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Sustainable nutrition between the poles of health and environment

Potentials of altered diets and avoidable food losses

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Summary

This article provides a synopsis of the main research findings from the book "Environmental protection with knife and fork – the ecological rucksack of the nutrition in Germany" ["*Umweltschutz mit Messer und Gabel – Der ökologische Rucksack der Ernährung in Deutschland*"] [1], various peer-reviewed publications [2–5] as well as the underlying dissertation [6]. The first part of the article presents an overview of current challenges in the transdisciplinary field of nutrition, environment and public health. After a brief presentation of the methods, in the results section life cycle assessment results are presented on product and consumption levels and possible courses of action are derived. The final chapter discusses the courses of action identified and formulates recommendations for appropriate measures.

Keywords: life cycle assessment (LCA), National Nutrition Survey I + II, dietary recommendations, ovo-lacto-vegetarian, vegan, food losses, food wastages

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Introduction

Food is a private matter. But not entirely; nutrition is also characterised by a substantial common welfare component. This is due to how deeply it is embedded in ecological cycles as well as due to prevailing diet-related disease burdens and corresponding healthcare costs. Nutrition is therefore a key issue of sustainable development. Production and consumption practices, but also political and cultural frameworks decide to what extent environmental and healthcare systems are influenced by the provision of foods and drinks.

Background: Benefits and costs of nutrition

Costs of diet-related diseases

Providing the population with an adequate supply of healthy and varied food is one of the main tasks of the agricultural and food sector. However, the increasing prevalence of western dietary patterns [7] has sparked debate about the increased risks not only to people's health, but also to the environment. Western dietary patterns, which are also being adopted by more and more people in emerging and developing countries, generally lead to a quantitatively better supply for large population groups. On the other hand, the oversupply of calories and certain ingredients, such as saturated and trans-fats, haem-iron (primarily in red meat) as well as simple carbohydrates and salt, have been criticised for playing a major role in the development of chronic diseases. These include cardiovascular and metabolic diseases, certain cancers as well as diseases of the skeletal system [8]. Whereas infectious diseases are currently on the decline around the world, a large rise of chronic degenerative diseases is forecasted by 2030 [9].

In Germany, healthcare expenditures rose nominally from €213 billion in 2000 to €294 billion in 2011 – accounting for an increasing share of the gross domestic product (from 10 % to 12 % in this period) [10]. It has been calculated that for the year 1990 around 30 % of all healthcare costs were caused by nutrition-related factors [11]. Although there are no current data for nutrition-related healthcare costs, as part of the Global Burden of Disease Study 2010 [12] it was calculated that 19 % of the disease burden in Germany, represented as the total number of disability-adjusted life years (DALYs), was attri-

Glossary

Attributional input-output life cycle assessment (LCA): descriptive LCA based on statistically sound, representative data (often national statistics), as distinguished from a consequential input-output LCA (see [1])

Efficiency: describes input-output/cost-benefit relationships, as distinguished from effectiveness (describing the overall impact/overall direction of distinct measures)

Consistency: freedom from contradictions, coherence – the term means that different policies do not thwart each other in their effects or even lead to contradictory developments

Roughage: fodder with a high fibre content which is mainly used for feeding ruminants

Rebound effect: describes the fact that successful measures can also have an adverse impact instead of the desired effect, for example if technical efficiency improvements are cancelled out by excessive demand for the products in question

Sufficiency: (from Latin *sufficere* = suffice) the term is used in ecology to describe an interest in the lowest possible consumption of resources (land, fertilizers, energy etc.)

butable to an unbalanced diet (14 %) and excessive alcohol consumption (5 %). For this reason it can be assumed that a more widespread adoption of a balanced diet, based for example on the official guidelines of the German Nutrition Society (DGE), would result in a further lessening of the financial strain on the healthcare system.

Environmental impacts of agriculture and food industry

Currently, supplying food and beverages in industrialised nations is usually coupled with intensive agro-industrial production methods which depend heavily on resource-intensive inputs in upstream agricultural processes (from the production of fertilizers, pesticides, machinery etc.). At the same time, the value chains for goods, which are of relevance in the agricultural and food industries, span the entire world, meaning that feed, food and drinks are among the commodities with the largest transport volumes worldwide.

In Germany, in relation to the corresponding environmental impacts, modern dietary habits are contributing significantly to current problematic constellations. The spectrum of environmental impacts ranges from 95 % of all ammonia emissions to 15 % of the final energy consumption. Agriculture and food production account for more than 50 % of land use. In addition to the extent of agricultural land use, the type of land cultivation is also crucial when it comes to how much of an influence is there on naturally occurring flora and fauna. Further, the nutrition is responsible for approximately 25 % of greenhouse gases released into the atmosphere. In addition to domestic impacts, effects are also caused abroad as a result of how interwoven Germany's agricultural and food sector is with European and global trade. Production and consumption practices in Germany are thus contributing to an aggravation of internationally relevant problems. These include rainforest and biodiversity loss as well as the excessive use of scarce resources, such as fossil fuels, phosphorous and freshwater [13, 14]. All these factors need to be examined and discussed in terms of their overall societal and ecological sustainability.

Against this backdrop, this article identifies starting points for more sustainable nutrition practices whilst considering the conflicting fields of the environment and health. Further, potentials for reduction are quantified and possible solutions discussed. The focus here is on the ecological and societal/health dimension of sustainability, while the economic side was not investigated primarily.

The author's reflections are based on the concept of strong sustainability[1], as opposed to that of weak sustainability. One major difference between the two is in the substitutability (interchangeability) of distinct forms of capital: While the concept of weak sustainability permits unlimited substitutability of human capital, natural capital and man-made (produced) capital, this is not possible according to the concept of strong sustainability, because the latter regards natural capital as the underlying, necessary determinant for all human activities. Environmental protection is thus assigned greater importance (see example in the box) [18].

[1] A fundamental contribution on the concept of sustainability can be found in Ernährungs Umschau 9/2011, pp. B33.

The UN initiative "The Economics of Ecosystems and Biodiversity" (TEEB) estimated global welfare loss caused by agriculture to be more than 2.5 trillion (10^{12}) US dollars in 2009. This was in contrast to just 2.1 trillion (10^{12}) US dollars officially generated by agriculture. Therefore every dollar earned through agriculture goes hand in hand with collateral damage to society as a whole worth 1.2 dollars [15]. Despite the fact that this is a global average, this number gives food for thought. Economically speaking, if all external follow-up costs were factored in, then agriculture in its current form would clearly be a loss-making affair [5]. Of greatest relevance here are the effects of the non-sustainable use of land and water resources, followed by human- and eco-toxic effects, and the emission of greenhouse gases. In relation to all economic sectors, studies by ROCKSTRÖM et al. [16, 17] have shown that our planet's boundaries have already been far exceeded in terms of biodiversity loss, nitrogen pollution and climate change. By contrast, the states of the following indicators are assessed as critical: phosphate pollution, ocean acidification, changes in land use (in favour of farmland) and use of freshwater. All these indicators are significantly influenced by agriculture and food systems.

Invalidity of the 'weak sustainability' approach

Some examples of where human activity ultimately interfered too much with ecosystems providing services:

- the development of the island nation of Nauru, where extensive phosphate deposits were found and mined during the 20th century, ultimately rendering 80 % of the land unusable for the people living there [18],
- the decline of the Rapa Nui people on Easter Island in the mid-19th century as a result of deforestation and farming methods, which finally promoted an exceeding level of erosion,
- the occurrence of dust bowls in the US in the 1930s after the prairie grass had been cleared on a huge scale and winds blew the uncovered topsoil away (for more see [19, 20])

Objectives of ecological and societal sustainability in the agricultural and food sector

In terms of solutions to sustainability-related problems in the areas of agriculture and food, it is important to differentiate between the following research perspectives: whether an analysis occurs on the production side and/or the demand side. Production and product analyses usually aim to economically and ecologically optimise processes in order to generate more benefits at lower cost by introducing a more favourable input-to-output ratio (efficiency approach). This technical approach is indeed legitimate within the production-specific analytical framework, although it does not go far enough since it fails to provide an overall assessment of the demand for diverse products and services. More efficient technology and design means that technical progress alone (e.g., improved feeding strategies, fuel-efficient tractors or more efficient coffee machines) usually leads to lower unit costs, and in turn lower sales prices for end consumers. Hence, up to a certain point of market saturation, such reduced prices can induce stronger demand, causing a so-called rebound dilemma [21]:

Environmental gains through a more efficient and thus more cost-effective production of goods are thus cancelled out by an increase in demand, which can ultimately lead to a net burden on the environment.

In an attempt to solve this problem, the strategy triad of efficiency, sufficiency and consistency was developed in the transdisciplinary research field of industrial ecology. HUBER [22] argues that it is only possible to open up a "truly sustainable development path" if the results of efficiency improvements can be reconciled, without any contradictions (i.e. consistently), with global environmental objectives. However, bearing in mind how vulnerable efficiency improvements are to rebound effects, this can only succeed if they are accompanied by sufficiency-based measures. On the level of nutrition policies, this means action aimed at counteracting increased consumption [23, 24].

Consequences for agriculture and nutrition

In order to embark on a "truly sustainable development path" in agriculture and nutrition, efficiency improvements in production, processing and as well as the in the in-home and out-of-home market are necessary, but these improvements are not enough. Sufficiency plays a role in avoiding food losses in agriculture and in the value chain as well as in avoiding food wastage in households, but with regard to society as a whole it cannot be an option. This is because nutrition is about supplying the human metabolism with not just a sufficient, but an optimal supply of macro- and micro-nutrients.

In view of the fact that the term 'sufficiency' is not only associated with preventing increased consumption, but also with abstinence, it is not

satisfactory to completely transfer the three criteria of efficiency, sufficiency and consistency to the agricultural and food sector. In addition, the fact that human beings are omnivores means they are able to feed themselves optimally from a variety of foods. As a result, to some degree they are able to replace some foods with others without damaging their health.

So in order to pursue a "truly sustainable development path" in the field of nutrition it is necessary to specify the notion of sufficiency and to reintroduce the criterion of substitution. In accordance with the *Zeitgeist*, one might also describe this criterion as transformation – transforming the old in favour of the new, or replacing the old with the new [25]. When applied to agriculture and nutrition, the three modified criteria of efficiency, sufficiency and substitution can be described, under the umbrella of consistency, by the following key questions:

1) **Efficiency:** How efficiently can agricultural commodities and foods be produced, processed, distributed, prepared and disposed of?

2a) **Sufficiency in terms of food losses/wastage:** To what extent can food losses be reduced in agriculture, along the value chain and in households?

2b) **Sufficiency in terms of consumption:** To what extent can groups of people with a positive energy and nutrient balance (overweight, obese) reduce their food intake?

3) **Substitution:** To what degree can foods whose production is resource-intensive be replaced – by consumers in households (consumption practices) but also in the food industry (recipe reformulation) – by offering more environmentally friendly and yet equally nutritious alternatives?

Since processes of production and consumption are inevitably intertwined depending on the products supplied, to a certain degree it is conceivable to take action within all of the above mentioned strategies on the production and consumption side in order to reduce environmental impacts. However, their success is determined by how heavily integrated any environmental protection policies are in both areas, and how well coordinated these are. For example, on the one hand more efficient refrigerators need to be developed and produced. On the other there is a need for informed consumers, who can actually afford to demand these products. This example could also be applied to more environmentally friendly coffee machines, stoves, etc. and finally also to more environmentally friendly foods and drinks.

In order to function optimally whilst at the same time taking into account the need to provide a healthy, balanced diet – so in order to be consistent – environmental protection must always be considered equally from a production and consumer perspective. Otherwise any potential may fizzle out or be nullified by rebound effects.

Method in brief

In order to not only qualitatively describe solutions, but also quantitatively demonstrate their potential, an analysis of representative production, supply and consumption statistics was performed by way of an attributional input-output life cycle assessment (LCA) according to ISO standard 14040/44 [26]. Regarding the agro-ecological assessment, data from the reporting module "Agriculture and Environment" from the System of Environmental and Economic Accounts (SEEA) [27] was used. This was extended by adding LCA data from upstream agricultural processes (fertilizers, pesticides, buildings) as well as from downstream processes (manufactoring, trade/transport, cooling, packaging).

Environmental indicator	Impacts on humans and nature
Greenhouse gas emissions (in CO_2e emissions)	Global warming, climate change, shifting of climate zones, extreme weather (droughts, flooding etc.) and resulting conflicts and migration
Ammonia emissions (in NH_3 emissions)	Acidification and eutrophication of water and soil, loss of ecosystem services, odours
Land use	Soil vitality, displacement of other ecosystems and their biodiversity, loss of ecosystem services
Blue water use	Water depletion, water scarcity, water stress and resulting water conflicts
Phosphorus use	Depletion of finite resources (resulting in resource conflicts), radioactivity, water eutrophication
Primary energy use	Depletion of finite resources such as coal, crude oil, natural gas (resulting in resource conflicts)

Tab. 1: **Impacts of environmental indicators on humans and nature** [1]
CO_2e = CO_2-equivalents

The system boundaries ranged from the agricultural production to the point-of-sale (in supermarkets, wholesalers). The system boundaries were thus defined as cradle-to-store. Related emissions in the use phase (individual transport to home, cooking and storing in the household/in restaurants) and in the waste phase have not been taken into consideration. A detailed description of the underlying method can be found in the publications [1–6] mentioned in the summary on page 22.

The whole array of food and beverages produced for humans was described using 24 product groups, which were applied equally in the National Nutrition Surveys. Corresponding environmental impacts were examined based on six environmental indicators (◆ Table 1).

The data on the food intake in Germany are based on the National Nutrition Surveys I and II from the years 1985–89 and 2006 [28, 29] – considering the dietary habits of around 25,000 and 19,000 people, respectively. It should be noted that data from the first National Nutrition Survey were only collected in the former West Germany. The data from the Nutrition Surveys enabled an evaluation not only of the national average, but also according to gender, age group, social group and federal state.

To answer the question of what ecological potentials are linked with healthy, nutritionally-balanced diets, a comparison was performed with the following dietary recommendations:

- Recommendations of the German Nutrition Society [30], which are valid in Germany, Austria and Switzerland (D-A-CH). Since 2013 they also explicitly consider a number of aspects of sustainability, such as climate protection.
- Recommendations of the Federation for Independent Health Consultation (*Verein für Unabhängige Gesundheitsberatung*, UGB) with less meat, but more legumes and vegetables). Besides health considerations these recommendations are also based on ecological and social constraints (e.g., preferably the intake of organically produced food). These process-specific recommendations have not been considered in the analysis [31].
- Recommendations of the US Department of Agriculture and US Department of Health (USDA/USDHHS) concerning ovo-lacto vegetarian and vegan diets [32]. In addition to recommendations on a standard diet, the Dietary Guidelines for Americans (2010) also includes food-based recommendations, which should be followed by those on an ovo-lacto vegetarian or vegan diet.

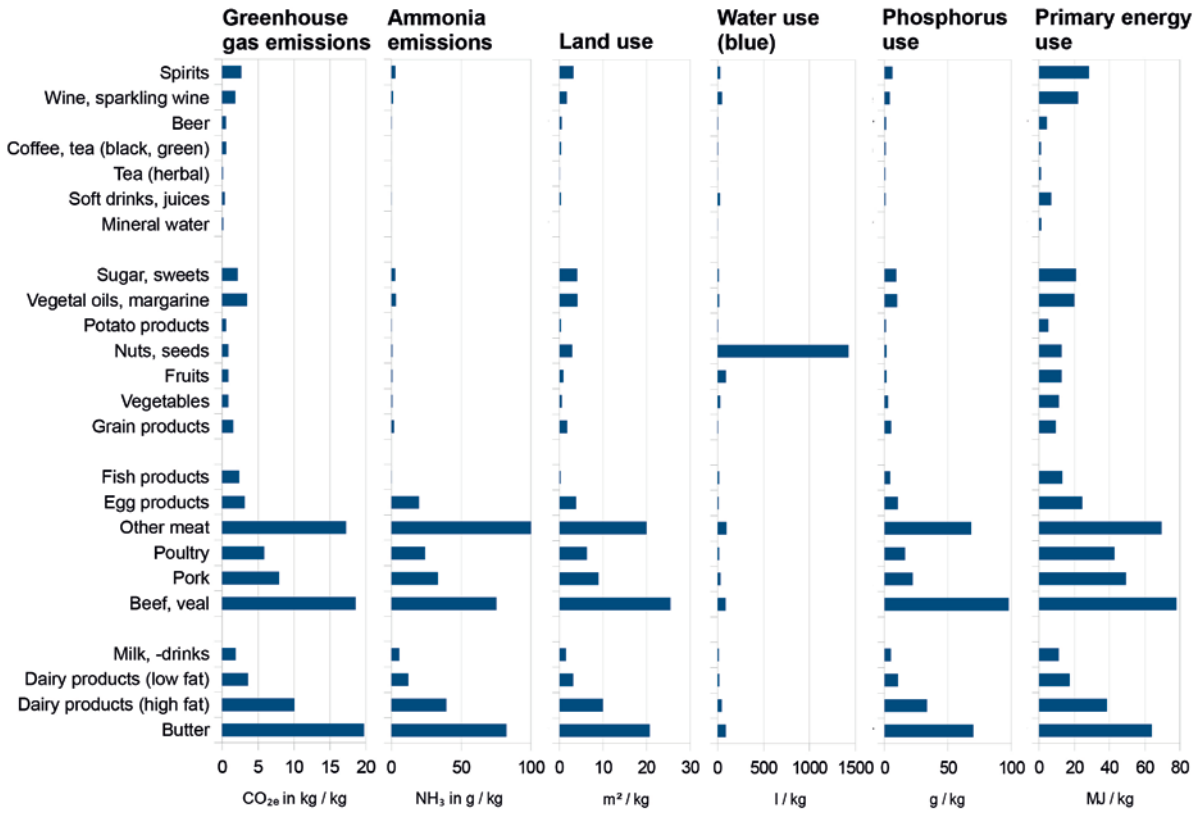

Fig. 1: **Environmental effects of foods and drinks (based on one kilogram)** [1]
Co_2e = CO_2-equivalents

Results I

An ecological map of food consumption in Germany

The results paint a clear picture when it comes to individual products (◆ Figure 1). Based on one kilogram of food, animal products, especially beef and veal as well as butter, display the highest environmental burdens. Drinks are dominated by spirits and wine/sparkling wine. All information provided here relates to the average product form available at the point of sale in Germany in 2006. In the case of wine/sparkling wine, for instance, this means: one kilo of fermented grape must in a disposable glass bottle with a wooden cork, sold in the retail food trade (usually a supermarket). 45 % of the grapes used for the wine were produced in Germany, and the other 55 % abroad. A detailed description of the underlying representative data for the products' respective life cycle stages can be found in [1].

When it comes to plant-based products, a more serious environmental impact per kilogram of product than in the animal products was only seen in terms of blue water use (◆ Box: "Focus: Blue water"), especially in the case of nuts and seeds. This can be explained by the fact that supplies of nuts and seeds considered in 2006 (peanuts, almonds, hazelnuts, sunflower seeds, walnuts, pistachios and cashew nuts) were predominantly produced in water-scarce southern countries. At 12,000 litres per kilogram of product, the water needed for pistachios – most of which were harvested in Iran – was highest. However, it should be emphasised here that the assessment only took into account so-called blue water, which is relevant from the viewpoint of water scarcity.

Taking population data in 2006 and the representative environmental factors presented in ◆ Figure 1 together, it was possible to extrapolate the data to the overall environmental impact of nutrition in Germany on a national level. The corresponding results are shown in ◆ Table 2. ◆ Figure 2, which provides a relative representation of the table's absolute values, shows that overall food and beverage consumption in 2006 caused significant environmental impacts abroad. At approximately 1 700 million m^3, the largest foreign share based on agricultural production is accounted for by blue water requirements, followed by land use at 58,500 km^2 and the greenhouse gas emissions released abroad, which amounted to 41.7 million t CO_2e.

For reasons of clarity, only a few selected results related to land use are shown in the following. As mentioned in the introduction, the aspect of agricultural land use is the most severe in terms of overall societal welfare losses. Key questions include: How much land is needed to support a healthy diet sustainably? What types of land are necessary for this? And, how intensively is this land cultivated?

◆ Figure 3 provides an overview of the land use of the foods consumed on national level. The largest area was needed to meet the demand for pork. Of the 40,000 km^2 of arable land required for this, around a third was located abroad, mainly due to the production of soy for animal feed. In the case of dairy products, which are also highly significant in terms of their land use, the foreign share is lower. Furthermore, due to the ability of ruminants to digest roughage, dairy products are still largely produced based on grassland (pastures and meadows). This can be regarded as a positive aspect, given the increased biodiversity and higher humus content of grassland compared to

Focus: Blue water

So-called **blue water** is the water that is in principal available to households and industrial enterprises, due to the fact that it is transported to the point of use via streams, rivers, and sometimes lakes and reservoirs, and finally water pipes. However, if the water is diverted beforehand for agricultural irrigation purposes, this can exacerbate water conflicts in producing countries.

It has to be distinguished from so-called **green water**. This term applies only to rainwater. Since it is only relevant where it falls as rain, snow or fog, its use does not compete with other sectors of consumption (such as private households or industry). As soon as green water remains on the Earth's surface and enters the natural water cycle via streams, rivers or gutters, it counts as blue water and is consequently taken into account in blue-water related LCAs.

Another category of water is so-called **grey water**. This is polluted wastewater which, for example, leaves a nut plantation laden with fertilizer and pesticides once it has been used for irrigation purposes. Grey water is thus not used as an indicator of water scarcity, but toxicity. Since there were no reliable data on the level of overall consumption patterns, grey water was not examined.

Studies which use a non-weighted sum total of all three water categories (blue, green and grey) without differentiating between the three should be regarded critically. This non-weighting aggregation merely produces artificial results, which can no longer be interpreted constructively and may therefore be likely to contribute to general confusion [33].

	Greenhouse gas emissions	Ammonia emissions	Land use	Water use (blue)	Phosphorus use	Primary energy use
	in million t CO_2e	in 1 000 t	in 1 000 km²	in million m³	in 1 000 t	in PJ
Production (domestic)	95.2	498	133.9	426	440	464
Production (abroad)	41.7	45	58.5	1 694	111	187
Processing	20.7	0	–	397	–	195
Trade, Transport	13.6	0	–	–	–	166
Packaging	17,9	0	0.45	142	–	219
Sum	189.0	544	192.9	2 659	552	1 231

Tab. 2: **Environmental impacts of total dietary consumption in Germany in 2006** [1]
CO_2e = CO_2-equivalents

arable land. Something which is also significant and in part unavoidable is the import and associated land use abroad of the product groups fruit, confectionery (due to cocoa), vegetable oils and fats, vegetables, coffee and tea.

From a purely commercial, economic point of view, there is nothing wrong with imports and exports or the 'trade in land' this implies. For example, while coffee and cocoa do not thrive in a central European climate, rye can be grown most efficiently in areas with a temperate climate. In terms of the environment, the only critical aspect turns out to be where countries' overall land use runs a deficit – when they 'import' more than they 'export' in order to satisfy the demand for food and drinks. This is a state which cannot function if transferred to a global level, since it is not currently possible to produce food on extra-terrestrial land – and nor will it be in the foreseeable future.

For Germany, however, this scenario is a reality. While only around 21,000 km² of land was 'exported' in the form of agricultural goods, virtual imports totalled around 64,000 km². So the net land deficit was some 43,000 km², which represents roughly 12 % of the domestic area of Germany. This additional area was exploited abroad. On the global level, for decades we have been seeing unbalanced land use practices as the area used for farming and grazing has expanded steadily – at the expense of natural areas, biodiversity and ecosystem services, which depend on these [34].

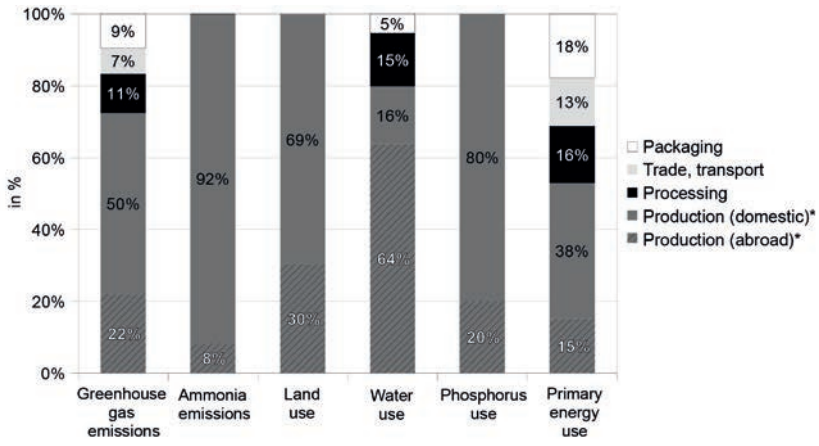

Fig. 2: **Environmental impacts of total dietary consumption in Germany in 2006 (relative)** [1]
*incl. emissions in the agricultural upstream chain (fertilizer, machinery production, etc.) as well as emissions from direct land use change (dLUC) and land use (LU)

Results II

Land use of different dietary patterns and avoidable food wastage

The average land use for nutrition per person in 2006 was 2,365 m² per year. Around a third of this (707 m²) was covered abroad, primarily for the production of the following products (in decreasing order of relevance): feed (soybean meal, palm cake), vegetable oils (soybean and palm oil), fruit, cocoa, coffee, vegetables and wine. Statistically, around 260 m² of land per person was exported in the form of agricul-

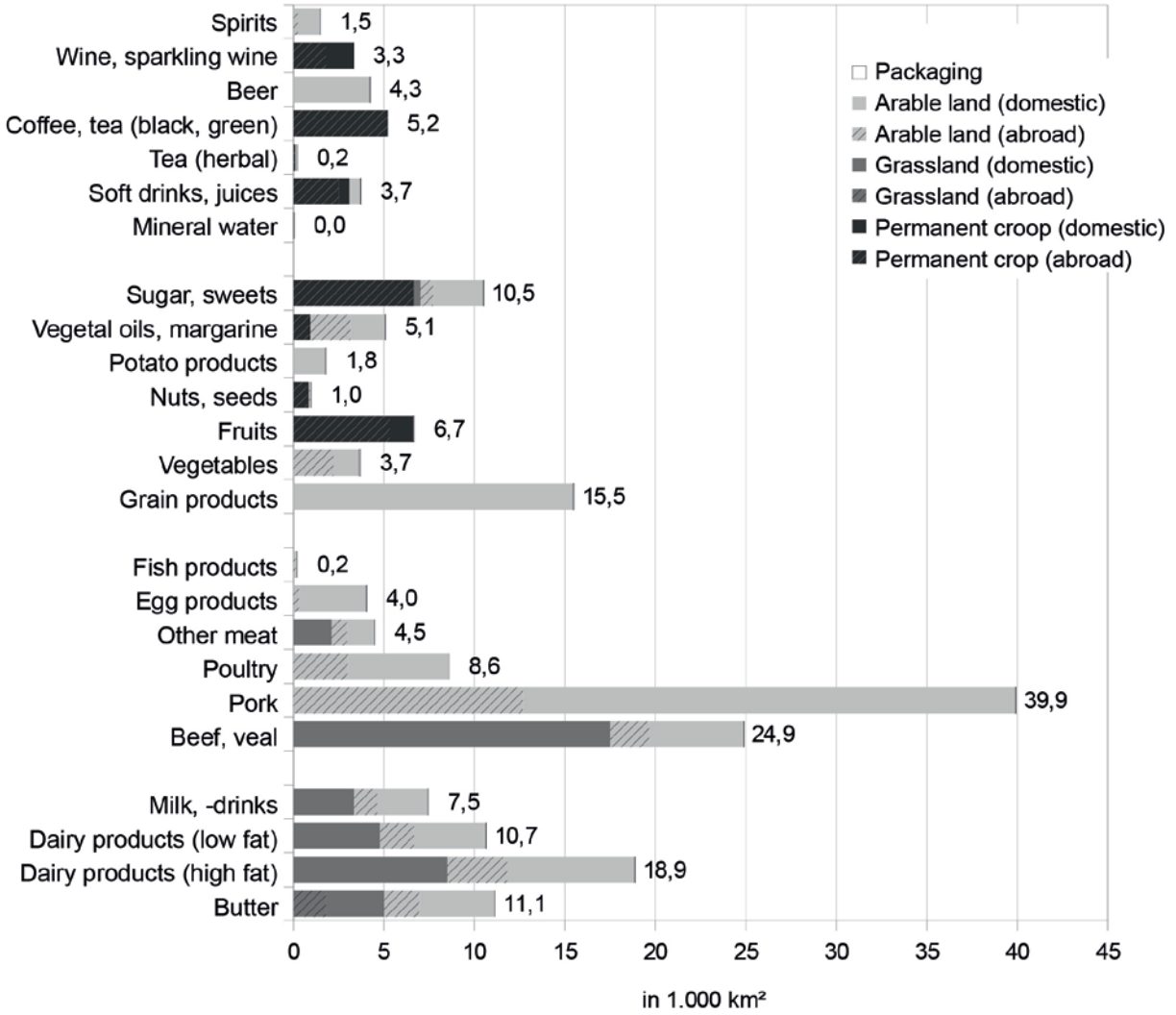

Fig. 3: **Total area required for the consumption of food and drink in Germany (in 1 000 km²)** [1]

tural products (mainly cereal, dairy and meat products). The remaining 445 m² represents the net area virtually imported per person and year.

In order to solve this land dilemma, we therefore investigated the question of what actions could be taken to offset this land deficit, on both the per capita and national level. Two approaches were considered:

- Firstly, in a retrospective comparison of the past five decades (1961–2007) diet-related environmental impacts were analysed. On this basis it was possible to derive clear tendencies for future developments. Results in particular concerning the years 1985–89 (National Nutrition Survey I) are shown in ◆ Figure 4.

„Which measures would apply to compensate for the land use deficit per capita and on country level?“

- Secondly, the potential for various actions to bring about change was investigated. A distinction was made here between two options.

(1) Bearing in mind the need to ensure a diet which is not just sufficient but as healthy as possible, on the one hand we calculated the environmental impacts resulting from the official dietary recommendations mentioned earlier.

(2) On the other hand the potential for reducing waste was investigated. Based on current data it was thus possible to estimate what the environmental gains

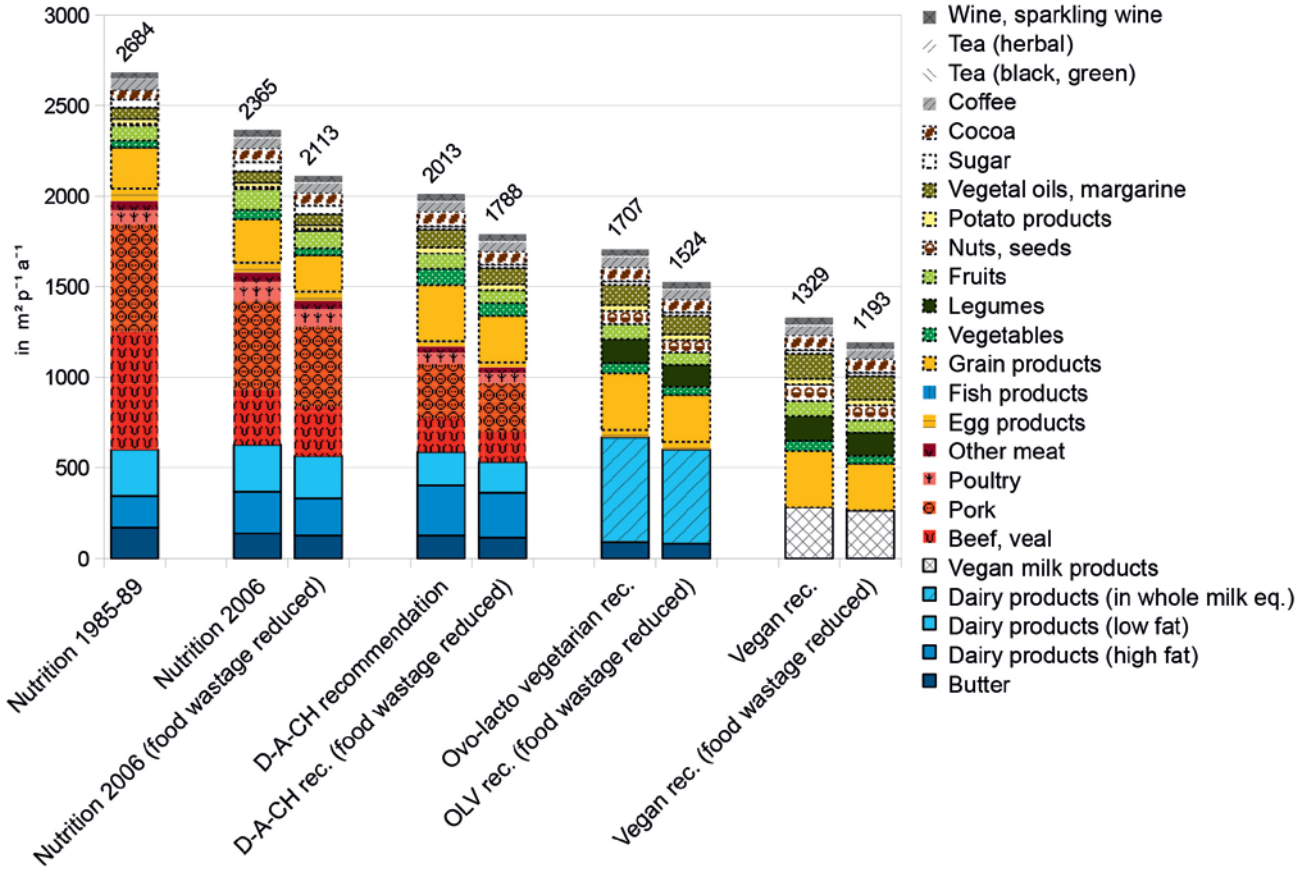

Fig. 4: **Land use for various dietary patterns and reduced food wastage in Germany (in m² per person and year)**
D-A-CH = Germany, Austria, Switzerland

would be if still edible food did not end up in the bin. In Germany, this amount is equivalent to 105 kg per person and year. 22.5 kg of this can be attributed to processing, 6.7 kg to food retail and wholesale, and 23.0 kg in the out-of-home market. In households, 53.0 kg of waste per person and year could be avoided [35].

As the results in ◆ Figure 4 show, regardless of dietary habits a reduction in avoidable food wastage could help achieve a land saving of around 10 %. However, based on the current situation (nutrition in 2006) this alone is not enough to solve the land dilemma described.

In order to at least offset Germany's land use deficit, the land required annually for nutrition would have to be no more than 1 848 m² per person. Even if everyone followed the dietary recommendations of the German Nutrition Society (DGE, D-A-CH), this would fall just short of the target. However, if the DGE's recommendations were applied in combination with a reduction in food wastage, this target could be achieved.

An ovo-lacto-vegetarian diet would result in a land use surplus, and a vegan diet even more so. This would free up large areas of land at home and abroad which, depending on the political democratic agenda, could be used for other things (for energy generation, as an ecological compensation site, for conservation purposes, etc.).

In this context, developments seen over the last two decades can be described as positive. Largely as a result of changes in consumption patterns, there was an average decline in land use of 12 % compared with the first National Nutrition Survey (nutrition in 1985–89). This is primarily due to the reduced consumption of beef and veal. However, quite a different picture was seen in the case of blue water (not shown here). Due to an increase in the consumption of fruits as well as nuts and seeds, the water requirements of nutrition have risen over the past two decades. If the supply situation from the year 2006, when nuts and seeds were predominantly imported from water-poor southern countries (Iran, Turkey, Spain), were applied to the dietary

recommendations, this would lead to an additional exacerbation of existing water conflicts in these countries. Given this situation, the consumption of domestically grown nuts and seeds is recommended.

Furthermore, the studies on which this article is based [1–6] showed that not all population groups would have to be addressed in the same way in order to exploit the potentials described. If different age and gender-specific nutritional needs are taken into account, it tends to be younger and middle-aged men who differ from the dietary recommendations the most. Consequently, they would have to make the greatest contribution in order to release the identified potential. However, there are also potentials among the female population for reducing the burden. An added complication in relation to the male population is the fact that the generally positive changes seen in people's dietary habits over the last 20 years tended to be caused mainly by women. This would imply that men were less willing to change their behaviour, something which should be taken into account in decisions on health and environmental policy. Various nutrition policies and their effectiveness and practicability are presented in Lusk et al. 2011 [24] and Meier et al. 2014 [4].

Conclusion

Non-sustainable production and consumption practices lead not only to an undesirable influence on scarce ecological resources and associated ecosystem services, but also to a substantial burden on healthcare and intra-generational tax distribution systems.

If the aim is to pursue corresponding environmental and health targets in a manner as effective and consistent as possible, then the agricultural and food sector should be viewed as an overall system because of its considerable potential impact. Bearing in mind the requirement to support a diet that is as healthy as possible, three basic strategies are available in order to reduce environmentally harmful effects:

1.) Efficiency improvements by way of a) production technology in agriculture, upstream sectors and the food industry as well as in restaurants and households, by way of b) agricultural production methods[2] (conventional, organic, conventional/organic optimised). However, rebound effects are possible here.
2.) Avoidance of food losses and wastage in production and processing as well as in distribution and in the use-phase.
3.) Changes in dietary patterns by replacing resource-intensive food and beverages with more resource-efficient and yet equally nutritious alternatives.

Although not directly examined, the saving potentials of technical changes (efficiency improvements) are estimated by other authors to be below 20 % [36, 37]. Taking just the yield increases of the past few years of the world's most important crops – maize, rice, wheat and soy – into consideration, these amounted to just 1.2 % per year on average. As such, if dietary patterns remain unchanged then these will not be enough by far to meet the nutritional requirements of 9 billion people in the year 2050 [38].

It was shown in the article that in Germany the potential to reduce the environmental burden by changing eating habits is far higher, and depending on the indicator investigated may be up to 90 % (ammonia emissions with a vegan diet). If the relatively moderate dietary recommendations of the German Nutrition Society (DGE) are taken as a basis, then reductions of around 15–20 % can still be expected. Furthermore, reducing avoidable food wastage could achieve an average saving potential of 10 %.

Overall, in terms of environmental benefits, consumption-side changes are more effective than taking action on the production side.

Accordingly, all three strategies should be pursued rather equally. If action is taken politically, by public institutions, by businesses or by other associations in order to reduce the environmental burden related to the consumption side, it should still be remembered that not all consumers can contribute equally to nutrition-related environmental benefits. The primary target group to address should be young and middle-aged men. Nevertheless, savings could potentially also be made among the female population. A comparison with the consumption situation in the late 1980s has shown that within the span of 20 years consumption changes have occurred which have resulted in a significant lessening of environmental impacts by 10–20 %. One exception however is the demand for blue water.

The greatest potential for environmental protection would result from a vegan, followed by an ovo-lacto vegetarian diet.

[2] Both conventional and organic agriculture have biophysical, "natural" limits of productivity. The question whether the world better be fed organically, conventionally or in a mixed form of organic/conventional must be answered elsewhere.

Given current production structures in the German agricultural and food sector, these diets, if adopted nationally, would involve a partial shift of production and the associated environmental impacts abroad. However, the domestic potential for environmental protection is significantly higher than the additional environmental burden this would cause abroad. In order to prevent such a shift abroad, this positive net impact would need to be accompanied by regulatory controls aimed at creating incentives for local producers to produce the corresponding products (vegetables, fruits, nuts/seeds, legumes).

From a public health perspective, the recommendation of a vegan diet should be thoroughly scrutinised, as the risk of potential deficiencies among certain population groups (infants, children, the sick, pregnant women, nursing mothers, elderly) is higher than with other diets.
Nevertheless, practice has shown in the US and Australia that it is possible to have recommendations concerning an ovo-lacto vegetarian diet, and even a vegan diet, added to the official catalogues of dietary guidelines. Subject to certain restrictions, the recommendations apply there from the age of two [39, 40]. In view of the significant potential for environmental protection these two diets offer, it should be considered whether to include these in the guidelines of the German Nutrition Society (DGE). With regard to a vegan diet, in order to minimise the risks of a potential undersupply of essential nutrients – especially protein, vitamin B_{12} and calcium – in susceptible population groups, the recommendations should be formulated for specific groups depending on the nutrients they require.

Solid data base essential

Conclusions can also be drawn in terms of the underlying data. Political decisions should be evidence-based and therefore require a solid basis of assessment. In terms of national departmental research, the analysis included results from the two National Nutrition Surveys (Max Rubner Institute) conducted in Germany as well as results from the German System of Environmental-Economic Accounting in the area of agriculture (Thünen Institute); these were supplemented using information from official agricultural statistics. In future, in order to continue to be able to answer diet-related ecological questions which are of national relevance, the underlying data mentioned should not only be updated regularly, but also be supplemented by additional aspects:

- The Nutrition Surveys should also gather additional socio-demographic data which have a bearing on the environmental impacts of nutrition, such as information about shopping habits, waste levels, kitchen equipment, self-sufficiency etc.
- For the reporting module of the System of Environmental-Economic Accounts in agriculture, it is important on the one hand that this is continued beyond the year 2010. On the other, it should be extended to include further environmentally relevant aspects in order to allow comprehensive conclusions to be drawn not just on the biophysical level, but also in terms of externalized monetary costs. The reporting module should also include the fishing and food manufacturing industries.

In order to embark on a "truly sustainable development path" in the area of agriculture and nutrition, it is further necessary to introduce sustainability analyses as standard and integrate these firmly within processes of corporate, economic and political decision-making.

Conflict of Interest
The author declares no conflict of interest according to the guidelines of the International Committee of Medical Journal Editors.

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