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IMPACT OF ORGANIC FARMING ON GLOBAL WARMING – RECENT SCIENTIFIC KNOWLEDGE

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ABSTRACT

It is not clear if conversion to organic farming is an option for reducing the impact of farming on global warming. For the purpose of assessment, available literature was evaluated. Different results of the impact of organic farming concerning greenhouse effect were found among the various sources (Bockisch et al. 2000, Fritsche & Eberle 2007, Flessa et al. 2002, Nemecek et al. 2005, Hülsbergen & Küstermann 2007, Haas et al. 2001, Smukalski et al. 1992, Korbun et al. 2004, Taylor 2000, Williams et al. 2006, Köpke & Haas 1995). The different conclusions of the studies depend on the products observed, the systems observed (system borders) and the structure and intensity of the systems (low or high external input and output).

It can be concluded that organic farming is less relevant to the greenhouse effect than comparable conventional farming systems. The higher emission of greenhouse gases in conventional systems is caused by purchased feedstuff from overseas, mineral fertilizer and pesticides. The higher yields per ha and animal unit are usually not able to compensate these negative impacts. Nevertheless, there are options for both conventional and organic farming to improve towards more climate-friendly farming patterns. For example, IP (integrated production systems) are comparable with organic farming systems (Nemecek et al. 2005). Organic farming has to be developed as well to reduce climatic impacts through higher output per hectare or per animal and higher energy efficiency in the whole product chain. An important factor is the Corg level of the soils (Mäder et al. 2002, Capriel 2006, Hoyer et al. 2007, Penman et al. 2003, Köpke 2006). Renewable energy can help to reduce fossil energy in farming and processing (SRU 2007, Rahmann et al. 2008). Mechanisation does not conflict with the goal of being more climate-friendly (Nemecek et al. 2005).

Keywords: *Global warming, organic farming*

INTRODUCTION

The anthropogenically induced climate change has increased the world temperature in the last hundred years by between 0.6 and 0.7 °C. All food production contributes to greenhouse gas (GHG) emissions. In 2005, German agriculture had a share of 108 mio t $CO_{2\text{-eq}}$, respectively 6.3 % of all German GHG emissions (worldwide agriculture contributes 13 %) (UBA 2007, Rahmann et al. 2008). Agriculture plays a large role in the GHG emissions of methane (44 mio t of CH_4) and N_2O (41 mio t) (Tab. 1). Mineral fertilizer (N_2O) and ruminant digestion (CH_4) are the main source of agricultural emissions. GHG emissions of livestock production have enormous global relevance (Steinfeld et al., 2006). In Germany, 30 % of the GHG emissions from agriculture can be allocated to dairy cows (Osterburg et al.; 2009). Food production is a function of consumption. In recent years, food production and consumption contributed 16 % of the total emissions per capita (1.6 t $CO_{2\text{-eq}}$) (ÖKO 2007).

The challenge of food production is to reduce the greenhouse gas emissions per product and not production unit (minimize $CO_{2\text{-eq}}$ emission per kg milk and not per cow or kg wheat and not per hectare). With this parameter it is not clear yet if organic farming has less impact on climate change than conventional farming.

Tab. 1 German agriculture-related GHG emissions in 2005 (mio t $CO_{2\text{-eq}}$)

Emission source	CO_2	CH_4	N_2O	Total
Livestock digestion	-	18.3	-	18.3
Organic fertilizer (manure)	-	5.0	3.1	8.1
Emissions from soil utilisation	42.4	-0.6	42.4	8.2
Soil carbonizing	1.7	-	-	1.7
Fossil energy use	6.7	0.0	0.1	6.8
Mineral N-fertilizer production	5.2	0.3	8.6	14.1
Total agricultural emissions	56.0	23.0	54.2	133.2
Total German emissions	885.9	51.4	66.4	1003.7

Source: compiled from UBA 2007

A literature review has been carried out to identify the present state of knowledge and to define scientific challenges to reduce emissions and develop and adapt organic farming under climate change (Rahmann et al. 2008). The assessment and the development should not ignore the multi-functionality of agriculture (preservation of biodiversity and biotopes, landscape, food security and safety, tradition and culture, protection of soil, water and air, animal welfare).GHG impact of organic farming in Germany

Organic farming is considered a low input - low output system (organic standards of the EU are defined in the regulations 834/2007/EC and 889/2008/EC). Because mineral fertilizer and chemical pesticides are prohibited, and feed additives and concentrate feeds are limited (low/medium input- low/medium output farming), the efficiency/output per hectare resp. animal is less than in conventional farming (medium/high input – medium/high output farming). Less animal units can be kept per hectare due to limitations in dung units (170 kg manure-N per hectare and year; 889/2008/EC). In Germany, organic farms keep only 0.69 livestock units (500 kg live weight) per ha and conventional farms 0.89 (2005/06; BMELV 2007). Different GHG balances have to be expected compared to conventional systems. Recent system comparisons still rely on single farm comparisons (Thomassen et al. 2008), special regions (Haas et al. 2001) or give raw estimates on productivity and on management differences between the farming systems (Basset-Mens et al. 2009). It is still unclear if lower productivity of organic systems in general has adverse effects on the GHG balance of the products. A literature review has been carried out to identify the recent knowledge (Rahmann et al. 2008). Comparative studies on crop production (Tab. 2, Tab. 3), animal husbandry (Tab. 4, Tab. 5 and Tab. 6) at the farm gate and place of purchasing food products (consumer level; Tab. 7) have been found. Some studies are done in countries adjacent to Germany but with comparable ecological and socio-economic framework conditions (e.g., Scandinavia, Great Britain, Switzerland). Comparison studies on arable crop production show big differences between organic and conventional (Tab. 2) as well as between different crops (Tab. 3). The studies show that organic farming has a clear advantage in terms of low GHG emissions per hectare. This is not the case if the GHG per product unit (e.g. kg) is considered. There is a overlapping between organic and conventional production. The GHG emission per kg legume crops is comparable to conventional production. This is due to the fact that legume crops like peas and beans do not need much fertilizer (mineral fertilizer contributes greatly to GHG emissions) in conventional systems like in organic farming, but achieve better production yields with the use of pesticides (pesticides have a low contribution to GHG emission). Overall, organic farming has low GHG emissions but integrated production is not very far from this level.

Tab. 2Emission of organic (EU standards) and conventional crop production in Germany (Index 100; numbers below 100 = organic has an advantage)

		Organic (EU) vs. conventional [a]	Organic (EU) vs. Integrated production [b]
Fossil fuel			
per hectare	non-legume crops	27 - 47	44 - 82
	legumes	72 - 94	72 - 94
per product unit	non-legume crops	29 - 92	69 - 133
	legumes	53 - 63	53 - 63
CO_2			
per hectare	non-legume crops	47 - 67	68 - 100
	legumes	88 - 102	88 - 102
per product unit	non-legume crops	74 - 127	100 - 164
	legumes	54 - 63	54 - 63
CH_4			
per hectare	non-legume crops	9 - 25	24 - 61
	legumes	66 - 91	66 - 91
per product unit	non-legume crops	14 - 35	7 - 83
	legumes	95 - 126	95 - 126
N_2O			
per hectare	non-legume crops	1 - 4	1 - 12
	legumes	74 - 88	74 - 88
per product unit	non-legume crops	1 - 69	3 - 150
	legumes	45 - 60	45 - 60
[a] high input – high output; [b] medium input – medium/high output (IP; integrated production)			

Source: Bockisch et al. 2000

Tab. 3GHG impact of organic and integrated production for different arable crops per hectare (kg $CO_{2\text{-eq}}$ ha^{-1} a^{-1}) and product unit (g $CO_{2\text{-eq}}$ kg DM^{-1}) in Switzerland

		Integrated production (IPintensiv)	Organic production (Bio Suisse-Standard)
Winter wheat	**ha**	4,126	3,424
	kg	692	913
Winter barley	**ha**	3,941	3,137
	kg	605	804
Potatos	**ha**	5,428	3,852
	kg	653	764
Rape	**ha**	3,817	2,946
	kg	1,304	1,549
Cow beans (feed)	**ha**	3,217	3,929
	kg	978	1,335
Peas (feed)	**ha**	3,209	3,443
	kg	961	1,300

Source: Nemecek et al. 2005

The British DEFRA study (Tab. 4) was discussed controversially throughout Europe. The result of the discussion was that a "single element" approach cannot be the relevant level for farming system comparison studies. The whole farming system has to be considered in assessments. This was done in the model calculation for dairy cows by Dämmgen and Döhler (2009) (Tab. 5). Organic dairy farming had lower GHG emission than conventional systems. The weak points of such results are the missing detailed data set. Model results are as good (or bad) as the data behind them. This is obvious, if the results of several studies are compared (Tab. 6). It shows that the range of the results is so wide, that reliability is not given.

Tab. 4 Energy utilization and GHG impact of livestock keeping in UK (per t of product)

		Energy utilization [MJ t^{-1}]	GHG emission [$CO_{2\text{-eq}}$ t^{-1}]
Milk	**Conventional**	25,200	10,600
	Organic	15,600	12,300
Beef	**Conventional**	27,800	15,800
	Organic	18,100	18,200
Pork	**Conventional**	16,700	6,360
	Organic	14,500	5,640
Lamb	**Conventional**	23,100	17,500
	Organic	18,400	10,100
Poultry meat	**Conventional**	12,000	4,570
	Organic	15,800	6,680
Eggs	**Conventional (cage keeping)**	13,600	5,250
	Organic	16,100	7,000

Source: Williams et al. (2006)

Tab. 5 Emissions from dairy farming depending on the farming method (kg $CO_{2\text{-eq}}$ cow^{-1} a^{-1})

Greenhouse gas	conv., stable silage, slurry	conv., pasture, silage, slurry	conv., pasture, straw bed	organic, pasture, straw bed
CH_4 (Digestion)	91.8	92.9	92.9	92.9
CH_4 (Stored)	18.2	15.1	4.4	4.4
CH_4 (Diesel)	0.0	0.0	0.0	0.0
Sum CH_4	110.0	108.0	97.3	97.3
N_2O (Stored)	0.94	0.77	0.83	0.83
N_2O (Fertilizer)	2.80	3.24	3.30	1.60
N_2O (Indirect)	2.88	3.86	3.88	4.19
N_2O (Fertilizer-manufacture)	0.13	0.12	0.12	0.00
N_2O (Diesel)	0.09	0.08	0.08	0.14
Sum N_2O	6.83	8.07	8.21	6.75
CO_2 (Fertilizer)	69	72	72	0
CO_2 (Fertilizer manufacture)	101	92	92	0
CO_2 (Diesel)	231	210	210	353
Sum CO_2	401	375	375	353
Sum greenhouse gases [tons $CO_{2\text{-eq}}$ cow^{-1} a^{-1}]	5.36	5.62	5.42	4.94

Source: Dämmgen and Döhler 2009

Tab. 6:GHG emission of milk production – results of several studies

Source	Unit	Conventional	Organic	Relation
Energy				
Abel, cit. in Taylor 2000	MJ t^{-1} milk	2,180	740	2.9 : 1
Scheitz, cit. in Taylor 2000	MJ t^{-1} milk	3,360	1,640	2.0 : 1
Bockisch et al. 2000	MJ/ animal	18,675	8,113	2.3 : 1
	MJ t^{-1} milk	2,721	1,474	1.8 : 1
Haas et al. 20001	MJ t^{-1} milk	2,700	1,200	1.9 : 1
Grönroos et al. 2006	MJ t^{-1} milk	6,390	4,410	1.4 : 1
Meul et al. 2007	MJ t^{-1} milk	4,385 2,576	-	
CO_2				
Bockisch et al. 2000	kg CO_2 cow^{-1}	1,395	764	1.8 : 1
	kg CO_{2-eq} t^{-1} milk	203	140	1.4 : 1
Haas et al. 2001	kg CO_{2-eq} t^{-1} mik	177	88	2.0 : 1
Weiske et al. 2006	kg CO_{2-eq} t^{-1} milk	129	83	1.6 : 1
CH_4				
Bockisch et al. 2000	kg CO_2 cow^{-1}	no data	13.96	
	kg CO_{2-eq} t^{-1} milk	no data	2.52	
Haas et al. 2001	kg CO_{2-eq} t^{-1} milk	706	846	1 : 1.20
Weiske et al. 2006	kg CO_{2-eq} t^{-1} milk	516	635	1 : 1.23
Sneath et al. 2006	kg CO_{2-eq} t^{-1} milk	9.6	8.1	1.18 : 1
Hensen et al. 2006	kg CO_{2-eq} cow^{-1} d^{-1}	16.1 (slurry) 32.2 (straw)		
N_2O				
Bockisch et al. 2000	kg CO_2 cow^{-1}	no data	10.23	
	kg CO_{2-eq} t^{-1} milk	no data	2.17	
Haas et al. 2001	kg CO_{2-eq} t^{-1} milk	417	365	1.14 : 1
Weiske et al. 2006	kg CO_{2-eq} t^{-1} milk	645	676	1 : 1.05
Abel zit. in Taylor 2000	kg CO_{2-eq} t^{-1} milk	611	538	1.13 : 1
Scheitz zit in Taylor 2000	kg CO_{2-eq} t^{-1} milk	778	691	1.12 : 1
Bockisch et al. 2000	kg CO_{2-eq} t^{-1} milk	no data	145	
	kg CO_{2-eq} t^{-1} milk	no data	27	
Haas et al. 2001	kg CO_{2-eq} t^{-1} milk	1,300	1,299	1 : 1
Casey & Holden 2005	kg CO_{2-eq} t^{-1} feed	1,156		
	kg CO_{2-eq} t^{-1} ECM	1,500		
	kg CO_{2-eq} t^{-1} ECM	195		
Weiske et al. 2006	kg CO_{2-eq} t^{-1} milk	1,290	1,394	1 : 1.08

Source: compiled by Rahmann et al. 2008

The impact of farming should not only consider one factor (e.g., GHG emission). For example, biodiversity, animal welfare, landscape and economics are further factors. For all these multi-functional factors, organic farming has big advantages compared to medium/high input – medium/high output conventional farming.

High market prices for organic products are an important factor. For example, the yield per hectare for winter wheat production is 42 % lower in organic farming than in comparable conventional farming systems (3.96 t ha^{-1} vs. 6.87 t ha^{-1}) (harvest year 2005). But organic winter wheat had a market price of 196.60 € t^{-1}, conventional only 95.10 € t^{-1}. Organic milk is usually 0.07 to 0.14 € kg^{-1} higher than conventional milk (2005/06: 0.36 vs. 0.24 € kg^{-1} ECM). Price differences are the reason that organic farms earn more money than comparable conventional farms (2005/06: 321 € vs. 304 € ha^{-1} a^{-1}, 21,446 € vs. 20,180 € $labourer^{-1}$ a^{-1}). Overall, organic farms had, with 321 € ha^{-1} in 2006, higher profits than comparable conventional farms (304 € ha^{-1}). The return for labor was, with 21.446 € LU^{-1} in organic farming, higher than in conventional farming (20.180 € LU^{-1}) (data from test farm survey results oft he German ministry of agriculture; BMELV 2007).

The previous tables show farm gate results. Transport, processing and trade of the food products are not considered at this level. Fritsche & Eberle (2007) calculated the GHG emission of food at the « place of purchase ». They used the GEMIS model (Globales emission model for integrated systems) (Tab. 7).

Tab. 7GHG impact of food products at retailer level (g CO_{2-eq} kg^{-1})

	Conventional	Organic
Vegetable (fresh)	150	127
Vegetable (tinned)	509	477
Vegetable (deep frozen)	412	375
Potatoes (fresh)	197	136
Fried Potatoes (deep frozen)	5,714	5,555
Tomatoes (fresh)	327	226
Bread	655	547
Cookies	931	831
Poultry (fresh)	3,491	3,033
Poultry (deep frozen)	4,519	4,061
Beef (fresh)	13,303	11,371

	Conventional	Organic
Beef (deep frozen)	14,331	12,398
Pork (fresh)	3,247	3,038
Pork (deep frozen)	4,275	4,064
Butter	23,781	22,085
Yoghurt	1,228	1,156
Cheese	8,502	7,943
Milk	938	881
Curd (fresh)	1,925	1,801
Cream	7,622	7,098
Eggs	1,928	1,539

Source: Fritsche & Eberle Conclusion

Organic farming has an advantage in less GHG emission per hectare. The prohibition of mineral fertilizer, chemical pesticides and restrictions in concentrate feed led to lower yields per hectare. Therefore the advantage of organic farming in lower GHG emission is not clear yet. Without doubt, the primary energy utilization is a clear difference between organic and conventional farming. Obviously there is an overlapping of the impact of organic and conventional farming systems in GHG emission. Best practice is necessary to avoid too high emissions. Organic farming cannot claim much less GHG emission and must develop organic farming systems to identify main sources of emissions and to reduce them. Science can help. Action fields are:

- optimised nutrient management
- improved seeds and breeds (higher yields, more resistance crops, water and nutrient efficient)
- better machine utilization
- reduced cropping measures (no/less tillage systems)
- improved dung storage and application techniques
- improved plant protection
- optimized feedstuff rations for animals (especially ruminants)
- renewable energy technology
- improved processing and trading
- changes in consumption habits

Research project „Climate effects and sustainability of organic and conventional farming systems - examination in a network of pilot farms" Because it is still unclear if lower productivity of organic systems in general has adverse effects on the GHG balance of the products, a Germany-wide study started in 2009. Representative assessments on 40 organic and 40 adjacent and comparable conventional farms in four German regions (North: coastal region, maritime climate; East: continental climate, large farm structure; South: Alpine grassland farms and productive areas in the pre-alpine region; West: low mountain areas, Lower Rhine Basin, continental climate) will be assessed in 2009 – 2012 for GHG emissions. The study considers soil, plant production, animal husbandry and manure handling. Half of the pilot farms (20 organic and 20 conventional farms) are dairy systems. The data are put into the models of REPRO (Hülsbergen et al. 2000) and GAS EM (Dämmgen et al. 2002).

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