Content

INTRODUCTION TO FARM PLANS

Formulation of farm mitigation plan

The base situation of the on-farm nutrient balance in the year 2020 of the 60 field study farms have been prepared as part of the project CCCfarming. The nutrient inventory has been performed with three Nutrient Management Tools, i.e AgreCalc from Scotland, ANCA from the Netherlands and Cap'er2 tool from France.

The goal was that a one-page development plus emission mitigation plan would be drawn up of each of the 60 CCCfarming field study farms. This would be executed by the local research team in discussion with the farm family on basis of the following work performed in this project:

- Description of farm (Task 1.1 of project plan)
- NPC balance of farm (Task 1.4 of project plan)
- Emission measurements with simplified method (Task 1.5 of project plan)
- Outcome of Kitchen Table interview performed with survey (Task 1.6 of project plan)
- Additional input of farmer

As a key part of composing the Farm Plan, the farmer could choose a small set of mitigation practices of which the effect on the nutrient balance and emissions was assessed through calculations. For this purpose, a list of mitigation practices was prepared based on an extensive inventory in the partner countries of interesting practices thought to reduce the GHG and ammonia emissions on dairy farm level. Also, results of the Kitchen Table interviews contributed to the composition of that list. Next, the most suitable practices were selected that fitted to be simulated by the Nutrient tools.

To present the list of the 17 chosen practices to the CCCfarming study farmers, the description of practices was translated into the local language. The project partners provided supporting farm data and information to make the tool simulations possible, as well as supporting data for the economic (MACC) calculations. These data were based on in depth conversations with the farmer and on expert knowledge.

Those study farms were selected that had fully completed data for either the ANCA or the AgreCalc tool. In discussion and agreement of the local project team with the farm family, 2 to 4 alternative mitigation practices were chosen for each farm. Next, the chosen practices were simulated by re-running the Agrecalc or ANCA nutrient accounting tool. The ANCA tool deals with GHG and NH_3 practices, while the AgreCalc tool focusses on GHG. But in the list of practices for the AgreCalc tool, nitrogen reducing practices were also listed. For these N-practices, the indirect positive (or negative) effect on GHG is taken into account by the tool. In fact, the repeated calculations that took place can be defined as a simulation of various practices, while the outcomes / environmental impacts were compared with the base calculations of each particular farm as done before.

- **Agrecalc**: a carbon footprint tool developed in the United Kingdom for agricultural production systems (link to website) designed to identify the main sources of GHG emissions and benchmark key performance indicators.
- **ANCA**: the Annual Nutrient Cycling Assessment tool, developed in the Netherlands for dairy production systems (link to website).

Per country, the ANCA tool was used to re-run the chosen practices for two farms, and the AgreCalc tool for the other farms. The obtained simulation results were compared with the base situation, i.e. farm data collected for the reference year 2020. As explained, the nutrient management calculation tools provide technical output. The framework for economic aspects of the alternative practices / mitigation measures was generated by applying a Marginal Abatement Cost Curve (MACC) approach. Based on these results "Farm plans" were prepared for each study field farm separately.
The framework of the Farm Plan contains the following information:

1. Description of farmers' future strategy on development of farm and reduction of emissions
2. Which mitigation measures / practices were already taken?
3. Which mitigation measures are planned to be implemented and how?
4. Expected effects on emissions (based on tool calculations)
5. Equipment involved, investment and economics
6. Attention points when implementing measures
7. Quote of farmer

OVERVIEW OF SIMULATED MITIGATION PRACTICES

A description of the mitigation practices, including some indication of the benefits and costs of implementing such a practice, are presented in below Table 1. Next, each of the project farms chose 2 to 4 preferable emission mitigation measures from this list, which practices were related to the needs of the individual farm and the local situation, for calculating, in fact simulating, the effects on the farm business.

Table 1: Scheme of presented mitigation measures

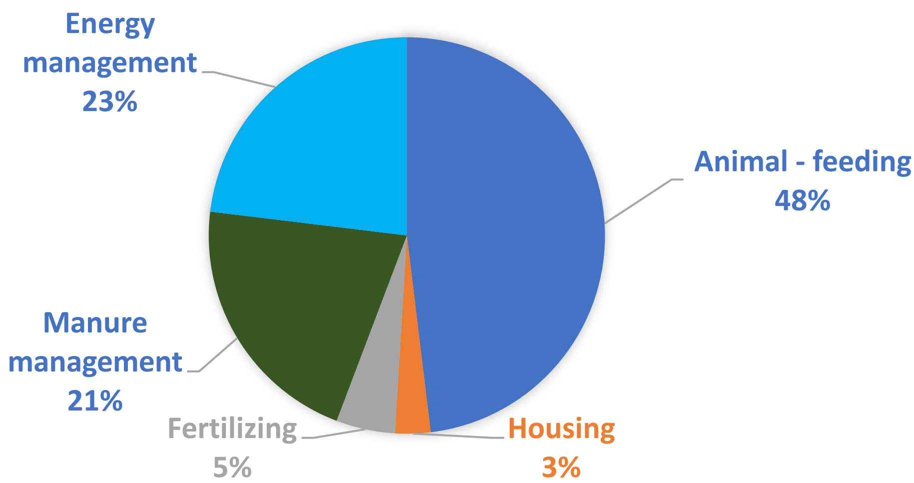
Measures	NH3	GHG	Explanation
I	II	III	IV
Increase feed efficiency	x	x	The aim of the measure is to improve the feed conversion rate (reduce required DM per kg FPCM). In this example we assume feed efficiency is improved through improved feeding, causing less feed is needed. We assume the feed ration composition is not changed and milk yield remains the same. **Mitigation practices include:** feed ration calculation; feeding plan preparation; precision feed distribution. **Farm benefits**: lower feed consumption. **Farm expenses***:* application of precision farming*.*
Low protein diets	x	x	The aim of the measure is to reduce the N content of feed ration ingredients, e.g. by reducing N content of concentrates. We assume milk yield and milk composition remain the same, the feed ration composition is not changed, and there are no changes in grass or crop management. **Mitigation practice include:** purchase/production of low protein feed; feed ration calculation; feeding plan preparation; precision feed distribution**.** **Farm benefits**: Less N in manure effects - less NH_3. **Farm expenses**: application of precision feeding.

I	II	III	IV
High digestible diet and change in crops		x	The aim of the measure is to reduce methane production by increasing the digestibility of rations. **Mitigation practice include**: purchase or production of high digestible feed; feed ration calculation; feeding / cropping plan preparation incl. land use; precision feed distribution. **Farm benefits**: the amount of fodder required decreases, thus alternative use of land possible. **Farm expenses**: change in work input for farmer (less or more work dependant on choices made in cropping and land use plan).
Use of probiotics in the barn		x	The aim of the measure is to use Probiotics for adult ruminants to improve fibre digestion by rumen microorganisms and reduce ruminant CH_4. **Mitigation practice include:** purchase/production of probiotics; precision probiotics distribution. **Farm benefits**: perhaps effect on growth and feed efficiency. **Farm expenses**: probiotic cost, increased additional work through precision feeding for farmers.
Methane blocker as feed additive		x	Effect on reduction CH_4 depends on ration daily. Milk yield and milk composition remains the same, assumed that the feed ration composition is not changed, and there are no changes in grass or crop management. **Mitigation practice include:** enteric methane inhibitor purchase; precision inhibitor distribution**.** **Farm benefits**: Use of 3-NOP reduces methane from 5 to 30%; a slight increase in fat% may be expected. **Farm expenses**: methane blocker cost; precision feeding.
Use of nitrification inhibitor for crops	x		The aim of the measure is to decrease nitrogen loses with nitrification inhibitors use to retard or prevent the conversion of ammonium-nitrogen to nitrate-nitrogen by nitrifying bacteria in soil. **Mitigation practice include:** nitrogen fertiliser with inhibitors use. **Farm benefits**: increased yield and recovery of fertilizer nitrogen by a crop, less nitrogen fertiliser demand. **Farm expenses**: additional expenses for the purchase of fertilizer with inhibitor.
Low emission floors	x		The aim of the measure is to separate the faeces and urine flows in the barn. **Mitigation practice include:** reconstruction of the barn floor by installing the appropriate type of floor**.** **Farm benefits**: animal welfare improves. **Farm expenses**: capital investment: floor type; extra storage; field application
Mechanical manure separation	x		The aim of the measure is to divide liquid manure into solid and liquid fractions by using techniques of manure separation. **Mitigation practice include**: purchase and installation of separation equipment; construction of production facilities. **Farm benefits**: possibility of two manure products: liquid and solid **Farm expenses**: capital investment: separator, electricity, field application (slurry, liquids, solids)
Manure acidification	x	x	Reduce N losses during manure management at field application. **Mitigation practice include**: purchase and installation of acidification equipment. **Farm benefits**: reduction in N losses **Farm expenses**: costs for equipment in barn and application in field; acid costs; possible additional equipment / fertilizer needed for liming the soil
Adding straw to slurry for covering the manure storage	x		The aim of the measure is to reduce N losses during manure management in the outdoor storage. Assumed is sealing the outdoor storage with straw cover. **Mitigation practice include:** straw cover installation**.** **Farm benefits**: reduce nitrogen losses, inorganic fertiliser saved. **Farm expenses**: additional work/equipment for adding straw to manure

I	II	III	IV
Conversion of manure lagoon to cylindrical storage (from open to tanks without covering)	x		Decrease is realized in surface m^2. The aim of the measure is to reduce N losses during manure management in the outdoor storage. **Mitigation practice include:** new construction of the cylindrical manure storage**.** **Farm benefits**: reduced manure management costs, and reduced fertilizer use. **Farm expenses**: investment in cylindrical manure storage
Covering manure storage	x		The aim of the measure is to reduce N losses during manure management in the outdoor storage. Assumed is sealing with outdoor storage impermeable cover. **Mitigation practice include**: purchase and installation of storage impermeable cover. **Farm benefits**: reduction in N losses **Farm expenses**: investment in manure storage cover; manure management somewhat more complicated
Low emission slurry spreading techniques	x		The aim of the measure is to reduce N losses during manure management at field application incorporate slurry directly into soil. **Mitigation practice include**: purchase and installation of application equipment; **Farm benefits**: reduction in N losses **Farm expenses**: investment in drain system + injector or in tank + injector; additional manure management efforts compared to traditional management, like mixing and spreading of the slurry
Anaerobic digester	x	x	The aim of manure fermentation in a biogas reactor is to ensure efficient manure management and production of valuable fertilizers for agricultural crops, as well as to reduce GHG emissions to a minimum in cattle farms. **Mitigation practice include**: purchase and installation of anaerobic digester equipment; mono (manure) and Co (other bioresources) use. **Farm benefits**: reduction in N losses; production of fertilizers; production of renewable energy sources (methane and heat) **Farm expenses**: capital investment in biogas installation; maintenance
Renewable energy sources on farm (RES)		x	The aim of the measure is the production of renewable energy on the farm. The following resources are used: solar, wind, ground heat or biomass (wood and agricultural by-products). **Mitigation practice include**: purchase and installation of RES equipment. **Farm benefits**: substitution of supplied energy consumption with that produced on the farm. **Farm expenses**: capital investment in RES equipment; maintenance
Energy saving equipment			The aim of the measure is to install energy-saving technology and equipment on the farm. **Mitigation practice include**: purchase and installation of energy-saving equipment. **Farm benefits**: used energy saving on the farm. **Farm expenses**: changing the technology used; capital investment in energy saving equipment; maintenance

The farmers' preferences of mitigation measures accumulated over all farmers in the CCCfarming project are shown in Figure 1.

Figure 1. Farmers choice of mitigation measures



There are significant variations in the chosen practices for simulation between the farms in the eight countries. The choices were determined by farmers and their consultants based on the practical needs and characteristics of the farm. The choices per country are listed in below table 2.

Table 2: Farmers choice of mitigation measures in eight countries

	Country							
Mitigation measures	LV	LT	PL	DE	NL	UK	FR	IT
Increase feed efficiency	■	■	■	■	■	■	■	■
Low protein diets					■			■
High digestible diet and change in crops						■		
Use of probiotics in the barn			■	■		■		■
Methane blocker as feed additive	■	■	■		■	■		■
Use of nitrification inhibitor for crops	■			■				
Low emission floors	■				■			
Mechanical manure separation						■		
Adding straw to slurry for covering the manure storage				■				
Covering manure storage	■	■	■	■		■	■	■
Manure acidification		■		■				■
Low emission slurry spreading techniques	■							
Renewable energy sources on farm (RES)	■	■	■		■	■		■
Energy saving equipment		■		■		■		

As shown in table 2, the farmers most often selected "Increase in feed efficiency", "Use of probiotics in barn", "Methane blocker as feed additive", "Covering manure storage", and Renewable energy sources" as preferred mitigation strategy from the 14 practices available.

PRINCIPLE OF THE TECHNICAL EVALUATION OF THE MITIGATION PRACTICES

The output of the simulation calculation results with tools were prepared separately and dedicated for greenhouse gases from AgreCalc tool and for ammonia from ANCA tool.

The following emissions criteria were estimated with the Agrecalc tool:

- Reduction of total farm emissions in kg CO_2e per hectare, compared to original, i.e. base situation
- Reduction of total farm emissions in kg CO_2e per livestock unit (LU), compared to original, i.e. base situation
- Emissions' reduction from whole farm production output in kg CO_2e, compared to original, i.e. base situation
- Total CO_2e emission from farming in kg CO_2e, compared to original, i.e. base situation

Calculation results with ANCA tool:

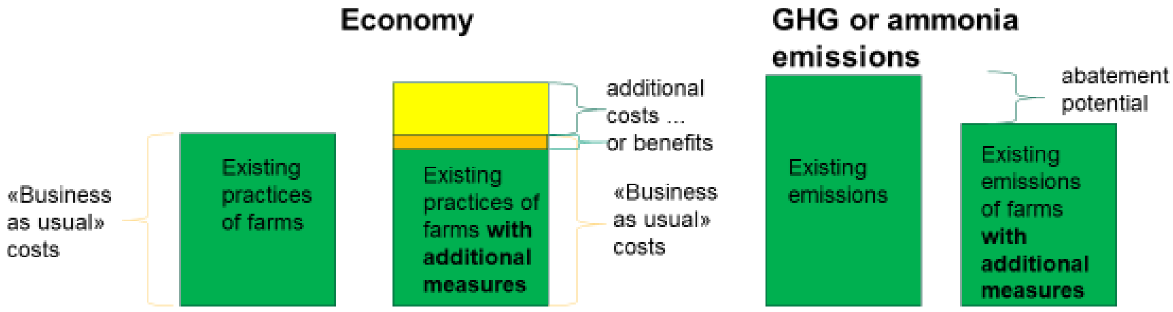
- Ammonia emission reduction from farm in kg NH_3, compared to original, i.e. base situation
- Reduction of ammonia emissions in kg NH_3 per Dutch livestock unit (LSU), compared to original, i.e. base situation
- Emissions' reduction from production of 1 ton of milk in kg NH_3, compared to original, i.e. base situation
- Reduction of total farm emissions in kg NH_3 per hectare, compared to original, i.e. base situation

PRINCIPLE OF ECONOMICAL EVALUATION OF THE MITIGATION PRACTICES

MAC curves are used in France (Pellerin S. et al., 2013), Ireland (Schulte R. et al., 2012), Great Britain (Spadavecchia L., 2014) as well as in other countries. Overall, one can find that the approaches and solutions are diverse (Eory V. et al., 2018). Latvia also constructs MAC curves for its agriculture (Popluga, D., et.al, 2017). In general, a MACC is a very useful instrument for an analysis of GHG emission abatement measures, yet it has limited opportunities to give a comprehensive insight into the effects on economic activity as a whole, as it does not have parameters of the social, economic as well as natural environments

Method. In order to evaluate the economic efficiency of the measures, it is not necessary to calculate all the management costs, but only those costs or incomes that change because of the implementation of the measures, i.e. the marginal costs should be calculated.

Figure 2. Scheme of MAC curve calculation



Data. Explanation of measures mainly describe the purpose, benefits and costs. There are significant variations in the simulation of farms in the application of each individual measure. They were determined by farmers and consultants based on the practical needs and characteristics of the farm. The data were offered by farmers and representatives of the countries, this applies both to data characterizing the activity, as well as prices, investments and others. If farmers or state representatives were unable to provide information, then statistical data and surveys were used, and these data were coordinated with country representatives.

The result. The information obtained in the calculations was used to create a Farm Plan, which describes the effectiveness of GHG and Ammonia reduction measures for each farm of the project. The aggregated MACC describes the total effect of all GHG mitigation measures of the farms (Figure3).

In these figures the X-axis characterizes the GHG or Ammonia emission reduction potential of each measure (t CO_{2e}, kg NH_3) resulting from the implementation of the measure. Therefore, Y-axis characterizes the costs of each measure. They are calculated per kg of reduced GHG or Ammonia emissions.

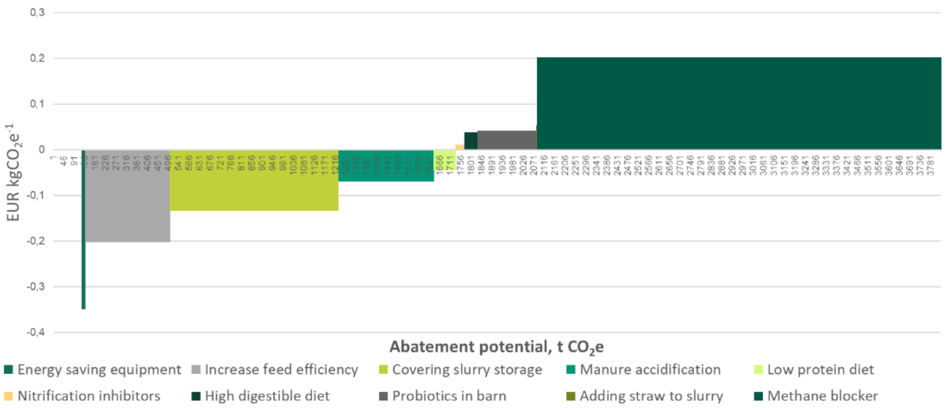


Figure 3. MACC of Pilot Dairy Farms*

*For the measure “Renewable energy production”, the cost (EUR - 11.84) is not shown, which is done for better visualization.

A number of measures has negative costs. This indicates that the measure creates not only a reduction in emissions, but also additional financial benefits. The opposite is the case with measures that have positive costs, when implementing the measures additional costs must be expected in order to achieve GHG emission savings. For example, the "Methane blocker" measure is very popular, which provides a large part of the GHG emission savings, but it generates 0.2 EUR in additional costs for each reduced ton of CO_{2e}.

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