

## EVIDENCE BRIEF

# The Environmental Impacts of Sustainable Dietary Patterns



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## Key Messages

- Diets lower in animal products (i.e., meat and dairy) have lower environmental impacts than usual average diets.
- Diets that adhered to dietary guidelines or healthy dietary patterns (e.g., Mediterranean) were often, but not always, associated with reduced environmental impacts.
- In general, the estimated environmental benefits of following a ‘healthy’ diet were less than following diets with reduced animal products.
- For any diet type, strategic replacement of foods and beverages with high environmental impacts will be critical in ensuring environmental benefits.
- There may be multiple strategies to optimize diet sustainability, such as reducing or excluding animal products; however, the evidence is inconclusive as to the best strategy to achieve a sustainable diet.

## Issue and Research Question

Sustainable diets are ambitiously described as “diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations... (and) are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.”<sup>1 (p.83)</sup> Sustainable diets are usually characterized as energy balanced, mostly plant-based, and with no to moderate intakes of meat and dairy products.<sup>2</sup> ‘Plant-based diets’ are often used synonymously with sustainable diets, but vary widely in terms of their inclusion of animal-based products.<sup>3</sup> Contrary to popular belief, plant-based diets do not require complete exclusion of meat or dairy products; flexitarian, pescetarian, Mediterranean, Nordic, Dietary Approaches to Stop Hypertension (DASH), as well as vegetarian and vegan dietary patterns are examples of plant-based diets.<sup>3</sup>

As a means to improve environmental health, human health, and social justice,<sup>4</sup> sustainable diets are an emerging focus of national dietary guidelines<sup>2</sup> and other dietary and food system interventions. For example, the 2019 Canada’s Food Guide recognizes that food production, processing, distribution, consumption, and waste impact the environment.<sup>5</sup> Health Canada recommends that Canadians follow healthy diets low in animal-based products and high in plant-based products to lessen environmental impacts on water, soil, and air.<sup>5</sup> In October 2019, Toronto joined 13 international cities (Barcelona, Copenhagen, Guadalajara, Lima, London, Los Angeles, Milan, Oslo, Paris, Quezon City, Seoul, Stockholm) in signing the C40 Good Food Cities Declaration – committing to increasing the consumption of “healthy plant-based food” and shifting away from “unsustainable, unhealthy diets” in their cities by 2030.<sup>6</sup>

Shifting population intake towards sustainable diets is immensely challenging<sup>4,7</sup> and requires exploring aspects of production (i.e., increase efficiency), consumption (i.e., shift consumer consumption patterns to drive production), and socio-economics (i.e., change the governance of the food system).<sup>7</sup> The evidence on sustainable diets is growing rapidly, yet uncertainty and complexity of defining and achieving sustainable diets remains. This evidence synthesis aims to examine review-level evidence regarding the sustainability of dietary patterns, focusing on nutritional and environmental outcomes.

This Evidence Brief asks: What dietary patterns are associated with environmental benefits?

## Methods

A literature search was conducted on November 29, 2019 by PHO Library Services for articles published between 2015 and the search date. The search involved four databases: Ovid MEDLINE, Ovid Embase, Ovid Global Health, and EBSCOhost Environment Complete. The following search terms were included, but were not limited to: diet, eating, food, environment, climate change, carbon footprint, and sustainable development. References from the included articles were hand searched for additional relevant studies. A forward search of a seminal paper published in January 2019<sup>4</sup>, and of three reviews<sup>8-10</sup> identified in the initial search, was completed on June 11, 2020 to identify any new reviews. The full search strategy is available upon request from Public Health Ontario.

Articles were eligible for inclusion if they: were systematic reviews, assessed population-based dietary intake, quantified the environmental impact of dietary intakes, were human studies, and were published in English. Reviews were excluded if they focused on environmental impacts of individual food types (as opposed to dietary patterns), single parts of the food system (e.g., agricultural production, food waste), or included data solely from developing countries (global studies were included).

Three reviewers independently screened titles and abstracts. Full text articles were retrieved, and reviewed by two reviewers, confirmed by a third. Consensus on included studies was achieved through discussion. Relevant information was extracted from each article by one reviewer on diet types and environmental impacts.

One reviewer conducted quality appraisals on all included articles, while a second reviewer completed quality appraisal on a subsample of studies for verification. The AMSTAR 2<sup>11</sup> was used to assess the quality of systematic reviews. Discrepancies in quality appraisal outcomes between the reviewers were resolved by consensus. More information on quality appraisal is available upon request.

## Main Findings

The search identified 1,942 articles, from which 73 were selected for full-text review. Seven review articles met the inclusion criteria. Three additional reviews were identified and met the inclusion criteria through forward searching.<sup>10,12,13</sup> One review that did not report on any studies unique from other reviews was excluded later.<sup>14</sup> Another review<sup>15</sup> only had one study each that was unique to their reviews but were retained in the evidence synthesis because it used different methods to assess the environmental impact of diets in the studies than other reviews (e.g., using GHG levels of diets as the exposure and nutrition as the outcome). Caution should be taken when interpreting results from these reviews as findings from studies repeatedly reviewed across reviews may be unintentionally overemphasized.

In the end, nine reviews were included in the synthesis. Two reviews were assessed to be of moderate quality,<sup>8,9</sup> while the remaining were assessed to be of low or critically low quality which was primarily due to lack of explicit methods documented in the reviews.

The reviews included studies with varied designs and methods for assessing diets and environmental outcomes. Diets were often measured through representative data on food consumption, food purchasing or food availability. Dietary intake was measured as actual intake or theoretical intake (i.e., modelled diets). Environmental outcomes most commonly included impacts on greenhouse gas emissions (GHGs), land, and water, often analyzed using a life cycle approach in individual studies. The impact of diets on environmental outcomes were usually assessed by comparing different types of actual diets (e.g., self-selected vegetarian diets versus omnivore diets) or comparing the average population diet (e.g., usual or habitual diet) to modelled diets (e.g., a theoretical vegetarian diet modelled from the average diet). In this report, “reference diet” is used to represent the usual, habitual, or average diet – commonly omnivore – to which alternative diets were compared.

Because few studies reported on nutritional outcomes of diets, such as nutrient content and dietary quality scores,<sup>15,16</sup> it was only possible to assess the evidence according to diet types that would generally be considered to be nutritious, including vegetarian, vegan, and Mediterranean diets, and diets that align with recommended dietary guidelines. Thus, this evidence synthesis focuses on the environmental impacts of diets to assess their sustainability, assuming these diet types are nutritiously superior to reference diets. Nutritional outcomes are included where possible.

There were two groups of alternative diets that were reviewed across included studies: (i) diets with reduced animal-based products, and (ii) diets generally considered ‘healthy’.

Overall, most alternative diets performed better on environmental outcomes than reference diets but to varying degrees due to a myriad of factors including differences in food selection between individuals, geographic and contextual factors, and methodological differences across studies. To this end, two

reviews stated that the evidence was inconclusive as to whether one diet type was more sustainable than others (e.g., vegan versus vegetarian).<sup>17,18</sup> However, there are consistent findings across reviews that highlight certain attributes of diets that may be more environmentally beneficial than current dietary habits. In particular, diets lower in animal products had consistently lower environmental impacts than average diets. Secondly, alternative diets that followed ‘healthy’ dietary guidelines or ‘healthy’ dietary patterns were often, but not always, associated with reduced environmental impacts. Comparatively, diets low in animal products had lower environmental impacts than that of ‘healthy’ diets.

## Diets with Reduced Animal Products

Eight articles reviewed the environmental impacts of diets that contained low amounts or no animal-based foods, including vegan and vegetarian diets.<sup>8,10,12,15-17</sup> Some reviews also explored the substitution of some or all meat and/or dairy with other foods.<sup>8,9,15,17</sup> Two examined the impacts of reducing energy intake through reducing calories from meat.<sup>15,17</sup> All reviews<sup>8-10,12,13,15-17</sup> reported consistent conclusions that diets with reduced animal products (meat and dairy), including low-meat diets, vegetarian diets, and vegan diets, have lower environmental impacts than the reference diets.

### Vegan

All reviews found that vegan diets had reduced GHGs<sup>9,10,12,16,17</sup> and land impacts,<sup>9,10,12</sup> but mixed impacts on water use and water footprints.<sup>9,10,12,13</sup>

### GHG

Compared to alternative diets assessed, vegan diets were associated with the lowest levels of GHGs.<sup>9,10,16,17</sup> Vegan diets had 32-49% lower GHGs than reference diets<sup>9,10,12</sup> The reduced GHG impact of vegan diets appeared to be superior to that of ‘healthy’ diets.<sup>9,10</sup> On the other hand, vegan diets had only slightly lower GHG levels relative to vegetarian diets.<sup>9,12,17</sup>

### LAND

Vegan diets used 50-87% less land compared to reference diets.<sup>9,10,12</sup> ‘Healthy’ vegan and vegetarian diets that met US dietary guidelines reduced land requirements more than a ‘healthy’ omnivore diet that met US dietary guidelines.<sup>10</sup> Vegan diets were similar<sup>10</sup> or slightly better<sup>9,12</sup> than vegetarian diets in terms of their impact on land, relative to usual average diets.

### WATER

Four reviews evaluated the impacts of vegan diets on water.<sup>9,10,12,13</sup> A meta-analysis of total<sup>a</sup>, green<sup>b</sup>, and blue<sup>c</sup> water footprints (adjusted for study location and other covariates) found that vegan diets had lower water footprints relative to reference diets (-25.2% total water footprint; -26.1% green water footprint; -11.6% blue water footprint) which was better than reduced meat diets (including vegetarian and ‘healthy’ diets, relative to the reference diet<sup>13</sup>). Reinhardt found less compelling results: the blue water footprint of vegan diets was similar or greater compared to the reference diet, as well as similar to reduced meat (including vegetarian) and ‘healthy’ diets<sup>10</sup>. Further, the green water footprint of vegan

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<sup>a</sup> Total water footprint is green water footprint and blue water footprint combined.<sup>13</sup>

<sup>b</sup> Green water footprint is “soil water derived from natural rainfall, which is a precious resource that supports world food production”.<sup>18 (p.936)</sup>

<sup>c</sup> Blue water footprint is “the consumption of freshwater from surface-water bodies (e.g., rivers, lakes) and groundwater”.<sup>18 (p.936)</sup>

diets was similar or less, compared to the reference diet. It should be noted that blue water footprints, although commonly used, are not a measure of water scarcity which is the primary environmental concern.<sup>18</sup>

Two reviews that assessed the impacts of vegan diets on water use found mixed results: Aleksandrowicz et al. included only one study which found that vegan diets had the worst impact on water use (+107%).<sup>9</sup> An updated review by Fresán and Sabaté<sup>12</sup> included four studies (including the one in Aleksandrowicz et al.<sup>9</sup>) in which three studies found increases in water use and one study reported a decrease in water use.

## Vegetarian

Vegetarian diets had reduced GHGs,<sup>9,10,15-17</sup> and lesser impacts on land,<sup>9,12</sup> and water.<sup>9,12,13,17</sup>

### GHG

Reviews cited that vegetarian diets had lower GHGs than the reference diets,<sup>9,10,12,16,17</sup> with median reductions in GHGs reported between 27% and 35%.<sup>9,10,12</sup> Interestingly, two reviews found studies reporting that the GHG impact of vegetarian diets was similar to the GHG impact for diets of 'optimized omnivores' (i.e., meat products are replaced with meat options that have lower GHG)<sup>17</sup> and low animal product eaters (e.g., once per day).<sup>10</sup>

### LAND

In both reviews that assessed the impacts of vegetarian diets on land use, vegetarian diets ranked second after vegan diets for their estimated reductions on land use of 42%<sup>12</sup> and 51%,<sup>9</sup> compared to reference diets.

### WATER

The water use associated with vegetarian diets was reportedly better than reference diets.<sup>9,12,17</sup> Two reviews stated that vegetarian diets had lower median water use (-29%<sup>12</sup> and -37%<sup>9</sup>), compared to reference diets (both reviews included an outlier where vegetarian diets were found to have 82% greater water use than reference diets). In a meta-analysis of water footprints, Harris et al. found that reduced meat diets (including vegetarian) had lower total (-17.8%), green (-18.1%), and blue (-5.5%) water footprints (adjusted for study location and other covariates), which was better than the impact of 'healthy' diets, but worse than for diets with no animal products (e.g., vegan diets).<sup>13</sup> This finding was similar to Auestad and Fulgoni who stated that vegetarian diets had a lower water footprint than usual diets, and 'healthy' diets.<sup>17</sup>

## Reduce and Replace Animal Products

Four studies examined the environmental impacts of various substitution foods replacing some or all meat and/or dairy.<sup>9,15,17</sup> A gradient exists between animal product intake and GHG emissions, whereby diets lower in meat (particularly ruminant and processed meats) and dairy, have lower GHG emissions than diets higher in animal-based foods.<sup>8,15,17</sup> Replacing some meat appears to reduce GHGs less than when all meat or all meat and dairy is excluded.<sup>8,10,12,15,16</sup> Reduced meat diets also had positive impacts on land,<sup>9,15,17</sup> and water.<sup>13</sup> Nonetheless, excluding all meat and dairy may not be necessary for environmental benefit.<sup>8,15,17</sup> For example, Auestad and Fulgoni cites one study that found that reducing alcohol, sweets, and hot drinks by 50% would reduce GHGs the same as reducing meat intake by 30%.<sup>17</sup> The choice of substitution food or beverage is highly important as some items can have higher environmental impacts than meat or dairy (e.g., the water use per calorie is higher in fruits, vegetables,



nuts).<sup>9</sup> Some reviews claimed that environmental benefits of alternative diets can be partly attributed to reductions in caloric intake relative to reference diets which are usually high calorie, energy-dense diets.<sup>15,17,18</sup>

## **GHGS**

Three reviews discussed substitution approaches to reduce meat intake and found consistent results on GHGs.<sup>9,15,17</sup> First, GHGs were more reduced when all ruminant (beef and lamb) meat and all dairy was replaced with monogastric (pork, poultry) meat, or when some meat and dairy was partially replaced with plant-based foods, compared to other substitution methods.<sup>9,17</sup> On the other hand, replacing all meat with dairy or partially replacing meat only with plant-based foods (while still consuming dairy) had minimal impacts on GHGs.<sup>9,15,17</sup>

Perignon et al. states that reduced energy intake and reduced energy density were two main factors identified in diets considered more sustainable (lower GHG and higher nutritional quality), which arose from eating more calories from starchy foods, fruit, vegetables, and nuts, and fewer calories from meat, mixed dishes, and alcoholic drinks, compared to the usual average diet.<sup>15</sup> Auestad and Fulgoni<sup>17</sup> and Perignon et al.<sup>15</sup> state that the environmental impact of balanced energy diets may be maximized when the reduction in calories comes from decreased meat intake and the calories from meat are not isocalorically replaced with other foods. According to one study reviewed by both Auestad and Fulgoni<sup>17</sup> and Perignon et al.,<sup>15</sup> GHGs were reduced by 2% to 12% when energy intake was reduced by eating 20% less meat and the calories of the meat (240kcal) were not replaced.<sup>15</sup> Simply reducing calories to match needs without changing the composition of the diet poorly reduced environmental impacts on GHGs, land, and water<sup>9</sup>

Ridoutt et al. cautions that diets with lower GHGs are not always nutritionally adequate due to lower intakes of animal-based products.<sup>18</sup> Nevertheless, diets that limits or excludes high GHG foods (e.g., meat and dairy) can be carefully constructed to reduce GHGs while maintaining nutritional quality.<sup>18</sup>

## **LAND**

Similar to the findings on GHG impacts, dairy or a combination of dairy and plant-based foods as a replacement for meat has little impact on land use.<sup>9</sup> Plant-based foods are better replacements in terms of reducing impacts on land use when they replace both meat and dairy.<sup>9,15</sup> Some reduction in meat and dairy (e.g., 30%) is associated with lower land use<sup>15,17</sup> but complete removal of meat and dairy had greater land impact reduction<sup>9</sup> (see Vegan). Aleksandrowicz et al. found that replacing all ruminant meat with monogastric meat (while still consuming dairy) had the greatest reduction on land use (-37%) and that partially replacing meat, or partially replacing, meat and dairy with plant-based had were not as impressive in terms of their reductions on land use (-16% and -10%, respectively).<sup>9</sup>

## **WATER**

Aleksandrowicz et al. was the only review to assess the impact of substituting meat and dairy on water use.<sup>9</sup> From three studies on partially replacing meat and dairy with plant-based foods, the median change in water use was -15%, ranked as 4/9 for all diet types assessed. Similarly, replacing ruminant meat with monogastric, while continuing to consume dairy, reduced water use by 11% (rank 5/9), as reported in one study reviewed by Aleksandrowicz et al.<sup>9</sup>

## Diets Considered ‘Healthy’

This section includes reviews on diets considered to be ‘healthy’, meaning that they follow national or other food-based dietary guidelines (e.g., Canada’s Food Guide), or that they adhere to a healthy dietary patterns (e.g., Mediterranean diet)

The evidence concluded that ‘healthy’ guidelines diets had lesser impacts than reference diets, but the results were inconsistent.<sup>10,13,16,18</sup> Similarly, most reviews stated that diets that followed ‘healthy’ dietary patterns (e.g., Mediterranean; New Nordic; Atlantic) had lesser environmental impacts than reference diets,<sup>9,13,16,17</sup> with the exception of a ‘healthy’ Mediterranean diet pattern that met the US Dietary Guidelines.<sup>10</sup> However, the cited environmental benefits of ‘healthy’ diets were consistently less than that from diets with reduced animal products.

## Healthy Guideline Diets

Six reviews discussed the environmental impacts of ‘healthy guideline’ diets.<sup>8-10,13,17,16</sup> There were mixed results on the impact of ‘healthy’ diets on GHGs, land, and water. Although reviews found positive results of following a recommended diet, not all recommended diets had lower environmental impacts than reference diets or other sustainable diet options described above. A global assessment of diets in 2016 (US, NZ, UK, Netherlands, Germany, Spain, France, Italy, Brazil, Australia) stated that “dietary patterns that adhered to dietary guidelines (in total, not in part) are more sustainable than the population’s current average amount of dietary pattern intake”;<sup>8 (p.1026)</sup> however, other reviews more recently published were less certain that diets aligned with food-based dietary guidelines were more environmentally friendly than reference diets.<sup>13,16,18</sup>

## GHGS

Five studies explored the impact of ‘healthy’ diets on GHGs.<sup>8-10,15,17</sup> Aleksandrowicz et al. found that diets following food-based guidelines reduced GHGs by a median of 12%, compared to the reference diet (ranked 9 out of 14 of all diet types).<sup>9</sup> Reinhardt et al. reviewed studies that evaluated the environmental impact of diets following the US dietary guidelines only.<sup>10</sup> Compared to the reference diet, a ‘healthy’ omnivore diet had mixed impacts on GHG ranging from a 23% reduction, to no difference, to a 9-12% increase. The variability in results may be due to differences in diet compositions, system boundaries, and food loss calculations.<sup>10</sup> Compared to other recommended healthy diets across the globe, Reinhardt stated that one study found that the ‘healthy’ omnivore diet in the US had higher GHG levels than recommended diets in other countries, including Canada.<sup>10</sup> Similar to Reinhardt et al., González-García et al. found mixed results of the environmental impact of ‘healthy’ diets from a variety of countries and concluded that “diets that follow food-based dietary guidelines (i.e., healthy diets) do not always result in lower GHG emissions”.<sup>16 (p.88)</sup> This is consistent with findings of actual diets by Nelson et al. who concluded that “not all diets with the highest nutritional quality were those with the lowest GHG emissions”.<sup>8 (p.1022)</sup> Thus the relationship between nutrition and GHG impacts is not linear nor clear, which risks trade-offs between sustainability factors when selecting foods.

Three studies reviewed the nutritional quality of diets and their GHG impact and found that more nutritious diets have higher GHG levels<sup>10,15,17</sup> due to higher intakes of fruits and vegetables,<sup>15,17</sup> lower intakes of sugars<sup>10</sup> or sweet foods.<sup>15,17</sup> Reinhardt et al. stated that diets with lower GHGs had less meat, dairy, and solid fats, and more poultry, plant proteins foods, oils, whole and refined grains, and added sugars.<sup>10</sup> Nonetheless, Aleksandrowicz et al. and Auestad and Fulgoni state that the environmental benefit of following food-based guidelines can be optimized by careful food selection.<sup>9,17</sup> When self-selected low GHG diets were assessed, Ridoutt et al. found that the high or low intake of energy-dense,

nutrient-poor foods (e.g., alcohol, sugar sweetened beverages, confectionary, baked and salted snacks, desserts, and processed meats) clearly separated low GHG diets that were of higher and lower nutritional quality, respectively.<sup>18</sup>

## LAND

Three studies reported on the impacts of healthy guideline diets on land demand with mixed results.<sup>9,10,17</sup> A 'healthy' omnivore diet that followed the US Dietary Guidelines had similar or decreased land use (10-30%) compared to the average US diet, but a lesser benefit to that of 'healthy' vegetarian or vegan diets that followed the US Dietary Guidelines.<sup>10</sup> Aleksandrowicz et al. reported that meeting healthy guidelines could moderately reduce land use (-20%), ranking healthy guideline diets as 7 out of 13 of all alternative diet scenarios reviewed in terms of its potential benefit on land requirements.<sup>9</sup> Further optimization of diet by selecting foods with low environmental impacts can reduce land use by 34%.<sup>9</sup> Auestad and Fulgoni reported that the land impacts of healthy guideline diets are geographically variable.<sup>17</sup>

## WATER

Four reviews reported on the impacts of healthy guideline diets on water.<sup>9,10,13,17</sup> Auestad and Fulgoni reported that healthy guideline diets had a lower water footprint than reference diets.<sup>17</sup> More specifically, a meta-analysis adjusting for study location and other covariates found that healthy guideline diets had lower total and green water footprint (-6% for both) but found no difference for blue water, compared to reference diets.<sup>13</sup> Reinhardt et al. reported that omnivore diets that follow the US dietary guidelines had similar or increased blue water footprint (15-35%) and similar green water footprint, compared to reference diets.<sup>10</sup> Aleksandrowicz et al. ranked healthy guideline diets as the second worst diet type in terms of their impact on water, reporting only a 6% decrease in water use.<sup>9</sup> However, a healthy guideline diet could be optimized by removing foods with high environmental impacts, reducing its water use by 15% compared to reference diets.<sup>9</sup>

## Healthy Dietary Patterns

Five studies<sup>8-10,16,17</sup> reviewed the environmental impact of dietary patterns generally considered 'healthy'. The Mediterranean dietary pattern<sup>d</sup> was most commonly reviewed as well as variations of the Mediterranean diet (New Nordic<sup>e</sup> and Atlantic<sup>f</sup> diets).

Most reviews stated that healthy dietary patterns were found to have modest environmental benefits compared than average diets.<sup>8,9,16,17</sup> Nelson concluded that the Mediterranean diet, and its variation the New Nordic Diet, had a lesser environmental impacts across various environmental outcomes compared to reference diets.<sup>8</sup> On the other hand, Reinhardt did not conclude that a 'healthy' Mediterranean diet that met the US dietary guidelines was different than the usual average diet (assessed for water use only).<sup>10</sup>

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<sup>d</sup> The Mediterranean diet is a plant-based diet than emphasizes vegetables, cereals, fruit, and fish and limits intakes of meat, eggs, dairy, and sweets. It is implemented differently in Mediterranean countries (e.g., Spain, Italy).<sup>16</sup>

<sup>e</sup> The New Nordic diet is a Scandinavian version of the Mediterranean diet.<sup>16</sup>

<sup>f</sup> The Atlantic diet is a plant-based diet emphasizing minimally processed, fresh, seasonal food with moderate meat (beef, pork, eggs) intake and inclusion of olive oil as main fat source.<sup>16</sup>



## GHG

González-García found that Mediterranean diets had low, although variable, GHGs depending on how the diet is implemented and study methods as well as high nutritional quality.<sup>16</sup> Aleksandrowicz et al. ranked Mediterranean diets as the tenth out of fourteen diet types in terms of its potential benefit on GHGs compared to reference diets, estimated to reduce GHGs by 10%.<sup>9</sup> The Mediterranean dietary pattern was ranked only slightly better than the New Nordic dietary pattern<sup>9</sup> and the Atlantic diet<sup>16</sup> for its impact on GHGs.

## LAND

Only Aleksandrowicz et al. reviewed land impacts of Mediterranean and New Nordic diets, reporting that they reduced land use by 20% and 18%, respectively, ranked sixth and eighth out of 13 diet types.<sup>9</sup>

## WATER

The water impacts of Mediterranean diet were studied by Aleksandrowicz et al., Auestad and Fulgoni, and Reinhart et al.<sup>9,10,17</sup> Aleksandrowicz et al. ranked Mediterranean as sixth out of nine diet types assessed, reporting a reduction in 10% in water use compared to reference diets.<sup>9</sup> Auestad and Fulgoni reported that Mediterranean has a lower water footprint compared to reference diets, where meat and dairy contribute more than 50% of water footprint.<sup>17</sup> Reinhardt et al. evaluated the Mediterranean diet that adheres to the US Dietary Guidelines and concluded that the water impact of a healthy Mediterranean diet was comparable to a healthy omnivore diet that adheres to the US Dietary Guidelines and the reference diet.<sup>10</sup>

## Discussion and Conclusions

The evidence is consistent that diets lower in animal-based products have lower impacts on GHGs, land and water than usual average diets.<sup>8-10,12,13,15,16</sup> A gradient of environmental benefits exists according to animal product consumption, suggesting that diets with the lowest or no animal-based products (i.e., vegan diets) have lower environmental impacts than diets with some animal products (i.e., vegetarian), or diets low in animal products (i.e., ‘optimized omnivores’).<sup>9,12,16</sup> Nonetheless, complete exclusion of animal products is not consistently promoted as the best or only means to achieve a more sustainable diet;<sup>8,10,15</sup> there may be alternatives to optimizing diet sustainability, such as reducing the amount of animal products without replacing its calories, strategically replacing animal products with selective meats or plant-based products that have lower environmental impacts,<sup>9,15</sup> reducing total energy intake,<sup>8,15,18</sup> or other dietary changes such as, reducing energy-dense, nutrient-poor foods or beverages.<sup>18</sup> More research is needed on isocaloric comparisons of diets to more comprehensively understand which foods are ideal sustainable substitutions for animal products.

The evidence on diets generally considered ‘healthy’ concluded that ‘healthy’ diets were inconsistently more sustainable than average diets.<sup>10,13,16,18</sup> Reviews found positive or mixed results on the impacts of ‘healthy’ diets, suggesting that there were environmental benefits of following ‘healthy’ dietary guidelines or dietary patterns in some cases but not all.<sup>10,13,16,18</sup> In general, the estimated environmental benefits of following a ‘healthy’ diet was less than for following diets with reduced animal products.<sup>9,10,17</sup> As with reduced animal product diets, strategic food choices are critical to glean environmental benefits from ‘healthy’ diets.<sup>9</sup>

An Ontario study created representative isocaloric dietary patterns based on actual food consumption, using food intake data based on a single 24 hour recall collected in the Canadian Community Health Survey – Nutrition 2015.<sup>19</sup> Vegan, Vegetarian, and Pescatarian dietary patterns made up approximately 12% of the population, while Omnivorous (25%), and its variants (i.e., No Pork (24%), No Red Meat

(22%), and No Beef (17%)) dietary patterns were more common.<sup>19</sup> Consistent with the findings of this review, carbon footprints were the lowest for the representative Vegan, Vegetarian, or No Red Meat dietary patterns (660, 845, and 973 kg CO<sub>2</sub> equivalents/person/year, respectively).<sup>19</sup> No Pork had the highest carbon footprint (2317 kg CO<sub>2</sub> equivalents /person/year), slightly higher than Omnivorous diets (1901 kg CO<sub>2</sub> equivalents /person/year). No Beef and Pescatarian dietary patterns had modest carbon footprints (1246 and 1376 kg CO<sub>2</sub> equivalents /person/year, respectively).<sup>19</sup> When actual dietary intake was adjusted to meet the 2007 Canada's Food Guide, by replacing, not eliminating, a portion of the high carbon foods using low carbon foods (e.g., replace beef with chicken) and beverages, carbon footprints of Omnivorous and No Pork diets decreased by 16% and 18%, respectively, which suggests that environmental benefits of healthy diets can be gained by strategic food selection, without complete exclusions of meat. Vegetarian, Vegan, Pescatarian, No Beef, and No Red Meat dietary patterns that were adjusted to meet the 2007 Canada's Food Guide had carbon footprints that were 5% to 34% higher than baseline dietary intake for these patterns due to increases in protein foods, but the carbon footprints for these diets were still lower than nutritionally balanced Omnivorous and No Pork diets.<sup>19</sup>

The results of this review reveal that plant-based dietary patterns with low to moderate intakes of strategically selected low carbon animal products may be a promising approach to improve sustainability of diets. More work is needed to ensure that the foods selected have low environmental impacts and are nutritious. The findings are complicated by several contextual and methodological considerations which limit the certainty of the conclusions and limits the generalizability of the results. Caution is advised when interpreting results of this evidence synthesis due to the emerging nature of the research and the methodological inconsistencies.

## Limitations

There was significant heterogeneity in methods used to measure dietary patterns and environmental outcomes between reviews and between the studies of those reviews which may have contributed to uncertainty and inconsistency in the results. Many of the studies do not use a common unit of comparison to account for the same amount of calories which make it difficult to compare the environmental impacts of diets directly. When caloric intake is not standardized across diets the difference in environmental impacts could be due to a lower absolute food intake rather than food choice.<sup>9</sup> Further, not all studies looked at the full supply chain, with some studies only considering the impacts from resource extraction to farm gate, and some considering a full cradle to consumption impacts. Two reviews highlighted the need for advancements in the methods for measuring diet sustainability and the need for high quality studies with common reliable and valid nutrition and environmental outcomes.<sup>17,18</sup>

Secondly, since this review focused on the whole of diets versus individual foods and beverage that make up diets, inter-individual differences within a dietary pattern are unknown. It is possible that two people within one dietary pattern (e.g., vegetarian) choose very different foods on a daily basis, leading to higher and lower environmental impacts. This issue likely exists across all dietary patterns to a greater or lesser extent. This review also focuses on population diets which may not reveal factors related to individual nutrient needs or individual baseline diets that could suggest for whom certain diets would be more sustainable. For example, since most Ontarians consume some animal products, reducing the amount or type may have meaningful impacts on the environmental benefits of diets across a population. Further evaluation into individual food intakes is required to understand which of these dietary strategies best optimize environmental sustainability for individuals and populations.

Thirdly, the evidence synthesis included research beyond Canada and thus overlooks important geographical contextual factors that may lead certain dietary patterns to be more or less

environmentally sustainable in Canada, or regions of Canada, compared to other areas. For example, if water scarcity is not a concern in Canada, the environmental impact of dietary patterns on water use or water footprints may be less important. Also, in warmer countries, yields are higher, meaning that the impacts per mass of food is less than in countries that have colder climates. Further, Canadian land may be unique in its appropriateness of land for grazing versus field crops. Thus, it is very important to compare diets within a country rather than across countries.

Related, there may be important geographical considerations in regards to 'healthy' dietary guidelines. As Reinhardt et al. stated that according to one study, the 'healthy' US dietary pattern had worse environmental impacts than 'healthy' diets from other countries, including Canada. As described earlier, adhering to the 2007 Canada's Food Guide was associated with a reduction in carbon footprint for Omnivore and No Pork diets, but not for other low carbon dietary patterns (e.g., vegetarian, vegan, No Beef which required increasing protein intakes to meet the 2007 Canada's Food Guide).<sup>19</sup> In 2019, Canada's Food Guide was updated to include environmental considerations, and thus it could be argued that dietary adherence to the 2019 CFG may be more sustainable than the 2007 version. Furthermore, since most of the reviews in this evidence synthesis were published between 2015 and 2018, it's possible that the science on environmental impacts of healthy dietary guidelines may not yet reflect the emerging inclusion of environmental considerations in national dietary guidelines.

Finally, this review was limited in the sustainability outcomes included due to limited research and logistical factors to maintain a manageable task. Although it was intended to evaluate the nutritional quality of dietary patterns, few reviews included any nutrient-based analyses; most reviews simply assumed alternative dietary patterns were more nutritious than usual omnivore diets. As nutritional adequacy of diets "is a fundamental requisite" when evaluating sustainable diets,<sup>17</sup> this shortcoming should be adequately investigated to ensure that more sustainable diets are also nutritious. The affordability or acceptability of diets – other key aspects of sustainable diets- were rarely discussed in the reviews and not included here. There were also gaps in the environmental outcomes included. GHGs were most commonly included, likely because carbon footprinting is more common and is seen as more relevant, but also because it is usually easier to quantify; fewer studies included water or land outcomes. Further, other environmental outcomes such as biodiversity, air quality, natural resource depletion, eutrophication, and invasive species,<sup>18</sup> were not included across reviews, because there are limited data or methods for accounting for these other environmental impacts. Without including multiple dimensions of sustainability, there are risks of unintentional trade-offs between components.

## Implications for Practice

The evidence on sustainable diets is rapidly emerging. This synthesis found consistent evidence that dietary patterns with lower intakes of animal products had lower environmental impacts than usual diets. The evidence is less consistent in regards to whether diets that follow national dietary guidelines or a 'healthy' pattern have lower impacts; many reviews found positive results in some, but not all, cases. The results of the evidence review should be interpreted with caution due to methodological and contextual factors that impact the certainty of the conclusions, and their applicability to Ontario and Canada. This review only included environmental outcomes of dietary patterns, namely impacts on GHGs, land, and water, however there are many other environmental impacts and dimensions of dietary sustainability, such as affordability and acceptability, which were not included. Care should be taken to ensure that recommendations for sustainable diets made in relation to environmental benefits do not have unintentional negative consequences on nutritional or other aspects of sustainability.

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## Specifications and Limitations of Evidence Brief

The purpose of this Evidence Brief is to investigate a research question in a timely manner to help inform decision making. The Evidence Brief presents key findings, based on a systematic search of the best available evidence near the time of publication, as well as systematic screening and extraction of the data from that evidence. It does not report the same level of detail as a full systematic review. Every attempt has been made to incorporate the highest level of evidence on the topic. There may be relevant individual studies that are not included; however, it is important to consider at the time of use of this brief whether individual studies would alter the conclusions drawn from the document.

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