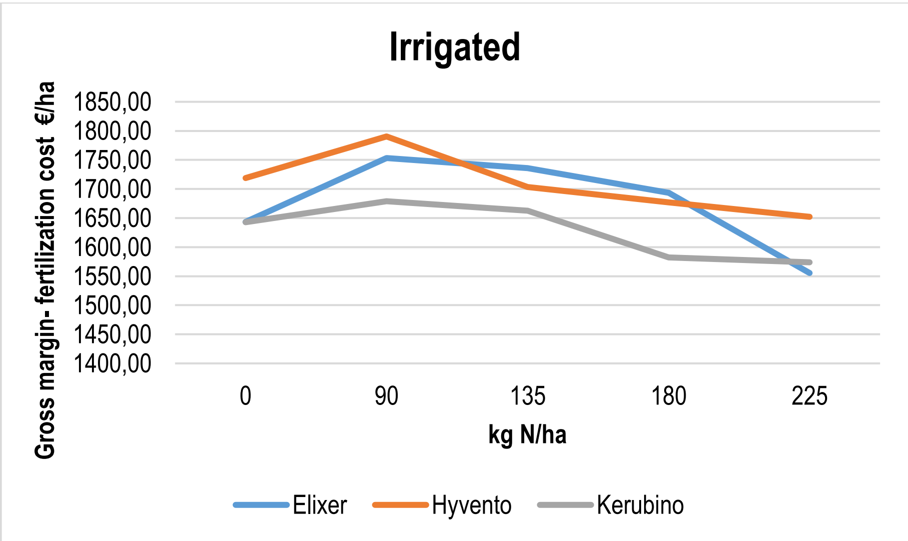

Figure 5. Irrigated

In the case of irrigated wheat with 90 kg N/ha fertilisation in all varieties there is a maximum gain. The variety Elixir also shows good performances at 135 and 180 kg N/ha.

Economic benefits of fertilization are observed only in the case of irrigation, but not exceeding 90 kg/ha of nitrogen fertilizer.

It should be borne in mind that the data only refer to one year's tests. So the results should be taken with due caution as different environmental climatic conditions can radically change the results. In 2019 due to drought there was little effect of nitrogen on yield. In a number of cases, the effect was even negative. The explanation for this is that the plants had used all the water from the soil before grain formation and after this there was no water left to fill the ears. Increased N fertilization leads to increased plant production and increase water use. The effect is known as "haying-off". For a long time this effect was practically unknown in the Brandenburg area. Due to rising temperatures it was frequent in recent years. A solution would be aiming for lower yields right from the beginning and seeding a lower number of plants per m². However, this would mean to reduce the potential yield even when the weather is good.

Following the procedure outlined earlier in sections 2 and 3, an additional whole farm cost/benefit assessment was carried out for the region to compliment the cost analysis on a per hectare and per tonne basis, presented in Figures 4 and 5, for the Brandanburg region in Germany. Aggregated data for the region from FADN for specialized COP farms was used. A number of assumptions are provided here firstly to provide a background to the whole farm costs and benefits analysis results for this specific case study:

• Average area for specialized COP farms for the region, based on FADN data, was 369.9 hectares, of which 247.2 hectares was devoted to cereals, and it was arbitrarily assumed that half of the cerall area was devoted to wheat for the purpose of this case study analysis.

Based on the above data and assumptions, the results for the whole farm analysis, are presented in Figure 6 below. The results indicate for the average size specialized COP farm, in the Brandenburg region of Germany, that the farm based net margin for the non irrigated case does not justify the fertilizer expenditure for any of the wheat genotypes examined. As was evident in Figure 4, the costs of fertilisation outweigh the benefits of increased remuneration due to the higher protein content across each of the genotypes examined. For example, for the elixir genotype the whole farm change in net margin was decreased by over €30,000 for the averge farm in Brandengurg, in a non-irrigated scenario, when the maximum of 225 kg of nitrogen was applied per hectare, compared to no fertilisation.

In the irrigated scenario, the maximum gain in net margin was apparent at 90ks of applied nitrogen per hectare across all three genotypes. For example-le, for Elixier there was a whole farm gain of over €3,000 associated with 90kg of applied nitrogen compared to no nitrogen applied. There was an €8,000 net benefit in whole farm terms for Hyvento at the 90kg of applied nitrogen compared to the no fertilisation applied, whilst the gain for Kerubino at the same fertilisation rate was €4,000 per farm.

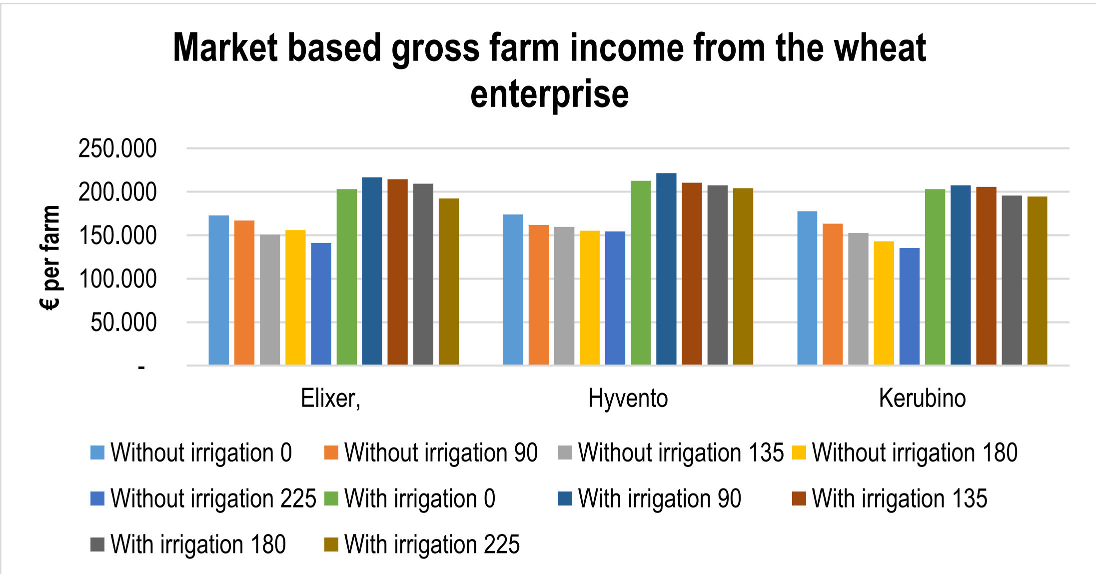

Figure 6. Farm scale market based gross income associated with wheat genotypes, fertilisation rate and irrigation application on specialist COP farms in Brandenburg, €uro per farm basis.

5. Feeding strategies and precision feeding tool focused on the reduction og GHG emissions on dairy farms in Catalonia.

The cost of conventional versus precision feeding devices for dairy cows was compared. The calculations were made for a farm with 120 dairy cows. The costs of feed, the cost of precision feeding equipment, the price of milk remuneration based on the percentage of fat and protein were evaluated and the following results were obtained. The two types of feeds with the costs compared are shown in *table 12.*

Table 12. Conventional vs precision feeding, feed ration and costs

Feed	Diet of conventional feeding kg/day	Diet of precision feeeding kg/day	Feed prices €/t	Conventional €/cow/day	Precision €/cow/day
Alfalfa hay	3,89	3,89	€ 135,00	€ 0,53	€ 0,53
Rye grass silage	3,5	3,5	€ 39,00	€ 0,14	€ 0,14
Rye grass hay	2	2	€ 109,00	€ 0,22	€ 0,22
Barley silage	6,51	6,51	€ 39,00	€ 0,25	€ 0,25
Barley straw	0,8	0,8	€ 20,00	€ 0,02	€ 0,02
Corn meal	9	8,9	€ 261,00	€ 2,35	€ 2,32
Canola meal	2	2	€ 340,00	€ 0,68	€ 0,68
Soybean meal	2,61	1,2	€ 458,00	€ 1,20	€ 0,55
Wheat middlings	1	0,65	€ 223,00	€ 0,22	€ 0,14
Fat	0,43	0,43	€ 500,00	€ 0,22	€ 0,22
			total €/cow/day	**€ 5,81**	**€ 5,06**

The type of feeds in the two diets are the same, but in different quantities for corn meal, soybean meal and wheat middlings where the precision feeding ration includes smaller amounts. As a result, the cost of the precision feeding is lower. The cost of conventional feeding is 5,81 €/cow/day, the cost of precision feeding is 5,06 €/cow/day. In order to evaluate the benefits, the milk yield from the two types of diet was considered. The data are shown in the *table 13.*

Table 13. Milk yield and quality according to conventional vs precision feeding

	conventional	precision
milk yield, kg/d/cow	35,00	34,70
fat yield, kg/d/cow	1,37	1,36
% fat	3,91	3,91
protein yield kg/d/cow	1,17	1,04
% protein	3,33	3,01
Total DM intake, kg/d/cow	26,20	24,70
CP intake, kg/d/cow	4,26	3,55
Energy intake (Net energy lactation, NEl), kg/d/vaca	42,64	39,73
Initial BW day 1	733,00	712,00
Final BW day 28	720,00	712,00
Urine excretion, L/d	24,20	26,10
N urine excretion, g/d	196,50	141,70
N fecal excretion, g/d	311,00	316,00
DM Diet digestibility, %	62,00	61,70

The milk yield in the precision feeding diet was slightly lower: 35 vs 34,7 kg milk/day/cow.

For the cost-benefit calculation, the selling price of the milk was taken into account, including the extra payment recognised for each 0.01 % of fat and protein. In addition, the cost of investment and maintenance and operating costs of the precision feed equipment were included (table 14).

Table 14. Precision feeding investment and value of extra payment for fat and protein milk contents

Investiments, costs, fat and protein milk content		
investment feed delivery milking parlour (precision feeding)	117,970.00	Euros
annual maintenance cost precision feeding equipment	1,200.00	Euros
milk price, euros/kg	0,32	euros/kg milk
extra payment for 0.01 % fat	0,00029	euros/kg milk and 0.01% fat
extra payment for 0.01 % protein	0,00017	euros/kg milk and 0.01% protein

Table 15 shows the results of the cost-benefit comparison of the two feeding systems compared for 120 dairy cows.

Table 15. Cost-benefit comparison

	conventional	precision
production kg/cow/y	10.675	10.584
extra payment for 0.01 % fat/kg milk	€ 0,001133	0,00113
extra payment for 0.01 % protein/ kg milk	€ 0,000566	0,00051
milk price correct fat and protein €/kg	€ 0,3217	0,3216
revenue €/y	€ 412.096,21	€ 408.497,08
diet €/cow/d	€ 5,81	€ 5,06
diet €/cows/y (305 d lactation)	€ 212.716,27	€ 185.268,83
equipment for precision feeding €/y		€ 12,997,00
cost € (only diet+ precision equipment)	€ 212.716,27	€ 198.265,83
margin over feed costs €/y	€ 199.379,94	€ 210.231,25
margin over feed costs €/y/cow	€ 1.661,50	€ 1.751,93

Precision feeding appears to have been economically viable with a margin over feed cost of 1.751,93 vs 1.661,50 €/years/cow.

The following graph shows the profitability point based on the number of cows.

In spite of slightly lower milk production and higher investment costs of precision feeding, due to lower feed costs, the precision feeding system generates a net benefit in the case of 120 lactating cows.

The graph below shows the margin over feed costs that can be achieved with different cow numbers. The break even point is around 65 cows *(Figure 7).*

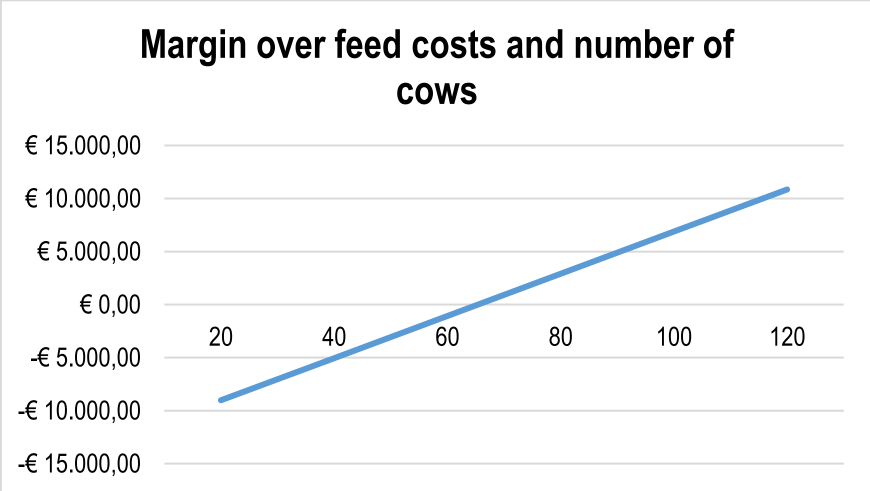

Figure 7. Margin over feed costs and number of cows

Following the procedure outlined in earlier sections, an additional whole farm cost/benefit assessment was carried out for the region to compliment the cost analysis on a per cow basis, presented in Table 15, for the Catalonia region in Spain.

Aggregated data for the region from FADN for specialized milk farms was used. A number of assumptions are provided here firstly to provide a background to the whole farm costs and benefits analysis results for this specific case study:

- The whole farm costs analysis (CA) was calculated on a total cost basis, as provided in table 15; rather than just direct costs, hence there is no need for overhead cost allocations based on FADN data;
- Average herd size for specialized milk farms for the region, based on FADN data, was 112.5 dairy cows.
- Average farm net income on specialized milk farms in 2019 for the region was €46,069.

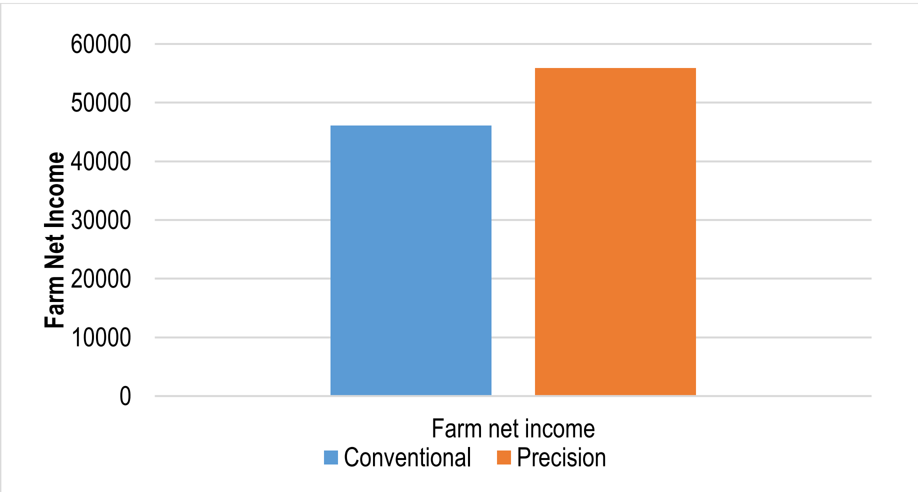

Figure 8. Farm scale net farm income associated with conventional versus precision feeding systems on specialist milk farms in Catalonia, €uro per farm basis.

Based on the above data and assumptions, the results for the whole farm analysis, are presented in Figure 8 below. The results indicate for the average size specialized milk farm, in the Catalonia region in Spain, that the farm based net farm income for the conventional case was €46,069 and the precision scenario was €55,905 indicating that the lower costs and lower yield potential of the precision scenario results in a higher economic benefit compared to the conventional scenario. Overall, on specialist milk farms in the region, the net impact of the precision scenario would result in an increase in returns of €9,836 per farm, which is equivalent to 21 percent of total family farm income in 2019, which was estimated at €55,905 (for the precision scenario).

6. Feeding strategies and production of bioenergy quality fertilizer from manure by means solar energy in Catalonia.

The fertilisation costs of the field trial of barley, wheat, triticale, pea and rape were analysed. Fertilisation and production data were obtained from experimental trials with plots of 0.02 ha. The results were then related to the hectare basis as a unit of measurement.

Mineral fertiliser inputs were the same for all crops: ammonium nitrate (27% N) 140 kg/ha, commercial price 350 €/t; ammonium phosphate (DAP 18%N 45%P_2O_5) 128 kg/ha, commercial price 690 €/t; potassium salt (KCl 60% K_2O) 168 kg/ha, commercial price 500 €/t.

The economic calculations were based on the amount of nitrogen distributed, as this is the most significant parameter for comparison with mineral fertilisers.

The amounts of nitrogen distributed as mineral fertiliser including ammonium nitrate and ammonium phosphate inputs were 163 kg/ha. A fertilisation efficiency of 100% is usually considered for mineral fertilisers.

A nitrogen content NT of 4,314% and TAN (total ammonia nitrogen) 2,934%, with a final moisture content of 10.5% was considered for the solid digestate with solar drying system (Prenafeta-Boldú et.al, 2021)

Considering a 68% efficiency (NT/TAN) for solid digestate, to obtain the same amount of nitrogen as 163 kg N/hectare 5,57 t/ha of solid digestae (163 kg/1.000/4.3%/68%) is needed. The quantity in m^3 of digestate corresponding to 5,57 t/ha, considering a starting moisture content of 89,5% and a final moisture content of 10,5%, is 47,514 t/ha, (Mi-Mf/100-Mi where Mi=Moisture initial, Mf=Moisture final). The operating costs of solar drying, that produces a stabilised fertilizer have been estimated at 4 €/m^3 of raw digestate. Hence, the drying cost per solar hectare was estimated at 190,06 €/ha (47,514 t/ha*4 €/m^3 ,considering approximately 1 t=1m3 of raw digestate).

Table 16. Prices and amounts of fertilizers.

	€/t	€/ha	kg/ha
Ammonium nitrate	€ 350.00	€ 181,48	518,58 (27% as N)
Ammonium phosphate (DAP)	€ 690.00	€ 191,67	278 (46% as P_2O_5)
Potassium salt	€ 500.00	€ 140,00	280 (60% as K_2O)

To these costs the costs of field distribution with fertiliser spreaders for mineral fertilisers and manure spreaders for dried digestate must be added. The cost of spreading mineral fertilisers with a 500-litre capacity fertiliser spreader was estimated at 0,5 €/kg, while the cost of spreading solid digestate was estimated at 3,84 €/t with two 8 m3 capacity manure spreaders, considering a distance of 3 km from the digestate storage point. *Table 17 and Figure 9* show the results obtained per hectare and per crop yield.

Table 17. Fertilization costs mineral vs solid digestate

		Barley min.	Barley digest.	Triticale min.	Triticale digest.	Wheat min.	Wheat digest.	Pea min.	Pea digest.	Canola min.	Canola digest.
Ammonium nitrate	€/ha	181,48	190,06	181,48	190,06	181,48	190,06	181,48	190,06	181,48	190,06
Di-ammonium phosphate	€/ha	191,67	0,00	191,67	0,00	191,67	0,00	191,67	0,00	191,67	0,00
Potassium salt	€/ha	140,00	0,00	140,00	0,00	140,00	0,00	140,00	0,00	140,00	0,00
Fertilizer spreaders	€/ha	52,24	0,00	52,24	0,00	52,24	0,00	52,24	0,00	52,24	0,00
Manure spreaders	€/ha	0,00	21,43	0,00	21,43	0,00	21,43	0,00	21,43	0,00	21,43
Hectare cost	€/ha	565,39	211,49	565,39	211,49	565,39	211,49	565,39	211,49	565,39	211,49
Yield	t DM/ha	6,95	6,78	6,37	5,95	7,12	7,07	4,86	4,70	4,28	3,14
Unit product cost	**€/t DM**	**81,32**	**31,19**	**88,72**	**35,57**	**79,36**	**29,91**	**116,28**	**45,02**	**132,14**	**67,40**

In all cases the costs of fertilisation with dried solid digestate are lower (Figure 9).

The calculation was made on the nitrogen component, which is considered the most important mineral. Next to nitrogen digestate contains phosphorus and potassium as well.

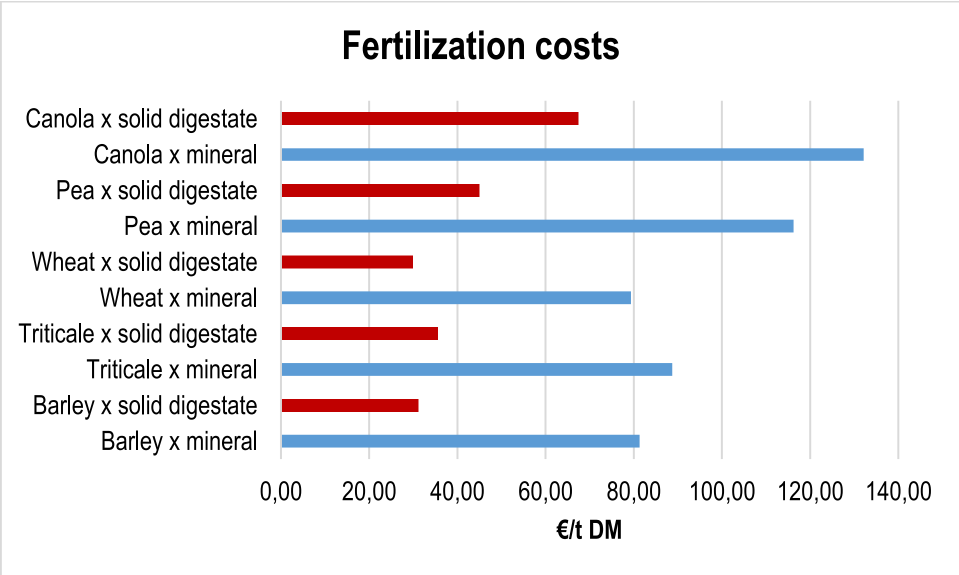

Figure 9. comparison fertilization costs

In all cases the costs of fertilisation with solid digestate obtained from solar drying are significantly lower than the costs of mineral fertilization.

Following the procedure outlined in earlier sections, an additional whole farm cost/benefit assessment was carried out for the region to compliment the cost analysis on per hectare and per tonne basis, presented in Table 17, for the Catalonia region in Spain. Aggregated data for the region from FADN for specialized COP farms was used. A number of assumptions are provided here firstly to provide a background to the whole farm costs and benefits analysis results for this specific case study:

• Average monetary values for specialized COP farms for the region, based on FADN data, for the following variables, for conventional systems was as follows, for 2019:

- Fertilizer spend: €5,596
- Market based gross output: €44,416
- Farm net income: €12,616

Based on the above data and assumptions, the results for the whole farm analysis, are presented in Table 18 below. The results indicate for the average size specialized COP farm, in the Catalonia region in Spain, that the farm based net farm income for the digestate case does not provide an economic benefit on a whole farm basis, when costs of the fertilizer (albeit significantly reduced) are taken into account with the reduced yield capacity of the digestate case, compared to the conventional fertilizer application from mineral sources. As was evident in Table 17, the costs of fertilisation for digestate are significantly lower than the costs associated with mineral fertilization across all crop categories, on average by about 63 percent. However, there is also a reduction in yield potential in the digestate fertilisation scenario, by on average 8 percent. On a whole farm basis, when total fertilizer expenditure is reduced by 63 percent, and total market-based output is reduced by 8 percent, the reduction in farm net income is approximately €28 in a whole farm basis.

Table 18. the results for the whole farm analysis

	€ per farm		
	Conventional (Mineral Fertilzer)	Digestate fertilizer	Difference
Fertiliser cost	5596	2070.52	+3525.48
Total output	44416	40862.72	-3553.28
Farm Net Income	12616	12588.2	-27.8

The difference of €27.8 is not significant especially knowing that the analysis refers to the values of fertiliser prices in 2019. In fact, in our case, if we consider the increase in raw materials in the following years, even a 1% increase would convert the balance in favour of the use of digestate even without considering the likely alignment of yields due to the possible improvement in the distribution efficiency of digestate.

7. Feeding strategies direct towards the feed autonomy on dairy farms in Austria.

Data from 22 dairy farms were analysed to assess the influence of the cost of concentrates feeds on milk production. The farms analysed are all small with an average of 14 dairy cows with a minimum of 4 and a maximum of 28 cows.

The average milk production per cow on all farms was 5.392 kg/cow/year with a minimum of 2.988 and a maximum of 6.847 kg/cow/year.

Only one farm feeds its cattle with only roughage, all other 21 farms used purchased or self-produced concentrates (six farms produce their own concentrates). The dry matter content of the concentrates in the diet varies greatly from farm to farm. The average percentage of concentrates in the diet was 7,4% with a minimum of 1,4% and a maximum of 19,4%.

No correlation was observed between milk production and the amount of concentrates in the diet *(Figure 10)*.

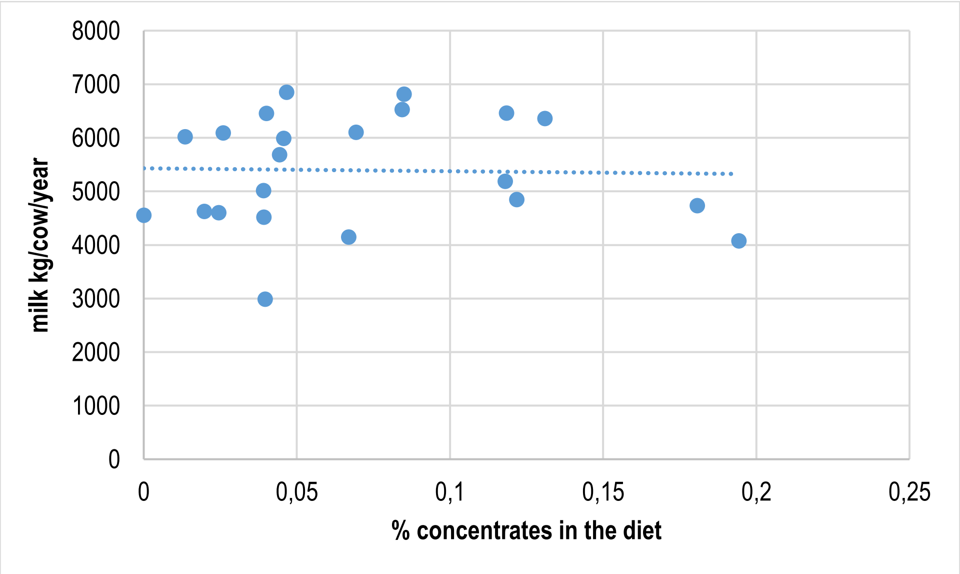

Figure 10. Milk yield and concentrate use

On small farms with few animals, different genetics, health problems and less attention to feeding there are yield differences compared to large stables, where the presence of specialist feeding systems can better control the concentrate.-yield relationship.

The average cost of the concentrates purchased was 0,64 €/kg DM (min: 0,57, max: 0,77), while the cost of self-produced concentrates and forages was estimated at 0,3 and 0,1 €/kg DM respectively.

The milk price of 2018 was 0,70 €/kg milk. This high value was due to a special pilot project in the study region.

In *Figure 11* the gross margin over feed cost is shown with the share of cows concentrates in the diet. No correlation appears between the use of concentrates and the gross margin.

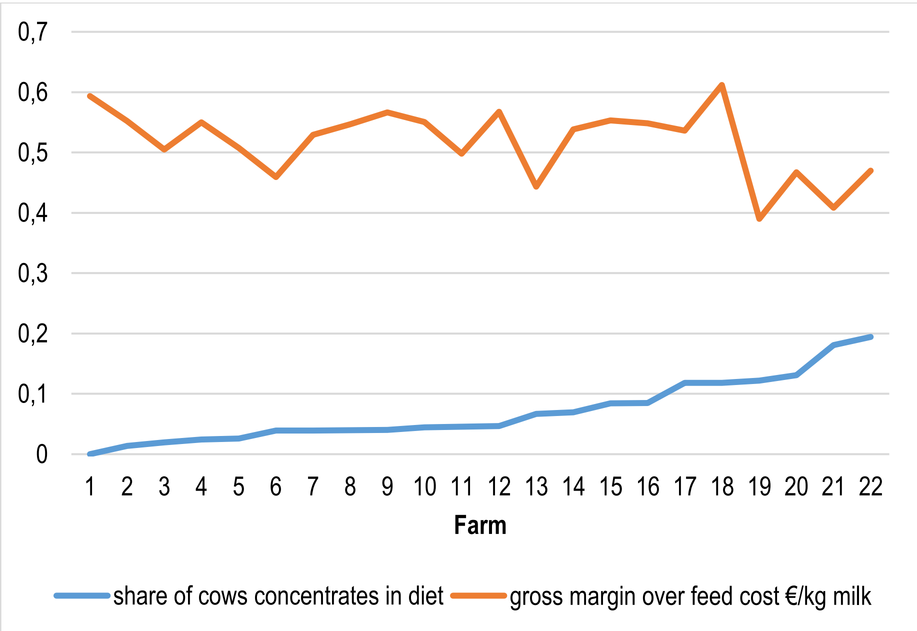

Figure 11. Gross margin over feed cost

In the 22 farms tested it does not seem to be particularly risky to give up or reduce the amount of concentrates in the diet, provided of course that the physiological/nutrional aspects of the cows' diet and animal welfare are carefully considered.

To further investigate the relationship between concentrate use and farm performance on specialist dairy farms, additional data was consulted to examine the relationship outside the strict confines of the case study region, with limited sample size. Two additional sources of data were consulted:

- Micro data from specialist Irish dairy farms, from the Teagasc, National Farm Survey (NFS) which is the data used for FADN for Ireland. This data was used as micro data was available, and it is an interesting case study for a region which has a demonstrated competitive advantage in grass production (Thorne et al., 2017).
- Representative farm data, from the International Farm Comparison Network for dairy (IFCN dairy), for 178 representative dairy systems internationally, where the relationship between concentrate feed use on a kg/head basis was examined in a univariate regression analysis with operating profit margin as the dependent variable (and concentrate feed use as the independent variable).

The data from Ireland, for the dairy enterprise, on specialist dairy farms, for the year 2019, was examined, with the data split into two groups based on performance relating to gross margin (per hectare). The variation in key economic and physical criterion for the different groups of farms, on the basis of gross margin, is presented in Table 19 below.

The population is split into three groups on the basis of gross margin per hectare, with dairy enterprise results presented for the best performing on third (Top), the middle third (Middle) and bottom third (Bottom). A wide variation across cost components is observed, with input expenditure higher for the bottom cohort, similarly a comparatively lower gross output on average results in a reduced net margin overall in the bottom one third grouping. The data presented in Table 19 indicates that as concentrate feed use increases, the gross margin (per litre) decreases.

Table 19. Output, costs and net margin: Top, Middle and Bttom thirds, 2020: Specialsit Dairy Farms (Ireland)

	Top	Middle	Bottom	Average
Gross Output	37.08	35.54	34.92	35.84
Conctrate feeds	5.06	5.35	6.53	5.65
Pasture & Forage	4.35	4.37	5.03	4.59
Other Direct Costs	3.52	3.69	3.90	3.70
Energy and Fuel	1.71	2.04	2.43	2.06
Hired Labour	0.90	0.34	0.46	0.56
Other Fixed Costs	7.53	7.75	7.95	7.74
Total Costs	23.06	23.54	26.29	24.31
Net Margin	14.02	11.99	8.63	11.54

Source: Teagasc, National Farm Survey, 2020

As detailed earlier, representative farm data from the IFCN dairy network for 2019 was also obtained to examine the relationship between concentrate feed use and operating profit margin. The details from the univariate regression are outlined in Table 20 below.

Table 20 shows that there was a significant inverse relationship between concentrate feed use (kg/head basis) and operating profit margin on the sample of representative dairy farms internationally, included in the IFCN dairy network in 2019.Henc,e the data from the case study region in Austria must be treated with caution given the additional findings from micro data in Ireland and the IFCN dairy network, which both found an inverse relationship between concentrate feed use and profit margin.

Table 20. Relationship between concentrate feed use and operating profit margin using data from the IFCN dairy network

```
. regress operatingprofitmargin concentratefeedused

      Source |       SS       df       MS              Number of obs =     178
-------------+------------------------------           F(  1,   176) =    4.34
       Model |  .16283901     1  .16283901             Prob > F      =  0.0387
    Residual |  6.60518348   176  .037529452           R-squared     =  0.0241
-------------+------------------------------           Adj R-squared =  0.0185
       Total |  6.76802249   177  .038237415           Root MSE      =  .19373

------------------------------------------------------------------------------
operatingprofitma~n |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------------+---------------------------------------------------------
concentratefeedused |   -.025167    .012082    -2.08   0.039    -.0490112   -.0013228
              _cons |   .2257155   .0280822     8.04   0.000     .1702943    .2811367
------------------------------------------------------------------------------
```

8. Conclusions ad recommendations

All calculations made in all tests must be considered as indicative, especially in agricultural where the climate and trends in raw material markets can change even significantly the results.
Several innovative technologies, able to enhance environmentally sustainable circular management of C, N and P, may lead to win-win solutions as they may generate positive economic results. In other cases their investment costs are not paid off by adequate economic benefits. Policies that provide economic incentives to investments in these technologies are needed, as society as a whole benefits of the positive externalities generated by the analysed technologies and practices

References:

Prenafeta-Boldú, F.X.;Fernández, B.; Viñas, M.; Noguerol, J.;Soler, J.; Illa, J. Combined Acidification and Solar Drying of Pig Slurries for Nutrient Recovery and Controlled Atmospheric Emissions.Agronomy 2021, 11, 222. https://doi.org/10.3390/agronomy11020222).