Environmental effects of protein-rich food products in the Netherlands
Consequences of animal protein substitutes

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Summary

Blonk Milieuadvies and the Nederlandse Vegetariërsbond (Dutch Vegetarian Association) have studied the consequences of substituting vegetable proteins for animal proteins in the Dutch diet of protein-rich food products. Our research focused on the environmental impacts: the greenhouse effect and land use activities, with possible biodiversity impacts. With regard to the animal welfare issue we quantified the animals kept according to different substitution scenario's. The research generated the following insights:

- Dairy products and meat products both contribute substantially to the greenhouse effect and the impacts of land use for protein consumption in the Netherlands.
- Replacing animal proteins with vegetable proteins reduces the greenhouse effects of consumption. The size of the reduction depends on the choice of vegetable alternatives. It is estimated that if the whole Dutch population eats only vegetable proteins (vegan menu) a reduction of 6 megatonnes CO_2-eq/year can be achieved. This amounts to 3% of total Dutch greenhouse gas emissions and 4% of Dutch greenhouse gas emissions from the final consumption of goods. A vegan menu also reduces the area of land needed to produce protein products by 12,500 km^2*year, which is equivalent to 37% of the total land area of the Netherlands.
- These figures represent an extreme switch in the national diet, which is not realistic in the short term. A more realistic scenario, like one meat-free day a week (although still not achievable overnight), gives a potential reduction of 0.5 to 1.1 megatonnes CO_2-eq/year, depending on the animal protein content of the meat substitutes (many meat substitutes contain animal proteins such as chicken-egg proteins or parts of dairy products). The largest reduction can be achieved from one day a week free of dairy products, meat and eggs (a 'vegan' day). One dairy-free day has the lowest potential. One meat-free dinner a week has the potential to deliver a reduction of 0.6 megatonnes CO_2-eq/year. Replacing meat with dairy products like cheese does not generally bring about a reduction.
- Changing the type of meat consumed also has a great reduction potential. If only chicken meat were consumed, the greenhouse effect of the consumption of protein-rich products would be reduced by 3.5 megatonnes CO_2-eq. Land use would be reduced at a rate of 11,000 km^2*year.
- If the Dutch ate according to the Dutch healthy food guidelines the CO_2-eq/year would be reduced by 1.4 megatonnes and land use by 5900 km^2*year. A more healthy food pattern (less meat, more fish and a little more diary products) will therefore reduce the greenhouse effect and diminish biodiversity loss from land use impacts. However, the positive effects on biodiversity loss have been overestimated because the biodiversity effects of fisheries were not taken into account. On the other hand, the reductions in greenhouse gas emissions and land use might be higher because the average consumption used in this study may be an underestimate (Table 1).
- The consumption of soy and other vegetable commodities from South America or South East Asia, the regions with high deforestation levels, differs little between a more vegetable-based menu and the average menu in the Netherlands. For every diet it therefore remains important to stimulate more sustainable crop growing practices, for example by selective sourcing of crop commodities in the production chains of both animal and vegetable products.
  With regard to animal welfare issues, the absolute numbers of animals kept in animal husbandry systems will decrease if less meat is consumed. However, according to the Dutch healthy food guidelines a vegetarian menu includes dairy products and eggs, and so the number of chickens and calves that are needed to produce the desired amount of eggs and milk (in systems where

animal welfare level is judged to be very low) will increase. A vegan menu has no relation to meat production and alternatives would have to be found for animal by-products, such as their use in pet food or non-food applications.

1 Introduction

According to the FAO report 'Livestock's Long Shadow'[1], the global meat and dairy production chains are responsible for approximately 18% of the greenhouse effect and 8% of all water consumption. The report emphasizes that animal husbandry systems threaten the sustainability of natural resources as global demand for animal proteins rises.

Since 2007 the consumption of meat and its environmental effects have enjoyed a more prominent position on the Dutch political agenda. It is generally thought that shifting from animal to vegetable protein consumption has great potential for reducing environmental burdens. To explore this presumption the Dutch ministries of VROM (Housing, Spatial Planning and the Environment) and LNV (Agriculture, Nature and Food Quality) commissioned this research into the effects of substitutes for meat and dairy products in the Dutch diet. We focused on the consequences of replacing animal protein consumption in the Netherlands with vegetable protein consumption. The major environmental burdens taken into account were the greenhouse effect, fossil energy consumption and land use activities to produce the protein-rich products for ten different national menus. The migration of soil minerals and the consequences for the number of animals kept in conditions of low animal welfare were explored in outline.

2 Methodology

The research looked at the product level and the menu level. First, the environmental burdens of a large number of meat, fish, dairy, egg and meat substitute products were calculated. An attributional Life Cycle Analysis (LCA) was made of the average production chains of protein products on the Dutch market to calculate their greenhouse effect, fossil energy consumption and land occupation. For animal products, for example, the production of feed components, the transport and processing of feed, the feed conversion rate and manure management were taken into account (*Figure 1*). If several by-products are produced during the same stage (for example, meat and animal by-products after slaughter), the resulting environmental burdens were allocated according to their economic value. This 'economic allocation method' is frequently used in LCAs.
To calculate the environmental burdens per menu, a calculation tool was developed with 8 different modules:

- 5 Process modules
  - Agricultural production
  - Animal husbandry
  - Slaughterhouse
  - Animal product processing
  - Retail
- 2 Assembly modules
  - Feed assembly
  - Food assembly
- 1 Menu composition module

[1] Steinfeld, H. G., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. & C. de Haan, 2006. *Livestock's Long Shadow - Environmental Issues and Options*. FAO, Rome, Italy.

Environmental indicators
Four environmental indicators were investigated:

1. Greenhouse effect: kg CO_2-eq (GWP 100)

Three greenhouse gases were taken into account:

- CO_2 (carbon dioxide) = 1 CO_2-eq
- N_2O (nitrous oxide) = 296 CO_2-eq
- CH_4 (methane) = 25 CO_2-eq

The method for calculating emissions from products has been described in different reports and is still under construction.[2,3,4,5,6].For emissions of nitrous oxide and methane from soil processes and husbandry we used emission factors from the Dutch National Inventory Report (NIR), except for production in Ireland and Brazil.[7] The emissions taken into account were:

- fertilizer application and production
- emissions from animal breeding systems
- manure management and application
- emissions due to drainage of peatlands (oxidation)
- fossil fuel combustion and production
- materials for packaging (whole life cycle)

Emissions which were not taken into account were:

- emissions from land conversion or land occupation (because the methodology for allocating emissions to certain products is problematic and still under development); a sensitivity analysis was performed to estimate the significance
- greenhouse gas background emissions from natural areas
- emissions from capital goods or means of transport

2. Fossil energy consumption: MJp (3rd order Gross Energy Requirement value)

Apart from the energy content of fossil fuels, electricity use, the refinement of fossil fuels and the avoided energy use from the incineration of packaging materials were taken into account.

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[2] IPCC, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*. Kanagawa (Japan): Institute for Global Environmental Strategies.

[3] Guinee J., 2002. *Handbook on Life Cycle Assessment Operational Guide to the ISO Standards Series: Eco-Efficiency in Industry and Science, Vol. 7*. ISBN: 978-1-4020-0557-2.

[4] BSI, 2008. Draft PAS 2050. *Publicly Available Specification PAS 2050 – Specification for the measurement of the embodied greenhouse gas emissions in products and services*.

[5] Blonk, T.J. & B. Luske, 2008a. *GHG emissions of meat:contribution analysis, methodology issues and set up of an information infrastructure* – Draft. Blonk Milieuadvies, Gouda.

[6] Blonk, T.J., Kool, A. & B. Luske, 2008b. *Berekening van het broeikaseffect van tuinbouwproducten; methodiekissues en voorstellen voor berekening*. Blonk Milieuadvies, Gouda.

[7] Brandes, L.J., Ruyssenaars, P.G., Vreuls1, H.H.J., Coenen, P.W.H.G., Baas, K., van den Berghe, G., van den Born, G.J., Guis, B., Hoen, V., te Molder, V., Nijdam, D.S., Olivier, J.G.J., Peek, C.J. & M.W. van Schijndel. *Greenhouse Gas Emissions in the Netherlands 1990-2005: National Inventory Report 2007*. Netherlands Environmental Assessment Agency (MNP) report nr 500080 006.

3. Land occupation: m^2*year

Land occupation was chosen as an environmental indicator to reflect the growing conversion of land for agricultural practices worldwide. The remaining areas of natural vegetation are coming under increasing pressure and the carbon sequestration by vegetation is decreasing. The contribution by animal production chains to (largely unsustainable) land use has been identified as very significant. Land use can be considered unsustainable when remaining biodiversity values are low or when there is loss of minerals, loss of organic matter, erosion, salination, etc. It can also be defined as unsustainable when it involves deforestation, either directly or indirectly.

4. Land occupation in the regions South America and South East Asia: m^2*year

In certain regions, like South East Asia and South America, most recent conversions from natural to agricultural land use have been for oil crops, like soy and oil palms. Land use in those areas area is quantified separately.

Chosen products

A broad but limited range of 34 products were chosen for the menus (Table 2). The products were selected using detailed consumption statistics and an estimation of the type of products which need to be included to obtain a realistic estimate of environmental burdens.

Most meat products in Dutch supermarkets originate from intensive farming systems. Pork is the most consumed type of meat, either as fresh meat or processed in all kinds of assembled products. Chicken is the second most consumed type of meat in the Netherlands. Minced beef from Dutch dairy cows is also very popular. Other meat products consumed are mostly locally produced, as well as relatively small amounts of beef from more extensive farming systems in Ireland and Brazil, and lamb. Besides protein, meat contains iron and certain vitamins that have an important nutritive value for humans.

Dairy products like milk and cheese are important protein- and calcium-rich products and are consumed extensively in the Netherlands. This study includes only the consumption of fresh milk products. Milk powder and other dairy non-protein products, like butter, were excluded.

In the category of fish products a selection was made using consumption statistics, including salmon from aquaculture, shrimps, mussels and several other fishery products.

In recent years, all kinds of meat substitutes have come onto the market. Many of these products (such as vegetarian burgers) are assembled products containing a wide range of food ingredients. Besides ingredients like vegetables, grains or starch, they also include limited quantities of animal proteins like chicken-egg protein, milk protein or cheese.

A different category of vegetarian products are based on specific processed proteins. Quorn is a product made by fermenting fungi. Valess is a 'vegetarian' product made from milk. Meatless is a product made from wheat or lupine as a substitute for meat or fat components in meat products.

Data gathering

Data about the production chains of the protein rich products were obtained from national information guides and databases,[8][9] the international literature, FAO data on fertilizer use[10] and yields, and directly from food companies. Data from companies were often the only available recent source for information on processed (vegetarian) products.

Menu composition

In total 10 menus (diets) were defined. The baseline menu is the recent average consumption of protein products per person per day, compiled from the 1998 results of the Dutch food consumption survey (VCP), which is performed every five years.[11] The 2003 survey was less comprehensive than the 1998 survey and focused on a specific target group, and the 2008 survey results were not available during the study. The consumption levels of product based on the 1998 figures were compared with data from other sources of estimates of Dutch consumption, such as Statistics Netherlands (CBS) and production and apparent consumption statistics from trade associations. Overall, the 1998 VCP figures were close to the apparent consumption figures. In some cases, like meat, they showed slightly lower consumption levels (*Table 1*); for other products, like cheese, higher consumption levels were found. For reasons of consistency, the consumption levels from the 1998 survey were used.

Four extreme variants of the recent average consumption were compiled:
-a classic omnivorous menu that meets the guidance of the Dutch Food Centre (Voedingscentrum);
-a classic vegetarian menu;
-a totally vegan menu;
-a menu with no dairy products.
All the menus were assembled in such a way that the nutritional content (iron, calcium and vitamin B components) sufficiently resembled the classic omnivorous menu based on the guidelines of the Dutch Food Centre.

Apart from these extreme variants, five more feasible menus were compiled by replacing the animal protein content of the recent average consumption with meat substitutes in different ways. These menus are:
-one meat-free dinner;
-one meat-free day;
-one dairy-free day;
-one day with 'hybrid meat products' (meat products in which 25% of the meat is replaced by Meatless);
-one animal-free day.
These menus did not all contain exactly the same nutritive value (see *Table 2* for definitions of the menus).

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[8] LEI, 2008. LEI Binternet. Accessed on 10 June 2008 from LEI binternet: http://www.lei.wur.nl/NL/statistieken/Binternet/
[9] PPO, 2006. *Kwantitatieve Informatie Akkerbouw en Vollegrondsgroenteteelt*. Praktijkonderzoek Plant & Omgeving, Lelystad.
[10] FAO, 2002. *Fertilizer Use by Crop*. FAO, Rome.
[11] Voedingscentrum, 1998. *Zo eet Nederland. Resultaten van de Voedselconsumptiepeiling 1997–1998.*

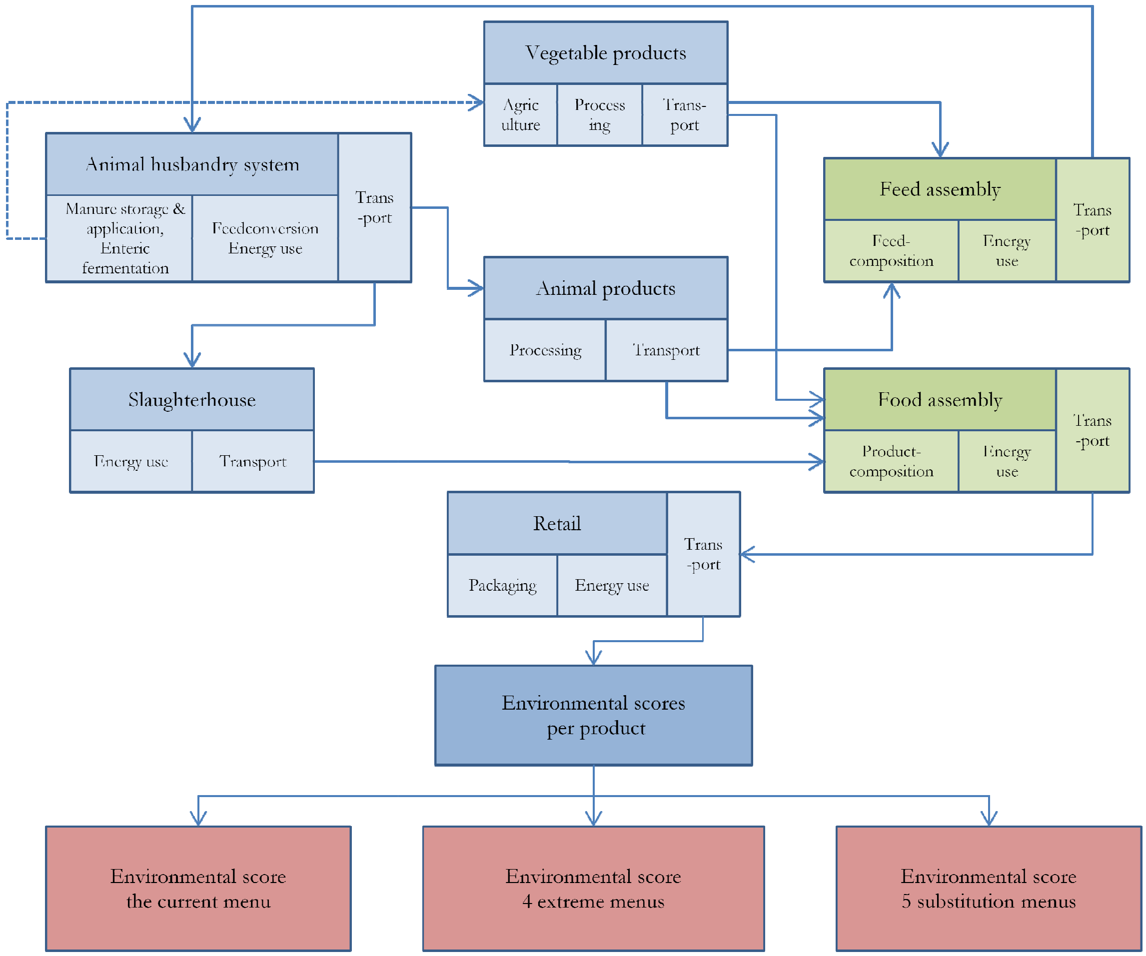

Figure 1. System definition

3 Results

3.1 Greenhouse gas effect

3.1.1 Results per product

The greenhouse gas (GHG) effects of the products were calculated across the production chain to the point of sale in a supermarket and reveal a wide range in effects. The scores for the meat products alone show a variation factor of 20. Brazilian beef is the meat type with the highest score, 60 kg CO_2-eq/kg, while Dutch chicken has a GHG score of 3.0 kg CO_2-eq/kg. Factors that influence the GHG score are:

- Feed conversion: Animals with a high feed conversion rate have to eat more to produce a certain amount of meat than animals with a low feed conversion rate. The more an animal eats, the higher the GHG score.
- Digestion process: animals with enteric fermentation live in symbiosis with bacteria that produce methane when digesting fibres.

Combining these factor leads to the conclusion that extensive farming systems, especially those with ruminants, have the highest greenhouse effect per kg. Animals in intensive farming systems, in which the animal husbandry systems have been designed to optimize growth and feed conversion, have the lowest GHG score. The GHG scores of the different meat types are shown in *Figure 2* and *Figure 3*.

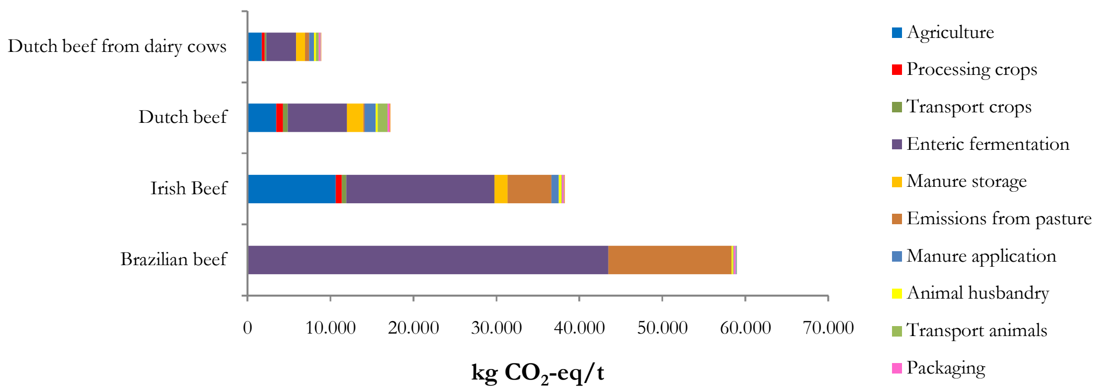

Figure 2. Greenhouse effect of several types of beef

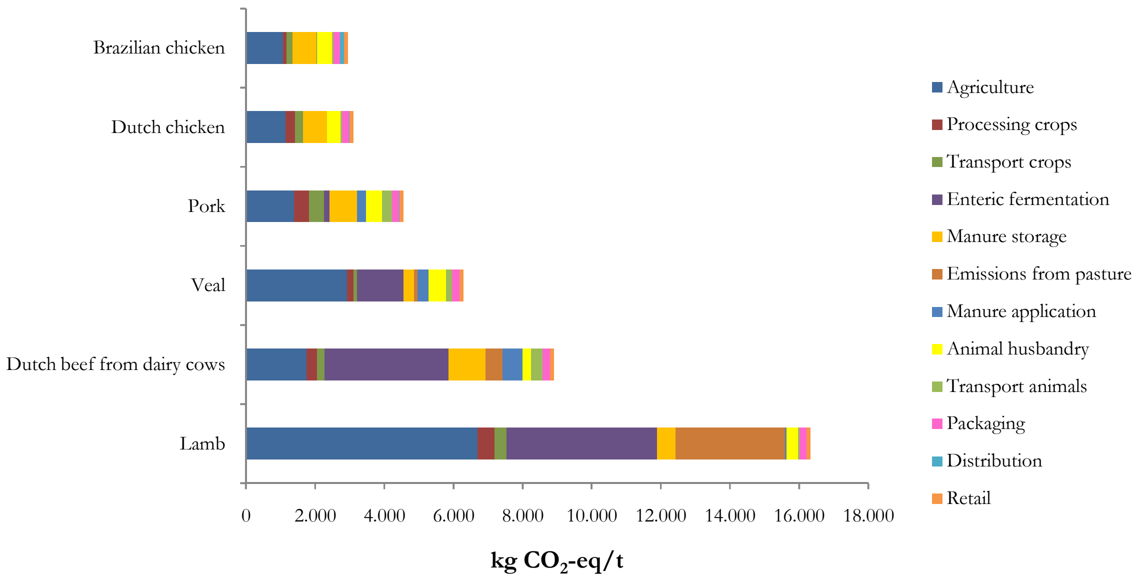

Figure 3. Greenhouse effect of several types of meat

The range in effects of meat and dairy substitutes is also very wide (*Figure 4*). Cheese, although not a real meat substitute (but in practice often used as one), has the highest GHG score (almost 9 kg CO_2-eq/kg). Meatless from wheat has the lowest score (0.5 kg CO_2-eq/kg), but cannot be considered a complete meat substitute on nutritional grounds. Most meat substitutes fall within a range of 1 to 2.5 kg CO_2-eq/kg. Many of these products contain proteins of animal origin.

Fish, crustacean and testacean products also show a variety of greenhouse effect scores, from 0.9 to 9 kg CO_2-eq/kg (*Figure 5*). Most of the greenhouse effect of fishery products is from the use of fuel during the fishery stage.[12] It must be noted that this is highly dependent on the type of vessel and the allocation of fuel use between the different by-catches made by a vessel.[13] Further research on this subject would be useful.

Beef, lamb, and dairy products have the highest greenhouse effect per kg of protein (minimally 30 kg CO_2-eq/kg protein). Pork has an average score of 24 kg CO_2-eq/kg protein and chicken meat is approximately half of this, 12 kg CO_2-eq/kg protein. The effects of the meat substitutes range from 6 to 20 kg CO_2-eq/kg protein, and fish products from 5 to 40 kg CO_2-eq/kg protein. In other words: if meat products are replaced with (vegetable) meat substitutes, on average a decrease in greenhouse gases can be expected. However, the size of the reduction is highly dependent on the specific substitution.

Between 30% and 70% of the greenhouse effect of protein products is caused by methane and nitrous oxide emissions. The highest fossil energy use per kg is for fishery products. Most vegetable protein products use less fossil energy than animal protein products, although extremes are found in both product groups.

[12] Thrane, M., 2004. Energy consumption in the Danish Fishery. Identification of keyfactors. *Journal of Industrial Ecology* 8(1):223–239.

[13] Thrane, M., 2006. LCA of Danisch Fish Products: New methods and insights. *International Journal of LCA* 9:1–9.

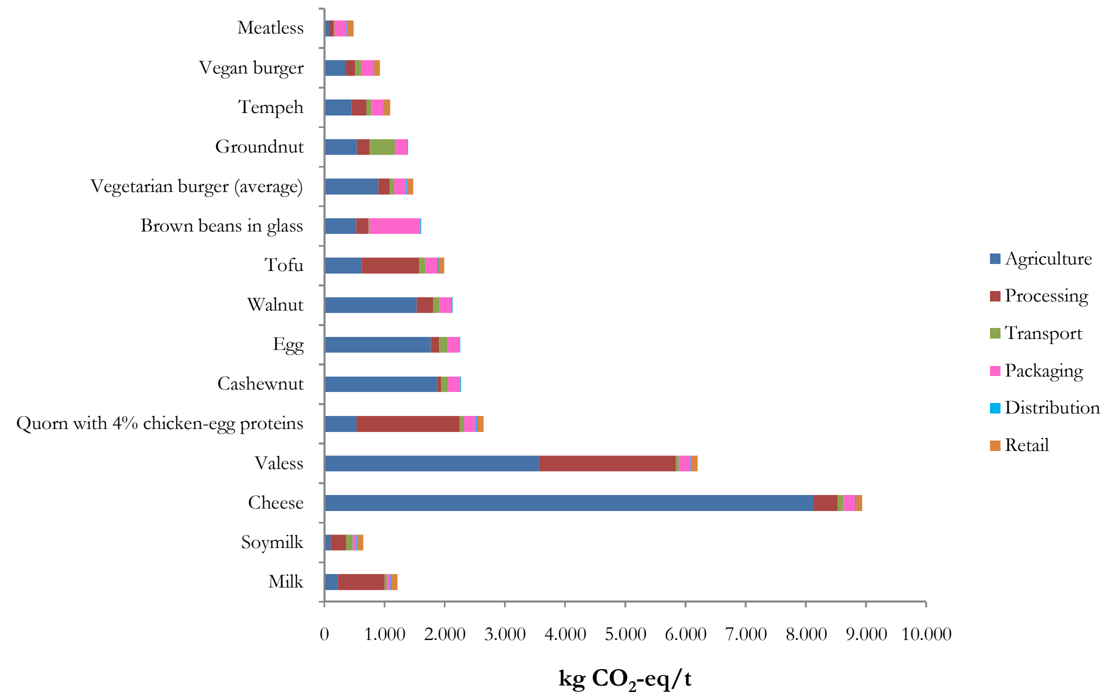

Figure 4. Greenhouse gas effect of dairy products, eggs and meat and vegetable substitutes

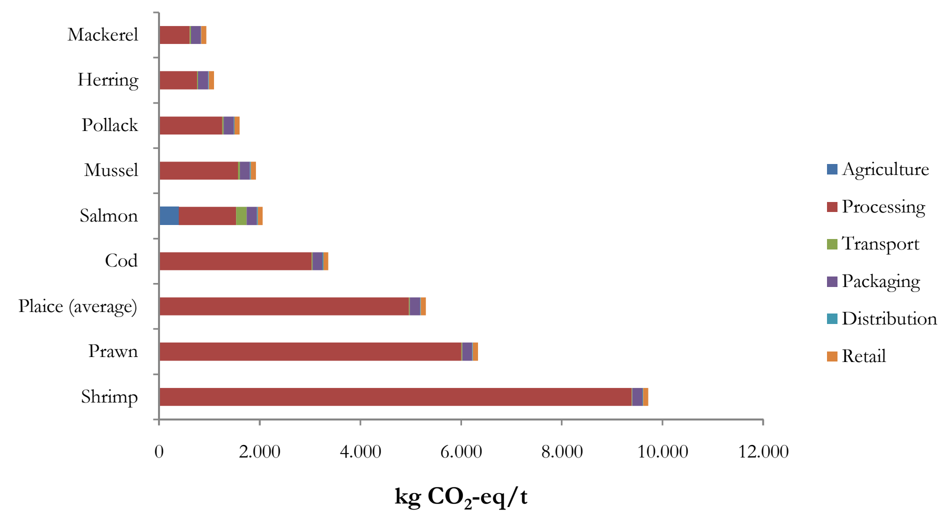

Figure 5. Greenhouse gas effect of fish, crustaceans and testaceans (only salmon is produced in aquaculture)

3.1.2 Results per menu

The protein content of the recent average menu of Dutch citizens has a GHG score of 1.7 kg CO_2-eq per person per day (pppd). More than half of this (54%) is caused by the consumption of meat products, with dairy consumption also making a major contribution (41%). A considerable reduction in greenhouse gases from the level of the recent menu can de achieved with a classic omnivorous menu that meets the good consumption guidelines (*Figure 6*). Replacing meat with dairy products generally has no reducing effect. A menu with less animal protein also has a lower greenhouse effect score. Of the less extreme menus, the most promising option is one vegan day a week (potential reduction of 12%).

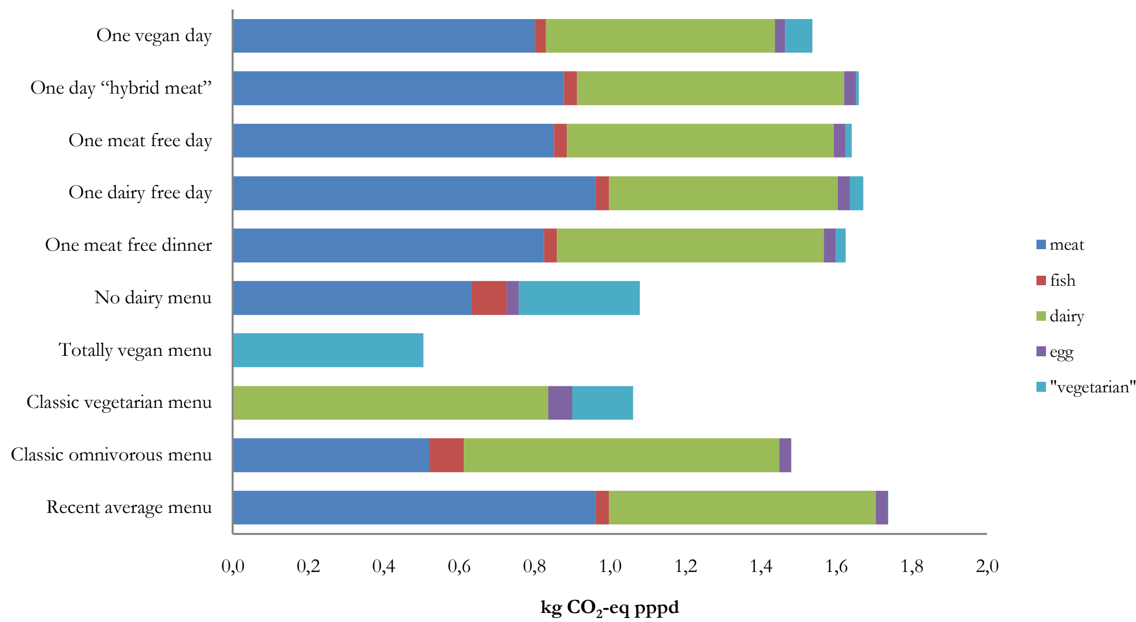

Figure 6. Greenhouse gas score for the consumption of meat, fish, dairy, egg and vegetarian products in different menus

3.2 Land occupation

3.2.1 Results per product

The areas of land used for the production of the different protein rich food products vary widely (*Figure 7* and *Figure 8*). The areas used for meat products vary by a factor of more than 90. The area of land used for the production of Brazilian beef is more than 200 m^2*year/kg, while for Dutch chicken it is 5.4 m^2*year/kg. Twice the amount of land is used for the production of lamb and beef than for pork, veal and chicken. An important difference is that the land used for the production of pork and chicken meat is arable only, much of which is for the cultivation of soy (35% and 60% respectively). Land use for Dutch and Brazilian beef is mostly grassland or nearby arable land for the production of fodder.

The range in land use for the meat substitutes is wide, varying by a factor of 100 (*Figure 9*). Cashew nuts have a low yield per hectare and have a land use score of 18 m^2*year/kg. Meatless is made out of wheat, which has a relatively high yield per hectare and a land use score of 0.3 m^2*year/kg. The amount of soy used to produce 1 kg of chicken meat is not necessarily higher than that needed for the production of vegetarian products. Producers of vegetarian products sometimes set higher standards for the cultivation and origin of the soy. Tofu, for instance, is made partly from biological soy and producers claim not to use soy from former deforested areas.

Except for cashew nuts, less land is used for the production of vegetable proteins (< 4 m^2*year/kg protein) than for the production of the same amounts of meat proteins (often > 4 m^2*year/kg protein). It must be noted, however, that on average the nutritive value of vegetable proteins is lower than that of protein of animal origin. In other words, one needs to eat more to get the same level of nutrition.

Aquaculture products take up land for feed production. However, many aquaculture species are (at least in part) fed with fish oil and fishmeal from fisheries. In this study land use for fisheries was not defined, although fisheries can have major environmental effects, including distortion of the food web at the ecosystem level and disturbing the sea floor. It will be worth including these environmental burdens in subsequent research.

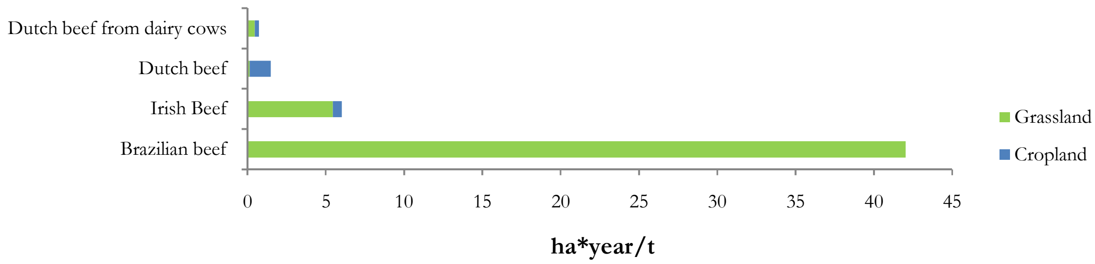

Figure 7. Land use for the production of beef in different farming systems

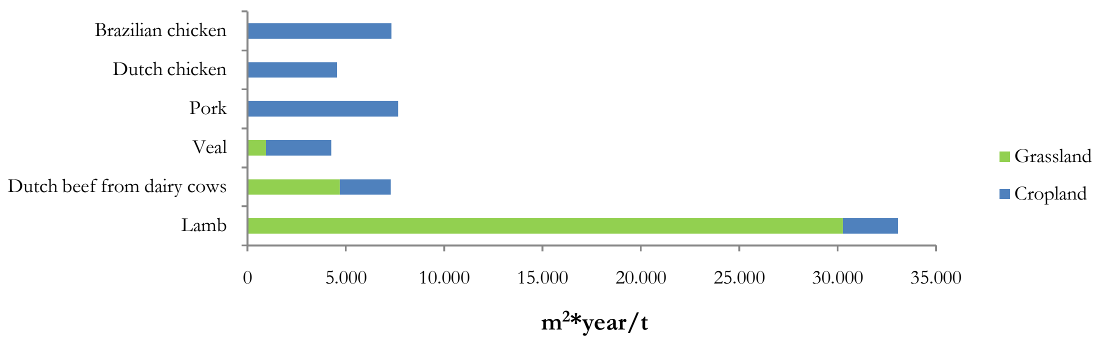

Figure 8. Land use different types of meat

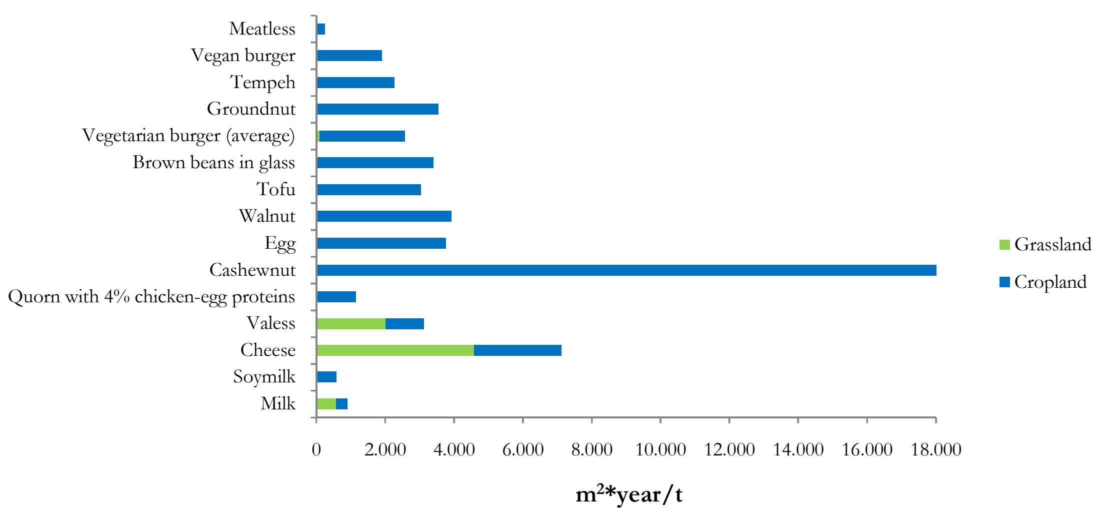

Figure 9. Land use for the production of dairy products, eggs, meat substitutes and vegetable protein products

3.2.2 Results per menu

The recent average consumption of protein products has a land use score of 18,000 km²*year. Approximately 9000 km² of this is extensive grassland in Brazil (8000 km²) and Ireland (1000 km²), and 4000 km² is for the consumption of other meat from more intensive animal husbandry systems. Land use for dairy products amounts to around 3000 km²*year, but has a more local character. The consumption of eggs in the Netherlands requires 350 km²*year, all of which is arable land (*Figure 10***)**.

Reducing the amount of animal protein in a menu also reduces land use (*Figure 11*).

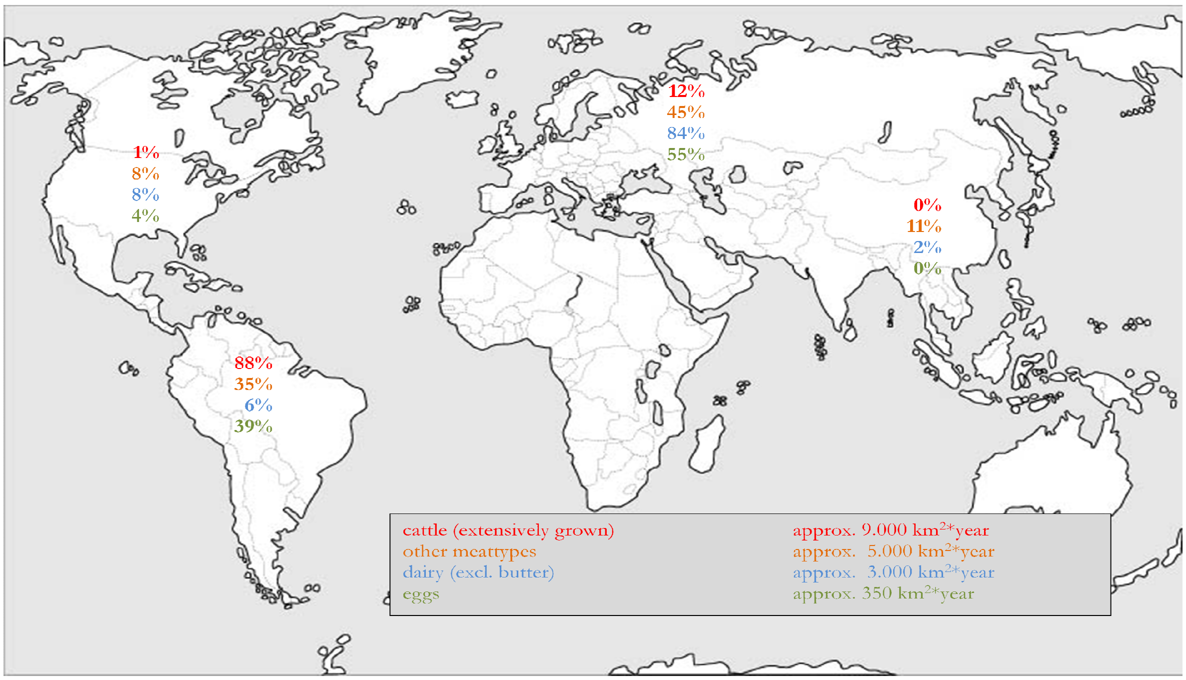

Figure 10. Land use in different regions for the recent average consumption of meat from cattle, more intensively reared types of meat, dairy products and eggs in the Netherlands

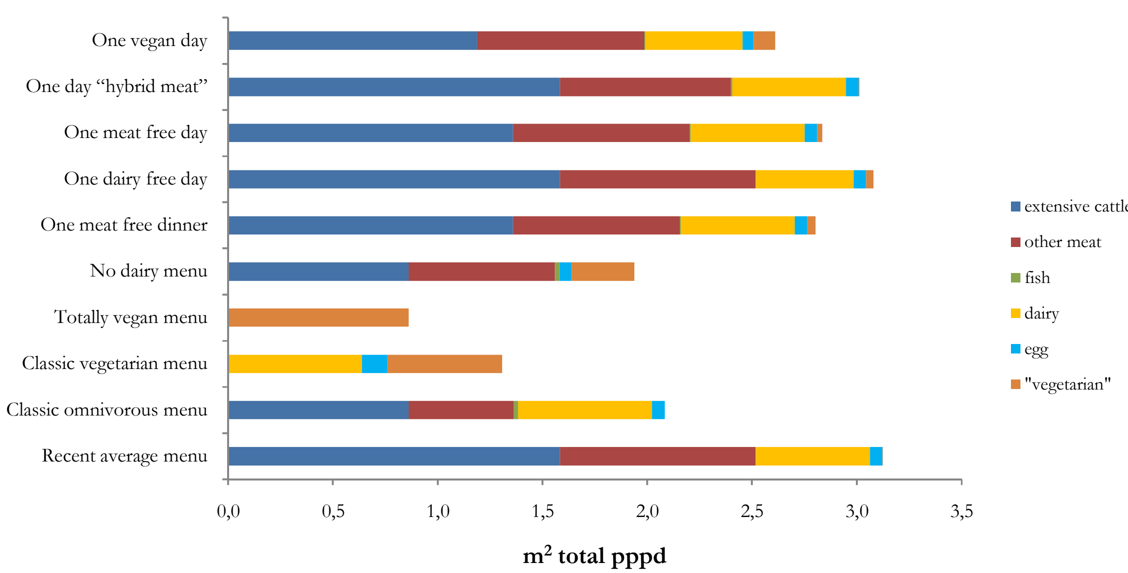

Figure 11. Land use for the consumption of meat, fish, dairy products, eggs and vegetarian products in different menus

3.3 Other environmental effects

3.3.1 Migration of minerals and metals

Two to six times as much vegetable protein is needed to produce a certain amount of animal protein. Converting vegetable protein to animal protein has two important environmental consequences: mineral exhaustion of soils in extensive pastureland and (especially in South America) significant impacts on local natural resources, and the accumulation of minerals in areas of high density animal production. The long distances in the global trade networks between the areas where feed or food is produced and where it is consumed by animals or humans mean that the accumulated minerals cannot easily be transported to depleted areas. Several solutions may be feasible, although they are not directly connected to consumption patterns.

Problems related to zinc and copper are very similar to those described above. Added via feed crops and fertilizers, these metals accumulate in the soil in intensive farming areas. Feed producers also add some zinc and copper to feed. The accumulation of these metals in Dutch soils is a neglected environmental problem.

3.3.2 Animal welfare

In the perception of consumers and experts, animal welfare in intensive animal husbandry systems is lower than in extensive farming systems. This is especially the case for chicken, veal and pork.[14] If the consumption of meat and meat products in the Netherlands were reduced, the numbers of animals reared for Dutch consumption and living in conditions with low welfare standards would also decrease. This is, however, not the case for all animals in animal husbandry systems. A vegetarian menu compiled according to the Dutch healthy food guidelines, for instance, has a higher egg and dairy component and therefore requires more chickens for eggs and more veal (connected to dairy production). Diary cows need to give birth to a calf once every two years to remain productive and about half of the calves will be bull calves, which are not suitable for dairy production. Moreover, most dairy farms use artificial insemination techniques instead of bulls and not all female calves are suitable for dairy production, which means that dairy consumption indirectly stimulates veal production. Animal production is avoided only if a vegan menu is consumed. Nonetheless, the absolute reduction in numbers of chickens and pigs in animal husbandry systems due to vegetarian consumption is much larger than the additional numbers of chickens and calves that are needed to produce eggs and dairy products. In total, fewer animals are kept in low welfare conditions.

3.4 Integrated comparison of some protein-rich products

Overall it can be said that the GHG scores, fossil energy use and land occupation (in South East Asia and South America) of the various meat types and meat substitutes are very different. Beef from Dutch dairy cows has a higher GHG score than pork – the type of meat consumed most in the Netherlands – and a similar land occupation score, but is located more locally (*Figure 12*). Most meat substitutes have a lower GHG score, fossil energy use and land use than pork. Cheese, however, has a significantly higher GHG score (*Figure 13*).

[14] De Jonge, F.H., Vaal, M.A., Jocelyn, J. & M. Ooms, 2008. *Kiezen voor Dierenwelzijn.* Varkens in Nood, Amsterdam.

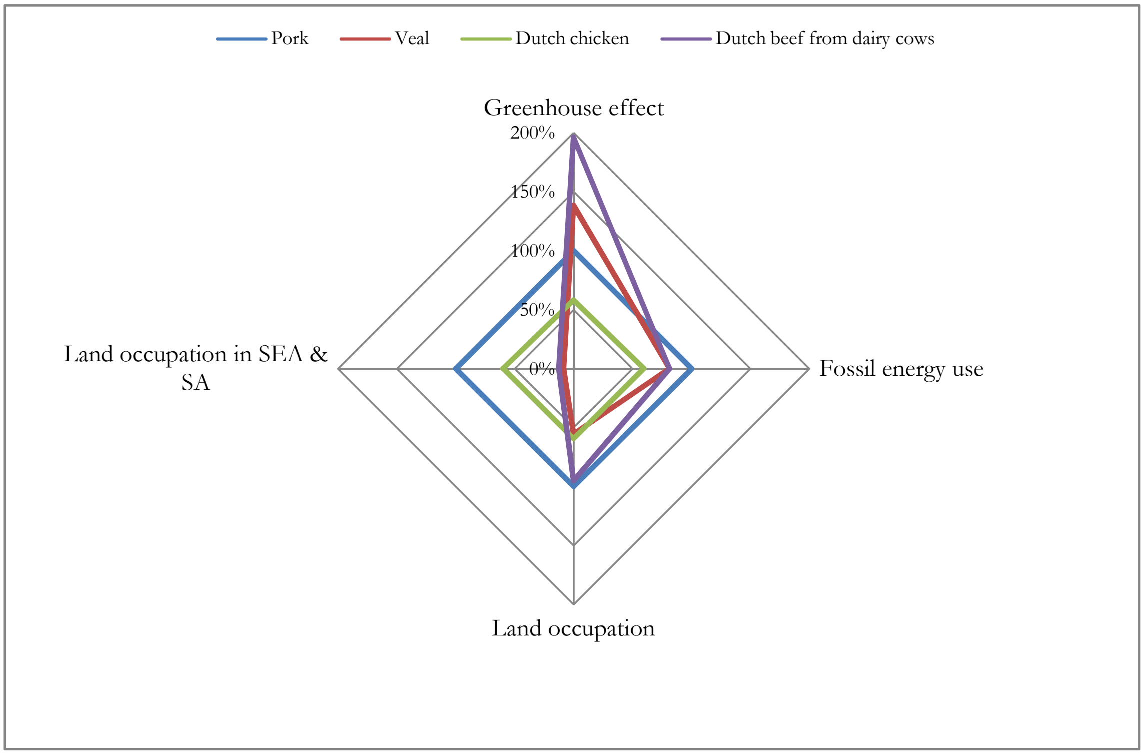

Figure 12. Environmental burdens of several types of meat compared with pork

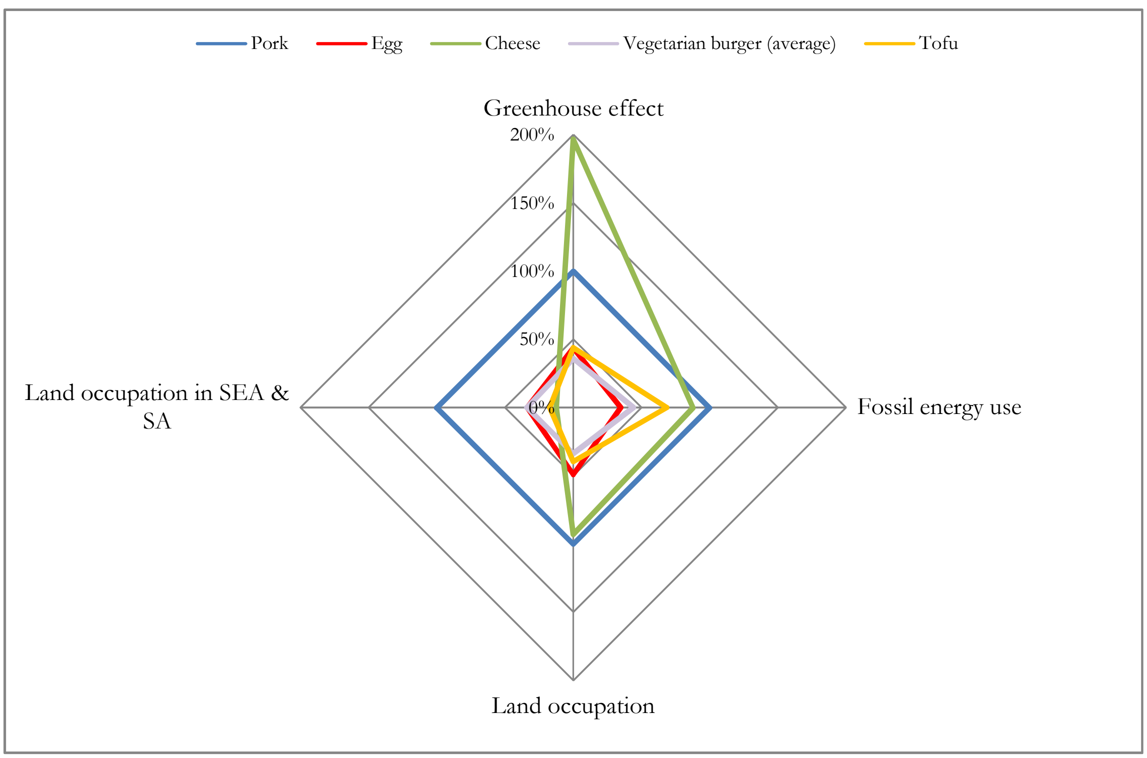

Figure 13. Environmental burdens of several meat substitutes compared with pork

4 Conclusions

4.1 Potential for reducing the greenhouse effect

The total greenhouse effect related to the consumption of protein-rich food products in the Netherlands is approximately 10 megatonnes CO_2-eq, which is nearly 5% of Dutch greenhouse gas emissions and nearly 7% of Dutch greenhouse gas emissions from final consumption.

- Replacing meat with vegetarian products with a low animal protein content (dairy products, chicken egg or vegetable oils) will reduce emissions significantly. Assuming that the average meat component in our daily food pattern is replaced with an average vegetable protein product, the reduction will be about 7 kg CO_2-eq/kg. On a yearly basis, complete substitution in the Dutch food pattern may save about 4 to 5 megatonnes CO_2-eq.
- A complete shift in the types of meat consumed may deliver a considerable reduction. Avoiding beef, in particular, has great reduction potential.
- Replacing meat with dairy products like cheese on average does not lead to a reduction in greenhouse gas emissions.
- Given the uncertainty about the exact composition of a totally vegetarian food pattern, the calculated reduction potential of a classic vegetarian menu, which also includes the consumption of dairy and egg products, is much less accurate. The reduction potential was calculated to be between 2 and 3.3 megatonnes CO_2-eq.
- Reducing the consumption of dairy products makes some reductions in greenhouse gas emissions if the substitute is soymilk and not greenhouse intensive types of meat (like chicken). The reduction potential may amount to 7 kg CO_2-eq/kg by replacing meat and 0.6 kg CO_2-eq/kg by replacing milk products. At the national scale, the potential may be 2–3.5 megatonnes CO_2-eq/year.
- The greatest potential for making reductions is by replacing both meat and dairy products with vegetable alternatives. At the national scale the reduction may amount 6 megatonnes CO_2-eq.
- Encouraging Dutch citizens to have one meat-free day or vegan day a week has a reduction potential of 0.6–0.7 or 1.1 megatonnes CO_2-eq/year nationally, provided that meat is not replaced with dairy products and that the reduction in meat consumption one day is not made up again another day.
- Encouraging the use of hybrid products may have a reduction potential of 0.5 megatonnes CO_2-eq nationally if 25% of all processed meat products are replaced with Meatless. Hybrid meat products have a reduced fat content and may also contribute to improved public health.
- The classic omnivorous menu that meets the guidelines for healthy food consumption could deliver a national reduction of 1.4 megatonnes CO_2-eq. This reduction potential may be larger if actual consumption levels are higher than the VCP concluded. As the Dutch guidelines for healthy food consumption are based on the recent Dutch situation, they result in a relatively high protein intake of dairy products, fish and meat.

4.2 Potential for reducing land occupation

The total are of land used for the consumption of protein-rich products in the Netherlands amounts to approximately 18,000 km²*year.

- Replacing an average kg of meat with an average meat substitute can reduce land use by 16 m². The reduction, however, is heavily dependent on the type of meat and meat substitute. Replacing intensively produced pork and chicken can reduce land use by 1–4 m²*year/kg substituted meat. The land use saving potential of replacing beef is between 4 and 400 m²*year/kg.
- Avoiding beef from extensive farming systems in the Dutch food pattern would significantly reduce the land use and greenhouse effect scores for the production of food.
- If the Dutch food pattern met the healthy food guidelines, land use for production would be reduced by approximately 33% to 12,000 km²*year. This is the result of lower meat consumption and higher fish consumption. Land use of the latter was not taken into account in this study because of the lack of a profound method.
- A vegetarian alternative food pattern in line with the healthy food guidelines has greater potential. Land use may be reduced to 8000 km²*year. Because this menu does not include fish, the land use value for the production of protein-rich food products is comprehensive.
- A vegan food pattern in the Netherlands will reduce land use to 5000 km²*year. As above, this estimate does not take account of the production of alternatives to animal by-products (*Figure 14*).
- A feasible menu with the greatest potential to reduce land occupation is the menu with one vegan day a week. The recent land occupation for protein-rich products will be reduced by almost 16% to 15,000 km²*year.
- One meat-free day or dinner could reduce land occupation by approximately 10% to 16,000 km²*year.

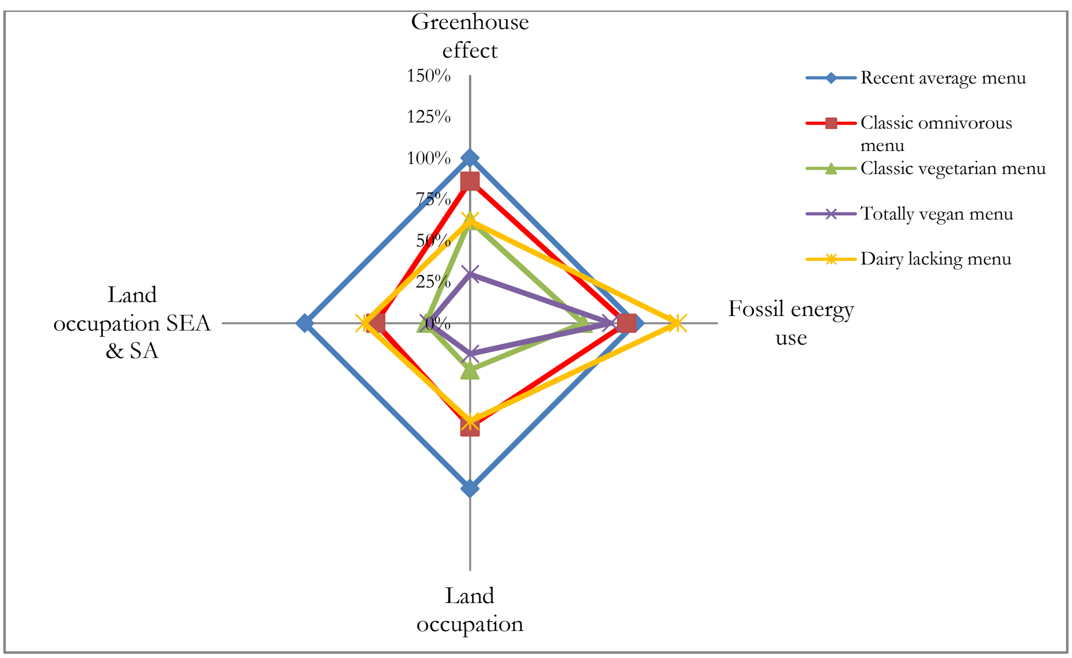

Figure 14. Environmental effects of the 4 alternative menus compared with the recent average menu

5 Discussion and recommendations for future research

The first comment concerns the uncertainty of the results, which is not defined in this study. The variation in the results is related to the premises in the calculations and the data, the uncertainties of which were not quantified.

The results of this study are useful to policy makers, non governmental organizations and other groups associated with sustainability in food chains. They show that the greenhouse effect and land occupation of the types of meat reared most extensively and under the highest animal welfare standards, like beef and sheep, are larger than animals from intensive farming systems. This contradiction between environmental impact and animal welfare makes the discussion about sustainable animal husbandry more difficult. Moreover, if the other environmental effects had been taken into account quantitatively, for instance the depletion and the emission and accumulation of minerals and metals, the environmental ranking might have been different. This report certainly does not give any definitive answers to the sustainability of meat production and consumption. What is important is that the discussion continues and that follow-up research remains focused on facts.

Avenues for methodological development could include investigating the use of grassland for dairy and meat production, and the effects of native and cultivated pastures on biodiversity.

The environmental effects of animal by-products and alternatives to animal by-products also deserve investigation. Lately the discussion about consumption and environment has focused on the consumption of meat, but meat makes up on average only half of an animal's live body weight. Slaughter by-products are used for a wide variety of applications: in food, pharmaceuticals, the oleochemical industry, fertilizers, feed components, etc. Altering meat consumption therefore affects other industries and applications, and withdrawal can lead to unforeseen environmental effects.

The land occupation of fishery products is still an unknown environmental effect in this study. It would be valuable to have a method for calculating the impacts of fisheries on biodiversity.

Research into the environmental consequences of altering dietary consumption patterns can best be broadened to comprise the total consumption of food products instead of just the protein-rich components. It is estimated that only 50% of the GHG effect of food production and consumption, including storage and preparation, is accounted for by the protein-rich component of the diet. Substitutes for protein products are probably interrelated on a dietary level with the replacement of many other products and the average menu of a vegetarian differs in many respects from the average menu of a meat eater. One observation of this study was the lack of reliable figures on a dietary level of how vegetarians eat. A second interrelation is the use of fat and vegetable oils for preparing meals. Production of animal proteins is accompanied by on average equal amounts of fat, which would create a serious rebound effect if preparing vegetarian products increased the use of baking oils.

Finally, exploring how changes in consumption patterns can alter the environmental effects of protein production raises the question of the environmental potential of optimizing current animal production chains. Answering this question is the first step towards meeting the challenge of making food production more sustainable.

Table 1. Dutch consumption pattern according to the VCP and other sources

	g pppd in accordance with VCP	kg pppy inclusive shrinkage, inedible parts	kg pppy inclusive losses at consumer	kt/y national scale according to VCP	kt consumed or sold according to other sources	Source
Potatoes, vegetables, fruit	342	162	179	2856	3400	On the basis of CBS[a] statline and Blonk (2004)
Bread	135	49	59	941	960	On the basis of CBS statline and Blonk (2006)
Drinks	1353	494	494	7904		
Meat, meat products, poultry	109	49	54	867	1000	On the basis of PVE[b] carcass weight converted to weight in retail
Seafood	10	4	4	70	PM	
Cheese	27	10	11	176	282	PZ[c] and CBS statline
Milk	383	140	147	2352	2100	PZ and CBS statline
Eggs	14	5	6	88	160	CBS statline, incl. eggs for the industry
Legumes	5	2	2	35		
Soy products	2	1	1	18		
Nuts, seeds and snacks	29	11	12	194		
Other products	230	84	92	1478		
	2639	963		15412		

[a] CBS – Statistics Netherlands
[b] PVE – Commodity Board for Livestock, Meat and Eggs (Productschap Vee, Vlees en Eieren)
[c] PZ – Dutch Dairy Board (Productschap Zuivel)

Table 2. Composition of the menus

Menu	Recent average menu	Classic omnivorous menu	Classic vegetarian menu	Totally vegan menu	No dairy menu	One meat free dinner	One dairy free day	One meat free day	One day 'hybrid meat'	One vegan day
Abbreviation	RA	CO	CV	TV	DL	MF dinner	DFday	MFday	Hday	Vday
Meat pppd	*109.0*	*58.9*	*0.0*	*0.0*	*86.1*	*93.4*	*109.0*	*99.6*	*94.8*	*93.1*
Fish pppd	*10.0*	*34.0*	*0.0*	*0.0*	*34.0*	*10.0*	*10.0*	*10.0*	*10.0*	*8.6*
Dairy pppd	*410.1*	*523.9*	*523.9*	*0.0*	*0.0*	*410.1*	*351.5*	*410.1*	*410.1*	*351.5*
Egg pppd	*14.0*	*13.8*	*28.0*	*0.0*	*13.8*	*14.0*	*14.0*	*14.0*	*14.0*	*12.0*
Vegetarian [15] *pppd*	*0.4*	*0.0*	*92.1*	*622.6*	*498.0*	*16.0*	*55.1*	*9.6*	*14.6*	*78.3*
Total pppd	*543.5*	*630.6*	*644.0*	*622.6*	*631.8*	*543.5*	*539.6*	*543.3*	*543.5*	*543.5*
Beef Brazil	2.6	1.4			1.4	2.3	2.6	2.3	2.6	1.9
Irish beef	2.6	1.4			1.4	2.3	2.6	2.3	2.6	2.3
Beef from Dutch dairy cows	13.9	7.6			7.6	11.9	13.9	11.9	10.4	11.9
Dutch beef	2.9	1.5			1.5	2.5	2.9	2.5	2.9	2.5
Pork	26.0	14.1			14.1	22.3	26.0	22.3	26.0	22.3
Pork meat products	33.0	17.8			31.3	28.3	33.0	33.0	24.8	28.3
Veal	1.5	0.8			0.8	1.3	1.5	1.3	1.5	1.3
Lamb	1.5	0.8			0.8	1.3	1.5	1.3	1.5	1.3
Chicken	15.0	8.1			21.6	12.9	15.0	12.9	15.0	12.9
Chicken meat products	10.0	5.5			5.5	8.6	10.0	10.0	7.5	8.6
Egg	14.0	13.8	28.0		13.8	14.0	14.0	14.0	14.0	12.0
Milk	383.0	498.0	498.0			383.0	328.3	383.0	383.0	328.3
Cheese	27.0	25.9	25.9			27.0	23.1	27.0	27.0	23.1
Salmon	2.0	8.5			8.5	2.0	2.0	2.0	2.0	1.7
Plaice	1.0	3.4			3.4	1.0	1.0	1.0	1.0	0.9
Mussel	0.5				0.0	0.5	0.5	0.5	0.5	0.4
Shrimp	0.5				0.0	0.5	0.5	0.5	0.5	0.4
Prawn	0.5				0.0	0.5	0.5	0.5	0.5	0.4
Herring	1.0	5.1			5.1	1.0	1.0	1.0	1.0	0.9
Mackerel	1.0	5.1			5.1	1.0	1.0	1.0	1.0	0.9
Cod	1.0	5.1			5.1	1.0	1.0	1.0	1.0	0.9
Pollack	2.5	6.8			6.8	2.5	2.5	2.5	2.5	2.1
Valess	0.1					0.1	0.1	0.1	0.1	0.1
Tempeh	0.1		15.2	7.6		0.1	0.1	0.1	0.1	10.0
Tofu			15.2	7.6		0.0	0.0	0.0	0.0	9.9
Soymilk				498.0	498.0	0.0	54.7	0.0	0.0	54.7
Brown beans in jars			11.4	22.8		0.0	0.0	0.0	0.0	0.0
Walnut			8.8	14.1		0.0	0.0	0.0	0.0	0.5
Cashew nut			17.6	14.1		0.0	0.0	0.0	0.0	0.5
Groundnut			8.8	28.1		0.0	0.0	0.0	0.0	1.0
Meatless				15.2		0.0	0.0	0.0	14.2	0.0
Vegetarian burger (average)	0.2		15.2			15.8	0.2	9.4	0.2	0.2
Vegan burger				15.2		0.0	0.0	0.0	0.0	1.4
Quorn with 4% chicken egg protein	0.1					0.1	0.1	0.1	0.1	0.1

[15] Vegetarian products often contain animal proteins like chicken egg proteins and milk proteins.