Reducing our environmental footprint

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before diagnosis. In addition, these participants have a higher risk of death. Subjects without dietary information (n = 154) were excluded. To exclude implausible values, participants in the highest and lowest 0.5% of the ratio of reported energy intake (based on the food frequency questionnaire (FFQ)) on energy requirement (estimated on the basis of basal metabolic rate (BMR)) were also excluded (n = 662). After these exclusions, 35 057 participants remained for the all-cause mortality survival analysis.

## Diet and environmental impact assessment

Usual daily dietary intake was estimated by a 178-item FFQ that has been validated against twelve 24-h recalls, and biomarkers in 24-h urine and blood [22,23]. Spearman rank correlation coefficients based on estimates of the FFQ and 24-h recalls were 0.51 for potatoes, 0.36 for vegetables, 0.68 for fruits, 0.39 for meat, 0.69 for dairy, 0.76 for sugar and sweet products, and 0.52 for biscuits and pastry in men. Results for women were similar.

Blonk Consultants assessed the environmental impact of the Dutch dietary habits [3]. To estimate sustainability scores, life cycle assessments (LCA) were performed for 254 food items. The LCA’s were cradle to grave and included production, processing, packaging, transport, storage, preparation, cooking, avoidable and unavoidable food waste (inedible parts) at home, and waste incineration. GHGE covers carbon dioxide (C02) emissions through the use of fossil fuels, methane (CH4) released during the rearing of cattle and the cultivation of certain crops, and nitrous oxide (N20) released from fertilizers, manure and ploughing of grassland [24,25]. GHGE is expressed as kg CO2-equivalents per day. Land use covers the surface needed for the production of food [24,25] and is expressed as m2\*year per day. These LCA data were combined with the EPIC-NL FFQ data to calculate individual daily greenhouse gas emission and land use for each of our participants. The LCA scores were based on current production practices and assumed equal in the nineties when the FFQ was assessed.

## Participants characteristics

At baseline, study participants completed a questionnaire on the presence of chronic diseases and related potential risk factors, and medical and lifestyle factors [18]. Body mass index (BMI) was calculated by dividing weight by height squared. Educational level was coded in low (lower vocational training or primary school), medium (intermediate vocational training or secondary school), or high (higher vocational training or university). The smoking of cigarettes, pipe, or cigars was categorized as current, former, and never. Physical activity was assessed with the validated Cambridge Physical Activity Score (CPAI) [26].

## Mortality assessment

Vital status of all EPIC-NL participants was obtained through linkage with the municipal population registries. The information on vital status for the EPIC-NL cohort is complete until 11 April 2011 for MORGEN and until 4 July 2011 for PROSPECT. These data were retrieved from the GBA (Dutch Municipality Basic Administration).

Participants were followed for the occurrence of cancer, cardiovascular disease, respiratory disease and other causes by linkage to several disease registries (Dutch Cancer Registry and Dutch Hospital Discharge Diagnosis Database). Primary cause of death was coded according to the International Classification of Diseases (ICD). Incidence of cancer deaths was coded as 140–239 (ICD-9) or C00-D48 (ICD-10), incidence of cardiovascular disease (CVD) deaths as 390–459 (ICD-9) or I00-I99 (ICD-10), incidence of respiratory system disease mortality as 460–519 (ICD-9) or J00-J99 (ICD-10). The remaining causes of death were merged into the category ‘other causes’. Cause-specific mortality data were available until 31 December 2010. This is the most recent linkage to the database of Statistics Netherlands.

## Statistical analysis

Participants were followed over time until death from any cause, loss to follow-up, or were censored on 11 April 2011 for MORGEN and 4 July 2011 for PROSPECT. In the cause-specific mortality analysis, the censor date was 31 December 2010 for both cohorts.

Cox proportional hazard models were used to estimate crude and adjusted hazard ratios (HRs) with 95% confidence intervals (CI) for GHGE and land use in association with mortality. Using manual backward selection, covariates were excluded from the final model when the HR did not change ≥10% [27]. This manual selection was performed because no other prospective studies investigated the effect of the environmental impact of the diet, and therefore, there are no established confounders. The covariates BMI, educational level, smoking habits, physical activity, alcohol intake, and waist circumference were omitted from the final model whereas age and gender were retained. The covariate age failed to meet the proportional hazards assumption according to the Schoenfeld residuals test (p < 0.0001). Adjusted models were Cox stratified by age (continuous) to correct for this. To test for linear trends across categories, we modelled GHGE and land use by including the median value of each quartile as a continuous variable. By adding interaction terms to the model, we assessed deviation from multiplicative interaction for age, sex, BMI, smoking, and waist circumference. None of these factors modified the studied association. A test model in which quartiles of exposure were created from total GHGE and land use divided by total energy intake, GHGE/kJ and m2/kJ, showed very similar results (results not shown).

To study the effect of a modelled substitution of meat by other food components, both meat and the replacement component were added as continuous variables in the same multivariate model. Similar to previous studies, the difference in the parameter estimates and covariance was used to estimate HR and 95% CI [16,17]. The models were adjusted for major dietary and lifestyle factors (age, gender, BMI, smoking status, physical activity, energy intake, and alcohol intake). The investigated substitution component sources were potatoes, total vegetables, total fruit-nuts-seeds, pasta-rice-couscous, cheese, milk-based desserts, or fish. These food groups were selected because they can replace meat in a hot meal. In addition, they represent highly acceptable food products that are consumed in significant amounts in the current Dutch diet (Tables 1 and 2), and thus represent acceptable substitutions for meat. The modelled substitution was a one-third reduction (35-gram) of the average (105-gram, standard deviation of 55-gram) total daily meat intake in EPIC-NL. For realistic scenarios, we substituted by equal food weight and not the same amount of dietary energy. For example, in case of applying iso-caloric substitutions, an additional 300 gram of vegetables is needed to compensate for the energy intake of 35 gram of meat and this was assumed not to be realistic. Another argument for substitution based on food weight is that a large part of the adult Dutch population is overweight. This suggests that energy intake is high compared with energy requirements. Effects

Table 1 Contribution of different food groups to daily intake and environmental impact in EPIC-NL

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| Food group | Gram/d (%) | C02–eq (%) | Land use (%) |
| Potatoes | 3.5 | 1.9 | 1.2 |
| Vegetables | 4.4 | 5.5 | 3.6 |
| Legumes | 0.3 | 0.3 | 0.3 |
| Fruit, nuts and seeds | 6.9 | 5.6 | 4.4 |
| Dairy  Cheese | 1.3 | 11.6 | 7.7 |
| Milka | 9.4 | 9.5 | 6.5 |
| Milk-based dessertsb | 3.5 | 4.1 | 2.6 |
| Meat  Non-processed meatc | 2.5 | 25.7 | 28.1 |
| Processed meatd | 1.1 | 5.6 | 6.1 |
| Cereals  Bread products | 5.0 | 3.4 | 4.8 |
| Pasta, rice and couscous | 1.6 | 1.5 | 2.6 |
| Fish | 0.4 | 2.1 | 0.8 |
| Egg | 0.5 | 1.2 | 1.8 |
| Fat | 0.9 | 2.3 | 5.0 |
| Sugar and confectionary | 1.5 | 2.5 | 1.7 |
| Cake and biscuits | 1.0 | 2.1 | 3.6 |
| Beverages  Non-alcoholic | 48.0 | 9.4 | 10.9 |
| Alcoholic | 4.8 | 3.4 | 5.1 |
| Condiments and sauces | 0.7 | 0.8 | 1.2 |
| Soups | 2.4 | 0.6 | 0.2 |
| Miscellaneous | 0.3 | 2.1 | 2.0 |

aconsists of milk, milk beverages (chocolate milk), and coffee milk; bconsists of (fruit)yoghurt, cream desserts, and milk-based puddings; cnon-processed meat: beef, pork, and chicken; dprocessed meat: liver-containing items, ham, and miscellaneous types.

on environmental impact were based on the food group average GHGE and land use. The average environmental impact of meat was based on the proportional daily intake, i.e. non-processed meat accounts for 80% of total gram per day intake of meat.

All statistical analyses were performed using SAS software (version 9.3, SAS Institute Inc., Cary, NC, USA). A two-sided p-value of <0.05 was considered statistically significant.

# Results

During a median follow-up of 15.9 years, 2563 deaths were registered. The observed EPIC-NL cohort median value of GHGE was 3.87 kg CO2-equivalents/d and for land use 3.61 m2\*year/d. While contributing 3.6% of daily intake weight (and 11% of daily energy intake), total meat intake accounts for approximately 30% of total dietary-derived GHGE and land use (Table 1). The impact of dairy and beverage consumption on the environment is substantial (dairy: 25% of GHGE and 17% of land use; beverages: 13% of GHGE and 16% of land use).

A higher energy, vegetables, fruits, dairy, meat, cereals, fat, soups, and alcohol intake, a lower age, an increased proportion of men, smokers, and higher activity level were associated with a higher environmental impact of usual diet. Educational level, waist to hip ratio, and body mass index (BMI) differed only slightly between the highest and lowest quartiles of GHGE and land use

(Table 2).

In the crude Cox proportional hazards analyses, we observed an inverse association of total greenhouse gas emission of usual diet with all-cause mortality. The HR (95% confidence interval) of highest versus lowest quartile of GHGE was 0.76 (0.68-0.85) (Table 3). After multivariable adjustment, model 1, no association with risk was seen (HR of 1.00 (0.86-1.17)). Additional adjustment for energy intake, model 2, did not change the association. The findings from the fully adjusted model, all possible confounders included, were essentially similar to the sparsely adjusted model (model 1). Hazard ratios of highest versus lowest quartile of GHGE for adjusted cause-specific mortality models were for cancer 1.01 (0.86-1.34), CVD 0.90 (0.63-1.28), 1.12 (0.52-2.39) for respiratory diseases, and 0.91 (0.64-1.30) for other causes of death.

In crude analysis, total land use of usual diet was inversely associated with all-cause mortality (HR of highest versus lowest quartile: 0.74 (0.66-0.82)) (Table 4). However, after multivariable adjustment, we found a statistically non-significant HR of 1.05 (0.89-1.23). Correction for energy intake did not alter the association. Cause-specific adjusted HR’s were 1.10 (0.88-1.37) for cancer, 1.07 (0.751.54) for CVD, 1.19 (0.58-2.46) for respiratory diseases, and 0.88 (0.61-1.27) for deaths by remaining causes.

Modelling a substitution of 35 g/d of total meat intake by an equal amount of potatoes, pasta-rice-couscous, vegetables, fruit-nuts-seeds, milk-based desserts, fish, or cheese has environmental or health benefits (table 5). Reductions in total daily greenhouse gas emissions were 10.8% for potatoes, 10.1% for pasta-rice-couscous, 10.0% for vegetables, 10.0% for fruits-nuts-seeds, 10.0% for milkbased desserts, 4.5% for fish, 0.6% for cheese, and 11.5% for reducing meat intake by 35 gram without replacements based on the average carbon footprint of the usual diet in EPIC-NL. Reductions in land use were 11.3% for potatoes,

9.7% for pasta-rice-couscous, 10.8% for vegetables, and

10.3% for fruit-nuts-seeds, 10.9% for milk-based desserts, 9.8% for fish, 4.5% for cheese, and 11.7% without any replacement. In addition, favourable health effects of the substitutions were observed. When compared, 35 gram of pasta-rice-couscous instead of meat was associated with an 11% (95% CI, 4% to 16%) lower risk. A substitution by vegetables was associated with a 9% (95% CI, 3% to 15%)

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| Table 2 Baseline characteristics by dietary greenhouse gas emission and land use in EPIC-NL  Greenhouse gas emission (CO2-eq/d) Land use (m2\*year/d)   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Characteristic | Quartile 1 <3.26 | Quartile 4 >4.56 | Quartile 1 <2.99 | Quartile 4 >4.28 | | No. of subjects | 8770 | 8769 | 8769 | 8769 | | No. of deathsa | 736 (8.4) | 570 (6.5) | 741 (8.5) | 558 (6.4) | | Person-yearsb | 15.8 (14.6-17.0) | 16.0 (14.7-17.2) | 15.8 (14.6-16.9) | 16.0 (14.7-17.2) | | GHGEb,c | 2.86 (2.56-3.07) | 5.12 (4.79-5.62) | 2.84 (2.55-3.14) | 5.10 (4.71-5.62) | | Land useb, d | 2.62 (2.31-2.88) | 4.78 (4.42-5.28) | 2.61 (2.31-2.82) | 4.80 (4.51-5.28) | | Age (years)b | 52 (44–59) | 48 (37–54) | 53 (44–60) | 48 (37–54) | | Male gendera | 896 (10.2) | 4521 (51.6) | 766 (8.7) | 4727 (53.9) | | BMI (kg/m2)b | 24.8 (22.4-27.1) | 25.5 (23.2-28.0) | 24.7 (22.3-27.0) | 25.5 (23.2-28.0) | | High education levela,e | 1601 (18.4) | 2025 (23.3) | 1640 (18.8) | 2141 (24.6) | | Current smokersa | 2466 (28.2) | 3086 (35.3) | 2179 (25.0) | 2607 (29.8) | | CPAI-‘active’a,f | 3249 (37.1) | 2488 (48.2) | 3379 (38.5) | 4070 (46.4) | | Waist circumference (cm)b | 81.0 (74.3-89.0) | 87.3 (80.0-95.8) | 81.0 (74.0-89.0) | 87.8 (80.0-96.0) | | Energy intake (MJ)b | 6.4 (5.6-7.3) | 11.0 (9.4-12.8) | 6.4 (5.6-7.4) | 10.9 (9.43-12.8) | | Ratio EI/BMRb,g | 1.1 (1.0-1.3) | 1.6 (1.4-1.9) | 1.1 (1.0-1.3) | 1.6 (1.4-1.9) | | Alcohol use (g)b | 2.1 (0.2-9.1) | 10.3 (2.2-24.0) | 1.5 (0.1-6.6) | 12.9 (3.5-28.0) | | Dietary intakeb  Potatoes | 69 (41–105) | 122 (75–179) | 66 (41–101) | 123 (76–180) | | Vegetables | 108 (82–140) | 138 (107–175) | 111 (84–145) | 134 (105–171) | | Legumes | 5 (2–11) | 8 (3–15) | 5 (2–11) | 8 (3–15) | | Fruit, nuts & seeds | 142 (92–250) | 192 (118–300) | 171 (109–262) | 170 (104–274) | | Dairy | 261 (143–402) | 533 (321–763) | 308 (171–466) | 453 (258–683) | | Non-processed meath | 41 (23–58) | 99 (84–125) | 36 (21–51) | 101 (87–126) | | Processed meati | 15 (6–27) | 40 (22–48) | 14 (5–23) | 43 (25–67) | | Cereals | 148 (11–193) | 233 (171–311) | 147 (111–191) | 238 (174–315) | | Fish | 6 (2–14) | 10 (−17) | 7 (2–14) | 9 (4–16) | | Egg | 11 (5–18) | 16 (9–29) | 11 (5–18) | 17 (10–29) | | Fat | 20 (13–28) | 34 (23–48) | 19 (12–27) | 36 (24–49) | | Sugar & confectionary | 31 (17–50) | 48 (27–76) | 31 (18–50) | 47 (25–76) | | Cake & biscuits | 22 (11–37) | 27 (14–45) | 22 (11–37) | 26 (13–44) | | Beverages | 1325 (1041–1670) | 1717 (1368–2140) | 1327 (1038–1678) | 1726 (1395–2135) | | Condiments & sauces | 12 (5–22) | 22 (11–33) | 11 (5–22) | 23 (12–34) | | Soups | 36 (17–72) | 72 (33–107) | 36 (17–72) | 72 (33–107) | | Miscellaneous | 5 (2–11) | 7 (3–15) | 6 (2–11) | 8 (4–15) |   a b th c  Values displayed as frequency (percentage); Values displayed as median with interquartile range (25-75 percentile); GHGE: greenhouse gas emission (C02-eq/d);  d 2 e f g  Land use (m \*year/d); college or university degree; Cambridge Physical Activity Score (inactive, moderately inactive, moderately active, active); Ratio of energy intake (EI) and basal metabolic rate (BMR); hnon-processed meat: beef, pork, and chicken; iprocessed meat: liver-containing items, ham, and miscellaneous types. |

lower risk of all-cause mortality and by fruit-nuts-seeds with a 6% (95% CI, 1% to 10%) lower risk. A shift to 35 gram more milk-based dessert was associated with a borderline non-significant 4% (95% CI, 0% to 9%) lower risk. Substitution by fish was associated with a 19% (95% CI, 3% to 33%) lower risk. 35 gram more cheese instead of meat (HR: 6% (95% CI, −4% to 14%)) or potatoes (HR: 0% (95% CI, −6% to 7%)) was not associated with a lower allcause mortality risk. Reducing intake of total meat by 35

gram without replacement was associated with a 4% (95% CI, 2% to 7%) lower mortality risk.

# Discussion

In this large prospective cohort of Dutch men and women, we observed that the total environmental impact of usual diet was not associated with all-cause or cause-specific mortality. This indicates that an environmental friendlier diet is not necessarily a healthier diet.

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| Table 3 Data for mortality risks according to greenhouse gas emissions of usual diet in EPIC-NL  Greenhouse gas emission (CO  2  -  eq/d  )  P  for  linear trend  <3.26  3.26 - 3.87  3.87 - 4.56  >4.56  All-cause mortality   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | No. of participants | 8770 | 8769 | 8771 | 8769 |  | | No. of deaths | 736 | 671 | 586 | 570 |  | | Person-years, median | 15.8 | 15.9 | 15.8 | 16.0 |  | | Crude HRa (95% CI) | 1 (REF) | 0.90 (0.81-1.00) | 0.79 (0.71-0.88) | 0.76 (0.68-0.85) | P < 0.0001d | | Model 1b HR | 1 | 0.97 (0.84-1.12) | 0.90 (0.77-1.05) | 1.00 (0.86-1.17) | P = 0.7959 | | Model 2b,c HR  Cause-specific mortality  Cancer | 1 | 0.96 (0.82-1.11) | 0.87 (0.74-1.03) | 0.95 (0.77-1.15) | P = 0.4266 | | No. of deaths | 327 | 324 | 274 | 268 |  | | Crude HRa (95% CI) | 1 (REF) | 0.99 (0.85-1.15) | 0.83 (0.71-0.98) | 0.81 (0.69-0.96) | P = 0.0031d | | Model 1b HR  CVD | 1 | 1.01 (0.89-1.33) | 0.93 (0.75-1.16) | 1.01 (0.86-1.34) | P = 0.7654 | | No. of deaths | 164 | 146 | 115 | 120 |  | | Crude HRa (95% CI) | 1 (REF) | 0.89 (0.71-1.11) | 0.70 (0.55-0.89) | 0.73 (0.57-0.92) | P = 0.0023d | | Model 1b HR  Respiratory diseases | 1 | 0.92 (0.67-1.26) | 0.83 (0.59-1.17) | 0.90 (0.63-1.28) | P = 0.4681 | | No. of deaths | 41 | 37 | 32 | 27 |  | | Crude HRa (95% CI) | 1 (REF) | 0.90 (0.58-1.40) | 0.78 (0.79-1.23) | 0.65 (0.40-1.06) | P = 0.0687 | | Model 1b HR  Other causes | 1 | 1.01 (0.53-1.91) | 0.76 (0.39-1.49) | 1.12 (0.52-2.39) | P = 0.9945 | | No. of deaths | 157 | 124 | 128 | 120 |  | | Crude HRa (95% CI) | 1 (REF) | 0.79 (0.62-0.99) | 0.81 (0.64-1.02) | 0.76 (0.60-0.96) | P = 0.0334d | | Model 1b HR | 1 | 0.83 (0.59-1.15) | 0.96 (0.68-1.35) | 0.91 (0.64-1.30) | P = 0.7902 |   a b c  HR: hazard ratio; Cox stratified for age (continuous) and adjusted for sex; Additional adjusted for energy intake. |

dp value for linear trend significant (p < 0.05).

Even though meat only contributed for 3.6% to the total weight of daily intake in grams, it is responsible for approximately 30% of dietary greenhouse gas emission and land use. A 35 g/d reduction or shift from total meat intake to vegetables, fruit-nuts-seeds, pasta-rice-couscous, or fish would significantly increase survival rates (4-19%), reduce GHGE (4-12%), and land use (10-12%).

In this study, the environmental burden of the usual diet was divided into quartiles of total GHGE and land use to analyse the influence of diets with a higher impact on the relative risk for mortality. For this division no impact on mortality risk was observed in the Cox survival models. Other studies have suggested that a healthier diet may also be more sustainable [3,15]. A diet according to the Dutch Dietary Guidelines would result in 8% less GHGE and decrease land use by 21% compared to the average diet. However, a healthier diet and diet with a lower environmental impact do not necessarily need to be equally sustainable. For example, a healthy diet that includes fruits and vegetables with a high GHGE, rice instead of pasta or potatoes and more meat has twice the GHGE compared to an equally healthy low-GHGE diet [28]. On the other hand, a less healthy diet, with high quantities of sugars and refined carbohydrates, small quantities of meat, fruits and vegetables, can also have a low GHGE. Our modelled substitution scenario resulted in healthier diets with reduced environmental impact. Substitutions of meat lead to a double benefit in both health and reduced environmental impact aspects. However, a healthier diet is not necessarily accompanied by a lower GHGE or less land use.

The Dutch diet is relatively high in animal-derived products and refined carbohydrates and low in fruit and vegetables. Within the dietary range of this cohort, there was no significant association between the overall daily GHGE and land use and mortality. Although total GHGE and land use were not associated with mortality, modelling a one-third reduction of total meat, a major contributor to dietary GHGE and land use, resulted in both reduced mortality risk as well as reduced environmental impact.

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| Table 4 Data for mortality risks according to total land use of usual diet in EPIC-NL  Land use (m  2  \*year/d)  P  for  linear trend  <2.99  2.99 - 3.61  3.61  –  4.28  >4.28  All-cause mortality   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | No. of participants | 8769 | 8771 | 8770 | 8769 |  | | No. of deaths | 741 | 669 | 595 | 558 |  | | Person-years, median | 15.8 | 15.9 | 15.8 | 16.0 |  | | Crude HRa (95% CI) | 1 (REF) | 0.89 (0.80-0.99) | 0.79 (0.71-0.88) | 0.74 (0.66-0.82) | P < 0.0001d | | Model 1b HR | 1 | 0.99 (0.86-1.15) | 0.99 (0.85-1.14) | 1.05 (0.89-1.23) | P = 0.6190 | | Model 2b,c HR  Cause-specific mortality  Cancer | 1 | 0.99 (0.85-1.14) | 0.97 (0.82-1.15) | 1.03 (0.84-1.25) | P = 0.8534 | | No. of deaths | 326 | 317 | 282 | 268 |  | | Crude HRa (95% CI) | 1 (REF) | 0.97 (0.83-1.13) | 0.86 (0.73-1.01) | 0.82 (0.69-0.96) | P = 0.0057d | | Model 1b HR  CVD | 1 | 1.05 (0.86-1.29) | 0.99 (0.80-1.22) | 1.10 (0.88-1.37) | P = 0.5291 | | No. of deaths | 164 | 151 | 112 | 118 |  | | Crude HRa (95% CI) | 1 (REF) | 0.91 (0.73-1.14) | 0.68 (0.53-0.86) | 0.71 (0.56-0.90) | P = 0.0010d | | Model 1b HR  Respiratory diseases | 1 | 1.03 (0.75-1.41) | 0.97 (0.68-1.37) | 1.07 (0.75-1.54) | P = 0.7666 | | No. of deaths | 44 | 30 | 34 | 29 |  | | Crude HRa (95% CI) | 1 (REF) | 0.68 (0.42-1.07) | 0.77 (0.49-1.20) | 0.65 (0.41-1.04) | P = 0.1086 | | Model 1b HR  Other causes | 1 | 0.81 (0.42-1.56) | 0.97 (0.49-1.90) | 1.19 (0.58-2.46) | P = 0.5950 | | No. of deaths | 162 | 133 | 122 | 112 |  | | Crude HRa (95% CI) | 1 (REF) | 0.81 (0.65-1.02) | 0.75 (0.59-0.95) | 0.68 (0.54-0.87) | P = 0.0016d | | Model 1b HR | 1 | 0.83 (0.60-1.16) | 0.98 (0.70-1.36) | 0.88 (0.61-1.27) | P = 0.6518 |   a b c  HR: hazard ratio; Cox stratified for age (continuous) and adjusted for sex; Additional adjusted for energy intake. |

dp value for linear trend significant (p < 0.05).

The 35-gram reduction of meat was well within the intake variation (standard deviation) of 55 gram and is thus a realistic scenario. Meat intake has been linked to an increased risk of mortality before [29]. In addition, other meat substitution studies reported reduced mortality [17] or cardiovascular risks [16]. Temme et al. showed that a complete replacement of meat and dairy by a variety of plant-derived foods would not affect total iron intake, reduce saturated fatty acid intake, and reduce land use by around 50% in Dutch female young adults [30].

Substituting high-GHGE with low-GHGE meats could also contribute to increased survival rates and reduced environmental impact. Replacing red meat with poultry would reduce the environmental impact (data Blonk Consultants ) and is associated with reduced mortality risk [17]. In addition, processed meat intake appears to be stronger associated with several morbidity outcomes than red meat [31]. Replacement of meat by fish can be considered controversial from an ecological point of view, because of sustainability concerns of the current ocean fishing and fish cultivation practices.

A New Zealand study presented findings of scenario development with linear programming that determined several dietary patterns to cover nutrient intake at low cost and low GHGE profiles [32]. The study suggests that these results could provide guidance to governments decisions around the focus of their food policies, i.e. food taxes, healthy food vouchers and subsidies. An UK study investigated the effect of incorporating the societal cost of GHGE into the price of foods [33]. A scenario in which a higher taxation rate is calculated for foods above GHGE average shows that this could save 7770 lives in the UK each year, reduce GHGE and generate tax revenue. These studies highlight the potential benefits of such policy measures on health and environment impact of the diet.

Table 5 Environmental impact of 35 gram modelled meat substitution by predefined food groups and all-cause mortality

|  |  |  |  |
| --- | --- | --- | --- |
| Substitute | Reduction GHGE (%)a | Reduction land use (%)a | Reduction mortality risk  (%, 95% CI)b |
| Potatoes | 10.8 | 11.3 | 0 (−6 – 7) |
| Pasta-ricecouscous | 10.1 | 9.7 | 11 (4 – 16) |
| Vegetables | 10.0 | 10.8 | 9 (3 – 15) |
| Fruit, nuts and seeds | 10.0 | 10.3 | 6 (1 – 10) |
| Milk-based dessertsc | 10.0 | 10.9 | 4 (0 – 9) |
| Fish | 4.5 | 9.8 | 19 (3 – 33) |
| Cheese | 0.6 | 4.5 | 6 (−4 – 14) |
| Remove 35 gram meat  (No replacement) | 11.5 | 11.7 | 4 (2 – 7) |

aBased on the average greenhouse gas emission (GHGE) and land use in EPIC-NL; bCox stratified for age (continuous) and adjusted for gender, BMI (continuous), smoking status, physical activity, energy intake (continuous), and alcohol intake (continuous); c: consists of (fruit)yoghurt, cream desserts, and milk-based puddings.

Our study has some strengths and limitations. The combination of sustainability of the usual diet and health was not previously studied in a large prospective cohort with a follow-up time of 16 years. The participants of this cohort were sampled from four different geographic areas in the Netherlands and therefore the results may be extrapolated to the Dutch population. In addition, mean GHGE and land use in our cohort were similar to the Dutch Consumption Survey of 1998 [3]. The dietary assessment took place only in the nineties, while nowadays people might have different eating patterns and eat foods that are produced differently. A FFQ is designed to rank people according to their diet. Therefore, the modelled substitution of the 35 g/d of meat was not based on actual intake but was estimated with usual intake. However, our outcomes clearly demonstrate health and environmental benefits from a dietary shift towards lower meat consumption.

The scope of this study is limited to substitutions of an equivalent quantity in grams. Future research may include iso-caloric substitutions or nutritional component equivalency of meat substitutions. In addition, within food groups the environmental impact can vary per product due to farming methods, animal feed, use of side products, transport, and growing conditions [24]. Taking the variety of distributions of environmental impact for every stage of the production process would allow for variance estimation of the environmental impact of a food group. This would further improve the GHGE and land use estimates used in our study. Other research may focus on the role of governmental decisions on consumer behaviour and its efficacy. Examples of governmental actions could be a foodlabelling system that indicates GHGE per 100-gram product, food taxes based on a combination of health aspects and environmental impact of a product, or media campaigns to inform consumers of environmental impact of foods.

# Conclusions

The Dutch diet is relatively high in animal-derived food products and refined carbohydrates and low in fruit and vegetables. Within the dietary range of this populationbased cohort, there were no significant associations between overall daily dietary-derived GHGE and land use and mortality. However, a modelled reduction of 35 gram meat which was replaced with vegetables, fruits, fish, or cereal-rice-couscous resulted in lower GHGE and land use as well as decreased all-cause mortality risk. The results of our study emphasise that a healthier diet is not necessarily a more sustainable diet, and the other way around. Nevertheless, a reduction of meat consumption can influence both health and environmental aspects.

Abbreviations

BMI: Body mass index; CPAI: Cambridge physical activity index;

EPIC: European Prospective Investigation into Cancer and Nutrition; FFQ: Food frequency questionnaire; GHGE: Greenhouse gas emission; HR: Hazard ratio; 95% CI: 95% confidence interval.

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

SB carried out the statistical analysis, prepared the tables and figures, and wrote the paper, taking into account comments from all the co-authors. EHMT and HBB-d-M initiated and designed this study. EHMT was the overall project coordinator. HBB-d-M and EHMT were members of the writing group and gave input on the statistical analysis and interpretation of the results. HBB-d-M, PHMP, WMMV, and YTS are members of the EPIC-NL steering committee. All authors provided comments and suggestions on the manuscript and approved the final version.

Acknowledgments

This work was supported by the ‘Europe against Cancer’ Program of the

European Commission (DG-SANCO); the Dutch Ministry of Public Health,

Welfare and Sports; the Dutch Ministry of Economic Affairs, the Dutch Cancer

Society; ZonMw (the Netherlands Organization for Health Research and Development); and the World Cancer Research Fund (WCRF). In addition, we thank Marjolein Geurts of the RIVM for reading and editing the manuscript.

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Received: 18 December 2013 Accepted: 2 April 2014

Published: 7 April 2014

References

1. Lang T, Barling D: Nutrition and sustainability: an emerging food policy discourse. Proc Nutr Soc 2013, 72:1–12.
2. Tukker A, Huppes G, Guinée J, Heijungs R, Koning A, Oers L, Suh S, Geerken T, Holderbeke M, Jansen B: Environmental Impact of Products (EIPRO) Analysis of the life cycle environmental impacts related to the final consumption of the EU-25. Brussels: European Commision, Joint Research Centre, Institure for Prospective Technological Studies; 2006.
3. Marinussen M, Kramer G, Pluimers J, Blonk H: The environmental impact of our diet - an analysis based on de nutitional consumption survey of 2007–2010 (in Dutch, summary in English). In Book The environmental impact of our diet - an analysis based on de nutitional consumption survey of 2007–2010 (in Dutch, summary in English). Gouda: Blonk Milieu Advies; 2012.
4. Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C: Food security: the challenge of feeding 9 billion people. Science 2010, 327:812–818.
5. Westhoek H, Rood T, Van den Berg M, Janse J, Nijdam D, Reudink M, Stehfest E: The protein puzzle. The Hague: PBL Netherlands Environmental Assessment Agency; 2011:221.
6. Lock K, Pomerleau J, Causer L, Altmann DR, McKee M: The global burden of disease attributable to low consumption of fruit and vegetables: implications for the global strategy on diet. Bull World Health Organ 2005, 83:100–108.
7. Sinha R, Cross AJ, Graubard BI, Leitzmann MF, Schatzkin A: Meat intake and mortality: a prospective study of over half a million people. Arch Intern Med 2009, 169:562–571.
8. Cordain L, Eaton SB, Sebastian A, Mann N, Lindeberg S, Watkins BA, O’Keefe JH, Brand-Miller J: Origins and evolution of the Western diet: health implications for the 21st century. Am J Clin Nutr 2005, 81:341–354.
9. Pimentel D, Pimentel M: Sustainability of meat-based and plant-based diets and the environment. Am J Clin Nutr 2003, 78:660S–663S.
10. Health Council of the Netherlands: Guidelines for a healthy diet 2006. The Hague: Health Council of the Netherlands; 2006. publciation no. 2006/21.
11. Scarborough P, Allender S, Clarke D, Wickramasinghe K, Rayner M: Modelling the health impact of environmentally sustainable dietary scenarios in the UK. Eur J Clin Nutr 2012, 66(6):710–715.
12. Hoolohan C, Berners-Lee M, McKinstry-West J, Hewitt C: Mitigating the greenhouse gas emissions embodied in food through realistic consumer choices. Energy Policy 2013, 63:1065–1074.
13. Vieux F, Darmon N, Touazi D, Soler L: Greenhouse gas emissions of self-selected individual diets in France: Changing the diet structure or consuming less? Ecol Econ 2012, 75:91–101.
14. Stehfest E, Bouwman L, van Vuuren DP, den Elzen MGJ, Eickhout B, Kabat P: Climate benefits of changing diet. Clim Chang 2009, 95:83–102.
15. Macdiarmid JI, Kyle J, Horgan GW, Loe J, Fyfe C, Johnstone A, McNeill G: Sustainable diets for the future: can we contribute to reducing greenhouse gas emissions by eating a healthy diet? Am J Clin Nutr 2012, 96:632–639.
16. Bernstein AM, Sun Q, Hu FB, Stampfer MJ, Manson JE, Willett WC: Major dietary protein sources and risk of coronary heart disease in women. Circulation 2010, 122:876–883.
17. Pan A, Sun Q, Bernstein AM, Schulze MB, Manson JE, Stampfer MJ, Willett WC, Hu FB: Red meat consumption and mortality: results from 2 prospective cohort studies. Arch Intern Med 2012, 172:555.
18. Beulens JWJ, Monninkhof EM, Verschuren WMM, van der Schouw YT, Smit J, Ocke MC, Jansen EHJM, van Dieren S, Grobbee DE, Peeters PHM: Cohort profile: the EPIC-NL study. Int J Epidemiol 2010, 39:1170–1178.
19. Boker LK, Van Noord P, Van Der Schouw Y, Koot N, de Mesquita HBB, Riboli E, Grobbee D, Peeters P: Prospect-EPIC Utrecht: study design and characteristics of the cohort population. Eur J Epidemiol 2001, 17:1047–1053.
20. Verschuren W, Blokstra A, Picavet H, Smit H: Cohort profile: the Doetinchem cohort study. Int J Epidemiol 2008, 37:1236–1241.
21. Blokstra A, Smit H, Bueno de Mesquita H, Seidell J, Verschuren W: Monitoring of risk factors and health in the Netherlands (MORGEN-cohort) 1993–1997. Lifestyle- and risk factors: prevalences and trends (in Dutch). Bilthoven: RIVM; 2005.
22. Ocke MC, Bueno-de-Mesquita HB, Goddijn HE, Jansen A, Pols MA, van Staveren WA, Kromhout D: The Dutch EPIC food frequency questionnaire. I. Description of the questionnaire, and relative validity and reproducibility for food groups. Int J Epidemiol 1997, 26:S37.
23. Ocke MC, Bueno-de-Mesquita HB, Pols MA, Smit HA, van Staveren WA, Kromhout D: The Dutch EPIC food frequency questionnaire. II Relative validity and reproducibility for nutrients International. J Epidemiol 1997, 26:S49.
24. Garnett T: Cooking up a storm: Food, greenhouse gas emissions and our changing climate. In Book Cooking up a storm: Food, greenhouse gas emissions and our changing climate. Food Climate Research Network, Centre for Environmental Strategy, University of Surrey; 2008.
25. IPCC: Climate change 2007: The physical science basis. Geneva: Cambrigde University Press; 2007.
26. Pols MA, Peeters P, Ocke MC, Slimani N, Bueno-de-Mesquita HB, Collette H: Estimation of reproducibility and relative validity of the questions included in the EPIC Physical Activity Questionnaire. Int J Epidemiol 1997, 26:S181.
27. Petrie A, Sabin C: Medical statistics at a glance. Oxford: Blackwell Pub; 2009.
28. Macdiarmid J: Is a healthy diet an enviromental sustainable diet? Proc Nutr Soc 2013, 72:13–20.
29. Rohrmann S, Overvad K, Bueno-de-Mesquita HB, Jakobsen MU, Egeberg R, Tjønneland A, Nailler L, Boutron-Ruault M-C, Clavel-Chapelon F, Krogh V: Meat consumption and mortality-results from the European Prospective Investigation into Cancer and Nutrition. BMC Med 2013, 11:63.
30. Temme E, van der Voet H, Thissen J, Verkaik-Kloosterman J, van Donkersgoed G, Nonhebel S: Replacement of meat and dairy by plant-