Economic assessment of agroforestry systems compared to other greenhouse gas mitigation options for suckler cow farming

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Abstract

Agriculture is responsible for a large share of global greenhouse gas (GHG) emissions, especially for methane and nitrous oxide emissions. Applying a bio-economic whole-farm model, we assessed five GHG mitigation options on their economic suitability to reduce emissions from grassland-based suckler cow farms.

Among the assessed options, only compensation by agroforestry systems and the choice of an adequate production system showed the potential to significantly reduce emissions. If an adequate production system is chosen, GHG emissions per kilogram of meat can be reduced by up to 18% – from 21.9 to 18 kg CO_2-eq./kg of meat – while total gross margin can be increased by up to 14%. Through the application of an agroforestry system, GHG emissions in all systems can be further reduced to 7.5 kg CO_2-eq./kg meat – equating to a reduction of GHG emissions of 48% to 66% – at costs between 0.03 CHF/kg meat and 0.38 CHF/kg meat depending on the production system and the state of the system before the reduction.

In contrast, the addition of lipids to the diet or a cover to the slurry tank has neither the potential to reduce GHG emissions significantly nor are they cost-effective enough to be implemented. Nitrification inhibitors can reduce GHG emissions up to 10%, but costs for this reduction are much higher than for agroforestry systems.

The application of agroforestry systems to suckler farming in Switzerland therefore seems to be an adequate option to reduce GHG emission significantly for a relatively low price.

Keywords: Greenhouse gas mitigation, whole-farm model, agroforestry, suckler farming

1 Introduction

Suckler farming is of increasing importance in Swiss agriculture because consumer demand is rising for meat produced by animal-friendly and environmentally friendly livestock husbandry. Nevertheless, the contribution of agriculture to climate-relevant emissions has emerged as a major concern for scientists, policy makers and the public. Methane (CH_4) and nitrous oxide (N_2O) constitute crucial non-CO_2 greenhouse gases (GHGs). From a global perspective, about 60% of nitrous oxide and about 50% of methane are associated with agricultural activities such as keeping livestock (here in particular from enteric fermentation) and soil cultivation (IPCC 2007). In Switzerland, agriculture accounts for up to 75% of nitrous oxide and 83% of methane emissions nationally (FOEN 2010).

Strategies to mitigate GHG and nitrogen emissions from agriculture can occur through (1) changes in plant and livestock production, (2) changes in the intensity of production activities, and (3) technological activities (cf. UNFCCC 2008). While the last group comprises, e.g., slurry additives and manure coverage, the first group involves enhanced grazing and agroforestry.

Agroforestry systems are a combination of a lignifying permanent crop with a crop or with grassland on the same area. One advantage of agroforestry systems is their ability to sequester carbon that is stored in the permanent crop's wood or as an enrichment of humus in the soil (SAFE 2005); therefore, agroforestry systems may improve the climate balance of agriculture by sequestering carbon. Because even for the next few decades, no experiment will cap the range for European agroforestry system cycles of 25–100 years, results of existing trials need to be extrapolated to assess the profitability of silvoarable systems. Thus, meaningful models and databases have been developed within the EU project on "Silvoarable Agroforestry for Europe" (SAFE) (SAFE 2005).

Both the high degree of heterogeneity in farming practices and the transboundary character of GHG and nitrogen emissions make it challenging to assess additional mitigation potential. Therefore, assessment of mitigation strategies necessitates an analysis at a more disaggregated level (e.g., at the farm level). In addition, the implications of agricultural production imply links between GHG, the nitrogen cycle and other environmental factors. Thus, a holistic view of the agricultural production process is required in order to evaluate different mitigation strategies.

This paper aims to assess the economic suitability of several mitigation strategies to reduce GHGs on grassland-based suckler farms for the following three races: Angus, Charolais and Galloway. Thus, this analysis includes (1) different animal production systems, (2) additional lipid supplements, (3) manure coverage, and (4) nitrification inhibitors. Additionally, this analysis also addresses the issue of agroforestry, which constitutes an economic opportunity for carbon-neutral animal production systems in Switzerland (Briner et al. 2011). To assess the options mentioned above, an integrated bio-economic farm model is applied, which links the agricultural production process to environmental factors. In this model, marginal abatement costs are calculated for the mitigation options mentioned above. In addition, average reduction costs of the different options are calculated because for both farmers and consumers it will be interesting to investigate how the reduction of GHG emissions changes the price of a product.

The paper is organised as follows: Section 2 provides an overview of mitigation and compensation strategies. Section 3 focuses on the methodological framework. Results and discussion are presented in Section 4, and conclusions are drawn in Section 5.

2 Selected mitigation and compensation strategies for agricultural GHG and nitrogen emissions

Compilations of mitigation and compensation strategies for agriculture are provided by, e.g., Martin et al. (2009) and UNFCCC (2008). With a focus on grassland-based suckler farming, this section addresses the following mitigation practices and their relative reduction potentials, which are included in this assessment: (1) different animal production systems, (2) additional lipid supplements, (3) manure coverage, (4) nitrification inhibitors and (5) the agroforestry system.

Different animal production systems

The animal production system has a major effect on the emission of GHG. Veysset et al. (2010) assessed differences of up to 10% in emitted GHG among grazing suckler farming, depending on the production system. Taking into account differences among production systems, we distinguish among three common Swiss production systems (Angus, Charolais and Galloway) in our analysis (table 1).

Table 1: Characteristics of the three production systems

	Angus	**Charolais**	**Galloway**
Weight of the cow [kg]	625	800	525
Calves per year [1/year]	1	1	1
Weight of calf at birth [kg]	36	45	27
Age at slaughtering day [month]	10	15	25
Average growth per day [g/day]	1100	1133	700
Live weight at slaughter [kg LW]	364	550	482
Carcass weight [kg CW]	204	308	270
Milk production [kg/year]	2500	3000	2000
Max. number of Livestock Units [LU]	35	35	35
Max. number of cows	35	26	18

The productivity per livestock unit (LU) for Angus and Charolais is quite high because after 10 and 15 months, the optimal live weight for slaughter must be attained, which is about 360 and 550 kg, respectively. Using nutrient-rich feed mixes, an average growth rate per day of about 1100 g is achieved. While the Angus and Charolais systems need to be managed rather intensively, the

Galloway system can be applied on marginal sites using low-nutrient feed mixes. Therefore, a live weight before slaughter of about 480 kg is reached after 25 months.

Additional lipid supplements

Lipid supplements to ruminants' diet lead to a significant decrease of methane emissions through decreased organic matter fermentation, activity of methanogens and protozoal numbers, and hydrogenation of fatty acids for lipids rich in unsaturated fatty acids (Johnson and Johnson 1995). However, the measured efficiency varies broadly, as Beauchemin et al. (2010) showed in a recent review. On average, a 1% increase of lipids in the feed mix led to an emission reduction of 5.6%. Martin et al. (2009) indicated an average emission reduction of 4.8% per 1% increase of lipids. In the context of lipid supplements, however, it is important that the level of lipids must not exceed 6% of total dry matter content or else a depression of fodder intake may occur. Based on these two review studies, our analysis assumes a 5% reduction per 1% lipid supplementation.

Manure coverage

Depending on the type of manure coverage and the temperature, a decrease or even an increase of methane, nitrous oxide and ammonia emissions occurs. Covering manure with a wooden lid leads to a reduction in methane emissions of 14% (winter) and 17% (summer), and a reduction in ammonia emissions of 28% (winter) and 54% (summer) (Amon et al. 2006). Using a floating polyethylene cover at a swine slurry lagoon leads to as much as a 99% reduction in ammonia emissions (Funk et al. 2004). As a consequence of reducing ammonia, indirect emissions of nitrous oxide are also decreased. Based on Amon et al. (2006), we apply in our model 15%, 35%, and 50% reductions in methane, nitrous oxide, and ammonia emissions, respectively.

Nitrification inhibitors

Mineralisation of nitrogen in soils results in the release of ammonium (NH_4^+) or ammonia (NH_3). In the process of nitrification, ammonium is oxidised via nitrite (NO_2^-) to nitrate (NO_3^-). Nitrate easily can be leached into the groundwater, causing eutrophication, and both nitrite and nitrate can be denitrified to nitrous oxide (McNeill and Unkovich 2007). The application of nitrification inhibitors (NI) (e.g. 3,4-dimethylpyrazole phosphate (DMPP)) lowers the nitrification rate by reducing the activity of *Nitrosomonas* bacteria (Zerulla et al. 2001). Weiske et al. (2006) showed a 49% reduction of nitrous oxide emissions when they applied DMPP on fertilised sites. A similar result of 48% (spring) and 61% (autumn) reduction in nitrous oxide emissions was demonstrated by Merino et al. (2005), who applied 1 kg of DMPP per hectare on slurry. Based on these and other studies, we assume a reduction potential of 50% for direct nitrous oxide emissions from pastures through the application of nitrification inhibitors.

The agroforestry system

Agroforestry systems contain a combination of a lignifying permanent crop with a crop or with grassland on the same area. Such systems result in diversified agricultural production, increased soil fertility, reduced nitrogen losses, improved landscape scenery and enhanced biodiversity (Jose 2009; SAFE 2005). Compared to monocropping, one advantage of agroforestry is the ability to sequester carbon through storage in the permanent crop's wood or through the enrichment of humus in the soils (Palma et al. 2007). However, similar to other land use systems, the potential for carbon sequestration under agroforestry depends on multiple factors, e.g., the carbon content in existing biomass, the turnover of trees and the environmental conditions (Jose 2009). Thus, even at the small scale, the level of carbon sequestration varies. Palma et al. (2007) revealed a sequestration potential of 2.1 C/ha/y to 3 t C/ha/y for agroforestry systems based on fast-growing hybrid poplars. Thus, we assume a sequestration potential of 2.5 t C/ha/y.

3 Data and Methods

The *Integrated Suckler Cow Optimisation* model (INTSCOPT) was designed to evaluate different GHG mitigation options. This model was constructed to allow quantification of all direct and indirect gaseous emissions from specialised suckler cow farms to assess mitigation and compensation options. INTSCOPT is based on linear programming (LP) because LP has proven to be a suitable method for considering both economic and environmental constraints, especially in the case of farming systems (Janssen and Van Ittersum 2007). The structure of INTSCOPT takes the form of a standard LP model, as described in table 2. The sources of the agronomic parameters *a* and the emission parameters *e* are described in the following subchapters.

Table2: General structure of the INTSCOPT model

	Cows	Calves	Sale of animals	Net energy intake	Buy concen-trates	Grassland int	Grassland low-int	Agro-forest int	Agro-forest low-int	
Herd structure										
LU	a	a								< 35
Feeding	+1	+1		-1						= 0
Forages				a		-a	-a	-a	-a	= 0
Concentrates				a	-a					= 0
Lipids				a	-a					= 0
Agronomic constraints										
Total farm area						1	1	1	1	= 25
Low-intensive area (PEP)							1		1	>1.75
Emissions	e	e			e	e	e	-e	-e	< E
Objective function	-CHF/ Head	-CHF/ Head	+CHF/ Head		-CHF/ ton	-CHF/ ha	-CHF/ ha	-CHF/ ha	-CHF/ ha	Z

To optimise a farm's profitability on a short time horizon, the most important indicator is the total gross margin. Hence, in the objective function of INTSCOPT, the overall gross margin Z is maximised. The general objective function is shown below:

$$Z = \sum returns - \sum assignable\ costs - \sum mitigation\ costs + \sum subsidies \qquad (1)$$

To optimise both profit and GHG emissions, an iterative procedure described by de Wit et al. (1988) has been chosen. The procedure consists of a number of optimisations of the total gross margin *Z*, whereas the GHG emissions *E* are lowered in every optimisation round. Afterward, the costs of the reduction are calculated as the difference between the gross margin in the initial state and the gross margin with reduced GHG emissions. For the calculation of the gross margin, we use data published for and commonly applied in farm extension (AGRIDEA 2009). The variable costs of the use of machinery are calculated using data reported by Gazzarin and Albisser (2010); thus, prices for the year 2009 are assumed. In the following sections, the crucial parts of the model, including the calculation of the emission factors, are described.

3.1 Animal production systems

Feed

For the optimisation of the feed mix, the year is split into two periods: winter and summer. Whereas in winter, hay and silage of different qualities are available, during the summer, fodder

from pastures also is part of the feed mix. In both periods, forage can be supplemented by concentrates and fat.
Determining the composition of the feed mix is part of the optimisation process. The daily energy requirement for every animal is calculated according to its weight and its needs (production, growth) in every period. These constraints are complemented by upper and lower limits of daily dry matter intake calculated on the basis of the animal’s weight. To guarantee the availability of crude protein in the feed mix, an upper and lower bound is defined, depending on the energy intake. The calculations of the feed requirements and the composition of the different feeds are based on data provided by Arrigo et al. (1994).

Buildings
The model assumes that the animals are kept in free-stall housing in which the number of stalls is flexible according to the age of the animals. Animals older than 15 months are kept in cubicles, whereas younger cattle are kept on deep litter. It is assumed that a change between the housing systems does not require much effort. Therefore, the only building constraint in INTSCOPT is the total number of LU, which in this case is 35 (cf. table 1). Because a cow and its progeny in the Galloway system result in a higher number of LU, the maximum number of Galloway cows is lower than those of the other breeds.

3.2 Nutrient balances

The outcome of the model is restricted by two different nutrient balances. The first balance (*Suisse-Bilanz*, AGRIDEA 2010) ensures that the modelled farm fulfils the *Proof of Ecological Performance* (PEP), which represents a criteria that must be met to receive direct payments in Switzerland. Because GHG and nitrogen emissions are linked, a second refined balance was calculated for nitrogen and incorporates the different compartments of the nitrogen cycle according to the methods in table 3.

Table 3: Methods for calculating the compartments of the N-cycle in INTSCOPT

N-Flow	Source	Influencing factors in INTSCOPT	Methodology
Into the system			
Fertiliser		Type of fertiliser/nutrient content	
Concentrate		Type of concentrate	Arrigo et al. 1994
Biological N Fixation		Land-use intensity	Schmid et al. 2000
Out of the system			
N Meat		Amount of meat produced	Arrigo et al. 1994
NH_3	Manure	Housing system, manure storage and spread, pasture management, manure storage	Reidy and Menzi 2005
	Land use	Type of fertiliser or manure, manure management	
NO_3	Land use		IPCC 1997
N_2O	Manure	Housing system, type of manure, manure storage	Schmid et al. 2000, Schmid et al. 2001
	Land use	Crop residues, NH_3 loss	
NO_x	Manure and fertiliser	Amount of N in manure and fertiliser	Schmid et al. 2000

3.3 Calculation of GHG emissions

INTSCOPT can assess all GHG emissions on a farm, including indirect N_2O emissions associated with N losses and selected pre-chain emissions from imported products. GHG emitted after the products have left the farm are not considered.

On-farm emissions

On-farm emissions are calculated applying the IPCC (1997 and 2000) methodology. Because emission levels are climate- and management-specific, these methodologies have been adapted to Swiss conditions. The various on-farm emissions, their sources and the underlying methods are described in table 4.

Table 4: Methods applied in INTSCOPT to calculate on-farm GHG emissions

Gas	Source	Influencing factor	Methodology
CH_4	Enteric fermentation	Animal-specific methane rate, feed mix, lipid supplementation	IPCC 1997, Minonzio et al. 1998
	Manure	Amount of different manures, feed mix, housing system, pasture management	
N_2O	Manure	Amount of different types of manure, manure management	IPCC 1997, Schmid et al. 2000, Schmid et al. 2001
	Land-use	Fertiliser, N-fixation, harvest residues,	
	Indirect	Loss of N in different compounds	Schmid et al. 2000, Table 3
CO_2	Tractor/ Machinery	Land-use intensity	IPCC 1997, Gazzarin and Albisser 2010

Pre-chain emissions

Pre-chain emissions are emissions associated with the importation of production factors into the farm system. Included are the production and the transport of concentrate feedstuff (Van der Werf et al. 2005; Bernesson 2004) and artificial fertiliser (Williams et al. 2006). However, pre-chain emissions for the construction of buildings and machinery are not considered.

3.4 Land-use

All land-use activities in INTSCOPT are grassland-based. They differ only in the intensity of the pasture and the presence or absence of trees. According to AGRIDEA (2010), three different grassland intensities are considered in INTSCOPT: intensive, mid-intensive, and low-intensive. For any grassland type, the model can establish an agroforestry system. Because of the increasing competition for sunlight and other resources, the yield of grassland under trees is reduced by 40% (Kern 2006).

4 Results and discussion

Model results show that highest total gross margin will be achieved with the production system based on the Charolais or Angus breed (table 5). Because of the low amount of meat produced in the Galloway system, its total gross margin is 14% lower than in the other systems.

Depending on the production system, GHG emissions per kilogram of meat (GHG_{prod}) range between 18 kg CO_2-eq./kg CW for the Charolais system and 21.9 kg CO_2-eq./kg CW for the Galloway system. These values are comparable to those reported by other studies, such as Casey and Holden (2006), which reports emissions of 20 kg CO_2-eq./kg CW of Irish suckler beef. However, the values reported in INTSCOPT are lower than emissions shown by Veysset et al. (2010) for Charolais based suckler cow systems in France (26.6 – 30.5 kg CO_2-eq./kg CW).

As indicated by Veysset et al. (2010), the production system has a significant impact on GHG emissions. This is also true for our analysis, as the amount of GHG emitted is correlated with the number of LU. Therefore, the Galloway system (175 kg CW/LU – 21.9 kg CO_2-eq./kg CW) emits a higher amount of GHGs per product unit than both the Charolais (280 kg CW/LU – 18 kg CO_2-eq./kg CW) and the Angus (259 kg CW/LU – 19.4 kg CO_2-eq./kg CW) systems.

Table 5: Economic optimum for different production systems

		Angus	Charolais	Galloway
GHG_{tot}	t CO_2-eq.	175	176	134
GHG_{prod}	kg CO_2-eq./kg CW	19.4	18	21.9
Meat production	kg CW	9050	9800	6113
Gross margin	kCHF	138	138	119

4.1 Mitigation options within the different production systems

In further optimisation runs, the farm model was forced to reduce GHG emissions stepwise by 2.5 t CO_2-eq. while keeping the animal husbandry system and the amount of meat production constant. Results for the Charolais and Galloway systems are indicated in figure 1, where marginal abatement costs are shown for each mitigation option and the combination of all mitigation options. Marginal costs of the different options in the Angus system are very similar to the Charolais system and therefore are not shown.

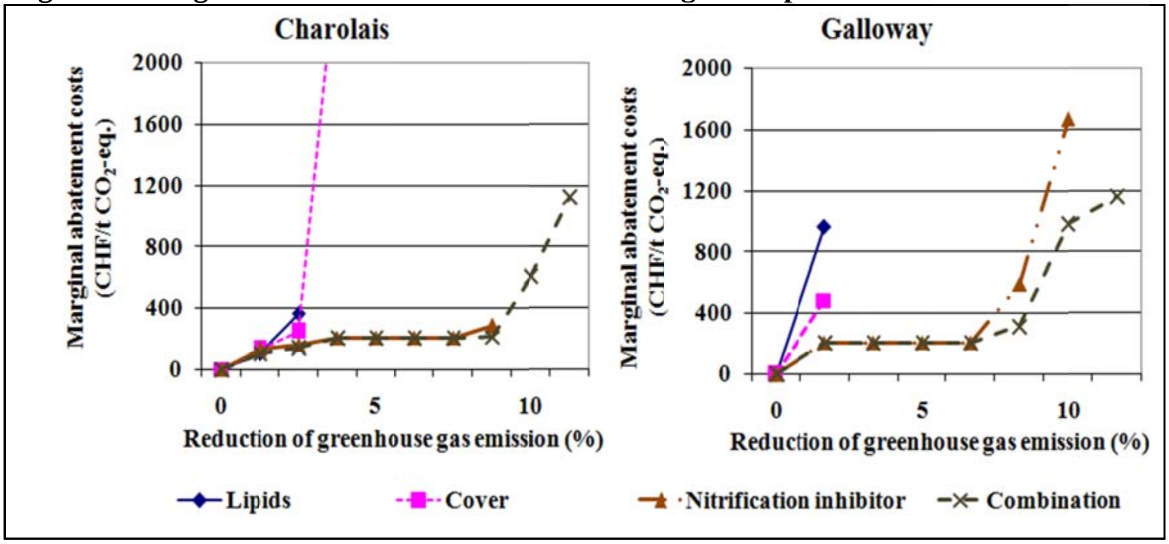
Both covering the slurry tank and adding lipids to the feed mix have a rather low impact. The addition of fat to the cow's feed increases its net energy concentration, which might cause fattening problems. Due to this limitation and the cow's large contribution to total CH_4 emissions, the impact of lipids is limited. Because Charolais cows are rather heavy, they require a higher energy concentration in the feed; thus, the addition of fat has a higher potential for GHG reduction in the Charolais system than in the Galloway system. These results are consistent with a study by del Prado et al. (2010), which reported for dairy cows (with a larger energy intake than suckler cows) a reduction potential of about 10% per kilogram of milk when lipids are added to the feed.

The curve progression for the marginal abatement costs of covering the slurry looks very similar to that of adding lipids to the diet – the potential is limited. The high abatement cost of the cover results from the small contribution of the slurry tank to total GHG emissions. Even a large reduction of this portion of the emissions reduces total emissions only marginally, but costs for the construction of the cover are high.

Nitrous oxide emissions constitute about 50% of total emissions and our analysis indicates that nitrification inhibitors (NI) can reduce these emissions significantly. In comparison to the mitigation methods of adding lipids and covering the slurry tank, the marginal costs of applying NIs are relatively low. As evident in figure 1, until a reduction of 7% to 9% of total GHG emissions, marginal costs are below 250 CHF/t CO_2-eq. The NI method of mitigation produces associated costs that are favourable in comparison to the lipid and cover options also because it reduces the need for expensive artificial N fertiliser. With the application of a combination of all mitigation options, GHG emissions can be reduced by 12%. These results are similar to those of other studies. For example, Hartmann et al. (2009) report a mitigation potential of 5% and 2% with the addition of lipids and the slurry tank cover, respectively. Neufeldt and Schäfer (2007) showed that mitigation options involving the reduction of either the intensity of crop production, additional feed, or the number of livestock decreased total emissions by 8% – 12% .

Our analysis shows that the sequestration of carbon in agroforestry systems potentially can reduce total GHG emissions. In the Galloway system, the establishment of an agroforestry system can reduce net GHG emissions to zero. In the case of the Charolais and the Angus systems, carbon sequestration in an agroforestry system has the potential to reduce emissions by 66% and 60%, respectively. In combination with other mitigation options in these systems, respective reductions of 77% and 70% can be reached. Agroforestry has a greater potential for the Galloway system because in this system, land is managed at a low-intensive initial state. Hence, land is available to compensate for the smaller forage production caused by the enlarged agroforestry area. In the other systems, land use in the initial state of the system is relatively intensive; thus, the potential to intensify land use is lower. Compared to the other mitigation options, agroforestry is relatively inexpensive. In all systems, a 50% reduction of GHG emissions is possible at marginal abatement costs of less than 57 CHF/t CO_2-eq.

Figure 1: Marginal abatement costs of different mitigation options



In table 6, average reduction costs per kilogram of meat are shown for different reduction levels. In all systems, the on-farm compensation is cheaper than the other mitigation options considered. Agroforestry is least expensive in the Galloway system. As described above, in the Galloway system, enough land is available for intensive use; hence, other adaptation methods (e.g., adaptations in the feed mix) are not necessary.

With the application of all mitigation options (including agroforestry) within the production system, GHG emissions can be reduced to 5 kg CO_2-eq./kg CW or lower. Because agroforestry has the lowest marginal abatement costs compared to the other options, it is applied predominantly, while the other options are applied secondarily. As mentioned above, in the Galloway system, agroforestry potentially can reduce emissions to zero. Thus, a reduction of the emissions to 5 kg CO2-eq./kg CW costs only 0.11 CHF/kg CW. In contrast, in the Angus and the Charolais system, agroforestry alone can reduce emissions only to a level of 7.76 kg CO_2-eq./kg CW and 6.12 kg CO_2-eq./kg CW, respectively. Such reductions cost 0.37 CHF/kg CW for the Angus system and 0.32 CHF/kg CW for the Charolais system. To reduce emissions further to 5 kg CO_2-eq./kg CW, other options to mitigate GHG must be applied, e.g., supplementing lipids in the diet and utilising NIs. These additional mitigation strategies significantly increase reduction costs to 0.5 CHF/kg CW and 1.14 CHF/kg CW for the Charolais and Angus systems, respectively.

For the purpose of comparing the results of this study to others, we calculate the average reduction costs per ton of CO_2-eq. The average cost of reducing emissions to a level of 5 kg CO_2/kg CW range between 12 CHF/t CO_2-eq. in the Galloway system and 69 CHF/t CO_2-eq. in the Charolais system. These calculated costs are similar to the costs of emission reduction in no-till systems, which were reported as 26 CHF/t CO_2-eq. by Freibauer et al. (2004). Because reduction costs depend on economic and ecological considerations, they must be calculated independently for every country and farming system.

Table 6: Average costs per kilogram of meat (CHF/kg CW) for the reduction of GHG emissions per kilogram of meat

Emissions per kilogram of meat [kg CO_2-eq./ kg CW]	Angus		Charolais		Galloway	
	Mitigate*	Agroforest**	Mitigate*	Agroforest**	Mitigate*	Agroforest**
20	na	na	na	na	0.44	0
17.5	0.53	0	0.08	0	na	0
15	na	0.01	na	0	na	0.01
10	na	0.24	na	0.11	na	0.02
7.5	na	0.38	na	0.24	na	0.03
5	na	1.14	na	0.50	na	0.11
2.5	na	na	na	na	na	0.25
0	na	na	na	na	na	0.37

* Scenario *Mitigate* includes a combination of all mitigation options without agroforestry systems

** Scenario *Agroforest* includes a combination of all mitigation options including carbon sequestration by agroforestry systems

na: not available, i.e., no convergence to a solution

5 Conclusion

The choice of the production system for suckler farming in Switzerland (Angus, Charolais or Galloway) impacts both GHG emissions per kilogram of meat and total gross margin. In addition, the production system influences the cost of applying different mitigation options. Depending on one's goal, a different combination of production system and mitigation options might be useful. Hence, when optimising a farm, it is necessary to assess the whole farm.

In our assessment of the economic suitability of mitigation strategies to reduce GHG emissions for common suckler farming systems in Switzerland, only the agroforestry system, with its carbon sequestration potential, leads to significant GHG emission reductions at reasonable costs. Depending on the land use in the initial state and the growth rate of the trees, it is possible even to reduce GHG emissions to zero.

Other mitigation options in our study (with the exception of nitrification inhibitors) do not have the potential to reduce GHG emissions significantly. They neither have the potential to reduce a large share of GHG emissions, nor are they inexpensive enough to make implementation possible.

Consumers are becoming more and more sensitive to climate change and are modifying their behaviour accordingly when buying meat in the grocery store (Vanclay et al. 2010). For farms to benefit from this consumer trend, the emissions of the whole value chain must be assessed and optimised. For the agricultural link of the value chain, agroforestry is a way to contribute to GHG mitigation and adapt to this future consumer trend.

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