Just eating healthier is not enough: studying the environmental impact of different diet scenarios for the Netherlands by Linear Programming

Marcelo Tyszler*,Gerard F.H. Kramer, Hans Blonk

Blonk Consultants, Gouda, The Netherlands
* Corresponding author. E-mail: *marcelo@blonkconsultants.nl*

ABSTRACT

Eating healthier or vegetarian and vegan diets are suggested options to reduce the environmental impact of the current diet. In this paper we investigate different scenarios and assess the reduction of environmental impact after restoring the nutritional adequacy by replacements. We used Linear Programming to find solutions that are as close as possible to the current diet, first without any food groups' constraints and later by imposing constraints on meat, fish, dairy and eggs. Finally, we use a similar technique to search for the closest diet that achieves the same environmental reduction as the most restricted option (no meat, fish, dairy or eggs), without restrictions on products. We show that it is possible to find less restrictive solutions than vegetarian or vegan diets that satisfy all nutritional requirements and have less environmental impact than the current one. Most important, these are closer to the current diet.

Keywords: Linear Programming; Food Policy and Nutrition; Environmental Impact; Greenhouse gas emissions; Food patterns

1. Introduction

Global food production faces a big sustainability challenge, which comprises many aspects. Global agriculture is the main contributor to biodiversity loss, water resource depletion and soil degradation due to the extent of land occupation and current farming practices (Searchinger et al. 2013). Searchinger et al. (2013) states also that the production of crops and animal products today releases roughly 13 percent of global greenhouse gas emissions (GHGe); the conversion of forests, savannas, and peat lands to agriculture roughly accounts for an additional 11 percent of global GHGe and that the ongoing expansion of cropland and pastures is the primary source of ecosystem degradation and biodiversity loss. Naturally, these estimates are uncertain and better monitoring of agricultural emission is needed (Tubiello et al. 2014). However there is broad consensus that in order to decrease the demand for natural resources and reduce GHGe food consumption and production have to become more sustainable, especially because the world's population is still increasing rapidly. The Food and Agricultural Organization (FAO) estimates that by 2050 agricultural production has to be increased by 70 percent (FAO 2011).

The central question is how to decrease the impact of the food system. There are two complementary routes: improvements on the supply side and changes in the demand of foods. Sustainable intensification of crop production (FAO 2010) and implementing technologies and practices to reduce emissions from livestock production (Gerber et al. 2013) have huge potential, as can be illustrated by the differences in GHGe from dairy worldwide (Hagemann et al. 2012). Changing food patterns and reducing food spoilage at home are some of the more direct options at the demand side. This paper focusses on food patterns with a lower environmental impact.

Several authors suggested that, for example, making healthier choices or adopting to Mediterranean type diets could reduce the impact (Duchin 2008; Carlsson-kanyama and Gonzalez 2009; van Dooren et al. 2014). This was contradicted by Vieux *et al* (2013) who compared self-selected diets from a French dietary survey on GHGe. They also pointed out that this approach does not take into account the effort that consumers have to make to adopt these dietary changes. An elegant way to design alternative options is to apply Linear Programming (LP) to minimize the amount of necessary changes in the current diet (Maillot et al. 2010). At the same time the inclusion of nutritional restrictions in the LP model safeguards an adequate intake of nutrients and energy.

In this paper we study the environmental impact of a few scenarios. We start with the current average Dutch diet of women between 31 and 50 years of age and search for the closest healthy diet, which satisfies all nutritional requirements. This will show that just eating healthier is not a guarantee of a more environmentally friendly diet. We continue by analyzing three predefined dietary interventions in which different types of animal-based products are eliminated from the diet. In particular we look at two common vegetarian-type diets and a vegan diet that also excludes dairy and eggs. Finally, we compare the necessary changes in these scenarios with an optimal solution calculated by LP after imposing only a restriction on the total environmental impact, using the same

target as can be reached maximally with the scenarios with product restrictions. Based on these analyses we obtain a good impression on how to find a food pattern which is not only healthy, but also low on environmental impact. Moreover, this diet pattern remains as close as possible to the current average situation.

2. Methods

2.1. Reference Profile and Nutritional requirements

As a case we have chosen a non-active woman between 31 and 50 years of age. This group was chosen because it has a relatively high requirement for iron, which can become critical if meat, an important source of iron, is removed from diets (Macdiarmid et al. 2012). Nutritional requirements were defined in close cooperation with the Netherlands Nutrition Centre (Voedingscentrum, The Hague) and are a compilation of the Dutch Food-Based Dietary Guidelines (FBDG) (Voedingscentrum 2011), national (Gezondheidsraad 2001; Gezondheidsraad 2006) and international recommendations (WHO et al. 2007) for energy and nutrients. To promote variation of diet, constraints were set on the maximum amount of each product in a weekly diet.

2.2. Current average Dutch diet

A simplified weekly current average Dutch diet is modelled with 207 products out of 1599 consumed by the survey population (n=3819) of the Dutch Consumption Panel (Rossum et al. 2011). This selection consists of the items contributing most to the total intake of the survey population (about 80% by weight). To compensate for the eliminated products, we scaled the remaining ones in such a way that the total amount within each product group was equal to the original average. The nutrient value of the observed average diet and our current diet was very similar[1].

2.3. Nutritional and Environmental data

Food composition data, including macro- and micronutrient content, was obtained from the Dutch Food composition table (RIVM 2011) while data on essential amino acids was collected from the United States Department of Agriculture Database (USDA 2012). Representative data on Greenhouse Gas Emissions (GHGe), Fossil Energy Use (FEU) and Land Occupation (LO) of all foods was collected from various sources and modelled from cradle to grave, including retail phase, the consumer phase and end of life of packaging materials (Kramer et al. 2013). Corrections were made for un-edible parts, raw to cooked ratios (RIVM 2012) and avoidable waste (Van Westerhoven and Steenhuizen 2010).

The individual environmental indicators were used to calculate a weighted score, based on the ReCiPe method (Goedkoop et al. 2013), which we call *p*ReCiPe. By combining the characterization, normalization and weighing factors of these three indicators we reach the following expression:

$$pReCiPe=0.0459*GHGe+0.0025*FEU+0.0439*LO$$

GHGe = kg CO2-equivalents/kg
FEU = MegaJoules/kg
LO = m2*year/kg

We omitted other contributing midpoints, due to a lack of reliable and consistent inventory data for all products in scope and the fact that these 3 indicators are the most important contributors to the ReCiPe single score (Sevenster et al. 2010).

[1] Comparative tables are available upon request.

2.4. Linear programming and a metric for changes (penalty score)

Optimization of diets was performed with Optimeal®, a commercial Linear Programming (LP) tool developed by Blonk Consultants. The algorithm is described in detail elsewhere (Kramer et al. 2013). In the LP model amounts and deviations are expressed per serving (Voedingscentrum 2013). The goal of the LP is to minimize changes such that the solution diet satisfies all nutritional and, optionally, environmental constraints.

The metric for changes is operationalized by a penalty score which, in turn, reflects the popularity of foods. Any deviation from the current diet contributes to the penalty score, but the penalty contribution of each serving change is food and directional dependent. More specifically, the amount of serving changes in a given food is multiplied by a normalization of the total quantity (grams) consumed of that food during the dietary survey (RIVM 2012). In that way, the more popular a food is, the lower its penalty for increases is and the higher its penalty for decreases is. Conversely, the less popular a food is, the higher its penalty for increases is and the lower its penalty for decreases is. The penalty score can be interpreted as a measure of distance between diets.

The reasoning behind this modelling is the principle that diets which are more similar to the current one are more likely to be accepted by the majority of the population than more extreme diets. Also removal of popular products or introduction of unpopular products is not likely to be easily taken into practice. By comparing the penalty scores of different diets it is possible to measure how similar they are to the current diet.

2.5. Dietary Scenarios

We study 6 dietary scenarios. We start by the current average Dutch diet (*Current Diet*), modelled as described above and use it as the starting point of all optimizations. The other 5 dietary scenario are optimized diets (minimal penalty score) such that the nutritional constraints are always met, thus healthy diets. The difference among the diets is the (additional) constraints imposed. The first scenario, *Closest healthy* diet, does not add any product or environmental constraints. Next we study 3 commonly discussed diets in the context of defining sustainable diets (van Dooren et al. 2014): a *Vegetarian M* diet, which excludes meat products; a *Vegetarian MF* diet, which excludes meat and fish and a *Vegan*[2] diet, which excludes meat, fish, dairy and egg products. Finally we look at a diet with 30% less environmental impact (*30% less*), which instead of imposing constraints on food groups includes only a constraint on the environmental impact. We choose this target, because it was the largest reduction achieved by the other pre-selected diets, which was in fact the vegan diet.

3. Results

The current diet in the Netherlands does not meet all dietary guidelines (Rossum et al. 2011), as in many other countries (Mensink et al. 2013) (see numbers in bold in Table 1). For instance, it is too low in dietary fiber and several vitamins and minerals, whereas the intake of saturated fat is too high.

To obtain a healthier diet that is as close as possible to the current one, more products have to be added than deleted (Table 2). The *p*ReCiPe score remains the same. Both GHGe and LO decrease, whereas FEU increases. This is mainly due to a increase in the amount of fish[3], and fishing is energy intensive. Furthermore, the *Closest healthier* diet contains more fruit, vegetables and legumes. The latter supplies both fiber and vitamin B1, which were below the recommended intake in the *Current* diet. To reduce the intake of saturated fatty acids (SAFA) several types of sausage and cheese are reduced.

---

[2] In the two dietary scenarios which exclude fish, it is not possible to meet the dietary guidelines for DHA+EPA. We had, thus, to ignore this nutritional constraint is these cases.

[3] The involved species, such as herring and farmed salmon, are currently not overfished.

Table 1. Constraints (Lower and Upper) in the Linear Programming model and properties of the current diet (per day):

Property	Lower	Upper	Current[1]
Energy (kcal)	1890	2110	1993
Protein (g)	50	125	84
Fat (g)	44	89	79
Saturated FA[2] (g)	-	22	**28**
Polyunsat. FA[2] (g)	-	27	15
Linoleic acid (g)	4	-	13
α-linolenic acid (g)	2.2	-	**2**
Trans FA[2] (g)	-	2.2	1
Cholesterol (mg)	-	300	191
Carbohydrates (g)	200	350	216
Dietary fiber (g)	30	-	**19**
Water (g)	2300	3800	3101
Alcohol (g)	-	10.0	4
DHA+EPA[3] (mg)	450	1000	**172**
Retinol act eq (µg)	700	3000	**668**
Vit B1 (mg)	1.1	-	**0.8**
Vit B2 (mg)	1.1	-	1.3
Niacin (mg)	13	-	18
Vit B6 (mg)	1.5	25	**1.4**
Folate equivalents (µg)	300	1000	**231**
Vit B12 (µg)	2.8	-	4.4
Vit C (mg)	75	-	80
Vit D (µg)	3.3	100	**2.8**
Vit E (mg)	8.0	300	12
Vit K (µg)	90	-	115
Calcium (mg)	1000	2500	1100
Phosphorous (mg)	600	3000	1550
Iron (mg)	15.0	25.0	**10.0**
Sodium (mg)	-	2400	2388
Potassium (mg)	3100	-	3330
Magnesium (mg)	280	530	334
Zinc (mg)	7.0	25	11
Selenium (µg)	50	300	**46**
Copper (mg)	0.9	5.0	1.1
Iodine (µg)	150	600	169
Tryptophan (g)	0.3	-	0.9
Threonine (g)	1.1	-	2.9
Isoleucine (g)	1.5	-	3.6
Leucine (g)	3.0	-	6.5
Lysine (g)	2.3	-	5.9
Methionine (g)	0.8	-	1.9
Cystine (g)	0.3	-	1.0
Valine (g)	2.0	-	4.3
Histidine (g)	0.8	-	2.4
Vegetables (g)	200	500	**139**
Fruit (g)	200	500	**124**

[1] *Bold numbers indicate values outside the constraints*
[2] *FA = fatty acids*
[3] *EPA (Eicosapentaenoic acids), DHA (Docosahexaenoic acid): both omega-3 fish fatty acids*

If we subsequently add constraints on meat and optimize to find the closest adequate solution (*Vegetarian M*), both LO and GHGe are lower than the initial value of the current diet. The *p*ReCiPe is reduced by 17%. Omitting meat from the current diet (*Vegetarian M*) forces more changes, because it is an important source of several nutrients that are already below the lower limit in the current diet: e.g. B1, B6, selenium and copper. To replace these nutrients from meat substantial amounts of cheese, fish, legumes and meat replacers are added to the diet. This explains the relatively modest reduction of impact in this scenario. Because of their high sodium content soups (goodies) are removed to make space for cheese. When we subsequently restrict fish (*Vegetarian MF*) and dairy and eggs (*Vegan*) the environmental impact decreases. To replace the essential nutrients from fish (e.g. vitamin B12 and D), a fortified soy drink, eggs and nuts are added to the *Vegetarian MF* diet. The absence of dairy and eggs in the *Vegan* diet has an additional impact on the nutrient intake. Alternative sources of vitamin B12, calcium, essential amino acids and many other nutrients have to be found in compensation. For instance, brown rice as a source of Se and niacin, vegetables as a source of vitamin K and retinol equivalents and more fortified soy drink for vitamins B2, B12 and D.

The reduction in *p*ReCiPe obtained with the *Vegan* diet is 0.13 points or 30%. The same reduction can be realized without forced restrictions on animal-based product groups. Interestingly, this "*30% less*" diet shows lesser shifts in amounts per product group than the *Vegan* diet in comparison with the *Current* diet. Savings are not only found by reduction of meat, beverages and goodies[4] but also by making more sustainable choices within categories[5]. The contribution of meat in total savings is more than 60% in comparison with the *Closest healthy* diet. Within the meat category both beef and chicken are reduced, and mainly pork products remain. This is an interesting finding, because chicken has a lower environmental impact per unit. Most likely, the balance between nutritive value and environmental impact is less favorable in chicken. More specifically pork contains more of several critical nutrients like Fe, Cu, Se, B2 and B12 (RIVM 2011). Within the beverages group beer and wine are reduced. In the group goodies soups are reduced but some apple syrup is added. The latter is added due to the regular fortification with Fe, a nutrient likely to become critical when meat is reduced. Dairy (liquid and cheese) even increases, when expressed in milk equivalents (1 gram of cheese is equivalent to 8.4 grams of milk (Kramer et al. 2013).

Within the fruit category apple sauce is replaced by some banana and melon. Other replacements are cheese for buttermilk (dairy) and herring for salmon and mussels (fish).

The amount of changes relative to the current diet are reflected by the penalty score (Table 2). Quite some changes are necessary to make the diet just healthier (*Closest healthy*). The more animal-based products are restricted, the higher the penalty score is after restoring the nutritive value. These restrictive strategies have a higher penalty score than the optimal solution when the upper limit for *p*ReCiPe is set at 0.29 points.

To illustrate how complex the implementation of these dietary scenarios can be and how many other options are overlooked, we plotted (Figure 1) the environmental score (*p*Recipe) of the 6 studied dietary scenarios against their penalty score. The plot also contains a possibilities frontier line which is calculated as the minimum penalty score such that a given environmental score level is achieved.

---

[4] Non-staple foods, with a low contribution to the nutrient intake (Voedingscentrum 2011). These include, e.g., sugar, cookies, snacks, sauces, jam, candy, etc.

[5] Due to space constraints detailed tables with the breakdown were not included. These are available upon request.

Table 2. Quantities of foods and environmental indicator in diets. Amounts per day.

	Current	Closest healthy	Vegetarian M	Vegetarian MF	Vegan	30% less
Food groups						
Potatoes, pasta, rice, etc. (g)	136	136	136	136	217	136
Bread (g)	145	145	145	145	163	145
Vegetables (g)	139	200	200	200	422	200
Fruit (g)	124	200	200	200	200	200
Dairy (liquid) (g)	334	313	334	312	0	280
Cheese (g)	38	9	22	21	0	15
Meat (g)	91	83	0	0	0	28
Fish (g)	18	41	80	0	0	40
Egg (g)	11	11	11	50	0	11
Oils, fats, fat spreads (g)	27	27	27	25	22	27
Nuts, seeds (g)	7	11	12	38	2	12
Water (g)	794	794	794	794	794	794
Beverages (g)	1451	1483	1451	1565	1828	1404
Legumes (g)	4	42	92	107	120	70
Meat replacers (g)	0	0	86	50	0	0
Goodies (g)	208	300	142	129	167	259
Environmental indicators						
GHGe (kg CO2eq)	4	3.6	3.1	2.7	2.4	2.5
Fossil Energy (MJ)	32	36	36	30	31	28
Land Occupation (m2*a)	4	3.8	2.7	3.1	2.4	2.4
*p*ReCiPe (Pt)	0.42	0.42	0.35	0.33	0.29	0.29
Penalty Score	0	63.01	100.76	138.20	365.5	89.44

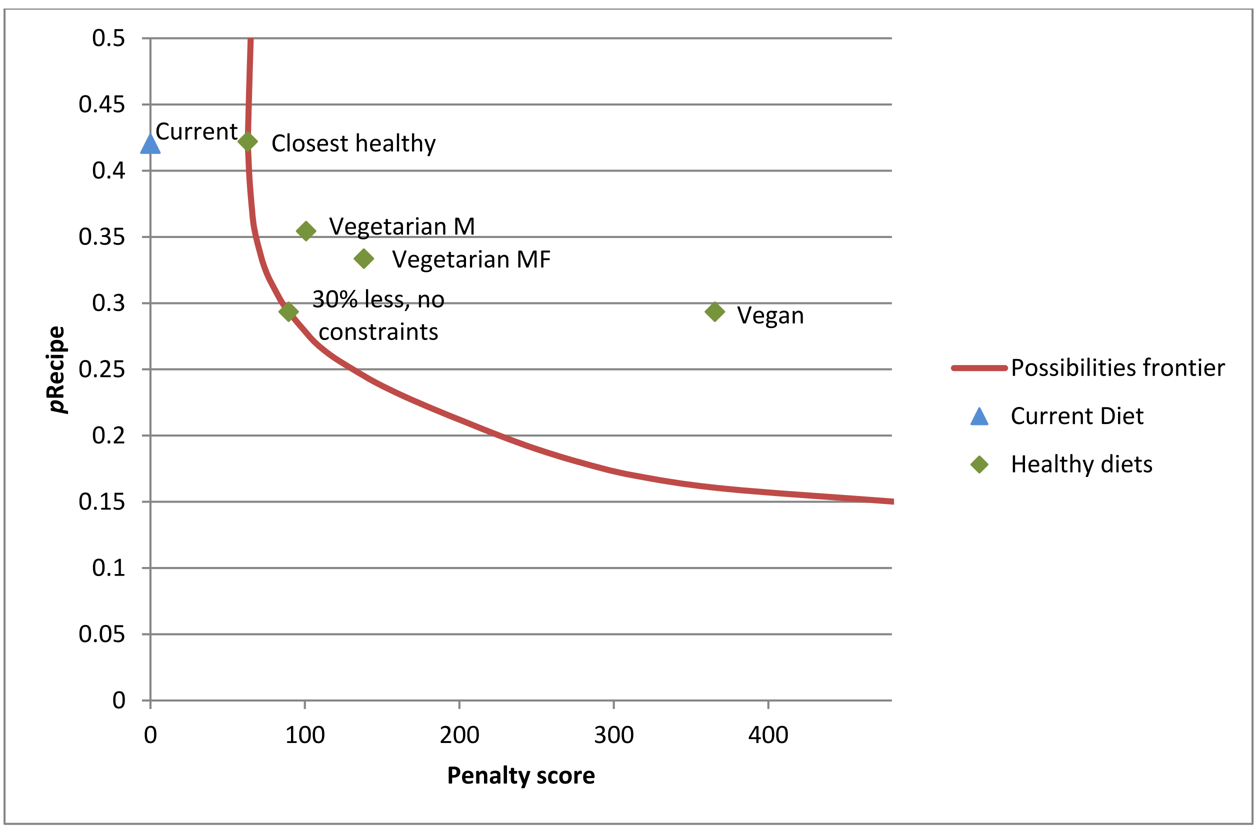

Figure 1. Penalty scores and environmental impact of the several dietary scenarios

In the figure, the closer a diet is to the frontier line, the more similar it is to the current a diet, while being healthy. The *Closest healthy* and the *30% less* are, by construction, on the frontier. Notice how much further the *Vegetarian* and *Vegan* diets are from the frontier. This does not indicate *per se* that a *Vegetarian* or *Vegan* options are not valid, but it does indicate that, if the goal is simply to reduce the environmental impact, there are many other options possible to reach the same environmental goal with less changes. These overlooked options still include animal-based products and are more similar to the current situation and, therefore, more likely to be accepted by a general population. Notice this diet resembles a so-called *Flexitarian* diet, which promotes the reduction of animal-based products, as a pre-defined intervention. This diet design is here, however, an outcome of a structured search procedure. Moreover, we selected the closest diet to the current which satisfies all nutritional requirements and achieves a 30% reduction of the environmental impact, the same level as the healthy *Vegan* scenario.

4. Discussion

4.1. Main observations

For the first time we compare different dietary scenarios using a metric for the distance between diets, taking popularity and environmental indicators into account. This improves on previous literature (Maillot et al. 2010). Our results indicate that just eating healthier is not necessarily beneficial for the environment. This supports the conclusions by Vieux *et al* (2013) who compared diet quality and GHGe from actual diets in France. The distance to the average current diet is larger when certain changes are enforced instead of left open. With relatively minor changes the environmental impact of a healthy diet (*Closest healthy*) can be improved with 30%. The optimal solution still contains 30% of the amount of meat quantity in the *Closest healthy* diet, whereas amounts of dairy (liquid and cheese), fish and egg almost remain constant. The reduced meat consumption is responsible for 60% of the reduction in environmental impact. Additional savings are realized in other categories like beverages and goodies. Our results also show that replacement scenarios of animal-based products should not be focused only on finding alternative sources of protein (Westhoek et al. 2011). To meet guidelines other nutrients like Fe, Ca, Se and vitamins B12 have to be replaced as well and might even be are more critical. In a comparison between the *Current* diet and the closest with 30% impact, reason for changes cannot be distinguished. Therefore, it is more meaningful to compare the *Closest healthy* diet with the closest with *30% less* impact. In this comparison all changes are induced by the restriction on the environmental indicator *p*ReCiPe. It shows that meat and beverages are still reduced, but also goodies (other than staple foods). Dairy (liquid and cheese) on the other hand even increases, when expressed in milk equivalents. Also legumes increase.

4.2. Validity and limitations

With the 207 products in the model we cover approximately 80% of the intake by weight. The other 20% represent 1392 products. It is possible that some of these products have a favorable nutritional and or environmental profile so that they would have been selected in the optimization. The quality and representativeness of included LCA data varies. For important product groups like meat, dairy, bread, legumes and vegetables we relied on data from a reviewed comparative LCA (Kramer et al. 2013). These data were obtained by applying a consistent LCA method regarding for instance allocation and system boundaries. Still, the quality of the LCI data in these studies varies. We are aware that data quality and variability could influence the outcome of the study..

Limitations of our environmental indicator are that it does not account for overfishing and makes no distinction between types of land use. We verified if this had an undesirable influence on the outcome, which was not the case. Overfished species were not increased. With regard to land use type, when this was taken into account a similar trend was found as in overall land occupation.

There is also variability in the food composition data we used but the present values represent the best estimate for products consumed in the Netherlands (Westenbrink and Jansen-van der Vliet 2013).

A limitation of the present study is that we only studied one group (women 31-50). We did not verify how different the outcome would be for men or other age groups. Differences could occur due to different nutritional requirements and due to different average diets. Another limitation is the lack of a good indicator for marine resource depletion. By ignoring this environmental impact a bias towards higher consumption of fish is introduced.

Finally, complex system inter-relations are not taken into account. For example, beef from the dairy production system and dairy products are not linked in the present model: they can be decreased or increased independently and different production systems are also not taken into account in this study. In the current system approximately 17 grams of beef is produced with every liter of milk. The diet with *30% less* environmental impact contains a quantity of beef that is higher than the amount associated with the suggested amount of dairy in the diet. The vegetarian diets, on the other hand, create a surplus of beef from dairy production. To incorporate these concerns an extended model, which is beyond the scope of this paper, would be necessary.

4.3. Sensitivity

The outcome of LP is sensitive to choices in restrictions and formulation of the objective function. Replacing the penalty score by a simple Euclidian Distance or the count of number of product changed, however, does not alter our qualitative analysis. The sensitivity to restrictions can be illustrated by the following observation. Some nutrients are almost exclusively delivered by one product group. In those cases the recommended amount of such a product group is very dependent on the level of one specific guideline. One example is the guideline for omega-3 fish fatty acids (DHA+EPA) in our model. Solutions without fish are therefore impossible and compared to the current diet, fish consumption should even increase to obtain a healthier diet. Wilson *et al* (2013) on the other hand, found optimized diets without fish because they did not include such a guideline.

4.4. General outcome

The average current diet in the Netherlands does not meet all dietary guidelines which are present as constraints in the Linear Programming (LP) model. The changes necessary to make it healthier, taking the popularity of products into account, does not change the environmental impact. Enforcing pre-defined dietary interventions, such as vegetarian or vegan diets has benefits for the environment, but results in an inadequate intake of omega-3 fish fatty acids when fish is left out of the diet. There is strong evidence that these fatty acids have a protective effect against fatal coronary heart diseases.

The choice for vegetarian or vegan diets in scenario studies can be argued to be arbitrary and ignore a whole set of possible diets which also satisfy nutritional constraints and yield a comparable or even lower environmental impact. The environmental improvement goal of 30% can be met by less drastic changes to the diet, if penalty scores of the different scenarios are compared. Another advantage is that substitutions are chosen based on objective criteria: a balance between nutritive value, popularity and environmental impact. Vegetarian diets have a systematic flaw because they contain dairy, but not the meat produced in dairy systems. Also solutions without fish have flaw, because they do not meet a guideline for omega-3 fish fatty acids. Our data shows that the reductions contributing most to the decrease of impact relative to the current diet are indeed in meat and cheese, and certain beverages like beer, wine and soft drinks, but they are all still part of the diet. On the other hand, legumes, fruit and vegetables are the most important additions to the current diet necessary to restore or improve the dietary quality.

The results we obtained when the constraints on groups were removed are quite similar to those obtained by MacDiarmid *et al* (2012). They also saw decreases in animal-based products and increases in plant-based foods. Because they ignored beverages, they missed the potential saving in this category. Because we observed similar trends we can confirm the validity of other studies that only used GHGe (Risku-Norja et al. 2009; Tukker et al. 2009; Stehfest et al. 2009; Vieux et al. 2012; Macdiarmid et al. 2012; Wilson et al. 2013). Only a few studies have addressed other impacts or used a single environmental indicator (Gerbens-Leenes and Nonhebel 2002; Tukker et al. 2009; Temme et al. 2013).

5. Conclusion

Within the Dutch context, eating according to nutrient requirements does not necessarily have a lower environmental impact. For women in the group of 31-50 we found that the closest healthy diet relative to the current diet in the Netherlands has the same environmental impact. It is possible however to find many other diets with reduced environmental impact which are healthier than the current situation, still includes meat, fish and dairy and eggs by using linear optimization. The method we propose is an innovative and systematic way of finding

improved diets which are close to the current average diet satisfying all nutritional and additional environmental constraints.

Providing a diet that meets dietary requirements is a prerequisite for (sustainable) diets. Simply omitting animal-based products from the diet is not a valid option: other products have to be added to guarantee nutritional adequacy. In that respect, protein should not be the only focus, as an adequate intake of other nutrients supplied by animal-based products are also at risk.

The scenarios presented in this paper illustrate that omitting animal-based products from the diet require substitutions to meet dietary requirements. These, in turn, reduce the positive environmental impact change. For the general populations these scenarios seem less attainable than a scenario in which the desired reduction in impact is added as a binding constraint in the LP model. In that case reductions in meat (beef, chicken) and beverages (beer, wine) are making the most important contributions. Eating of legumes and (sustainable) fatty fish should be promoted. On the other hand, consumption of goodies should be discouraged, both for health and for the environment.

6. References

Carlsson-kanyama A, González AD (2009) Potential contributions of food consumption patterns to climate change 1–4. Am J Clin Nutr 89:1704–1709. doi: 10.3945/ajcn.2009.26736AA.1704S

Van Dooren C, Marinussen M, Blonk H, et al. (2014) Exploring dietary guidelines based on ecological and nutritional values: A comparison of six dietary patterns. Food Policy 44:36–46. doi: 10.1016/j.foodpol.2013.11.002

Duchin F (2008) Sustainable Consumption of Food: A Framework for Analyzing Scenarios about Changes in Diets. J Ind Ecol 9:99–114. doi: 10.1162/1088198054084707

FAO (2011) THE STATE OF THE WORLD ' S LAND AND WATER RESOURCES FOR FOOD AND AGRICULTURE - Managing systems at risk. Rome, Italy

FAO (2010) SUSTAINABLE DIETS AND BIODIVERSITY SUSTAINABLE DIETS AND BIODIVERSITY. Rome, Italy

Gerbens-Leenes P., Nonhebel S (2002) Consumption patterns and their effects on land required for food. Ecol Econ 42:185–199. doi: 10.1016/S0921-8009(02)00049-6

Gerber PJ, Steinfeld H, Henderson B, et al. (2013) Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Rome, Italy

Gezondheidsraad (2001) Health Council of the Netherlands. Dietary reference intakes: energy, proteins, fats, and digestible carbohydrates; publication no. 2001/19R; The Hague, The Netherlands. 1–174.

Gezondheidsraad (2006) Health Council of the Netherlands. Guidelines for a healthy diet 2006/Richtlijnen Goede Voeding 2006; publication no. 2006/21. The Hague, The Netherlands

Goedkoop M, Heijungs R, Huijbregts M, et al. (2013) ReCiPe 2008, A LCA method which comprises harmonised category indicators at the midpoint and the endpoint level; Report 1 Characterisation.

Hagemann M, Ndambi A, Hemme T, Latacz-Lohmann U (2012) Contribution of milk production to global greenhouse gas emissions. An estimation based on typical farms. Environ Sci Pollut Res Int 19:390–402. doi: 10.1007/s11356-011-0571-8

Kramer GFH, Broekema R, Tyszler M, et al. (2013) Comparative LCA of Dutch dairy products and plant- based alternatives. Gouda, the Netherlands

Macdiarmid JI, Kyle J, Horgan GW, et al. (2012) Sustainable diets for the future: Can we contribute to reducing greenhouse gas emissions by eating a healthy diet? Am J Clin Nutr 96:632–9. doi: 10.3945/ajcn.112.038729

Maillot M, Vieux F, Amiot MJ, Darmon N (2010) Individual diet modeling translates nutrient recommendations into realistic and individual-specific food choices. Am J Clin Nutr 91:421–30. doi: 10.3945/ajcn.2009.28426

Mensink GBM, Fletcher R, Gurinovic M, et al. (2013) Mapping low intake of micronutrients across Europe. Br J Nutr 110:755–73. doi: 10.1017/S000711451200565X

Risku-Norja H, Kurppa S, Helenius J (2009) Dietary choices and greenhouse gas emissions – assessment of impact of vegetarian and organic options at national scale. Prog Ind Ecol An Int J 6:340. doi: 10.1504/PIE.2009.032323

RIVM (2011) NEVO-online version 2011/3.0. http://nevo-online.rivm.nl/. Accessed 31 Jan 2013

RIVM (2012) consumption_food_nut.dat Version 20111125, part of the Dutch National Food Consumption Survey 2007-2010.
Rossum CTM Van, Fransen HP, Verkaik-Kloosterman J, et al. (2011) Dutch National Food Consumption Survey 2007-2010. 1–148.
Searchinger T, et al. (2013) Creating a Sustainable Food Future - World Resources Report 2013–14: Interim Findings. 1–144.
Sevenster M, Blonk H, Van der Flier S (2010) Environmental analyses of food and food waste/Milieuanalyses voedsel en voedselverliezen. 1–76.
Stehfest E, Bouwman L, Vuuren DP, et al. (2009) Climate benefits of changing diet. Clim Change 95:83–102. doi: 10.1007/s10584-008-9534-6
Temme EH, van der Voet H, Thissen JT, et al. (2013) Replacement of meat and dairy by plant-derived foods: estimated effects on land use, iron and SFA intakes in young Dutch adult females. Public Health Nutr 1–8. doi: 10.1017/S1368980013000232
Tubiello FN, Salvatore M, Cóndor Golec RD, et al. (2014) Agriculture, Forestry and Other Land Use Emissions by Sources and Removals by Sinks - 1990-2011 Analysis. 1–76.
Tukker A, Bausch-Goldbohm S, Verheijden M, et al. (2009) Environmental impacts of diet changes in the EU. 1–96. doi: 10.2791/88996
USDA (2012) Release 25 of the USDA National Nutrient Database for Standard Reference. http://www.ars.usda.gov/Services/docs.htm?docid=22771.
Vieux F, Darmon N, Touazi D, Soler LG Food Consumption and Greenhouse Gas Emissions : Changing Food Consumption Patterns or Consuming less ? 1–15.
Vieux F, Darmon N, Touazi D, Soler LG (2012) Greenhouse gas emissions of self-selected individual diets in France: Changing the diet structure or consuming less? Ecol Econ 75:91–101. doi: 10.1016/j.ecolecon.2012.01.003
Vieux F, Soler LG, Touazi D, Darmon N (2013) High nutritional quality is not associated with low greenhouse gas emissions in self-selected diets of French adults. Am J Clin Nutr. doi: doi: 10.3945/ajcn.112.035105.
Voedingscentrum (2011) Richtlijnen voedselkeuze 2011.
Voedingscentrum (2013) Eettabel. 1–207.
Westenbrink S, Jansen-van der Vliet M (2013) NEVO-online 2013: background information (in Dutch). 1–24.
Van Westerhoven S, Steenhuizen F (2010) Bepaling voedselverliezen bij huishoudens en bedrijfscatering in Nederland. 1–65.
Westhoek H, Rood T, Berg M van den, et al. (2011) The protein puzzle. 1–221.
WHO, FAO, UNU (2007) Protein and amino acid requirements in human nutrition - Report of a join FAO/WHO/UNU expert consultation (WHO Technical Report Series 935). 284.
Wilson N, Nghiem N, Ni Mhurchu C, et al. (2013) Foods and dietary patterns that are healthy, low-cost, and environmentally sustainable: a case study of optimization modeling for New Zealand. PLoS One 8:e59648. doi: 10.1371/journal.pone.0059648

This paper is from:

Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector

LCA Food 2014

8-10 October 2014 - San Francisco

Rita Schenck and Douglas Huizenga, Editors
American Center for Life Cycle Assessment

The full proceedings document can be found here:
http://lcacenter.org/lcafood2014/proceedings/LCA_Food_2014_Proceedings.pdf

It should be cited as:

Schenck, R., Huizenga, D. (Eds.), 2014. Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector (LCA Food 2014), 8-10 October 2014, San Francisco, USA. ACLCA, Vashon, WA, USA.

Questions and comments can be addressed to: staff@lcacenter.org

ISBN: 978-0-9882145-7-6