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The potential for reducing greenhouse gas emissions from health care via diet change in the U.S.

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ABSTRACT

We created three model healthy alternative diets (HADs) for the US based on USDA recommendations and compared them to the standard American diet (SAD). We estimated the relative risk (RR) for changes in consumption of the foods for three non-communicable diseases based on published meta-analyses. We then calculated the changes in health care costs resulting from reduced RR with the change from SAD to HADs, and the changes in downstream greenhouse gas emissions (GHGE) attributable to these costs. We found significant reductions in disease, health care costs and GHGE. Because we were conservative in the degree of diet change, and in selecting only the highest quality data on disease risk for foods, these results likely underestimate the total potential of diet change to mitigate GHGE. Significantly greater GHGE mitigation is anticipated from larger changes in diet and inclusion of more food-disease risk reductions. In addition, upstream mitigation of GHGE from HADs from changes in the agrifood system will be larger than those presented here for downstream effects—these estimates are included in the larger project on the potential contribution of diet change to mitigating climate change, for which this paper develops a key methodological component.

Keywords: Climate, diet, health care costs, non-communicable diseases, nutrition

1. Introduction

The composition of the diet has a substantial impact on our health and the climate. During recent decades the composition of the standard American diet (SAD) in the US has become markedly less healthy, and these changes, in combination with an increasingly sedentary lifestyle, have resulted in an epidemic of non-communicable diseases (NCDs)(Grotto and Zied 2010). In the US, 35% of the adult population suffers from cardiovascular disease (Go et al. 2014), 9.3% has diabetes(CDC 2014), and 40% is estimated to be diagnosed with cancer during their lifetime (SEER NCI 2014). The epidemic of non-communicable diseases is an important contributor to increasing U.S. health care costs to almost $3 trillion per year, representing 18% of the total US GDP in 2014, and 20% by 2022 (CMS 2013:Table 1). The toll of these diseases can be greatly reduced by adopting a healthy lifestyle, including healthy diets (WCRF/AICR 2007, WHO/FAO 2003).

Our overall goal in this paper is to develop a methodology for assessing downstream mitigation potential, and to use it to estimate the effect on greenhouse gas emissions (GHGE) from the health benefits associated with the adoption of a moderately healthier counterfactual diets by the US population based on USDA recommendations. Our results significantly underestimate potential diet change emissions mitigation potential, because they are based on a limited number of diet change and food-disease links, and do not included upstream GHGE. The research reported here will be expanded in scope to include these aspects, as part of a larger project.

2. Methods

The boundaries of our study were the US, although data for diseased risk were from various countries. The reference year was 2013, and we adjusted data to 2013 based on trends or indices. The system boundaries were the stages of the health care sector associated with the studied diet related diseases.

We estimated the effect of dietary change on GHGE, NCDs, and health care costs in four steps. In step 1, we defined the reference diets, the SAD loss-adjusted food availability at the consumer level in the US (USDA ERS 2014), and healthy alternative diets (HADs). In step 2, we estimated the changes in disease prevalence from dietary change, based on RR (relative risk) estimates found in the literature. In step 3, we estimated changes in health care expenditures from dietary change, based on changes in disease risk from step 3, using the most recent reliable expenditure data. In step 4, we calculated changes in GHGE from changes in health care costs from step

3, using data in the Economic Input-Output Life Cycle Assessment (IO-LCA) based at Carnegie Mellon University (GDI 2014).

2.1. Step 1. Developing dietary scenarios

To analyze the effect of dietary change on health and GHGE in the US, we used as a reference the SAD and compared it with three counterfactual healthy alternative diets (HAD-1, -2, and -3) (Table 1). Dietary intake levels in SAD were based on per capita loss-adjusted food availability data by weight for 2012 (USDA ERS 2014). These data estimate the average actual food intake in the US in cooked weights, based on amounts available at farm gate, adjusted for losses from farm gate through post consumer stages (Muth et al. 2011). In order to distinguish between unprocessed and processed meat, and between whole grains and refined grains which are aggregated in the data provided by the USDA, we assumed that consumption of processed meat accounted for 22% of total meat intake (Daniel et al. 2011), and consisted of 90% red meat, and that consumption of whole grains and refined grains accounted for 90% and 10% of total grain consumption, respectively (Lin and Yen 2007, USDA 2010).

Table 1. Per capita intake[1] of reference (SAD) & model (HAD) diets (g day^{-1}).

Food	SAD	HAD-1	HAD-2	HAD-3
Red & processed meat	92	51	25	0
Fruits & vegetables	328	657	657	657
Beans and peas	7	15	50	84
Total grains	167	131	131	131
Whole grains	17	79	79	79
Refined grains	150	52	52	52

[1] Intake levels in cooked weights. Basis for RR calculations.

To create the HADs, we adjusted SAD only for foods for which (i) USDA dietary recommendations were consistent with international nutrition and health authorities (USDA 2010, WCRF/AICR 2007), (ii) there were documented GHGE synergies, and (iii) there were high quality data on contribution to disease (section 2.2). The dietary recommendations for which there are documented GHGE synergies were: (i) eat no more calories than needed to maintain a healthy body weight, (ii) increase the proportion of calories coming from plant-based food, iii) reduce the consumption of meat (especially coming from red and processed meat), and iv) reduce the consumption of foods with low nutritional value (Garnett 2011). Creation of the HAD diets thus involved only a portion of the total SAD diet; we did not change any other food groups (e.g. unprocessed white meat, fish, dairy, eggs).

In HAD-1 we increased the intake of fruits, vegetables and whole grains, and reduced the intake of red and processed meat and refined grains from the levels in the SAD to the USDA recommended levels (USDA 2010). Processed meat was limited to 10 g of cooked meat per day based on the recommendation by the WCRF that processed meat should be avoided or limited as much as possible (WCRF/AICR 2007). We assumed that whole grains and refined grains contributed to 60% and 40% of total grain intake, respectively, based on the USDA recommendation that at least half of the grain consumption should come from whole grains (USDA 2010). We limited fruit juice to 20% of total fruit consumption based on the USDA recommendation that the majority of fruit intake should come from whole fruits (USDA 2010). By using whole food-based recommendations (e.g. vegetables), as opposed to nutrient-based recommendations (e.g. fiber), we reduced the risk of double counting health effects from nutrients found in various food groups.

We converted recommended food consumption levels provided by the USDA (USDA 2010) into grams day^{-1} using serving size weights given in (USDA ERS 2014). According to these data, one ounce equivalent of meat and grains equals 28.3 g (cooked weight) and 22 g, respectively (USDA 2011); one cup of vegetables, beans and peas, and fruits including juices is equivalent to 123 g, 73 g (cooked weight) and 187 g, respectively).

Intake levels in HAD-2 and HAD-3 are the same as in HAD-1, except that consumption of red and processed meat was further reduced and replaced by an increased intake of beans and peas. For validation, the nutritional content of all dietary scenarios studied was estimated, and found to provide 3500-3900 kJ day^{-1}, i.e. about one third of the average recommended daily energy intake for adults (NCM 2004).

2.2. Step 2. Changes in disease prevalence with changes in diet

We based the selection of diseases to be included in this study on a literature review of epidemiological meta-analyses of research on the relationships between specific foods and diseases. The literature review was performed in the NCBI Pub Med database in March 2014 using as keywords the selected foods groups (e.g. "vegetables") and different NCDs (e.g. "coronary heart disease"). The diseases included in the review were coronary heat disease (CHD), hypertension, adult onset diabetes myelitis (AODM) and a range of cancers. We selected peer reviewed meta-analyses of prospective cohort and randomized controlled trial (RCT) studies, published between 2005 and 2014, that provided RR with 95% confidence intervals (CI). We judged the evidence for the diet-disease relationship as insufficient, probable, or convincing, depending on the RR estimates found and number of studies supporting the relationship: *convincing* if minimum two meta-analysis supported the relationship and if all meta-analysis located showed significant reductions in disease risk from the studied changes in diet; *probable* if a minimum of one meta-analysis located supported the relationship and if the most recently published meta-analyses with significant results showed a reduced risk from the studied changes in diet; and *insufficient* if the criteria for convincing and/or probable were not met. We chose estimates for reduced risk of disease conservatively by only including RR estimates where the evidence was convincing or probable, which limited the diseases studied to CHD, AODM and colorectal cancer (CRC).

The health effects of changing the diet from SAD to HAD were estimated by calculating a revised RR (RR_{re}) for each food-disease RR, assuming a log-linear dose response relationship between food intake and health outcome, as reported in the meta-analyses (Eq. 1):

$$RR_{re} = RR^{((x-y)/u)} \qquad \text{Eq. 1}$$

where RR is the original RR obtained from meta-analyses for diet food f (e.g., processed meat) and disease d (e.g., CHD), x is the level of f in the HAD, y is the level of f in the SAD, and u is the unit increase reported in the meta-analysis identified for disease d. The reductions in RR for a unit change in food consumption were assumed to follow a uniform dose-response relationship across the range of intake levels in the SAD and HAD. When there was more than one meta-analysis RR for a food-disease combination, we used an arithmetic average of the *RR*s. For the relationship between whole grains and CHD, no dose-response RR estimates were located; therefore, a RR value based on the comparison of a high vs. low consumption was used to estimate this health effect. This was considered valid due to the large difference in intake levels of whole grains between the SAD and HADs.

We then calculated the combined effect of the changes in all of the foods contributing to the RR for each disease (RR_{cd}) by multiplying them, based on the assumption that the effect of each food was independent (Eq. 2) (Ezzati et al. 2006):

$$RR_{cd} = RR_{re1} * RR_{re2} * RR_{re3} * \ldots RR_{ref} \qquad \text{Eq. 2}$$

where RR_{re1}, RR_{re2}, RR_{re3}, and RR_{ref} are the recalculated RR values for each of the individual food changes in the diet. Finally, to construct the 95% confidence intervals around the relative risk estimates for the HAD we conducted a Monte Carlo simulation (Rubinstein 2007) with 5000 iterations in which the individual RR estimates were allowed to vary randomly according to a lognormal distribution.

2.3. Step 3. Changes in health care costs from changes in disease prevalence

The Medical Expenditure Panel Survey (MEPS 2011) is a standard source for health care cost data, but has widely recognized methodological limitations, so we used the most recent data for expenditures for the three diseases from alternative sources. Expenditures for CHD and CRC were from (Heidenreich et al. 2011, Mariotto et al. 2011), with spending category percentages assigned by percentages for all heart conditions by MEPS (AHRQ 2014). For AODM, which accounts for 90% of all forms of diabetes mellitus, we used (ADA 2013) for costs and spending category assignments, assuming that category expenditure distribution would remain constant.

Expenditures for each disease were then adjusted for inflation to 2013$. Because health care spending in the United States increases at a rate different than the standard rate of inflation, we used the Bureau of Labor Statistics consumer price index for medical care (BLS 2014) to adjust for inflation of medical expenditures.

2.4. Step 4. Change in GHGE due to changes in health care costs (ΔGHGE-H)

In order to estimate GHGE for health care expenses for each disease, we identified subcategories of expenses, since the types of services vary substantially (e.g., diabetes requires more prescription medications than heart disease). Subcategories were assigned in alignment with the relevant Carnegie-Mellon IO-LCA (GDI 2014) categories of medical expenditures: hospitals, pharmaceutical manufacturing, physician’s offices, and home health services. CRC was assumed to have the same proportion of economic activity in those categories as all forms of cancers, CHD was assumed to have the same proportion of economic activity in categories assigned to all heart conditions, both taken from MEPS category spending assignments. The same method was used for AODM in the broader category of diabetes mellitus.

We then used the IO-LCA to determine an initial GHGE for each disease. However, because the IO-LCA uses CO_2e, or global warming potential (GWP), values from older IPCC assessments of various GHGs, we adjusted the GWP for CH_4 from 21 to the most recent IPCC GWP of 34 for a 100-year time frame, and 86 for a 20-year time frame (IPCC 2013:714, Table 8.7). We did this only for CH_4 because the N_2O GWP changed only a few percent.

Since the Carnegie-Mellon assessments were based on 2002 emissions levels, we adjusted for measured decrease in carbon intensity in the US economy from 2002-2011 (EIA 2013), and projected this to 2013. We assumed that the decrease in carbon intensity experienced by the US economy was the same as that in the health care sector.

Finally, we assumed that the RRre associated with HADs would result in a proportional decrease in expenditure.

3. Results

Changing from the SAD to HAD-1 reduced the RR of CHD, AODM and CRC by 20-40%, and HAD-2 and HAD-3 further reduced RR by 5-9%, respectively (Table 2, Fig. 1). The reduced RR of disease also resulted in an a 25-33% reduction in total health care costs for these diseases, and a total reduction in the US of 20-33 million MT CO_2e yr^{-1}, and 65-106 kg CO_2e $person^{-1}$ yr^{-1}.

Table 2. Reduction with change to HADs in disease, health care costs, and GHGE.

Diet change from SAD to	Reduction in									
	Relative risk of disease						Health care costs ($B yr^{-1}) (of $219.5 total for diseases)	Downstream GHGE (kg CO_2e $person^{-1}$ yr^{-1})		
	CHD		AODM		CRC			CH_4 GWP =21	CH_4 GWP =34	CH_4 GWP =86
	Combined effect	95% CI	Combined effect	95% CI	Combined effect	95% CI				
HAD-1	40%	29-51	35%	28-44	20%	13-26	54	64.5	69.0	87.0
HAD-2	45%	31-67	41%	32-50	25%	17-32	65	74.5	79.7	100.5
HAD-3	45%	32-58	43%	34-53	29%	20-37	72	78.5	84.0	105.8

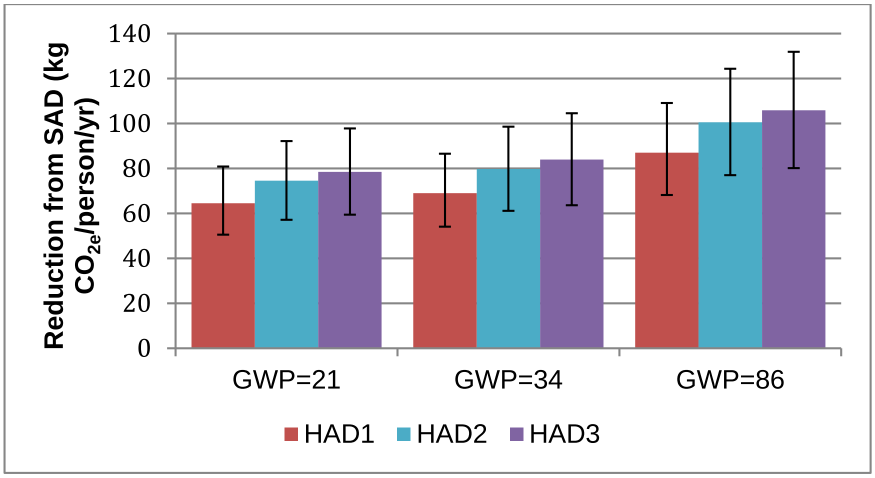

Fig. 1. Downstream reduction in CO_2e person^{-1} yr^{-1} for a CH_4 GWP of 21, 34, and 86.

4. Discussion

4.1. Results in relation to previous studies

Research on the combined effects of diet on the environment and nutrition is new but expanding. In recent years nutritional aspects have increasingly been incorporated into environmental and LCA assessments of food and diets, however, so far this has only included epidemiology to a limited extent. A small number of studies have examined the effect of healthier counterfactual diets on reduced morbidity and mortality, and on GHGE upstream (Aston et al. 2012, Scarborough et al. 2012), and on the effects of diet on GHGE via improved health, for example, by linking increased body weight to increased GHGE from higher fuels energy use (Edwards and Roberts 2009). However, the link between diet, health and GHGE from associated health care costs which we estimated in this paper has to our knowledge not previously been attempted. This study also fills a geographical gap, as most research on GHGE from dietary scenarios is limited to European settings (Hallström 2013)

4.2. Limitations of the research

The results of this study are largely dependent on the assumptions underlying the data we used for food consumption, RR, health care expenses, and GHGE. Of special concern when combining RR estimates as in this study, is the risk of double counting. We designed the study to minimize the risk of double counting by only using RR-estimates coming from meta-analyses that adjusted for influencing confounders, such as other types of food intake, physical activity level and history of disease. Despite these efforts, the risk of double counting remains, meaning that the health effects from the studied dietary change may be overestimated.. The overall uncertainty in results was also estimated with Monte Carlo Analysis. However, other assumptions we made would have resulted in under estimation of GHGE reduction from our counterfactual diets (see below).

4.3. Policy implications

The downstream GHGE reduction for HADs is equivalent to removing 4.3-7.0 million automobiles from the US roadways; it is also significant compared with other mitigation measures, for example, 1.9-2.4% of the Obama Administration’s goal of a 17% reduction below 2005 US emissions levels by 2020. When upstream GHGE reductions from the HADs are added these numbers will increase significantly.

Although our results showed substantial potential benefits from dietary change, the total potential of diet change to simultaneously improve health and reduce GHGE is likely underestimated because it only included only a small subset of the possible foods and food-related NCDs. The total assigned expenditures for the diseases studied amounted to only $220 billion, less than 8% of the projected total health care spending for the US in 2013 od $2.9 trillion (CMS 2013:Table 1). Therefore, the savings we found from switching to HADS of $B 76-94 yr^{-1} are likely a small portion of the potential savings, given that many more diseases and conditions are associated with diet. These savings (assuming consumer rebound is not significant), could be used for programs to support diet change and to retrain workers whose jobs would disappear as a result of the macroeconomic benefits of diet change.

But how realistic are the behavior changes required for the HADs? For HAD-1, the intake of unprocessed red meat and processed meat is reduced by 17 grams and 24 grams, respectively. The required change in meat consumption corresponds to eating one quarter pounder less per week and 1.5 sausages per week instead of 5.5. In order to reach the intake levels of fruits and vegetables and whole grains in HAD-1, the consumption in the SAD would have to increase by 2 and more than 4 times, respectively. Regardless of actual behavioral changes that could result over the coming decades, the attribution of GHGE to current behaviors remains a significant policy challenge.

In HAD-2 and -3 we decreased and eliminated red and processed meat. Lower intake levels of meat are also not a concern from a health perspective as long as reductions in meat consumption are compensated for by increased intake of other foods. Guidelines for healthy lacto-ovo-vegetarian and vegan diets are, for example, provided by the USDA (USDA 2010). In fact, there is increasing evidence that animal foods are a significant risk factor for many diseases (e.g. Farvid et al. 2014, Jakobsen et al. 2009, Kim et al. 2013), and also contribute disproportionately to the GHGE of the food system (Garnett 2009).

5. Conclusion

There is growing awareness of the importance of diet in determining GHGE and health care costs. We have reported here a methodology for quantifying this relationship. Our results show that it is possible to estimate the effects of changing to healthier diets with a high level of probability for the small proportion of foods and related diseases for which adequate data exist. The effects are significant in terms of improved health, reduced costs, and GHGE reductions. The methodology developed here is a key component of our larger project to estimate the net GHGE mitigation potential (from agrifood system change to health care) of diet change for a range of diets as alternatives to the SAD. Given the urgency of mitigating emissions over the short term in order to avoid catastrophic climate change, the mitigation potential of diet change should be investigated more thoroughly for incorporation into national, state and local climate policies.

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