Jesko Hirschfeld, Julika Weiß, Marcin Preidl, Thomas Korbun

The Impact of German Agriculture on the Climate

Main Results and Conclusions

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INSTITUTE FOR
ECOLOGICAL ECONOMY RESEARCH

Jesko Hirschfeld, Julika Weiß, Marcin Preidl, Thomas Korbun

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Commissioned by foodwatch e.V.

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Deutsche Wildtier Stiftung
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Abstract

The agriculture in Germany accounts for more than 13 percent of the German total greenhouse gas emissions. In climate protection strategies (i.e. the energy and climate programme of the federal government), the contribution of the agriculture is usually still neglected. Therefore, the purpose of this study is the evaluation of climate impacts of the agricultural production in Germany, with respect to the most important agricultural products – wheat, pork, beef and milk. The research focuses on, to what extent conventional and organic farming are different in their climate impacts and which advantages and disadvantages can be found in different systems. The performances of the climate assessment show that organic farming normally is more climate friendly than conventional agriculture. That primarily results from large amounts of mineral fertilizer used in the conventional agriculture which causes high greenhouse gas emissions during production and application. On the other hand, the demand for space throughout ecological production processes is higher than in conventional systems. Furthermore, a significant potential for climate protection can be seen in the water logging of drained moorland whose current agricultural utilization leads to extensive greenhouse gas emissions. Altogether, the agriculture could contribute to the attainment of Germany's climate goals. This could be achieved through changes in production methods as well as abandoning or extensification of the used moorland areas. For this purpose, the study identifies central starting points as well as discusses potential synergy effects and conflicts with environmental and animal protection goals.

Although the study focusses on the German agricultural sector, most of its conclusions can be transferred also to other countries where agriculture produces at similar levels of intensity. The central recommendations, namely conversion from conventional high intensity of fertilizer use to organic farming or other practices with lower intensities, the re-wetting of drained moorland, hold to a similar degree for agriculture worldwide. And another central conculsion is valid internationally as well: The conversion to a more climate friendly agriculture will not be possible without changing consumption patterns to reduce the demand for meat and milk products in favour of vegetarian products. This is mainly a challenge in industrialized countries with highly climate-unfriendly consumption patterns.

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1 Aim of the Study

In the debate about strategies for combating climate change, political and public attention has so far focussed mainly on the energy sector, industry, transport and private households. The role of agriculture is frequently disregarded, although it is responsible for over 13% of greenhouse gases emitted in Germany, namely 133 million tonnes.[1] Apart from financial support for energy crop cultivation, agricultural policy at German and European level has so far ignored the effects of agriculture on the climate. The Federal Government's energy and climate change programme also disregards the greenhouse gas emissions from agriculture.[2]

What has been lacking is a systematic overview which clearly sets out what agricultural products are currently being manufactured with what impact on the climate whilst also showing where measures to combat climate change can most effectively be taken in the agricultural sector. Nor has there been any systematic comparison of the effects of conventional and organic farming on the climate. As the Federal Government wrote in its response to a minor interpellation from the parliamentary group Alliance 90/The Greens on the topic of agriculture and climate protection in May 2007: "To the Federal Government's knowledge, no thorough, generally recognised and comprehensive comparison has yet been made of the difference in greenhouse emissions between conventional and organic farming" (DEUTSCHER BUNDESTAG 2007, p. 1).

The aim of this study is therefore to estimate the impact on the climate of agricultural production in Germany with reference to the major agricultural products. Special attention will be devoted to examining the extent to which conventional and organic farming differ in their effects on the climate as well as the advantages and disadvantages of individual methods. The potential for mitigating climate change in the agricultural sector will be explored on the basis of this analysis.

In the production of plant and animal commodities, agriculture emits large quantities of methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). This occurs at various stages in the production process:

– Mainly fossil fuels are consumed in land tilling operations. Effects on the climate vary according to the frequency of vehicle passages and the intensity of the tilling.

– Greenhouse gas emissions from the manufacture of fertilisers and pesticides are to be attributed to the agricultural production sectors which employ these intermediates in the growing of foodstuff and animal feed.

– In livestock farming, digestion processes produce methane and nitrous oxide inter alia which are released into the atmosphere to differing degrees depending on how the animals are kept, the construction of animal pens and the methods for storing and spreading manure. [3]

1 Data for the year 2006, DEUTSCHER BUNDESTAG 2007, p. 2. This data also includes the intermediates which agriculture receives from other sectors (e.g. energy expended in manufacturing fertiliser) as well as emissions due to the release of greenhouse gases from the agricultural use of moorland. The figure of 133 million tonnes of carbon dioxide equivalent (Mt CO_2 eq.) does not include greenhouse gas emissions caused by the cultivation of animal feed imported from abroad.

2 Cf. BUNDESREGIERUNG (2007): Cornerstones of an integrated energy and climate programme.

3 Liquid and solid manure, slurry and silage juices.

– The effects on the climate of growing animal feed are attributable to animal production. In addition to the effects of domestic production, account must also be taken of the impact on the climate caused elsewhere by the production of imported feedstuffs and by their transport to Germany (Cf. DEUTSCHER BUNDESTAG 2006).
– Depending on how the humus is managed and the water balance is controlled, considerable quantities of CO2 can be released due to decomposition processes in the soil – especially as a result of the drainage of moors and wetlands (DEGRYZE et al. 2004, REES et al 2004). On the other hand, by rewetting previously drained moorland, carbon can be stored long-term in the ground and thus extracted from the atmosphere. (SCHÄFER et al 2005). [4]

In livestock farming, the extent of climate-relevant emissions depends to a considerable degree on the production process used to generate a particular product. Above all, the composition of feed rations, the type of livestock housing and mucking out methods as well as storage areas and the spreading techniques for manure are decisive factors in the level of impact on the climate. One kilo of meat and one kilo of milk can be produced at very different "costs to the climate".

In the crop-growing sector it is primarily the use of fertilisers and pesticides as well as the drainage of wetlands which determine the extent of the "climate costs". Due to greater use of fertilisers, numerous conventional production processes result in higher greenhouse gas emissions than those employed in organic farming. However, such comparisons must take into account that crop, fattening and milk yields are typically lower in organic than in conventional farming. As a rule, organic processes thus require more area per product unit than the corresponding conventional processes. Per litre of milk and kilo of wheat, the differences in the effects of conventional and organic faming on the climate are often less marked than if calculated per dairy cow or per hectare of area under cultivation. The higher productivity of conventional farming thus offsets some of its detrimental impact on the climate. With regard to individual processes, however, organic farming has a less favourable carbon footprint in some cases than conventional farming.

Both conventional and organic farms have considerable potentials for mitigating climate change since operating programmes have mostly been developed without regard for their impact on the climate but primarily with business concerns in mind.

Apart from financial support for energy crop cultivation, there are currently no targeted agricultural policy measures aimed at improving the carbon footprint of German and European agriculture (OSTERBURG et al. 2008, p. XI). Some agricultural policy measures can have positive side-effects for climate protection – such as the Fertiliser Ordinance, by reducing the quantities of fertiliser spread on land (and thereby also nitrous oxide emissions)and cutting greenhouse gas emissions in the manufacture of mineral fertilisers. Agri-environmental programmes that promote the conversion of arable into grassland, extensive grassland use and the rewetting of wetlands can have a positive impact on the climate (POVELLATO 2006, p. 20ff.). However, a number of other policy measures continue to work in the opposite direction –export subsidies, milk quota regulations and the sugar regime *inter alia* support the maintenance of a resource-intensive agricultural sector and thus exacerbate the negative effects on the climate of conventional farming in particular (ZDANOWICZ et al. 2005, p. 40).

If agriculture is to make a larger contribution to combating climate change, climate-friendly production methods will have to be employed to an increasing extent. It is first necessary to gather, collate

4 Against this background, the German Expert Council on Environmental Affairs calls in its latest report for the conservation and expansion of wetlands and moors (SRU 2008).

and compare data on the effects of current production techniques on the climate. Strategies for more climate-friendly farming methods and agricultural policy can then be derived from this. The purpose of this study is to make a contribution to this process.

Methodology

With regard to the impact of agriculture on the climate, there are a number of individual studies on specific production processes, farming sectors and climate pollutants as well as highly aggregated estimates of total emissions at national and global level. But there is no integrative view of the farming industry as a whole, including all possibilities for adaptation and options for action, from which to derive relevant recommendations for a climate-friendly reorganisation of the agricultural sector.

This study has therefore chosen the following approach in order to examine the impact of agriculture on the climate:

An evaluation of specialist literature provided an initial overview of the international status of research and surveys on the effects of agriculture on the climate. To prepare the subsequent steps, emission data relating to the entire sector are discussed (cf. chapter 2 of the Summary); national and international detailed studies referring to individual types of farm and individual production processes are presented in the unabridged version. The main factors influencing the extent of effects on the climate are identified, the main causes named and points of departure established for a systematic comparison of conventional and organic farming. The aim of this meta-analysis is also to compile structured data for the subsequent step of climate accounting. To this end, the results of the individual studies identified in the literature evaluation were assembled to form a differentiated overall picture of the impact of agriculture on the climate.

A comprehensive climate accounting process was then conducted. In a detailed analysis of four central agricultural products (wheat, pigmeat, milk, beef), the adjusting screws for influencing the effects of agricultural production processes on the climate were identified. Such a detailed analysis is necessary in order to adequately portray the differences between alternative production and livestock farming methods.

The climate accounting method developed for this study is described in greater detail in chapter 3 of the Summary. Research into national and international studies produced climate-relevant data on the individual stages of production (including intermediate products and operating resources) and transferred to a specially developed evaluation grid. The climate accounting is conducted on the basis of typical processes which are described in greater detail in the unabridged version of the study. To avoid portraying just the current status quo, the study examined not only average conventional and organic farms but also one farm from the leading 10% in each sector. The analysis can thus show where there is potential for mitigating greenhouse gas emissions if greater efforts are made in the agricultural sector to combat climate change in future. The unabridged version of the study contains a detailed explanation of how the effects of the individual production stages on the climate were derived as well as a discussion of the effects of different conventional and organic production processes on the climate.

The study looks separately at the emissions from land use which are of special relevance to German agriculture's carbon footprint. By releasing the carbon stored in the ground, agricultural production on drained moorland generates a level of greenhouse gases many times higher than the farming of "normal" (mineral) arable and grassland. To complement the climate accounting, the unabridged version of the study therefore sets out and discusses those additional greenhouse gas emissions resulting from varieties of land use that are particularly detrimental to the climate. These additions affect all production processes (e.g. beef and milk production as well as crop growing) that take place on moorland – both conventional and organic processes.

The results of the climate accounting are presented in chapter 4 of this Summary. Two hypothetical extreme scenarios are formulated on the basis of these results to obtain a rough estimate of the overall potentials for reducing greenhouse gas emissions from German agriculture. As a rule, more climate-friendly production processes require considerably more land area than current average farming practice. This restriction is of crucial importance when discussing the feasibility of implementing the scenarios for protecting the climate formulated here.

In addition to its impact on the climate, agriculture causes a number of other environmental effects, including water pollution from nutrients and pesticides as well as the destruction of biotopes. Intensive farming affects biodiversity whilst some extensive forms of land use can promote biodiversity. Particularly in view of the area requirements of climate-friendly production methods, there may be a conflict between the use of land for agricultural purposes and the nature conservation interest in fallow land and wooded areas. Ethical aspects also have to be taken into account when assessing the advantages of different forms of livestock farming.

The aim of differentiated and comprehensive climate accounting within the framework of this study is to identify points of departure for a more climate-friendly reorientation of both individual farm management and agricultural policy. The study therefore concludes with recommendations for a more climate-friendly agricultural sector.

2 The impact of German agriculture on the climate

Over 13% of all greenhouse gas emissions in Germany are caused by agriculture; that was approx. 133 million tonnes of carbon dioxide equivalent (Mt CO_2 eq.) in 2006. The Federal Government published these figures in its reply to a minor interpellation by the parliamentary group Alliance 90/The Greens.[5] In addition to the direct emissions from agricultural production, this calculation also takes account of the intermediates used in the farming sector – e.g. the provision of mineral fertilisers by the chemical industry or the supply of power by the energy industry.[6] By comparison: in 2005, the iron and steel industry accounted for approx 43 Mt CO_2 eq., the fuel consumption of private households 113 Mt CO_2 eq., road transport 152 Mt CO_2 eq. and the public utilities 325 Mt CO_2 eq. (UMWELTBUNDESAMT 2007).[7]

However, this does not include the “exports” of greenhouse gases contained in animal feed imports resulting primarily from the cultivation of soya in Latin America and from the necessary transport to Germany. Around 4 million tonnes of soya meal, 0.4 million tonnes of vegetable oil and fat as well as approx. 1.2 million tonnes of cereals are imported as feedstuff.[8] Their production in Latin America, the USA, Asia and Africa is responsible for at least 3 Mt CO_2 eq. of greenhouse gas emissions. If one takes not only the emissions from the cultivation of these imported feedstuffs but also adds the negative impact on the climate from their transport to Germany, the greenhouse potential of animal feed imports is at least 6 Mt CO_2 eq. which would have to be combined with the emissions from the German agricultural sector, increasing these by approx. 5% to 139 Mt CO_2 eq. per year.

Previous studies and reports have frequently used different systematic methods to record the climate-relevant emissions from agriculture or the delineations between the respective accounting areas. Correspondingly there is also a difference in the quantity of greenhouse gas emissions attributed to agriculture:

In one calculation based on the methodology used by the Intergovernmental Panel on Climate Change (IPCC) [9], agriculture’s share of Germany’s greenhouse gas emissions is put at only 6.2% (UMWELTBUNDESAMT, 2007, p. 44), contrary to the Federal Government’s figure quoted above. However, this calculation only includes emissions from animal digestion, the management of manure and part of the emissions from agricultural land. (Source group 4 Agriculture based on IPCC method; UMWELTBUNDESAMT, 2007, p. 340). This disregards *inter alia* emissions from the manufacture of fertilisers and pesticides.

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5 DEUTSCHER BUNDESTAG 2006.

6 Figures for the year 2005, UMWELTBUNDESAMT, 2007, p. 162.

7 As stated in the National Inventory Report – without the intermediates of the other sectors. UMWELTBUNDESAMT, 2007, p. 87ff.

8 Figures for 2005/2006; BMELV (2007, p. 117

9 The IPCC (Intergovernmental Panel on Climate Change) with headquarters in Geneva was founded in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO). The IPCC’s task is to establish the current state of the global climate system and its impact on human social systems and to set out the possibilities of political counter-measures. The IPCC publishes climate reports and issues guidelines for the compilation of national emission inventories. The IPCC is also known as the World Climate Council.

WEGENER, J., LÜCKE, W., and HEINZEMANN, J. (2006) add to the IPCC source group 4 "agriculture" further greenhouse gas (GHG) emissions attributable to the agricultural sector (land use and changes in land use as well as energy emissions). On this extended basis, they put agriculture's share at 11.1% of Germany's total greenhouse gas emissions. Whilst the changes in methane (CH_4) and nitrous oxide (N_2O) emissions are only slight, the higher proportion of overall emissions is due primarily to the additional CO_2 emissions (WEGENER, J. et al., 2006, p.106). Furthermore, the authors draw attention to the fact that the result depends crucially on the system parameters chosen. In order to portray the full effects of agricultural production on the climate it would also be necessary to include the manufacture of input factors, e.g. the production of mineral fertilisers, fuels, pesticides, seed preparation etc (cf. WEGENER, J. et al., 2006, p.112). If all this is included, agriculture's share of GHG emissions rises to 13.3% of Germany's total greenhouse gas emissions, the figure quoted above (DEUTSCHER BUNDESTAG 2006). CO_2 emissions (42%) account for the biggest share of greenhouse gas emissions, closely followed by nitrous oxide emissions (41% of CO_2 equivalent) and methane (17 % of CO_2 equivalent).

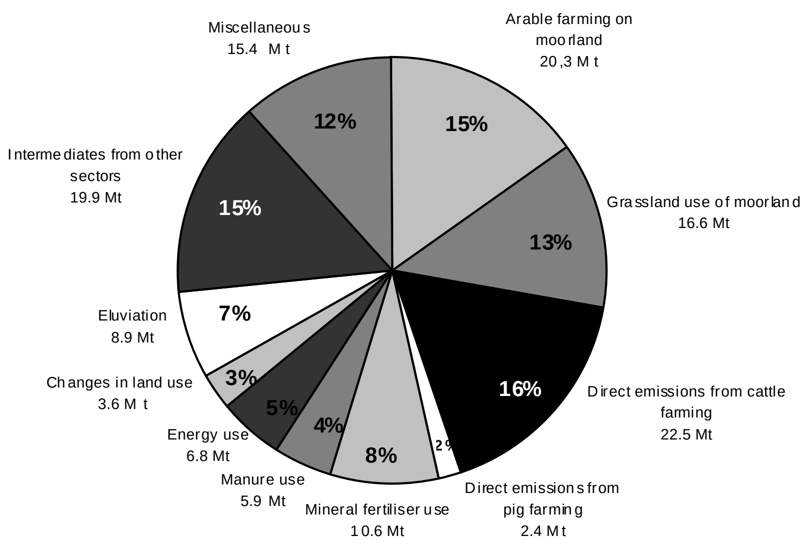

Fig. 2.1: Shares of different direct sources of greenhouse gas emissions in the agricultural sector in 2004 [in % and MMTCDE]

Source: abstracted from WEGENER, J. et al. (2006) pp.107-109 and DEUTSCHER BUNDESTAG (2006), diagram: IÖW

Figure 2.1 summarises the main sources of agricultural emissions. It clearly shows that the use of drained moorland for arable and grassland farming accounts for the largest contribution, namely 28% of greenhouse gases emitted by agriculture. The next largest sector is direct emissions from cattle farming, which is accountable for 16% of the greenhouse potential solely from digestion processes and the management of manure. It should be noted that these direct emissions make up only part of the overall emissions attributable to cattle farming. For example, cattle farming is almost fully responsible for the grassland use of moorland and also for parts of the other emission sectors which correspond approximately to the areas where animal feed is grown (cf. also Figures 2.2 and 2.3). By contrast, pig farming produces “only” 2% of agriculture’s overall emissions in the form of direct emissions – but as with cattle farming, these figures for direct emissions do not include those from the growing of animal feed and the use of other intermediates. Figure 2.3 gives an idea of the not insignificant area devoted to the production of pigmeat. Direct emissions from poultry farming account for about 0.5% and appear in Figure 2.4 under “miscellaneous”. However, full climate accounting of poultry farming would also have to take account of greenhouse gas emissions linked to the growing and supply of feedstuff. The spreading of mineral fertilisers (8%) and manure (4%) on the land represents further relevant percentages. Eluviations are responsible for 7% of climate-relevant emissions.

However, a comprehensive portrayal of the contribution of individual livestock farming methods to overall emissions must also include *inter alia* emissions from the cultivation of animal feed crops. 10.6 million hectares, approx. 62% of farmland in Germany (BMELV 2007, p. 120), are used to grow feedstuff for animal production.[10] In addition, a further 2.6 million hectares (approx. 25% of the German area under feed crop; source: DEUTSCHER BUNDESTAG, 2006, p.11) are used abroad for the cultivation of imported feedstuff which are not reflected in the diagrams. Overall, livestock farming accounts for around 95 Mt CO_2 eq. or 71% of the effects of German agriculture on the climate, with cattle farming responsible for well over half.

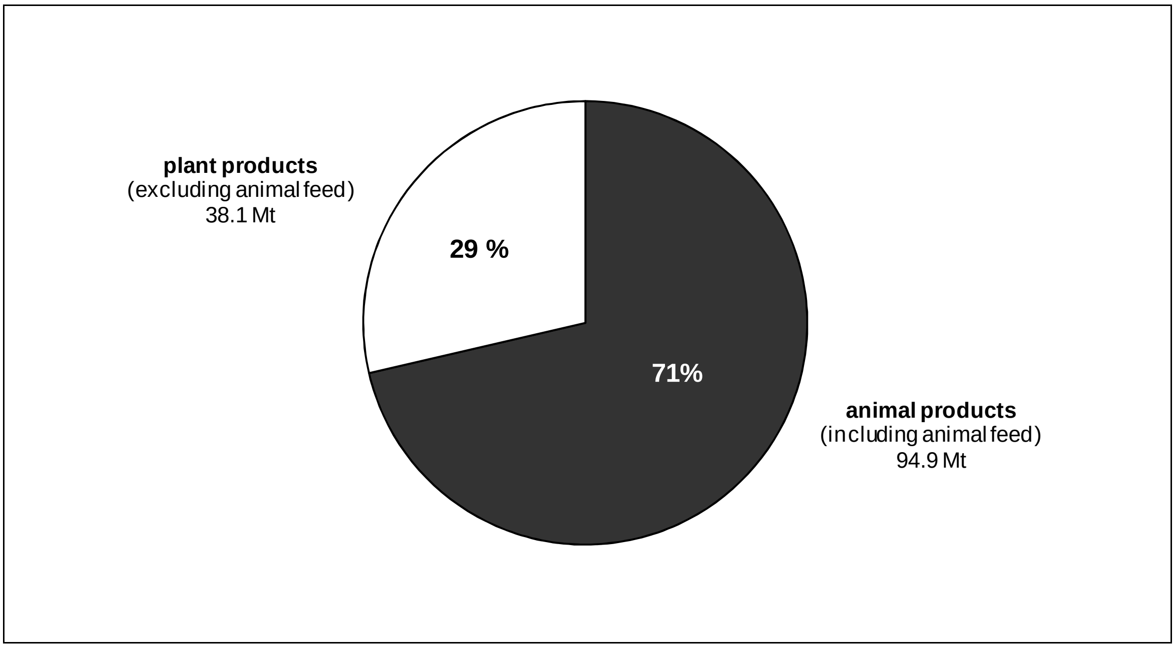

Fig. 2.2: Shares in the greenhouse gas emissions of German agriculture in 2006 [in % and Mt CO_2 eq.]
Source: own calculation based on WEGENER, J. et al. (2006) and DEUTSCHER BUNDESTAG (2006), diagram: IÖW

10 Including grassland.

The areas of land used for the farming of cattle, pigs, poultry, horses and sheep as well as for crop growing not devoted to the production of animal feed are illustrated in Figure 2.3.

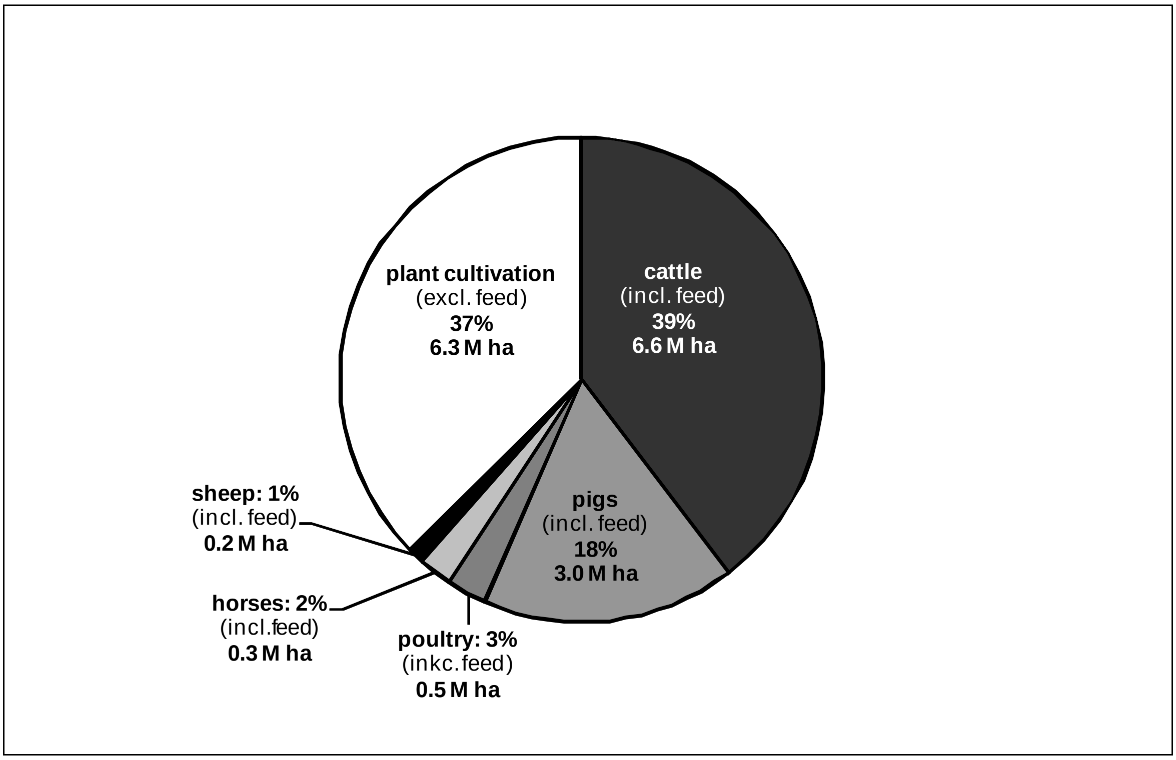

Fig. 2.3: Areas devoted to livestock farming and crop cultivation as a proportion of farmland in Germany in 2006 [in % and M ha]
Source: Own calculation based on BMELV (2007), diagram: IÖW

Almost 40% of Germany's agricultural land is used for cattle farming (milk and beef production), 18% for pig farming. By contrast, crop cultivation for the production of foodstuffs (without animal feed) and energy crops accounts for a good third of agricultural land. Poultry, horse and sheep farming together make up 6%.

3 Climate accounting method

Accounting for the impact on the climate of various agricultural production processes is based on the methodology of ecological accounting, a standardised method for compiling and evaluating the environmental impact of a product. All the environmental effects of the production process and the preceding stages of production (e.g. energy generation, production of auxiliary and operating materials) are included. Ecological accounting is particularly suited to a comparative examination of the environmental impact of different products which fulfil the same purpose or the same function (comparative life-cycle assessment). More recent approaches to the assessment of the impact of products on the climate, such as the carbon footprint, are also based on the methodology of ecological accounting (cf. EPLCA 2007). According to EN ISO 14040, ecological accounting consists of setting the goal and scope of the study, the life-cycle inventory analysis (LCA), the impact assessment and evaluation.

The aim of climate accounting is to compare the effects on the climate of different agricultural production processes. Of the numerous relevant impact categories, only the greenhouse effect is taken into account. The anthropogenic emission of greenhouse gases exacerbates the natural greenhouse effect, which leads to global warming. In the context of this study, the most important greenhouse gases in the agricultural sector, namely carbon dioxide, methane and nitrous oxide, were examined.[11]

The accounting areas examined are set out in detail for the individual processes in the unabridged version of the study. This climate accounting of the individual processes does not include the impact of changes in land use (e.g. agricultural use of moorland or the clearance of rainforest areas) or the potential sink effect of humus build-up. However, these aspects are generally addressed in the study.

The life-cycle inventory analysis (LCA) involves the collection of statistics relevant to the effect of products on the climate as well as the compilation and, where necessary, calculation of the data. In order to establish the effects of production processes on the climate, the climate-relevant data on the individual stages of production (including intermediate products and operating resources) are researched from current studies and literature. GEMIS (Global Emission Model for Integrated Systems), version 4.4, is used to calculate the climate impact (cf. FRITSCHE and SCHMIDT 2007). The methodology for accounting the climate impact, especially from pigmeat production, is also based partly on the ecological account in the study by KORBUN et al. (2004).

A lot of production methods are multi-output processes and thus have other products beside the one in question, which are described as by-products. Within the framework of a life-cycle assessment, the material and energy flows of the production process and the related environmental impacts have to be distributed accordingly to these various products. This distribution is called the allocation of material and energy flows or environmental impacts. There are various allocation methods. The most common are mass allocation, where distribution is according the weight of the different products, and monetary allocation, where distribution is according to product prices (cf. HOCHFELD and JENSEIT 1998). In this study, monetary allocation is applied where there are

11 Emissions of other greenhouse gases were only taken into account if they were already included in the framework of chains of intermediates in the GEMIS database

relevant by-products (e.g. in the context of milk production, fattening calves and the meat of older dairy cows sent for slaughter).

The impact assessment structures data from the life-cycle inventory analysis according to its ecological relevance (classification) and summarises impact categories (characterisation). Since not all GHG emissions contribute to the greenhouse effect to the same extent, the emissions are weighted according to their share of this impact. The greenhouse potential is represented with the aid of the Global Warming Potential (GWP), which has the impact of carbon dioxide as its reference base. The impact of greenhouse gases is denoted in the form of carbon dioxide equivalents. The IPCC (2001) gives methane an equivalence factor of 23 for an observation period of 100 years, i.e. methane is 23 times more effective as a greenhouse gas than carbon dioxide; the equivalence factor for nitrous oxide is 296.

The last step in ecological accounting is evaluation, in which conclusions are drawn and specific actions derived from the ecological account. Details of the climate accounting for different processes in the production of wheat, pigmeat, milk and beef can be found in the unabridged version of the study.

4 Conclusions for a more climate-friendly agricultural sector

In the context of this study, the impact of German agriculture on the climate was analysed through a detailed climate accounting of representative and typical agricultural production processes. This chapter gives a summary overview of the results of this climate accounting. This summary is complemented by a rough calculation of the overall effects for climate protection which a more climate-friendly agricultural sector could achieve. These considerations lead directly to possible areas of conflict between climate protection, competing demands on land use and animal welfare issues on the one hand. On the other hand, they point to synergy effects, for example with water pollution control and the maintenance of biodiversity. Finally, points of departure for reorientation to a more climate-friendly agricultural sector are derived from this analysis.

4.1 Summary of climate protection potentials (land use, individual processes and overall view)

a) Climate protection through re-wetting and conservation of moors and wetlands

The role of land use in agriculture's carbon footprint has so far gained little public attention. Around 30% of German agriculture's greenhouse gas emissions are generated on 5% – 8% of the agricultural land because moors are drained and the carbon-rich peat soil is used as grassland or for arable farming. The exploitation of drained moorland is responsible for approx. 3.7% of Germany's overall greenhouse gas emissions.

Arable farming on drained moorland is the most damaging form of agricultural land use for the climate. The negative impact on the climate resulting from the extraction of carbon stored in the ground per hectare of moorland exploited is many times greater than the negative effects on the climate that would result from the use of similar processes on non-moorland. According to the National Inventory Report, approx. 18 tonnes of CO_2 equivalent are released annually for every hectare of moorland exploited for grassland use; for arable use the figure is even higher, namely 40 tonnes of CO_2 equivalent – and this solely from the extraction of an organic substance which had collected in the ground over many years (UMWELTBUNDESAMT 2006).

The majority of drained moorland is used as permanent grassland, either as pasture for grazing or to grow basic feed for beef production. Regional focal points for moorland exploitation are the northern federal states of Lower Saxony, Schleswig-Holstein, Mecklenburg-Western Pomerania and Brandenburg. There moorland areas account for between 31% and 57% of the total area used as grassland.

b) Climate protection through conversion of agricultural production processes

With its low use of nutrients, organic farming mainly has clear advantages over conventional farming (in terms of climate protection) in its crop-growing activities. Per kilogram of wheat, organic farming causes less than half as many greenhouse gas emissions as conventional wheat growing (141g of CO_2 equivalent per kilo of wheat in organic-plus processes compared to 365g in conventional-plus processes).

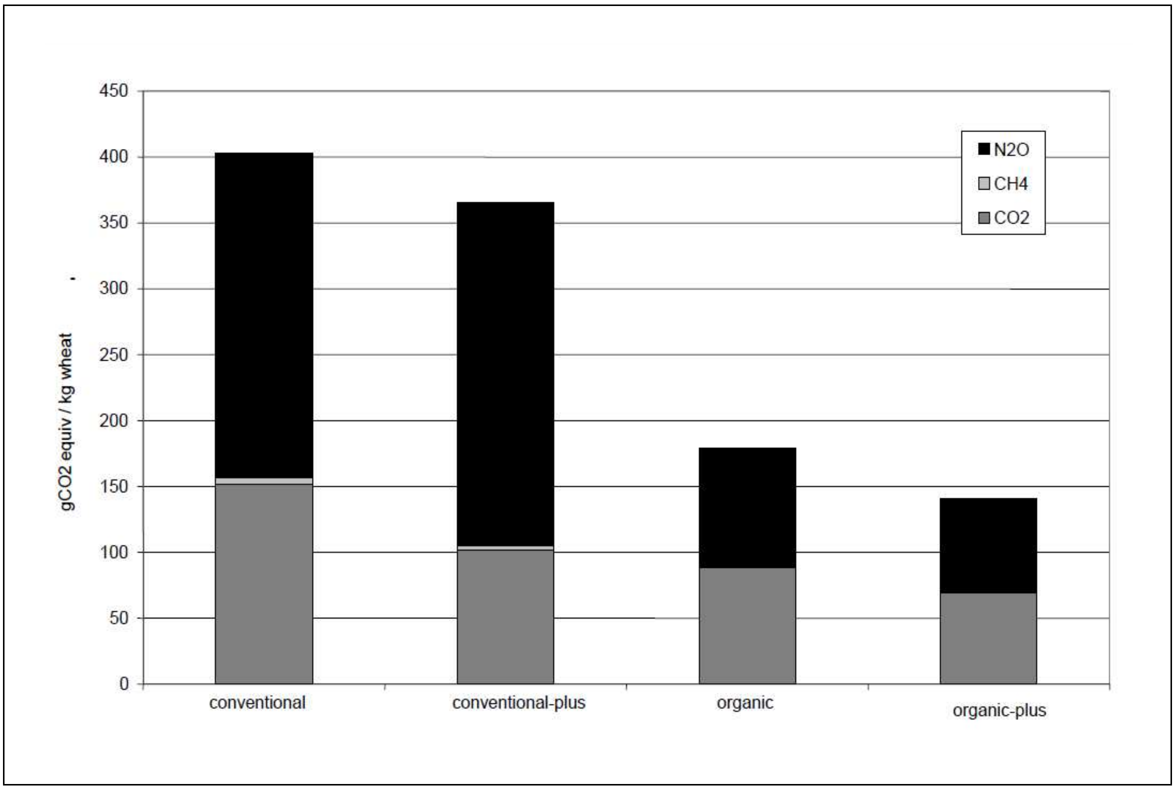

Fig. 4.1: Greenhouse gas emissions from the cultivation of winter wheat [in gCO2 equivalent per kilo of wheat]

There are similar differences throughout the crop-growing sector. Above all, the use of mineral nitrogen fertiliser in conventional farming is proving to be particularly harmful to the climate: the manufacture of mineral fertiliser is energy intensive and thus linked to high CO_2 emissions. The more intensive spreading of fertiliser on arable land in conventional farming also produces higher nitrogen surpluses, which lead to nitrous oxide emissions three times greater than in organic farming.

Livestock farming is responsible for over 71% of German agriculture's greenhouse gas emissions, with cattle farming (for milk and beef production) by far the largest emitter.

Organic pig fattening produces 40% fewer GHG emissions per kilo of pigmeat (1.70 kg CO_2 equivalent per kilo of pigmeat compared with 2.79 kg in conventional pig fattening).

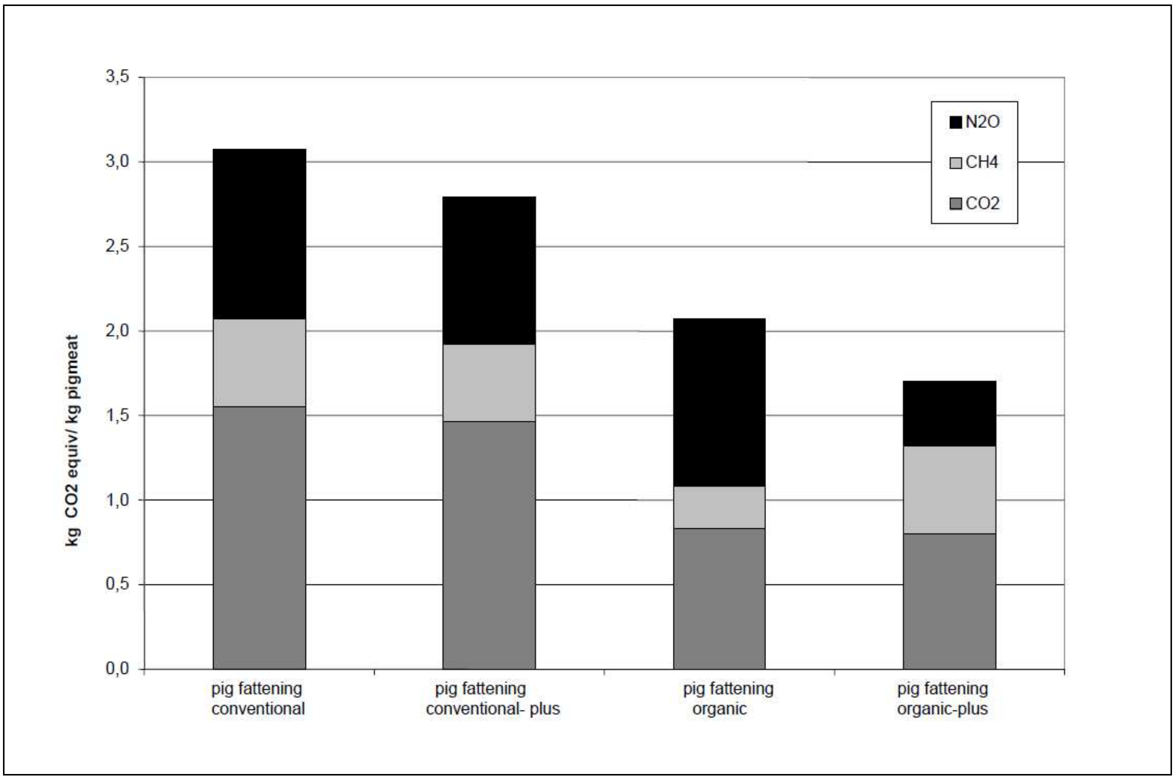

Fig. 4.2: Greenhouse gas emissions from the production of one kilo of pigmeat [slaughter weight; ex-farm][12]

9% of GHG emissions can be saved per kilo of milk in organic dairy farming (630g CO_2 equivalent per kilo of milk compared with 700g in conventional milk production). This only relatively small advantage is due inter alia to the much lower milk yield from dairy cows farmed and fed organically. The organically farmed cow produces much fewer CO_2 equivalents than a conventional dairy cow (approx. 5,000 kg per year compared with 7,000). But this advantage for the climate from organic milk production is partly offset by the lower milk yield: it makes a considerable difference whether this quantity is spread over 7,500 kilos of milk per year (in leading organic farms) or over 9,500 kilos of milk (as in leading conventional farms).

12 Greenhouse potential including intermediate products for pigmeat from four pig-fattening farms: one average conventional farm (conventional), one technologically leading conventional farm (conventional_plus), one average organic farm (organic) and one technologically leading organic farm (organic_plus).

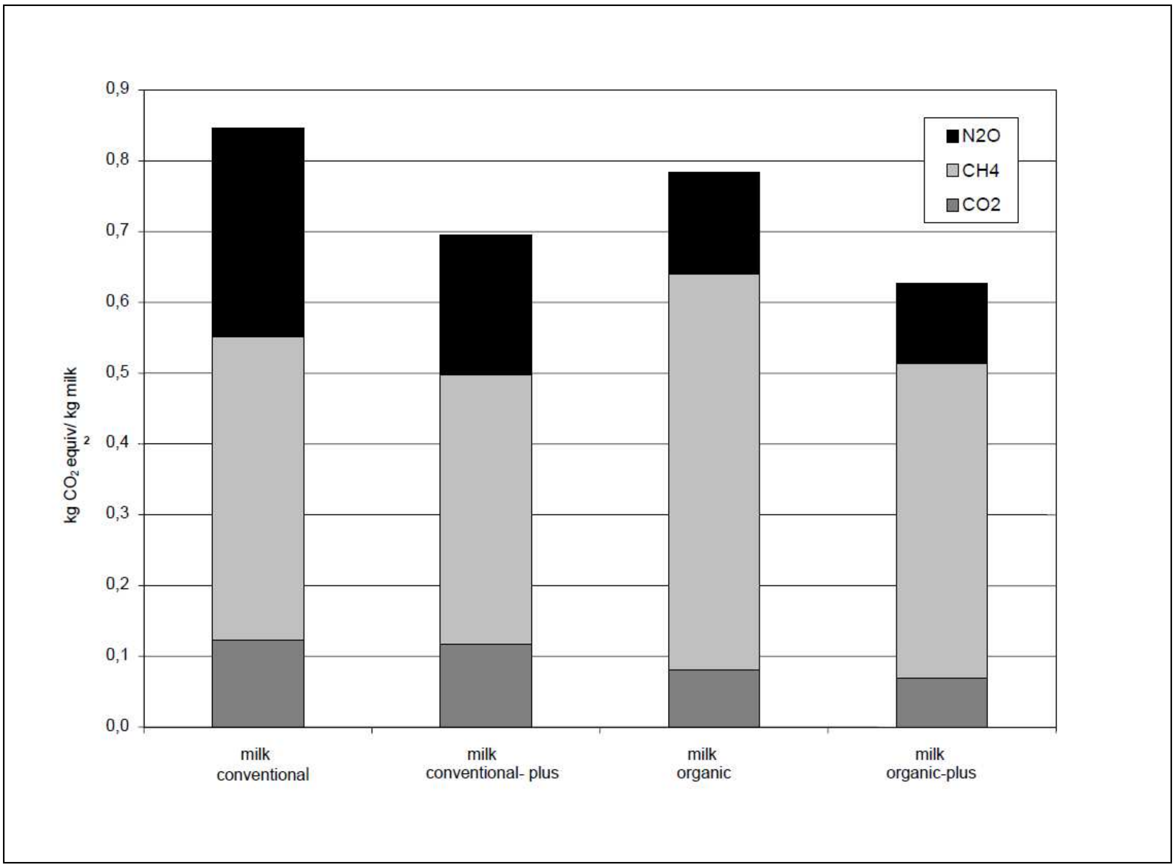

Fig. 4.3: Greenhouse gas emissions from the production of one kilo of milk [raw milk ex-farm][13]

The picture for beef production is inconsistent. There is a whole range of different processes for conventional and organic cattle farming: bull fattening of calves from dairy cows or suckler cows; ox fattening; the slaughter of older dairy cows or suckler cows. The most important conventional beef production processes are bull fattening of calves from dairy cows, the slaughter of older dairy cows and, in third place, bull fattening of calves from suckler cows. The most important organic beef production processes are ox fattening of calves from suckler cows and the slaughter of older dairy cows.

In some beef production processes, conventional cattle farming is ahead in terms of effects on the climate, in others organic cattle farming. The most climate-friendly form of beef production is the slaughter of older dairy cows.[14] This is due to the fact that this meat is a by-product of milk production and the majority of greenhouse gas emissions are attributable to the milk production. Here the meat from organically farmed dairy cows (at 3.1 kg CO_2 equivalent per kilo of beef) is ahead of that from conventional dairy cows (4.8 kg CO_2 equivalent per kilo of beef).

13 Greenhouse potential including intermediate products for milk from four dairy farms: one average conventional farm (conventional), one technologically leading conventional farm (conventional_plus), one average organic farm (organic) and one technologically leading organic farm (organic_plus).

14 However, the meat from older cows is not of the same quality as meat from bull or ox fattening. It is mainly processed into mince or sausages.

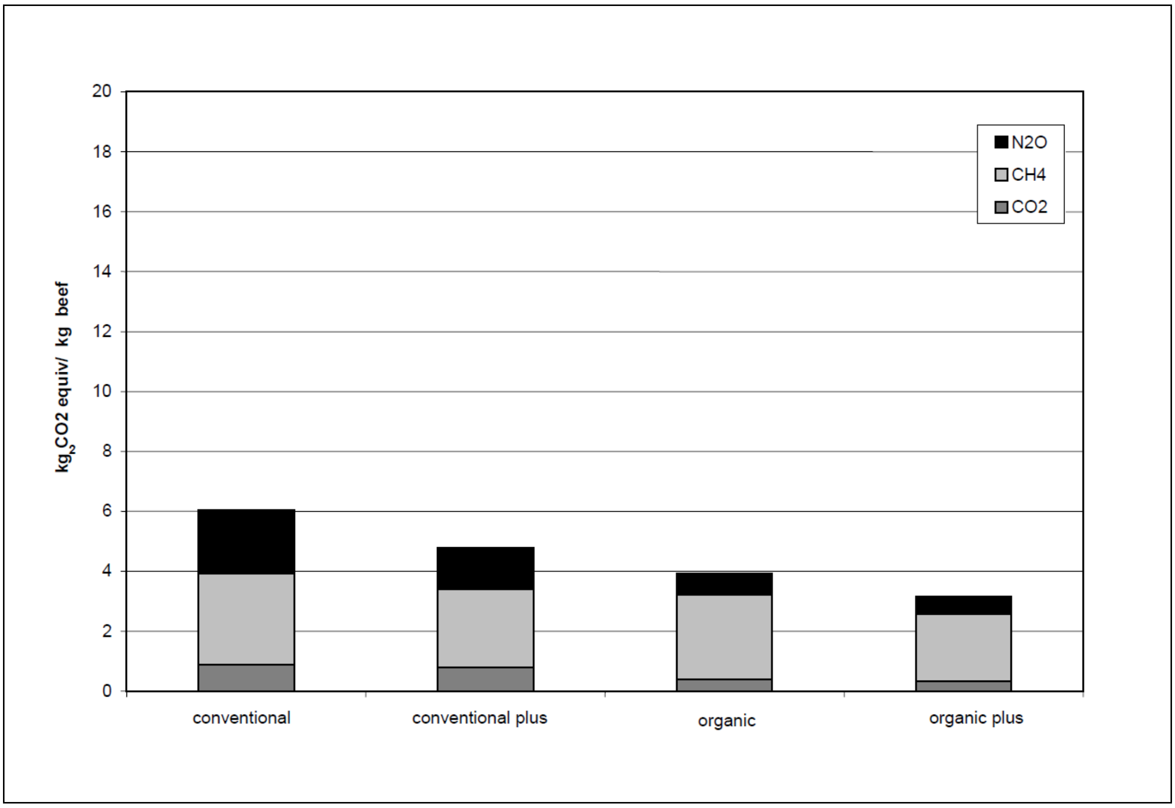

Fig. 4.4: Greenhouse gas emissions from the production of one kilo of cow meat from dairy cattle

The next most climate-friendly process is the standard method of conventional beef production: the fattening of bull calves from dairy farming (7.9 kg CO_2 equivalent per kilo of beef). Here too (like the older cows), the male calves are regarded as a by-product of milk production. But the marked advantage for the climate of conventional bull fattening over organic fattening (11.0 kg CO_2 equivalent per kilo of beef) stems primarily from the fact that the animals are kept on fully slatted floors which systematically generate lower emissions than organic systems with litter. This is an area of possible conflict between animal welfare and climate protection goals. (cf. also section 4.2).

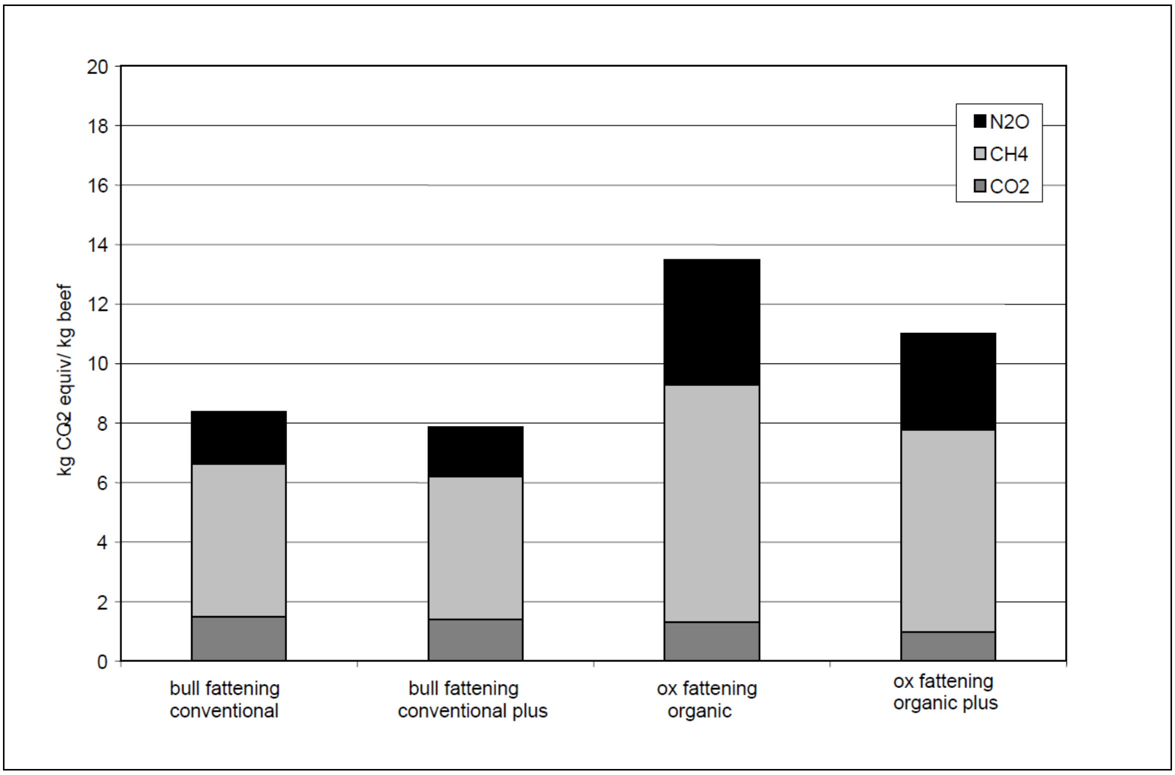

Fig. 4.5: Greenhouse gas emissions from the production of one kilo of beef from ox or bull fattening of calves from dairy cattle

The processes of suckler cow farming have a generally less favourable carbon footprint. (14.1 kg CO_2 equivalent per kilo of beef) It is noticeable here that the effects of meat produciont on the climate are not partly offset by the additional milk production (as in dairy farming). Consequently, all emissions are attributed solely to the meat production. If one compares conventional and organic farms within these suckler cow rearing processes, the organic farms have a 10%-30% better carbon footprint. This is due primarily to the way in which their feed is grown, since mineral fertilisers are used in conventional operations.

In general, the analysis permits the conclusion that the slaughter of older dairy cows is the most climate-friendly method of producing beef. The favourable carbon footprint results above all from the fact that the cow meat is a by-product of milk production. Since milk production is responsible for the major profit element from dairy farming, the effects of dairy farming on the climate are attributed predominantly to milk.

This study did not conduct any separate climate accounting for the production of poultry meat. Some of the existing studies on climate accounting see advantages in organic poultry fattening others in conventional methods – overall a neck-and-neck race between the different processes which is decided by how the accounting area is defined, the selection of feed and the feed conversion rates. In view of the minor climate relevance of poultry meat production compared with beef and pigmeat as well as the contradictory data, improving the carbon footprint of poultry farming was not taken into account in the rough calculation of the hypothetical overall potentials for reducing greenhouse gas emissions (cf. figure 4.2)

According to the results of the research project "Converting food systems", the production of poultry meat in organic chicken fattening (with chicken-run) generates 1.14 kg CO_2 equivalent and in conventional chicken fattening (deep litter) 1.66 kg CO_2 equivalent per kilo live weight (WIEGMANN et al 2005; UMWELTBUNDESAMT). The approx. 15% lower emissions from organic poultry farming stem above all from the more climate-friendly cultivation of feed. However, this advantage can be partly offset in conventional poultry fattening by a higher feed conversion rate (inter alia because the birds have fewer opportunities to move around). As a result, another study (WILLIAMS et al. 2006) comes to the conclusion on the basis of a different methodological approach that organic poultry fattening generates higher greenhouse gas emissions than intensive conventional fattening.

c) Climate protection through energy recovery from manure in biogas plants

The use of biogas plants can considerably reduce the impact of livestock farming on the climate. Electricity and heat generated from biogas can replace electricity from the German grid and thus mitigate the greenhouse gas emissions from the use of fossil fuels. The utilisation of animal excrement in biogas plants is particularly interesting since the fermentation of manure makes this better to apply and greenhouse gases from the storage and spreading of manure is additionally reduced. (cf. KEHRES; AMON and DOHLER 2006). This study examined whether the carbon footprints of animal products change as a result of the use of excrement in biogas plants and the correspondingly substituted emissions in the generation of electricity.

The carbon footprint of milk and meat production improves if the respective manure is employed in a biogas plant. Solely from the substituted quantity of electricity in the methods of pig farming and milk production considered, this accounts for a 10%-13% reduction in greenhouse emissions. (The detailed results are set out in the unabridged version of the study). The mitigation potential is particularly high in the case of cattle fattening where GHG emissions fall by up to 25% with the use of a biogas plant, especially in the extensive processes with suckler cow farming. In addition, there are the direct emissions from the manure which are avoided through pre-treatment. Biogas plants thus represent a very relevant measure in combating climate change, especially in the case of extensive cattle fattening.

The additional utilisation of renewable raw materials in biogas plants was not examined in this study. Growing crops specifically for use in biogas plants, in particular intensively cultivated crops such as silage maize which are harmful to the climate and pollute the water, can worsen the carbon and ecological footprint of the use of biogas plants. The high level of fertiliser use associated with the cultivation of these crops is the prime cause of this negative effect on the climate. The ecological footprint is worsened by the resulting water pollution, exacerbated still further by the susceptibility to erosion of arable land under maize crop. The use of liquid and solid manure is therefore particularly advantageous if combined with plant residues which are subsequently spread with the fertiliser and can help to improve the humus balance of agricultural land.

d) Area requirements as a limiting factor in conversion

The guidelines for organic farming stipulate that organic crop growing must do without the application of mineral fertilisers. As a result, crop yields are generally 10%-40% lower than in conventional farming. Conversely, this means that organic farming requires more arable land than conventional farming to produce a tonne of wheat. Since over half the crops produced in Germany are used as livestock feed, these differences in yield also have an effect on the area requirements of different livestock farming methods. In addition, there are different rates of feed conversion in livestock farming which also affect area requirements.

With regard to the use of agricultural land, wheat cultivated on average organic farms (at 2.8 m^2 per kilo of wheat) requires almost twice as much space as wheat grown on average conventional farms (1.3 m^2 per kilo of wheat). In the case of high-yield farms, the gap between organic and conventional crop growing is smaller (cf. Table 4.1). The same also applies to the growing of other field crops.

Tab. 4.1: Agricultural land requirement for the different livestock and crop farming methods examined
Source: own calculations and FAL (2000)
* kg slaughter weight, milk or grain Getreide
**conventional methods are stated as bull fattening, organic methods as ox fattening

	conventional	conv_plus	organic	oganic_plus
	m² / kg*			
pigmeat	**7.0**	**6.4**	**11.8**	**11.0**
milk	**1.2**	**1.2**	**2.3**	**2.2**
bull/ox fattening** *from dairy farming*	**11.1**	**10.4**	**36.6**	**29.4**
ox/bull fattening** *from suckler cow farming*	**21.0**	**20.2**	**41.7**	**35.8**
older cow meat *from dairy farming*	**8.4**	**8.0**	**11.7**	**11.2**
older cow meat *from suckler cow farming*	**18.2**	**17.5**	**31.4**	**27.0**
winter wheat	**1.3**	**1.3**	**2.8**	**2.2**

Whilst considerably fewer greenhouse gases per kilo are generated by organic pig fattening than by conventional farming methods, organic production requires considerably more agricultural land. The area requirement for the cultivation of animal feed in the two model organic farms is approx. 70% higher than in the conventional farms (cf. Table 4.1).

Organic farms also have a greater area requirement for the production of milk. Due to their lower crop and milk yields, organic farms require almost twice as much agricultural land as conventional farms to produce one kilo of milk. This is due to the much greater use of forage and roughage.

The most extreme differences in area requirements between organic and conventional farms appear in the fattening of bulls and oxen which were transferred as calves from dairy cattle. Here the area requirements of organic farms are in some cases up to three times greater than in conventional fattening – once again, this is due primarily to the high percentage of extensively produced forage and roughage.

For the production of one kilo of beef from suckler cow farming, the area requirements of organic ox fattening are about two-thirds greater than those of conventional bull fattening.

Suckler cow farming with the rearing of weanlings accounts for a significant proportion of the area requirement. Also in the case of bull fattening, calf-rearing (including the proportional consideration of dairy farming) has a high area requirement. However, it should be noted here that this area-extensive fattening process on marginal land is often the only worthwhile form of land management. Extensive pasture management can also have landscape conservation functions. It is only in the production of cow meat that the area requirement of organic farms is "merely" about 40% higher than conventional farms (cf. Table 4.1).

Any comparison of the area requirements of conventional and organic livestock farming related to German agricultural land must take into account that conventional livestock currently transfers a not inconsiderable part of its area requirements abroad – namely 25% of the agricultural land used in Germany for growing animal feed (approx. 2.6 million hectares). This study has included the indirect effects on the climate of cultivating and transporting this feed in its climate accounting.

Changes in land use and the clearance of forest areas can have additional negative effects on the climate. Since existing data on the estimated role of specific processes in the impact on the climate caused by changes in land use abroad do not permit any reliable statement on the dimension of these effects, they have not been attributed to German livestock farming in accordance with this study's definition of accounting areas. This aspect requires further research.

4.2 Scenarios for climate protection potentials in German agriculture

This study focuses on the climate accounting of individual, central methods of crop growing and livestock farming in Germany. However, the overall potential of climate protection in German agriculture does not emerge directly from this analysis. What follows is therefore the construction of two hypothetical extreme scenarios to explore this overall potential. It should be pointed out from the outset that this is a theoretically achievable potential which would presumably encounter considerable difficulties when faced with the practice of actual implementation.

The scenarios examine the effects on the climate of converting current average agricultural practice to more climate-friendly methods of production. The status quo, described in terms of the respective average processes "conv" and "organic"[15] in the statistically available production shares in Germany (relative shares of approx. 95% "conv" and 5% organic across all processes), is compared in each case with the more climate-friendly conversion methods. These scenarios refer to the main crop-growing and animal farming techniques shown in Table 4.2.[16]

Scenario I presupposes that the quantity of agricultural goods currently produced in Germany (base year 2006) is to be produced in a more climate-friendly way, resulting in an additional area requirement.

Scenario II presupposes the restriction that agricultural land area is not extended (since negative effects on the climate would simply be shifted abroad via imports of agricultural goods). Because the more-climate friendly techniques of organic farming have a greater area requirement than conventional methods, conversion results in restrictions on production quantities. In Scenario 2, the initial step is to convert all crop-growing processes which are directly connected with human food production (i.e. without feed-crop areas for animal production). The second step calculates the quantities of animal products that can still be produced on the basis of the area remaining. This leads to a fall in the production of meat and milk whilst the supply of plant foods remains constant.

15 The different processes are described in the unabridged version of the study.

16 This does not include poultry fattening since it proved impossible to derive a clear advantage for the climate from individual methods on the basis of existing data. Also excluded are crop-growing and animal-farming techniques that account for less than 2% of area use or overall production quantity (e.g. vegetable cultivation and sheep farming).

Scenario I: Constant production with growing area requirement by complete conversion to optimal climate protection techniques

Scenario I presupposes that the present quantity of agricultural products produced in Germany is to be maintained in future at the same level and in the same composition but using more climate-friendly techniques. All currently drained moorland will be rewetted.

Climate-friendly agricultural production methods use less fertiliser than is usual in conventional farming. Compared with current practice, this results in a reduction in overall greenhouse gas emissions on the one hand, but in general also to a greater area requirement due to the lower yields and production output of more climate-friendly techniques.

With one exception, this hypothetical calculation compares the average conventional method (as an approximate depiction of current practice) with more climate-friendly techniques. As a rule, the most climate-friendly methods are the “organic plus” methods. The one exception is bull or ox fattening from dairy calves where conventional methods are more favourable for the climate than organic fattening processes. With regard to this method, the conversion from organic to conventional fattening is taken into account (but this accounts for less than 0.1% of the mitigation potential due to the small overall scale of organic cattle fattening).

Scenario Ia: Status quo versus optimal climate-protection production methods

In the first version of Scenario I, all methods are hypothetically fully converted to the respective optimal climate-protection methods. With the exception of the cattle fattening process mentioned above, these are all “organic plus” methods.

In theory, such a conversion could mitigate the greenhouse gas emissions of German agriculture by a total of 20% (27 Mt CO_2 eq.). These figures emerge if one compares the effects on the climate of the respective optimal methods with those of average practice in conventional farms and a projection made for overall agricultural production based on the respective annual production volume (cf. Table 4.2). In addition, there is the complete rewetting of moorland previously used for farming as well as expansion of the use of manure in biogas plants.

The rewetting of farmed moorland (approx 1.4 million hectares) would achieve a long-term reduction in greenhouse gases of approx. 37 million tonnes per annum or approx. 28% of current agricultural GHG emissions. This estimate is based on simplifying assumptions: on the one hand, that virtually all drained moorland areas could be rewetted and on the other, that previous CO_2 emissions from drained moorland would fall to zero and no additional CO_2 storage would take place. This is both an over- and under-estimation of the real possible effects. It is an over-estimate in the sense that not all moorland areas can actually be rewetted – for example, because the water balance in some regions has changed in such a way that there is no longer sufficient water for rewetting. The proportion of moorland where rewetting would be completely impossible is not known. On the other hand, the assumption of zero CO_2 emissions is an under-estimation of the long-term climate-protection potentials of rewetting because growing (peat accumulating) moors store carbon dioxide, thereby removing CO_2 from the atmosphere. The above figure does not take this potential additional climate-protection effect into account.

Tab. 4.2: Theoretically possible greenhouse gas mitigation potentials related to overall agricultural production in Germany: optimal climate-protection techniques compared with current average practice[17]

Source: IÖW, own calculations on the basis of climate accounting as well as data from the FAL (2000) for potatoes,, sugar beet and rape, from the FiBL (2007) on humus build-up and statistics from the National Inventory Report (Umweltbundesamt 2005) on greenhouse gas emissions from the use of moors. Figures in columns 2 und 4 rounded up to nearest 100,000.

Product or Technique*	**Overall Production output in Germany 2006** in tonnes	**GHG Emissions 2006** in tonnes CO_2 equivalent	**Mitigation Potential** as percentage of product-related emissions	**Mitigation Potential** in tonnes CO_2 equivalent	**Mitigation Potential** as percentage of overall emissions of German agriculture
Grain without feed grain	23,380,000	9,200,000	-65%	**-5,800,000**	**-4.4%**
Potatoes	11,624,000	700,000	-9%	**-100,000**	**< -0.1%**
Sugar beet	25,285,000	1,100,000	-47%	**-500,000**	**-0.4%**
Rape	5,052,000	4,100,000	-56%	**-2,200,000**	**-1.6%**
Pigmeat	4,213,000	13,000,000	-43%	**-5,800,000**	**-4.3%**
Milk	27,995,000	23,800,000	-25%	**-6,000,000**	**-4.5%**
Beef	1,284,000	9,600,000	-13%	**-1,300,000**	**-1.0%**
Humus build-up on arable land			-500 kg/ha/year	**-5,400,000**	**-4.1%**
Biogas plants			-10% GHG animal production	**-4,600,000**	**-3.5%**
Rewetting of moorland		36,900,000	-100%	**-36,900,000**	**-27.7%**
Overall potential for reducing greenhouse gases				**-68,600,000**	**- 51.6 %**

Together with an almost total conversion to organic farming and an expansion of biogas plants, it would be hypothetically possible to mitigate agricultural GHG emissions by up to 68.6 Mt CO_2 eq., i.e. more than half. This would be about a quarter of the 270 Mt CO_2 eq. of greenhouse gas emissions which the German government intends to prevent by the year 2020 according to its present climate change target, over and above the reductions already achieved.

However, the hypothetical conversion from current practice to the most climate-friendly methods would result in an additional requirement for agricultural area of approx. 11.5 million hectares (cf.

17 Apart from “bull/ox-fattening from dairy calves”, the mitigation potential is defined as conversion from average conventional [conv.] to organic, best-practice farming [organic plus]. In the case of “bull/ox-fattening from dairy calves”, the GHG mitigation potential lies in the conversion of organic ox fattening from dairy calves to conventional bull fattening, since this is a more climate-friendly technique. The rewetting of moorland used for agricultural purposes refers to all forms of farming conducted there.

Table 4.3). That corresponds to about 68% of the area currently used in Germany for agriculture. Since the agricultural areas in Germany would therefore not be sufficient to maintain current production levels in the event of such of conversion, shortages (assuming constant patterns of demand and consumption) would have to be met by products from abroad that fulfilled the same climate-friendly criteria – which might also be limited on a global scale.

This scenario would thus only be feasible with additional imports if the supply situation of consumers were to be maintained. Since there would also be competition for the use of additional agricultural areas abroad, it is doubtful whether the net balance of the global effects of this scenario on the climate would actually prove to be positive. If, for example, forest is cleared abroad to provide additional arable farming areas, the overall impact of such a strategy turns out to be more harmful to the climate than the original solution.

Tab. 4.3: Theoretically required additional areas for conversion to the respective "optimal climate-protection" methods compared with current average practice (at home or abroad)
Source: IÖW, own calculations on the basis of climate accounting, as well as data on farmed moorland from the National Inventory Report (Umweltbundesamt 2005)

Product*	**Additional area required** in hectares
Crop-growing (without animal feed)	**4,100,000**
Pigmeat (inc. animal feed)	**1,700,000**
Milk and beef (inc animal feed)	**4,300,000**
Rewetting of moorland areas	**1,400,000**
Total additional requirement for agricultural area	**11,500,000**

Other comparisons were also analysed within this scenario:

Scenario Ib: Status quo versus conversion to organic average [organic]

If one were to convert the current conventional practice [conv] to current average organic methods [organic], which have lower output and yields than the leading organic farms [organic plus], the greenhouse gas mitigation potential would not be reduced by 20% (27 Mt CO_2 eq.) but by only 15% (20 Mt CO_2 eq.). The overall potential for avoiding GHG would thus be reduced by 7 million tonnes and, together with humus build-up and biogas use, would be limited to a total of 61.7 Mt CO_2 eq.[18] By contrast, the additional area requirement would increase by 3.3 million hectares to 14.8 million hectares due to the lower output and yield: that would be 87% of Germany's current agricultural area.

18 It should be borne in mind here that the majority of GHG avoidance can be achieved by rewetting farmed moorland, regardless of what production methods are currently employed there and to which methods the other agricultural areas are converted.

Scenario Ic: Status quo versus conversion to conv_plus farms

Conversion to the respective leading conventional farms [conv_plus] was calculated as a further scenario. The result is a marked decrease in the saving potential to just 7% (9.8 Mt CO_2 eq.) compared with the scenario presented in Table 4.2. The overall avoidance potential is 17.3 million tonnes less than the organic plus scenario and still accounts for 51 Mt CO_2 eq. Here too, the rewetting of moorland – which applies to all methods – is responsible for the majority of total reductions. However, in view of the higher area yields and output, the additional area requirement would be less in this case, namely just 1 million hectares compared with 11.5 million hectares in the scenario with the most climate-friendly organic plus version.

A comparison of the three versions of Scenario I shows that the greatest advantages for the climate can be achieved by converting current agricultural practice to organic farming. However, these advantages are diminished if these organic farms do not also increase their efficiency compared with current average organic farms.

The comparison also shows that increasing the efficiency of conventional farming would by itself also have a positive effect on the climate, albeit 17 Mt CO_2 eq. less than could be achieved by more comprehensive conversion towards organic farming. This is due primarily to the higher quantities of fertiliser used in conventional farming. If fertiliser quantities were greatly reduced, the GHG mitigation potential in the conventional sector could draw closer to that of conversion to organic farming.

With higher yields and output per area unit, conventional farming achieves a higher area efficiency than organic farming. This also applies to the conv plus methods examined in this study where the use of mineral fertilisers was reduced and replaced by the spreading of manure.

Most of the climate-protection effects of agriculture can be achieved by rewetting moorland (36.9 Mt CO_2 eq.). In addition, the use of liquid and solid manure in biogas plants can avoid 4.6 Mt CO_2 eq. This basic package of agriculture measures for combating climate change, which altogether account for 41.5 Mt CO_2 eq., can be carried out regardless of the extent to which additional climate protection effects are achieved by converting farming methods.

Conversion to more climate-friendly conventional farming methods [conv plus] could avoid a further approx. 10 Mt CO_2 eq., whilst full conversion to average organic methods [organic] could save a good 20 Mt CO_2 eq. in addition to the basic package, i.e. twice as much as conversion to more climate-friendly conventional methods. Conversion to optimal organic methods [organic plus] could avoid 27.1 Mt CO_2 eq. over and above the basic package.

Scenario II: Full conversion to optimal climate protection techniques on German agricultural land

Scenario II is based on the question: If the quantity of plant production for human consumption is kept constant, how many animal products can still be produced on the current area used for agriculture? Plant production remains constant in terms of the quantity produced and is fully converted to climate-friendly production. All moorland is rewetted and taken out of food production. Livestock farming is conducted on the remaining areas, also using optimal climate protection techniques.

Scenario IIa: Status quo versus optimal climate-protection production methods [organic_plus] with constant total area

Keeping the quantity of current plant production for human consumption and energy production (in simplified terms, total plant production minus feed production) at a constant level using climate-friendly cultivation methods would require approx. 5.5 million hectares more area under crop than today in the event of conversion to the most climate-friendly techniques [organic_plus] and the rewetting of all drained moorlands.

If one presumes that no additional areas abroad are to be used, the production of meat and milk would have to be reduced correspondingly. Consequently 5.5 million hectares fewer would be available for feed production for livestock farming. If the structure of animal production were retained (i.e. a constant division of area use were maintained for example between feed for fattening pigs and dairy cows), overall animal production would have to be reduced by 69%. In other words, only 31% or less than one-third of current animal products could be produced on the remaining 5.1 million hectares of fodder area.

This calculation also factors in livestock farming being converted to climate-friendly techniques and therefore requiring a greater area for the production of one litre of milk or one kilo of pigmeat – on what is already a much reduced area in Germany due to the additional requirement for crop growing.

Such a radical reduction in animal production would of course have additional climate protection effects. Such a scenario would bring an additional reduction of 23 Mt CO_2 eq. This would mitigate overall agricultural GHG emissions by 92 Mt CO_2 eq. or 69% of greenhouse gases currently emitted by German agriculture. – assuming a constant supply of plant-based food and a reduction in meat and milk supply to just under a third of current levels.[19]

19 This scenario calculation does not take account of the additional production of special plant substitutes in meat production, such as vegetables, protein or oil crops. This would require a more detailed examination of anticipated consumption patterns. The result would be a slight further reduction in animal production.

Scenario IIb: Status quo versus conversion to average organic methods [organic] with constant total area

Due to the higher additional area required for conversion to average organic methods [organic], animal production would have to be reduced even further, which would once again slightly increase the climate protection effect compared with the organic plus conversion scenario. The use of less efficient organic methods on the same area of agricultural land would require a reduction of up to 86% of current animal production. The additional savings of 3.9 Mt CO_2 eq. compared with the organic plus version of Scenario II would be achieved at the cost of a further 17% restriction in animal production.

Scenario IIc: Status quo versus conversion to [conv_plus] methods

Converting the present average conventional practice [conv] to more climate-friendly conventional methods [conv_plus] would, as in Scenario I, considerably mitigate the positive GHG avoidance effect compared with organic plus methods, but would make it possible to maintain meat and milk production at a higher level than in the first two versions of Scenario II. Here animal production would only have to be reduced by 11% - in this case solely due to the rewetted moorland being no longer available. Since this, on the other hand, accounts for a significant proportion of the overall reduction, GHG emissions would still be mitigated by 42% (56 Mt CO_2 eq.).

The above scenarios are hypothetical. Scenarios that envisage gradual further growth of organic farming and a reduction in fertiliser use in conventional farming initiated by political regulations are likely to be closer to reality. Medium-term increases in the efficiency of organic farming and a reduction in the use of fertiliser in conventional farming are quite conceivable. This would not only make sense in terms of protecting the climate but also macro-economic sense in terms of protecting the environment and preventing water pollution (cf. following section 4.3).

The impact on the climate and the area requirements of livestock farming and crop-growing methods examined in this study have been derived on the basis on the basis of typical methods employed by average conventional and organic farms as well as the most efficient leading farms in each category [conv, conv_plus, organic, organic plus]. This approach made it possible to identify systematic differences in the product-related carbon footprints of the methods studied, from which the potential for reducing agricultural GHG emissions can be derived. However, due to the great variety of farm types, calculations made on the basis of the definition of typical farms do not paint a completely representative picture of German agriculture.

The extrapolations conducted in this study to derive scenarios with relation to the overall sector therefore primarily provide information on the *direction and relative dimension of changes* of greenhouse gas emissions and area requirements resulting from a comprehensive reorientation to more climate-friendly farming methods. From this it is possible to develop important starting points for a climate change policy that utilises the potentials of agriculture (cf. Section 4.4 “Measures for more climate protection in the agricultural sector”).

Due to the methodological approach using typical farms and the great range of data fluctuation in various sectors, there are varying degrees of uncertainty attached to statements on the *absolute amount of aggregated effects*. Since the effects on the climate of the various methods are closely linked with certain input factors of special relevance to the climate (such as the use of fertilisers or feeding with imported soya), for which statistics are kept on the quantities used in the German agricultural sector, it is relatively easy to estimate how many GHG emissions would be achieved by converting to these methods. With regard to the area requirements of conversion and the emission effects of individual aspects (e.g. manure management in the pen), the lack of standardised procedures in practice leads to a broader scattering of accounting results.

The statements in this study are based on the latest state of knowledge, although further research is needed to refine and substantiate the results presented here – for example, with regard to emissions from different forms of livestock housing or the effects of draining and rewetting moors and wetlands.

In order to obtain more reliable findings for the overall GHG avoidance potential and additional area requirement it would be necessary to conduct a nation-wide, representative survey of the various land management parameters relevant to the climate in conjunction with an evaluation of detailed soil maps and regional climatic conditions.

4.3 Conflicts and synergies with other goals

When examining the impact of agricultural production on the climate, it is important not to not lose sight of the other environmental effects of agriculture. Otherwise, a one-sided improvement of effects on the climate may jeopardise important environmental protection and animal welfare goals.

a) Climate protection versus animal welfare?

There are a number of trade-offs between climate protection and animal welfare: “climate-friendly” livestock farming methods are not necessarily “animal-friendly”. To some extent, climate protection and animal welfare move in different directions: litter, and deep-litter methods in particular, cause high GHG emissions compared with litterless fully slatted floors. However, measurements from sloping-floor pens for fattening pigs show that litter systems can also be operated in a climate-friendly manner if the removal of liquid and solid manure is improved – for example by more frequent mucking out and by separating the dung, urine and litter areas as effectively as possible.

The impact on the climate per litre of milk or kilo of poultry meat can be improved by increasing the corresponding animal yields – e.g. by increasing the milk yield per cow or enhancing the conversion rate of feed in meat gain. However, this may also impinge on animal welfare aspects. Detailed ethological studies are required to ascertain animals’ needs in terms of movement and exercise, material to occupy them and species-specific housing conditions. Broilers convert their feed into weight gain faster and to a higher degree if they have less room to move due to crowded conditions. This may be welcome in terms of protecting the climate – but not from an animal welfare point of view.

Increasing the milk yield of cows – which now stands at 10,000 kilos of milk per annum for high-yield cows – presents a similar dilemma. Milk yield can also be improved by reducing outdoor exercise: if the cow spends longer periods lying on a special mattress in the cowshed, more energy is available for milk production than if the cow can go outside or has access to grazing areas.

In an expertise for the Federal Ministry of Agriculture, the Scientific Advisory Board on Agricultural Policy, Sustainable Land Management and the Development of Rural Areas states that, within certain limits, animal health and performance go hand in hand. However, the conflicts between performance and health are greater in the high-performance sector (WISSENSCHAFTLICHER BEIRAT 2005, pp. 37.38) Against this background, the Board calls for breeding not to be geared solely to high performance but also to fertility, useful life expectancy and sickness rates, as well as for monitoring programmes to ensure that animal health is better monitored in practice .

SUNDRUM & LOSER (2008) point out that livestock farming according to organic principles does not automatically mean better animal health than in conventional farming. They regard the quality of farm management as the main cause of variations in health status and animal losses between the different farms.

Objective limits to animal-friendly enhancement of performance, which would be desirable in many cases from a one-dimensional climate-protection perspective, are not defined in the literature on animal ethology. Whilst there is a set of indicators for judging whether certain farming methods are animal-friendly, there are differences in practice due to different management methods of individual farms within the same type of farming. (KTBL 2006a; KEMPKENS 2008).

b) Climate protection and water pollution control

One area where climate protection does not conflict with the achievement of other positive environmental goals is water pollution control. Decreasing the use of mineral fertiliser serves not only to protect the climate but also to control water pollution. By reducing the quantity employed, energy spent in the manufacture of mineral fertiliser is saved, less N_2O is emitted when it is spread on the fields and less nitrogen is leached into ground and surface water. This reduces not only the costs of climate change but also further external costs of fertiliser use – a genuine synergy effect.

c) Climate protection and the protection of biodiversity

Similar synergy effects can be achieved with regard to the protection of biodiversity. The rewetting of wetlands and a reduction in the use of fertiliser on agricultural land can restore biotopes and relieve the burden of land use. Space is created for the resettlement of displaced species, some of which are under threat. Extensive grazing of rewetted wet meadows by beef suckler cows is one of the options for retaining rewetted moorland locations in agricultural use.

However, these positive effects must also be weighed up against those of alternative landscape conservation measures and climate-friendly usages – for example the re-establishment of alluvial forests in river floodplains or the extensive production of biomass, e.g. by cultivating reeds in rewetted wetlands.

4.4 Measures to combat climate change in the agricultural sector

Apart from promoting the cultivation of biomass as an energy resource, the Federal Government has so far made no discernible efforts to combat climate change in the agricultural sector. However, in view of the significant role which agriculture plays in Germany’s greenhouse gas emissions (133 million tonnes or 13.3% of total emissions – plus the emissions caused by imported feed from abroad), this is an urgent requirement. As this study shows, agriculture could make a considerable contribution towards achieving Germany’s climate change goals. With an extremely consistent climate change policy, agriculture could avoid over half its current emissions – the equivalent of up to 6.7% of Germany's total industrial emissions.

This requires two things: not only must climate change policy take account of the agricultural sector but agricultural policy must also be examined with regard to its impact on the climate. Agricultural support measures and regulations which help to maintain a level of intensity and production that is harmful to the climate must be scrutinised if agriculture is to make a substantial contribution to climate protection. These include inter alia export subsidies, the sugar regime, area-based premiums without stricter conditions on the use of fertiliser than at present as well as support programmes which make the continued use of marginal areas worthwhile, although these ought to be rewetted from a climate protection point of view.

This comparative analysis of the impact on the climate of individual main methods of crop growing and animal farming leads to the following specific points of departure for a more climate-friendly approach to agricultural production:

1. Rewetting of drained moorland

The draining and agricultural use of moorland cause almost 30% of greenhouse gas emissions from German agriculture. Rewetting could stop these emissions in the medium to long term and even act as a sink in the medium term, i.e. absorb carbon from the atmosphere. This would avoid up to 37 Mt CO_2 eq. of greenhouse gas emissions.

In its latest expertise, the Expert Council on Environmental Affairs also emphasises the synergies between nature conservation and climate protection through the conservation of moors and wetlands. It calls for strict protection of existing wetlands, the rewetting of drained moorland and in general for a strengthening of current carbon stores and sinks (SRU 2008, pp. 194, 200).

Rewetting does not necessarily mean that these areas can no longer be used at all. Special forestry uses, such as the planting of black alders, or the extensive cultivation of reeds or reed canary grass to produce biomass for energy are possible (WICHTMANN UND SCHÄFER 2007).

2. Conversion to organic farming

Conversion to organic farming methods brings positive effects for the climate in several ways: by saving mineral fertiliser and pesticides, by largely doing without imported feed and through a positive humus balance on organically farmed soils.

Reducing the use of mineral fertilisers accounts for many of the differences identified in climate accounting between conventional and organic crop growing. This also affects the carbon footprint of livestock farming via animal feed. The climate advantage of organic farming identified by this study in many crop-growing and animal husbandry methods is thus due in large part to the more sparing use of manure in organic farming which does not depend on mineral fertilisers.

However, since organic farming systematically produces lower yields, the consequences of greater area requirements must be taken into account if this method is expanded. If there is only a limited amount of land available, the consequence of converting to organic farming is that the structure of area use and agricultural production has to be altered. To secure supplies of plant-based food, the production of animal products (meat and milk) would have to be reduced if land availability remains constant (cf. Scenario II in Section 4.2).

3. Improvement of fertiliser management in conventional farming

There is potential for climate protection not only in full conversion to organic farming but also in the reduction of fertiliser use in conventional farming. Reducing the use of mineral fertilisers and including liquid and solid manure in fertiliser planning or making manure available to arable farms without livestock could lead to a marked mitigation of greenhouse gas emissions both per hectare of agricultural land and per kilo of harvested crop.

Mineral nitrogen fertilisers harm the climate twice: the energy-intensive production of these fertilisers releases large quantities of carbon dioxide and nitrous oxide; when spread on agricultural land they once again release nitrous oxide. Reducing surplus nutrients by improving fertiliser strategies thus has a doubly positive effect on the climate.

4. Improving livestock housing to protect the climate whilst taking animal welfare aspects into account

Greenhouse gas emissions from livestock farming depend largely on the type of housing and manure management. Rapid removal of excrement via slurry channels and more frequent mucking out can reduce emissions considerably in the pig fattening and cattle farming sectors.

In several studies, fully slatted floors come off better than deep litter systems as climate protection techniques. Tying stalls with litter, daily mucking out and a slatted area for the removal of excrement could represent a good compromise in ethological terms between animal welfare and climate protection. In measurement studies, this type of housing achieves equally favourable or even better emission values than fully slatted floors. However, organic farms in particular must take active measures here to protect the climate since numerous existing systems, such as deep-litter methods or dung mattresses, are assessed in greenhouse gas measurements as highly damaging for the climate, especially due to their nitrous oxide emissions. Several million tonnes of CO_2 equivalent could be avoided in this way.

5. Increasing yields and performance – whilst taking account of environmental protection, climate protection and animal welfare aspects

Greenhouse gas emissions per litre of milk vary greatly according to the cow's milk yield since each cow is responsible for a high basic amount of emissions which can be divided among more litres of milk if the milk yield is high. Similar effects can be achieved by increasing the feed conversion rates of pigs and poultry as well as by increasing the yield per hectare in crop growing. In terms of performance and yield, organic farming is currently 10% - 50% below conventional farming. This worsens the carbon footprint per kilogram of organically produced food and improves the carbon footprint of conventional farming. If the organic sector were to increase its yields and performance, it could further extend the advantage it already has in many areas over conventional farming with regard to climate protection.

To ensure that more climate protection in the agricultural sector does not create or exacerbate problems elsewhere, strategies for increasing animal performance and crop yields must also take environmental protection and animal welfare aspects into consideration.

6. Expanding the use of liquid and solid manure in biogas plants

The production of biogas in a biogas plant can replace electricity from the German power grid and thus mitigate the effect of livestock farming on the climate. The possible reduction in greenhouse gases in the pig-farming and milk-production methods examined in this study is up to 10% and 13% respectively. The mitigation potential is much higher for cattle fattening where the use of a biogas plant can reduce up to 24% of emissions.

7. Improving the climate protection techniques of cattle farming

The farming of cattle to produce milk and meat is responsible for about half of all agricultural GHG emissions in Germany. That is why special attention must be paid to improving climate protection in this sector. In addition to the above-mentioned improvements in housing and increases in performance (which conform to animal welfare principles) consideration must be given to more efficient meat production within the “cattle farming system”. As the climate accounting in this study has identified, the combined production of milk and meat is the most favourable in climate protection terms. The lowest GHG emissions are attributed to meat from older dairy cows. The most climate-friendly methods of cattle fattening are those which fatten the “surplus” male offspring of dairy cows. From a climate protection perspective, as little beef as possible should therefore be produced outside the milk production system. This would entail a reduction in suckler cow farming.

Experiments are currently being conducted to improve the composition of feed in order to mitigate methane emissions in particular. Here too, climate protection, animal health and achievable performance levels have to be weighed up against one another.

From a climate protection point of view, cattle farms should not use drained moorland for grassland, otherwise the negative effects of production on the climate are multiplied. However, in Lower Saxony, Schleswig-Holstein, Mecklenburg-Western Pomerania and Brandenburg, 30% - 50% of cattle farming is still conducted on drained moorland. Extensive cattle farming methods would be possible on rewetted areas, although lower performance levels would have to be accepted.

An overall ecological evaluation of the various methods must also take account of other dimensions beside climate protection. For example, suckler cow farming methods, which are particularly detrimental to the climate, are regarded as particularly animal-friendly. They can also assume an important role in landscape conservation, such as maintaining extensively used grazing areas or nature reserves or using rewetted grassland.

8. Reduce the import of animal feed whose production is particularly harmful to the climate

German meat production currently shifts part of its GHG emissions abroad, namely to places where feed is grown which is then imported to Germany and fed to animals here. By increasing the pressure to exploit existing forest areas and the resulting clearance and use of former forest areas, the growing of soya in South America causes considerable negative impact on the climate on a scale of at least 10 Mt CO_2 eq., or possibly much more depending on the method of calculation. If one presupposes a limited area for agricultural use (and this is the case if further deforestation if to be avoided to protect the climate and biodiversity), the production of animal feed is also in direct competition with the production of foodstuffs.

In addition to the negative impact on the climate of crop growing, the greenhouse gas emissions caused by the transport of imported feed must also be taken into account. Compared with the corresponding organic farming methods, the carbon footprint of conventional pig and poultry farming in particular is considerably worsened by the climate effects attributed to the production and transport of imported feed.

9. Need for research into more climate-friendly agriculture and food

Exploring more climate-friendly options for land use

In order to make agriculture more climate-friendly, the effects of agricultural processes on the climate must be better researched and climate-friendly forms of livestock farming and crop growing developed further. In the livestock farming sector, for example, there are still considerable uncertainties about the impact of different farming methods on the climate. Further detailed measurement studies are required to provide sound proof of the differing emissions from different types of housing. Ethological and medical studies must also be undertaken to clarify which forms of housing and levels of performance (especially in dairy farming) are appropriate or defensible in animal welfare terms. That is the only way responsible decisions can be taken in those areas where the interests of animal welfare and climate protection collide. It is also important to find climate-friendly systems of land use which reconcile global and national food security, the production of biomass to replace fossil fuels, social issues of regional development as well as the requirements of environmental protection and nature conservation. This is also a particular task for socio-ecological research.

Need for research into more climate-friendly consumption patterns.

This study is deliberately focussed on the production-side aspects of the agricultural sector in order to elaborate the difficulties and potentials of climate protection in agricultural production. As the overall scenarios for reducing greenhouse gas emissions have shown, however, a consistent climate change policy would also require a restructuring of agricultural production. Without a corresponding change in consumer behaviour, food which could no longer be produced in sufficient quantities in Germany as a result of consistent climate change policy would have to be imported from abroad. This would export the GHG emissions and no climate protection effects would be achieved in global terms.

It is therefore essential to make the impact on the climate of different agricultural products and production methods transparent – which is also the intention of this study. Production and consumption patterns can only be changed in the direction of greater sustainability on the basis of transparent information.

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