Energy risk management as a driver for reducing greenhouse gas emissions from farming

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ABSTRACT

Instead of focusing on GHG emissions, farmers might be more willing to implement improvements in farming systems if the benefits were shown in terms of energy use and energy risks. Reducing energy costs has a direct benefit to farmers, and moving a farm's net energy budget towards a surplus improves the farm's resilience for energy price fluctuations. We developed a tool for strategic energy management analysis of farms. The tool uses life cycle assessment approach for estimating the embodied energy inputs of the farm, and quantifies the energy outputs in form of agricultural products and surplus of renewable energy produced at the farm. We demonstrate the benefits of the tool by using a case study of a dairy farm in the United Kingdom. We compare the energy balance and GHG emissions of the farm with two alternative scenarios. The results show that synergies between energy risk management and GHG mitigation exist.

Keywords: agriculture, embodied energy, greenhouse gas emissions, tools, energy risk

1. Introduction

Many tools for estimating greenhouse gas (GHG) emissions from farming are widely available (Bochu et al. 2013; Hillier et al. 2011). However, the farmers' willingness to use such carbon calculators is often low due to lack of direct benefits gained by using them (Elbersen et al. 2013). Instead of focusing on GHG emissions, farmers might be more willing to implement improvements in their farming systems if the benefits were shown in terms of energy use and energy risks. Reducing energy costs has a direct benefit to farmers, and moving a farm's net energy budget towards a surplus improves the farm's resilience for energy price fluctuations. Our hypothesis is that reduction in embodied energy inputs and increase in on-farm bioenergy production helps to reduce GHG emissions, partly because of synergies between energy, but largely because it motivates farmers to take action.

We developed a tool, called Energy Positive, for strategic energy management analysis of farms. The tool uses life cycle assessment approach for estimating the embodied energy inputs of the farm, and quantifies the energy outputs in form of agricultural products and surplus of renewable energy produced at the farm. The assessment helps to identify the main energy inputs of the farm and to compare alternative farm management scenarios in terms of energy risks. The tool shows how the farm's input costs reflect fluctuations in energy prices.

We demonstrate the benefits of the tool by using a case study of a 350 ha dairy farm located in the United Kingdom. We compare the current energy balance of the farm with two alternative scenarios: a low GHG emission scenario and a high renewable energy production scenario. In order to test our hypothesis, we analyze the GHG emissions of those scenarios by using the Carbon Calculator developed by the European Commission (Bochu et al. 2013).

2. Methods

2.1. General approach

LCA was used for comparing energy balances and GHG balances of a case study dairy farm located in the Southern England, in the United Kingdom. The impacts of various management choices on GHG emissions and energy balance were modelled. The functional unit (FU) was the whole farm.

The system boundaries included the production of farming inputs (e.g. fuels, fertilizers and pesticides), machinery manufacturing and farm operations, including crop cooling and drying. The soil carbon emissions and sequestration were not taken into account, because net sequestration or emission only occurs when the soil management type has been changed until a new equilibrium level is reached. Energy balances were calculated by using the Energy Positive tool, whereas GHG emissions were calculated with European Commission carbon calculator (available from: http://mars.jrc.ec.europa.eu/mars/Projects/LC-Farming). The methodology of the EC's carbon calculator has been explained elsewhere (Bochu et al. 2013). The Energy Positive tool calculates the LCA based primary energy balances of farms based on data from Williams *et al.* (2006). The biogas yields for manure and straw were based on data from Michel et al. (2010)

2.2. Case study farm

The case study farm is a 350 ha dairy farm located in southern England in the United Kingdom. The farm has 200 milking cows (production level 6000kg milk/cow/yr), 50 heifers and 50 calves. All feed is produced at the farm utilizing 253 ha (Table 1). The livestock is grazing 50% of the time in a year.

Table 1. Details of the feed production system.

Area (ha)	**Crop**	**Tillage**	**N fertilizer (kg/ha)**	**Manure (kgN/ha)**	**Pesticides (yes/no)**	**% clover in grassland**	**Yield (t/ha)**
25	Corn silage	full	200	50	Herb, fung		40
25	Wheat	low	150	50	Herb, fung		7
60	Clover-grass	full	30	no	Herb, fung	50	11
10	Barley	full	120	25	Herb, fung		5
133	Permanent pasture	No-till	no	no	no	no	7

2.3. Alternative production scenarios

The impacts of some alternative production scenarios were assessed. To enable smooth comparison, the farm area, number of animals and product output were assumed to be the same in each scenario. The impacts of the following practices were assessed:

1) No-tillage: applied to the whole agricultural area.
2) Reduced use of synthetic nitrogen fertilizer: the use of synthetic N fertilizer was halved for corn silage and wheat. Barley was replaced with a legume crop. The clover content of the clover-grass was increased to 75%.
3) Anaerobic digester: the livestock manure and straw from wheat was assumed to be used for biogas production. It was assumed that 50% of the manure produced by the whole cattle was used for anaerobic digester, resulting in biogas yield of 50,000 m^3 (22.2 MJ/m^3). The biogas yield for straw was assumed to be 7.1 GJ tDM^{-1} (Berglund and Börjesson 2006), and straw yield 3tDM/ha. It was assumed that 12% of the biogas energy was used for the running the biogas reactor (heating, pumping and mixing). The biogas was assumed to be used for electricity generation, yielding 30% electricity and 50% heat. The rest was assumed to be lost.
4) Solar panels: were assumed to be installed on south-facing roof surface area (500 m^2).

2.4. Method for estimating GHG reduction potential of the mitigation actions

The methods for estimating the GHG mitigation potential of the mitigation actions are explained in more detail in (Bochu et al. 2013) and only summarized here:

1) No tillage: the mitigation effect is calculated based on increase in soil carbon, reduction of CO2 emissions from fuel consumption and increased N2O emissions.
2) Reduced use of synthetic nitrogen fertilizer: avoided emissions from manufacturing of synthetic N fertilizers, and the change in emissions due to replacement of barley with a legume crop and increase of

the clover content in clover-grass. The emission factor for synthetic N fertilizer production is based on data from Wood and Cowie (2004), varying between 5.1-7.1 t CO_2-eq/t N depending on the type of N fertilizer used.

3) Anaerobic digester: avoided N_2O and CH_4 emissions from manure storage, and avoided emissions from manufacturing of N fertilizers due to reduced N losses as NH_3 and N_2O.
4) Solar panels: avoided emissions from electricity production (average UK electricity mix used as a reference).

3. Result

Table 2 shows the GHG mitigation actions recommended by the carbon calculator and the mitigation potential per ha for the base scenario. The mitigation potential for no-tillage and biogas production are different between Table 2 and 3 due to the fact that the mitigation potential presented in Table 2 includes increase in carbon storage in the soil whereas that is not included in the results presented in Table 3.

The results in Table 3 show that in the case of milk production, there is not direct correlation between energy input and GHG emissions. The main GHG emissions sources are enteric fermentation, N_2O emissions from soils and manure management, which all are independent of energy use. The main energy inputs are electricity use and production of fertilizers.

The results also show that combined effect of all mitigation actions included in the study resulted in nearly energy positive farm even when not considering the surplus energy produced at the farm. The same actions however, reduced only 23% of the GHG emissions.

Table 2. Results of mitigation action recommendations generated by the carbon calculator for the base scenario.

Rank	**Actions**	**tCO_2e saving/ ha/ year**	**New level of tCO_2e/ ha/ year**	**% saving**
	Current situation		5.34	
1	No-tillage	0.50	4.85	9.3%
2	Biogas production	0.41	4.93	7.8%
3	Reduce methane from enteric fermentation	0.34	5.00	6.5%
4	Agroforestry	0.26	5.08	4.9%

Table 3. Results of the impact of various farming practices on the carbon footprint and embodied energy input of the farm (changes relative to the base level).

	Base		**Relative change compared to the base case (as % of the base case)**							
			No-till		**Reduced N fertilizer**		**Anaerobic digester**		**All together**	
	GHG (tCO_2-eq)	**Energy (GJ)**	**GHG**	**Energy**	**GHG**	**Energy**	**GHG**	**Energy**	**GHG**	**Energy**
Tractor fuel	26	491	-0.7	-5.4	0.0	-5.7	-0.6	-4.6	-1.3	-15.7
Enteric fermentation	862	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manure management	134	0	0.0	0.0	0.0	0.0	-7.8	0.0	-7.8	0.0
Direct N_2O emissions from soils	167	0	0.0	0.0	-1.4	0.0	-1.4	0.0	-2.9	0.0
Indirect N_2O emissions from soils	14	0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	0.0
Electricity purchased (i.e. on the grid)	68	1089	0.0	0.0	0.0	0.0	-5.0	-45.1	-5.0	-45.1
Mineral and organic fertilizers (processing and transportation)	81	559	0.0	0.0	-2.8	-9.1	-3.4	-11.6	-6.2	-20.7
Other crop inputs (seeds, pesticides)	0	275	0.0	-1.5	0.0	-7.9	0.0	-7.9	0.0	-17.3
Total	**1352**	**2414**	**-0.7**	**-6.9**	**-4.3**	**-22.7**	**-18.3**	**-69.2**	**-23.3**	**-98.8**

4. Discussion

In this paper, a fairly simple case study was presented. Perhaps more significantly, the Energy Positive tool also enables comparison of alternative management scenarios on the farm – allowing farmers to see how structural changes to their farm system would influence their energy budget in the future. All of these outputs can be linked to financial data, and given existing concerns about energy costs, this may motivate farmers to take a fresh look at their farm systems. Energy intensity of farms and their products will be of interest to people further along the food chain, in particular retailers, who are increasingly aware of the need to manage risk in their supply chains.

The critical difference between Energy Plus and existing tools is that it focuses on energy and energy cost risk management, not carbon or GHG emissions. Farmers find this much more compatible with their business needs. Energy Plus is a scenario-based strategic planning tool, not a detailed auditing tool. This allows the user to think beyond simple ‘efficiency adjustments’, compare the implications of structural changes to their land management system, and make strategic-level decisions.

5. Conclusion

The results show that synergies between energy risk management and GHG mitigation exist. Therefore, we conclude that focusing on energy risk instead of climate change may be a more effective way of motivating farmers to implement improvements in their farming systems. However, especially in livestock farms with ruminants extra mitigation actions are needed to reduce the GHG emissions from enteric fermentation.

6. References

Berglund M, Börjesson P (2006) Assessment of energy performance in the life-cycle of biogas production. Biomass and Bioenergy 30:254-266

Bochu J-L, Metayer N, Bordet C, Gimaret M (2013) Development of Carbon Calculator to promote low carbon farming practices – Methodological guidelines (methods and formula), Deliverable to EC-JRC-IES by Solagrohttp://mars.jrc.ec.europa.eu/mars/Projects/LC-Farming

Elbersen BS, Andersen E, Frelih-Larsen A, Jones P, Kuikman P, Naumann S, Oñate J, Staritsky I, Von Troggenburg J (2013) EU wide Farm-level Carbon Calculator. Lot 2: Testing the Carbon Calculator

Hillier J, Walter C, Malin D, Garcia-Suarez T, Mila-i-Canals L, Smith P (2011) A farm-focused calculator for emissions from crop and livestock production. Environmental Modelling & Software 26:1070-1078

Michel J, Weiske A, Möller K (2010) The effect of biogas digestion on the environmental impact and energy balances in organic cropping systems using the life-cycle assessment methodology. Renewable Agriculture and Food Systems 25:204-218

Williams AG, Audsley E, Sandars DL (2006) Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities, Bedford, www.silsoe.cranfield.ac.uk, and www.defra.gov.uk

Wood S, Cowie A (2004) A review of Greenhouse gas Emission Factors for Fertiliser Productionhttp://www.leaftc.co.uk/downloads/cc/GHG_Emission_Fertilizer_Production_June2004.pdf

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