The impacts of dietary change in Finland: food system approach

Ellen Huan-Niemi[1], Minna Kaljonen[2], Marja Knuuttila[3], Jyrki Niemi[1] and Merja Saarinen[1]

[1]Natural Resources Institute Finland (Luke), Latokartanonkaari 9, 00790 Helsinki, Finland

[2]Finnish Environment Institute (SYKE), Latokartanonkaari 11, 00790 Helsinki, Finland

[3]Natural Resources Institute Finland (Luke), Lönnrotinkatu 7, 50100 Mikkeli, Finland

e-mail: ellen.huan-niemi@luke.fi

This study examined what kind of policy instruments and actions are needed for sustainable dietary change and how a large-scale dietary change would impact the climate, thus analysing the economic impacts of transitioning from animal-based diets to alternative plant-based diets. The transition would require the support of horizontal measures that can be implemented throughout the food system. Shifting the emphasis toward the drivers of food demand and consumption will increase the role of new policy instruments and the actors involved in the food system. Collaborative research between environmental and nutritional sciences with economics and policy analysis is necessary to link nutritional health and environmental objectives with economic and social impacts. Less resource-demanding diets would reduce the impact from the food system and lower greenhouse gas (GHG) emissions. Drastic changes in diets and food consumption in Finland would have an impact on primary agricultural production, but the output from the food processing industry would only be slightly affected. However, a successful transition would involve considerable investments in the agricultural and food industry.

Key words: alternative diets, climate impact, economic impact, policy dialogue, dietary model, input-output analysis

Introduction

The food system is a contributing force to climate change, biodiversity loss, the depletion of freshwater resources, unsustainable changes in land use, and the pollution of aquatic and terrestrial ecosystems through excessive inputs of nitrogen and phosphorus via fertilisers and manure. The environmental effects of the food system can be lessened through dietary changes towards healthier and more plant-based diets (Garnett et al. 2015, Aleksandrowicz et al. 2016, Röös et al. 2018, Lawrence and Friel 2019). A synergistic combination of measures will be needed to effectively mitigate climate change and environmental pressures from the food system. There is growing scientific evidence that climate change mitigation and adaptation in the food system necessitates not only developing more sustainable and resource-efficient production methods and technologies, but also changing diets and tackling food loss and waste (Godfray et al. 2010, Reisch et al. 2013, Springmann et al. 2018, IPCC 2019, Willett et al. 2019). The dietary changes are also called upon for dealing with obesity and related non-communicable diseases (Reisch et al. 2017, Willet et al. 2019). For people who currently have a high intake of red meat, reducing meat consumption may have substantial health benefits (Godfray et al. 2018, Willet et al. 2019). Therefore, global ruminant numbers could be decreased to make a substantial contribution to climate change mitigation goals and yield important social and environmental co-benefits (Ripple et al. 2014).

In Finland, as in the Nordic countries and Europe as well, the prospect of a significant decrease in the consumption of animal-based foods has generated concerns on its likely impact on domestic agriculture and the agri-food industry. Meat and dairy products are currently a central part of the Finnish diet (Valsta et al. 2018), and this also shows in consumers' shopping baskets: meat and dairy products account for almost 32% of the average household's food purchases (Latvala and Mikkola 2020). Furthermore, livestock production in Finland represents 47% of the market turnover for primary agricultural production as well as almost half of the turnover from the agri-food industry (Luke 2020). The possibilities for a rapid increase in the production and supply of plant-based foods in Finland are limited. On average, 50% of the fruits and vegetables purchased in Finland are imported (Saarinen et al. 2019).

Driven by consumer demand, companies in the meat and dairy processing industry have started to produce plant-based food products in Finland and other European countries. The consumers have the opportunity to influence the emerging plant-based food market with their purchase decisions (Vainio et al. 2016). Much of the raw materials for the new pulse-based food products are, however, still imported due to the lack of legume production in Finland. As the demand eventually changes from animal-based to more plant-based foods, food producers and retailers will need to follow the trend developing into an established norm (Danish Food Cluster 2019).

Manuscript received May 2020

This background raises several questions: How would drastic changes in food consumption affect agriculture and food production, and their operational environment? Would the Finnish agri-food industry be able to produce more plant-based foods to substitute animal-based foods in the diet? How a large-scale dietary change would impact greenhouse gas (GHG) emissions and nutritional intake in Finland and what are the policy instruments that could support the transformation to plant-based diets?

Addressing these questions necessitates multidisciplinary assessment across the food system activities (Creutzig et al. 2018, Niles et al. 2018, Swinburn et al. 2019). In this paper, we first demonstrate how dietary change would impact GHG emission, whilst taking into account the nutritional adequacy of the diets. The assessment is based on the assumption that dietary change cannot be looked at only concentrating upon consumption, but rather we need comprehensive understanding of the interplay between various elements and activities in the food system (Mason and Lang 2017, Parsons et al. 2019, De Schutter et al. 2020). Hence, the economic impacts on primary agricultural production and the agri-food industry are examined, while the food system actors are engaged to deliberate upon the policy mixes needed for sustainable dietary change.

Material and methods

The methodology is divided into three different parts: 1) determination of alternative diets; 2) assessment of the economic impacts on Finnish agriculture and the agri-food industry; 3) analysis of policy mixes.

Determination of alternative diets

The climate impacts of the different diets are calculated by using the FoodMin dietary model (Saarinen et al. 2019), which combines nutritional assessment with the environmental life cycle assessment (LCA) of diets. For the environmental assessment, the model covers the environmental impacts of the domestic and imported foods in a diet, a review of consumer waste, carbon dioxide (CO_2) emissions from domestic agricultural land used for food production, and CO_2 emissions from food processing. The starting point is to examine, on average, the current diet and to establish four alternative diets with a review of the nutritional contents for the diets. The current diet is based on the National FinDiet 2017 Survey (Valsta et al. 2018), and evaluation of nutritional quality based on Fineli® database, and Finland's national nutrition recommendations. The four alternative diets are: (i) a diet containing half of current meat consumption (but still containing dairy products), (ii) a diet containing one third of current meat consumption (but still containing dairy products), (iii) a diet replacing meat with fish (but still containing dairy products), (iv) and a vegan diet, totally without meat and dairy products. The 'diet' refers to all food products consumed by an individual.

The premise of this study is that the alternative or modified diets must comply with the national nutrition recommendations and the environmental impacts of each diet can be changed by modifying the diet's food products selection. Therefore, in each diet, the nutrients intake complies with the Finnish nutritional balance recommendations (National Nutrition Council 2014) with minor exceptions, such as the intake of vitamin D in diets other than the fish-rich diet. The vegan diet has the biggest nutritional challenges. Due to this, for some product categories, products with the poorest nutritional value are eliminated from the selection and in the case of the vegan diet, the role of enriched products is emphasised more than in the case of the other diets. In terms of nutritional quality, the best diet is the fish-rich diet, which also contains dairy products, but without meat.

Assessment of economic impacts on Finnish agriculture and the agri-food industry

The economic impacts of dietary changes on agricultural production and the agri-food industry in Finland are evaluated with a traditional demand model of input-output analysis. Input-output analysis is a commonly utilised method in calculating the economic impacts. The fundamental idea of the analysis concerns the flows of products from production sectors to the utilisation sectors and final demand. The method is described in the literature by Miller and Blair (2009) and applied in the analysis of food-chain production with a corresponding classification of ten industries (Knuuttila and Vatanen 2017). The input-output model itself is constructed from observed economic data for a specific region (e.g. state, county, and municipality). This data is arranged in an interindustry transactions table with rows describing the distribution of industry's (group of producers alike) products (output) throughout the economy. Thus, the rows indicate how the industry's output is used as inputs by itself and other industries as well as consumed by end-users as final demand (households, investments, exports). The input-output model

then consists of a system of linear equations describing the distribution of an industry's products throughout the economy. As the transactions table compiles the rows in a matrix form, the columns then describe the array of inputs required by the industries to produce its' output.

The analysis uses a traditional demand model based on household´s consumption expenditure. In the input-output model, aggregated industry outputs, X, depend on final demand, Y, and interindustry input uses are depicted by the matrix equation:

$X = (I-A)^{-1}Y$,

Where,

X = output of *n* industries

Y = final demand of *n* industries

$(I-A)^{-1}$ = total requirements matrix (known as the Leontief inverse)

I = *n x n* identity matrix (ones on the main diagonal and zeroes elsewhere)

A = the technical coefficients matrix ($A_{ij}=Z_{ij}/X_j$, a_{ij} depicting the use of industry x_i output as input by industry y_j)

At the calculation level, the model utilises an extended industrial classification for food manufacturing. The model depends on the existence of an exogenous sector, disconnected from the technologically interrelated productive sectors. In this case, the exogenous sector activity comes from the consumption purchases by households. As the demand for an industry's products change, the input-output model estimates the effects of this exogenous change (e.g. change in household consumer demand) on the other industries' production (output).

The model used in this study is based on input-output data of the National Accounts of Statistics Finland. The data describing the production technology and the interaction between different industries are from the year 2015. It includes both direct effects of a change in demand for foodstuffs from the processing industry and indirect effects of a change in demand for raw materials from domestic primary production. The input-output analysis focuses on the output and value added effects for Finnish agricultural production and the agri-food industry. The current price ratios, input structures, production technologies, and import ratios are assumed to remain unchanged in the input-output analysis.

The consumption of different food products changes in the alternative diets; and the calculation of economic impacts in Finland are based on changes in the volumes of food products consumed in each diet. For the economic modelling, relative changes in food consumption are used to estimate the changes in monetary expenditure. Hence, the changes in food consumption represented in euros correspond to the physical changes in the categories of food products consumed in the alternative diets. The underlying assumption is that no changes occur in the prices of food products in the alternative diets.

The simulations are based on different diet options and changes in the final demand for food industries. The beginning for the calculation of economic impacts is the current food consumption, with statistical data for both volume (in kilograms) and monetary expenditure (in euros). For the evaluation of output impacts, the consumption of food products in kilograms in the current diet is classified into ten product classes according to the industrial classification of the input-output model (Table 1). Food consumption in kilograms for the diets, according to the Finnish nutritional balance recommendations, is divided into the corresponding products of their manufacturing industries, thus allowing the measurement of food consumption in euros.

The classification of food products is the simplest with meat, fish and dairy products. The classification is the most difficult with cereal products which can be consumed either as grain mill products or as bakery products. In addition to processed food products, household consumption includes fresh food products that are consumed unprocessed such as apples, berries, citrus fruits, potatoes, onions, vegetables, eggs, and nuts and seeds. Processed fruit and vegetable products are classified in their own categories of food products. These classifications matter because the consumption of processed food products increases value-adding to the raw material by expanding

the share of intermediate products with various goods and services; simultaneously, there is a relative reduction in the proportion of raw materials. The largest share of raw materials in the categories of food products is for milk, meat and vegetable oil, and the smallest share for bakery products and processed food products such as prepared meals and sweets.

Table 1. Percentage of food products consumed (in kilograms) by product categories used in the input-output analysis for the current and alternative diets

	Current diet	Meat cut to half	Meat cut to one third	Fish-rich diet	Vegan diet
1. Fresh food products	20	24	25	20	26
2. Meat products	8	3	2	0	0
3. Fish products	2	1	1	3	0
4. Fruit and vegetable products	12	14	14	15	18
5. Vegetable and animal oils and fats	2	2	2	2	2
6. Dairy products	24	21	21	21	0
7. Mill and starch products	1	1	1	1	5
8. Bakery products and pasta	7	11	11	12	13
9. Other processed products	15	15	15	19	26
10. Non-alcoholic and alcoholic beverages	9	7	7	7	9
All products	100	100	100	100	100

Assessment of policy mixes

The analysis of policy mixes for sustainable dietary change is based on document analysis, and stakeholder survey and dialogue. First, we evaluated a number of national policy programmes (including e.g. the comprehensive government programmes for food and climate, specifically for organic production, local food and aquaculture as well as the nutrition guidelines and agricultural policy) to identify how the current policy measures address the needs and means for dietary change. A survey was sent in August 2018 to 145 recipients from 96 different organisations (covering agriculture, food industry, restaurants, food services, retailers, public administration, civic organisations and research). In the survey, the respondents were asked to assess the functioning of the current policy measures and needs for additional actions. The respondents were also asked to evaluate the need for new measures and the feasibility of the measures. All together 54 people responded to the survey with a response rate of 37%. The respondents were well represented from the different sectors in the food system (Fig. 1).

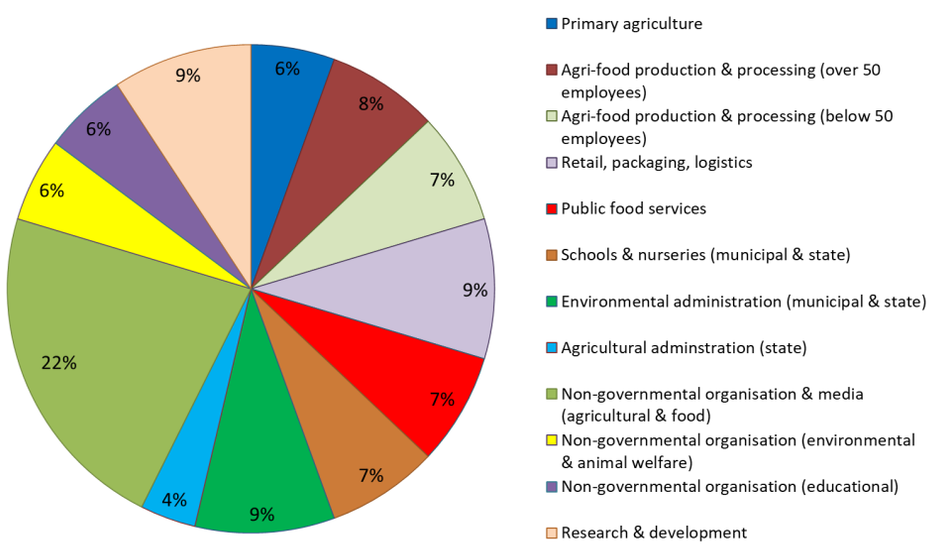

Fig. 1. Respondents of the survey according to the different sectors in Finland

In addition to the survey, a dialogue workshop was organised to vision and deliberate on future actions in September 2018. The respondents from the survey were invited to the workshop. All together 30 people participated in the workshop, representing agriculture, food industry, public food services, restaurants, retailers, non-governmental organisations, and public administration from municipalities to Ministries (agriculture and forestry, environment,

social affairs and health), and research. The results concerning climate and economic impacts of dietary change were presented at the workshop after which the future actions for sustainable dietary change were deliberated in smaller sector-specific groups. The measures suggested by these groups were edited by the research group, and the representatives from the different Ministries had also a possibility to comment on the measures. The mix of policy measures presented in this paper is an outcome of this iterative deliberative process.

Results

The climate impacts of current and alternative diets

According to the FoodMin model calculations (Saarinen et al. 2019); the CO_2 emissions of a diet decrease as the share of animal-based products in the diet decrease (Fig. 2). Compared with the current diet, CO_2 emissions can be decreased by 13% and 19% in the 'Meats cut to half' diet and 'Meats cut to one third' diet, respectively. The CO_2 emissions from the fish-rich diet can be decreased by 30%, which is higher than for diets containing meat, but lower compared to the vegan diet. Shifting to the vegan diet would decrease CO_2 emissions by 37% from the current diet. The entire food system is estimated to contribute roughly 25% to 30% of greenhouse gas (GHG) emissions in Finland.

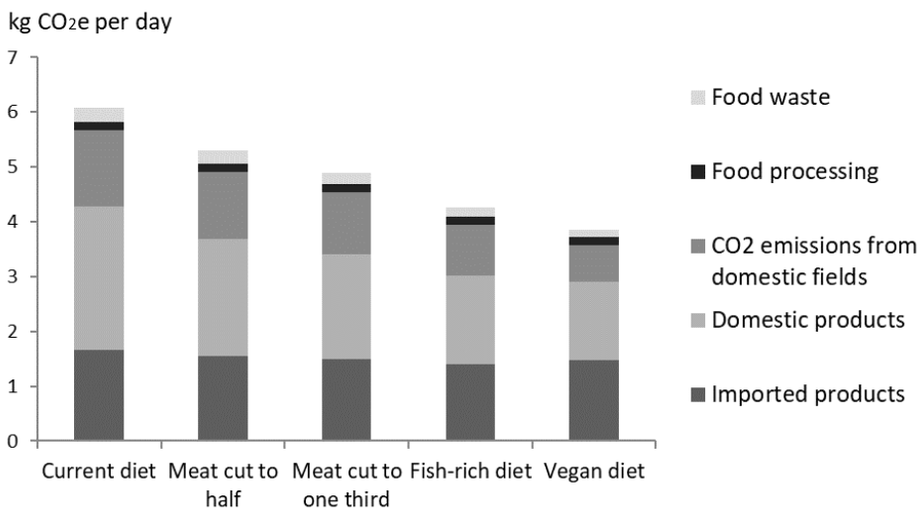

Fig. 2. Climate impact of the current diet and alternative diets, kg CO_2e per day (Saarinen et al. 2019)

The economic impacts of dietary changes

Food processing industry

According to the input-output analysis, food processing industry output in Finland slightly decreases due to the alternative diets, with the exception of the vegan diet (Fig. 3). In the diet containing half of current meat consumption, the output decreases by 3%; in the diet containing one third of current meat consumption, the output decreases by 7%; and in the fish-rich diet, the output decreases by 6%. On the contrary, in the vegan diet (totally without meat and dairy products), the output increases by 2%.

Even though the output of the food processing industry does not change considerably between the alternative diets compared with the current food consumption, the changes in production within the processing industry are considerable. According to the results, in the alternative diets, the growth outlook for the food industry is the greatest in further processing of cereals and legumes, with some of the growth channelling into the industry of prepared meals and dishes, particularly in the vegan and fish-rich diets. Hence, in the vegan diet, the increase in the output of cereal-based food processing in the grain mill and bakery industries compensates for the decrease in the processing output of animal-based products such as meat, dairy and fish.

The results only include the domestic output of the food processing industry due to the demand of households' consumption in the alternative diets. The figures do not include the share of domestic food processing ending up for food exports and usage as inputs for other industries.

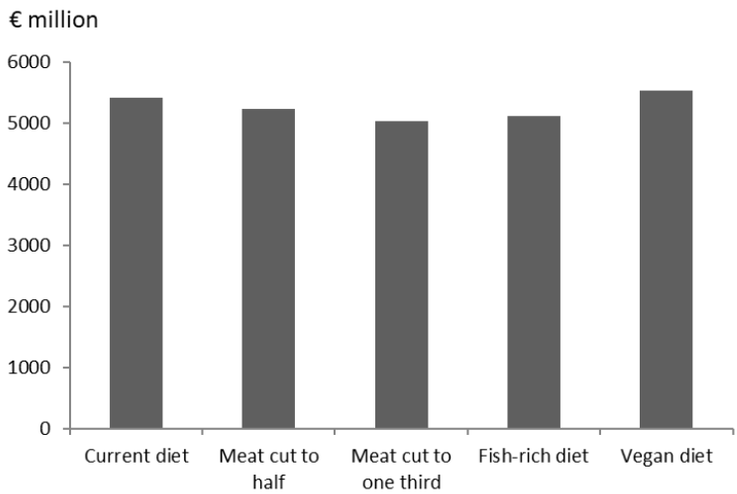

Fig. 3. Food processing industry output (€ million) according to the input-output analysis

Primary agricultural production

According to the input-output analysis, primary agricultural output in Finland remains at the current level with the diet containing half of current meat consumption. In the diet containing one third of the current meat consumption, agricultural output decreases by only 2%. In the vegan diet (totally without meat and dairy products), agricultural output decreases by 23%, and in the fish-rich diet agricultural output decreases of by 16% compared to the current diet. Therefore, agricultural output for the vegan diet declines the most compared to the other diets (Fig. 4).

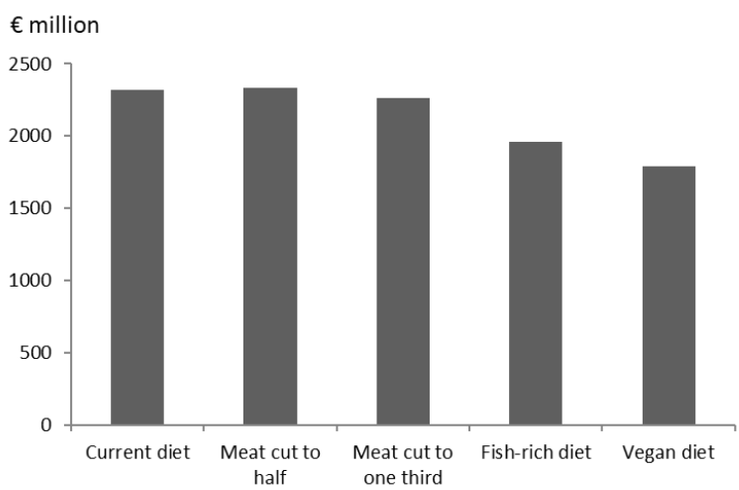

Fig. 4. Primary agricultural output (€ million) according to the input-output analysis

These results only include production needed for domestic consumption. Production for export or production for the use of industries other than the food industry is not included in the results. The results thus illustrate the impact of households' demand for food consumption on domestic agricultural production.

The limitations of the input-output analysis

The results produced by the input-output analysis include both direct effects on the processing industry for the change in consumer demand and the indirect effects on domestic agricultural production and other sectors (e.g. energy, transport and various service sectors) for the change in demand for raw materials. The simulations made by the input-output model are performed with the current fixed coefficients for inputs needed in production. Therefore, the results of the input-output analysis illustrate a situation where all production in the economy is created by the production technology at the year 2015 without any changes in the use of labour, capital or

intermediate products utilised in the agricultural and food processing industries or domestic inputs industries. However, changes in food consumption due to the alternative diets are so large that, in the real world, investments in primary agricultural production and food processing are necessary. Changes in the demand for food products may also affect the product prices, and thus altering the coefficients of the input-output model. Thus, the results produced by using fixed coefficients may not correspond to a situation whereby production would have been technically and economically adapted to the requirements of the alternative diets.

The policy mixes for sustainable dietary change

Sustainable dietary change requires a mix of policy measures to be implemented throughout the food system (Garnett et al. 2015, Mason and Lang 2017, De Schutter 2020). In food system governance, the interplay between public and private instruments is of critical importance (Mason and Lang 2017). Traditionally, policy instruments have been divided into informational, economic and regulatory policy instruments (Bemelmans-Videc et al. 1998). Behavioural policy instruments or nudges are increasingly important as part of the food and environmental policy mixes to induce sustainable dietary change (Behavioural Insights Team 2020, Mason and Lang 2017, Reisch et al. 2017). Dessart et al. (2019) reviewed findings from the last two decades that demonstrate behavioural factors can lead to more realistic and effective policies. Therefore, the potential contribution of behavioural instruments for nudging consumers towards more sustainable diets and less food waste are vital to induce behavioural change.

In Finland, sustainable agricultural production has mainly been steered by agricultural subsidies and environmental regulation. Shifting the emphasis toward diets and food consumption will increase the significance of other policy instruments and actors in the changing food system. Table 2 summarises the results concerning the future policy mixes identified and deliberated in the survey and workshop amongst the actors in the food system.

Table 2. Policy mixes for sustainable dietary change suggested by the actors in the Finnish food system

Informational instruments	Integration of environmental criteria into the national nutrition recommendations Enhancing food education in schools	Informational guidance and behavioural instruments for nudging consumers towards more sustainable diets and less food waste in retail, food services and restaurants Development and harmonisation of eco- and health labelling
Economic instruments	Targeting of agricultural subsidies to the reduction of CO_2 emissions from agricultural lands, and diversification of field crop varieties Combinations of health-based and environmental taxes	Creation of new value chains for plant-based food products
Regulatory instruments	Emissions reduction targets set in line with the climate policy Binding nutritional quality and low-carbon targets for public food service providers	Green Deal and materials efficiency agreements between the government and private corporations to support sustainable dietary changes

Source: Saarinen et al. 2019

The food system actors emphasise that the food industry and retailers will play significant roles in sustainable dietary change in the future. Creating new value chains for plant-based foods requires significant investments from both primary agricultural production and the food processing industry. In addition to developing information systems or labelling schemes for food items on climate or health effects, retailers and restaurants should also use nudging innovatively to guide their customers towards more sustainable diets (Kaljonen et al. 2020). The combination of informational and nudging instruments refers to the use of not only labels, but also the positioning of products, default choices, digital apps and other methods in guiding and nudging consumers to make sustainable choices and eat more healthily and sustainably (Thaler and Sunstein 2008, Reisch et al. 2017). Materials efficiency or green deal agreements between the state and industry would help the private actors to commit to the sustainability targets in the long-term. For example, agreements have been made on material efficiency and reduction of food waste. In the future, they should be directed more explicitly towards enhancing healthy and sustainable diets as well.

The analysis, however, highlights that these private measures need much stronger support from the public policies, if any meaningful and long-term changes are to be foreseen in the diets. This requires clear strategic targets as well as effective and fair combination of informational, economic and regulatory policy instruments along with innovative behavioural instruments of the private sector.

In Finland, public food services have had a significant role in promoting healthy eating habits for a long time. The integration of environmental criteria into the national nutrition recommendations (Nordic Council of Ministers 2012, National Nutrition Council 2014), would support the public food services in developing their practices more sustainably. Based on the survey and workshop, public food service providers are very motivated to support sustainable dietary change (see also Kaljonen et al. 2019). Binding nutritional quality with low-carbon targets for public food service providers is needed to strengthen their efforts, as well as safeguarding resources from the municipalities to implement the measures.

Public policies also affect food prices through agricultural subsidies (Lehtonen and Irz 2013, OECD 2020) and taxation (Wirsenius et al. 2011, Edjabou and Smed 2013, OECD 2020). In the future, the interplay between agricultural subsidies and taxation need to be assessed together to better understand how they can be used to support climate friendly production and consumption. In the case of agricultural subsidies, special attention should be paid to the reduction of carbon emissions from organic soils and diversification of crop varieties, especially for legumes. It is also important to assess the impacts of health-based and environmental taxes together, as well as to consider the costs and fairness of different taxation models.

Discussion

The results underline how GHG emissions from the food system can be reduced from 13% to 37% in the alternative diets. Climate policy was one of the main themes of Finland's Presidency of the Council of the European Union (EU) in 2019. The Finnish government program has very ambitious climate objectives: compared to the EU's objective to be climate-neutral by 2050, Finland aims to be carbon neutral by 2035. Therefore, reducing GHG emissions from the food system via dietary change will help in achieving the ambitious climate objectives of Finland.

The input-output analysis shows how changes in diets affect the outputs of primary agricultural production and food processing industry with different impacts, especially concerning the vegan diet. The policy analysis, hence, calls for greater attention to the policy mixes guiding both food production and consumption as well as strategic guidance of public policies.

A successful transition toward a more plant-based diet would involve considerable investments in the agricultural and food industry, particularly to increase legume production and processing. It is quite challenging for Finland to considerably increase production of plant-based and protein-rich food because the current competitive advantage of Finnish agriculture lies in livestock and greenhouse production, not so much in plant production. Furthermore, the possibilities for agricultural producers to increase production of plant-based and protein-rich food vary regionally. Southern Finland, where the largest plant production farms are located, has the best prerequisites for increasing pulses production, which require a sufficient heat summation. Elsewhere in Finland due to poorer farming conditions, the replacement of livestock production with more diverse plant production will be significantly more difficult compared to Southern Finland. A substantial drop in the demand for meat and dairy products may cause considerable local economic and social problems, particularly in the main livestock production regions, e.g. several regions in Southwest Finland, Ostrobothnia and North Savo. The result could be a decrease in employment and tax revenues in many rural municipalities.

Another obstacle is the lack of facilities suitable for interim processing or pre-processing and the supply of plant-based and protein-rich ingredients or raw materials such as a flour or protein isolate needed by the agri-food industry. Therefore, a dietary change would involve considerable investments in the agri-food industry, particularly to promote legume production and new food processing. More development of new and enticing meat-replacement products from legumes (Fabaceae and *Vicia faba*), currently considered as feed crops, will be needed. There should be increased demand for shared activities between the actors in the food chain, including continuous research in legume farming to boost Finnish legume production. A successful transition would also require the development of new value chains for innovative food products to respond to the change in consumption.

The magnitude of changes in food consumption calls for concerted policy support (see also Mason and Lang 2017, De Schutter 2020). The analysis of policy mixes highlights the necessity to look at both production and consumption, when developing policies for sustainable dietary change. The existence of major vested interests and centres of power makes the political economy of dietary change, however, highly challenging. Furthermore, history suggests that change in dietary behaviours in response to interventions is slow. But social norms can and do change and this process can be aided by the coordinated efforts of civil society, health organizations, and government, as has been observed also in the case of smoking cessation (Godfray et al. 2018).

The nutrition recommendations have a deep foothold in the Finnish food policy with strong support from the Nordic guidelines. In Finland, the recommendations also have a direct link to consumption patterns by guiding the public food supply in kindergartens, schools and elderly homes, for example. According to our study, a stronger integration of environmental considerations into the nutrition recommendations would offer one plausible way to give strong public guidance for sustainable dietary change. This would also assist public food services in developing their procurement practices to be more sustainable. Public procurement can play a significant role in building new value chains for plant-based products.

Public policies such as agricultural subsidies and taxation can also induce changes in food production and consumption. According to the OECD (2020), the unilateral implementation of a carbon tax in agriculture has been shown to reduce the competitiveness of the implementing countries, as compliance costs impose economic welfare losses on domestic producers. Consumer taxes have been shown to be potentially effective in supplementing supply-side emissions mitigation policies. They can be effective in limiting carbon leakage when applied to both domestic and imported food products. However, consumer taxes are not effective at incentivizing dietary shifts because of the low elasticity of demand to the price changes for agricultural goods. A high consumption tax on ruminant meat may promote inequality in the society because consumers with high incomes can afford to buy meat, but consumers with low income may not be able to afford to buy meat.

Considering that many developed countries and a number of emerging economies are already subsidising their agricultural sector, governments could redirect existing agricultural support to address environmental externalities and improve mitigation policies. The OECD (2020) literature review suggests that abatement payments such as agricultural subsidies could both preserve domestic comparative advantage and prevent carbon leakage in the implementing countries.

Various studies reviewed by Godfray et al. (2018) indicated that there will be a substantial increase in the demand for meat; and there is widespread agreement that most of the increase in meat consumption will occur in low- and middle-income countries. The biggest challenge is sustainable dietary transition for consumers with increasing average individual incomes in middle-income countries. The transition of Western diets toward less resource-demanding diets would reduce GHG emissions in developed countries, but it is also important to halt the shift toward more meat consumption in middle-income countries and emerging economies, especially populous countries such as China and India, which would further increase the impact of the food system globally. Therefore, there is a need for concerted efforts to reduce the impact of the food system globally and not only in the developed countries alone.

Conclusions

Sustainable dietary change would require the support of horizontal policy measures that can be implemented throughout the food system. In Finland, the sustainability of the food system has mainly been steered through agricultural subsidies and environmental regulations. Shifting the emphasis toward the drivers of food demand and consumption will increase the role of new policy instruments and actors in the transitioning food system.

The transition toward less resource-demanding diets in Finland would reduce the impact from the food system and lower GHG emissions from 13% to 37%, indicating that the vegan diet has the least impact on the climate.

Drastic changes in diets and food consumption in Finland would have an impact on primary agricultural production; however, the output from the food processing industry would only be slightly affected. Food processing industry output would decrease by less than 10% in diets containing less meat and fish-rich diet, although output would increase by 2% in the vegan diet. In contrast, primary agricultural output remains close to the current level with diets containing less meat, but output would decrease by 23% in the vegan diet and 16% in the fish-rich diet.

The prospect of a significant decrease in the consumption of animal-based foods in Finland may cause considerable local economic and social problems, particularly in the main livestock production regions. The possibilities for agricultural producers to increase production of plant-based and protein-rich food vary regionally in Finland. The result could be a decrease in employment and tax revenues in many rural municipalities. A successful transition toward a more plant-based diet would involve considerable investments in the agricultural and food industry, particularly to increase legume production and processing. Sustainable dietary change, hence, calls for concerted policy support and strategic guidance from public policies. Support and guidance is needed both for the dietary change and for the affected sectors and regions to cope with the negative impacts from the desired changes.

Collaborative research between environmental and nutritional sciences with economics and policy analysis is necessary to link nutritional health and environmental or climate objectives with economic and social impacts. The input-output analysis can reveal the economic impacts of policy instruments to improve nutritional health and achieve the environmental or climate objectives. Policy analysis is required to screen and evaluate the policy mixes across the food system activities.

Acknowledgements

The authors would like to thank the researchers and advisory board of the FoodMin project as well as the participants of the policy dialogue for their active contributions. The authors would also like to thank the two anonymous referees for their helpful and constructive remarks in improving this article. The research was funded by the Finnish Government's assessment and research activities (VNK/1773/48/2017). The funding from the Strategic Research Council of the Academy of Finland (no: 327284 and 327634) was used for writing and finalising this article.

References

Aleksandrowicz, L., Green, R., Joy, E.J.M., Smith, P. & Haines, A. 2016. The impacts of dietary change on greenhouse gas emissions, land use, water use, and health: A systematic review. PLoS ONE, Public Library of Science 11(11), e0165797. https://doi.org/10.1371/journal.pone.0165797

Behavioural Insights Team 2020. A Menu for Change: Using behavioural science to promote sustainable diets around the world. https://www.bi.team/wp-content/uploads/2020/03/BIT_Report_A-Menu-for-Change_Webversion_2020.pdf.pdf.

Bemelmans-Videc, M.-L., Rist, R. & Vedung, E. 1998. Carrots, Sticks and Sermons. Policy Instruments and their evaluation. New Brunswick, New Jersey, USA: Transaction Publishers.

Creutzig, F., Roy, J., Lamb, W. F., Azevedo, I. M. L., de Bruin, W. B., Dalkmann, H., Edelenbosch, O. Y., Geels, F. W., Grubler, A., Hepburn, C., Hertwich, E. G., Khosla, R., Mattauch, L., Minx, J. C., Ramakrishnan, A., Rao, N. D., Steinberger, J. K., Tavoni, M., Ürge-Vorsatz, D. &. Weber, E. U. 2018. Towards demand-side solutions for mitigating climate change. Nature Climate Change 8: 260–263. https://doi.org/10.1038/s41558-018-0121-1De Schutter, O., Jacobs, N. & Clément, C. 2020. A 'Common Food Policy' for Europe: How governance reforms can spark a shift to healthy diets and sustainable food systems. Food Policy. https://doi.org/10.1016/j.foodpol.2020.101849

Danish Food Cluster 2019. Food Innovation Talk on plant-based foods with AAK streamed live on May 15, 2019. https://danishfoodcluster.dk/foodinnovationtalk.

Dessart, F.J., Barreiro-Hurlé, J. & van Bavel, R. 2019. Behavioural factors affecting the adoption of sustainable farming practices: a policy-oriented review. European Review of Agricultural Economics 46: 417–471. https://doi.org/10.1093/erae/jbz019

Edjabou, L.D. & Smed, S. 2013. The effect of using consumption taxes on foods to promote climate friendly diets-The case of Denmark. Food Policy 39: 84–96. https://doi.org/10.1016/j.foodpol.2012.12.004

Godfray, H.C.J., Aveyard, P., Garnett, T., Hall, J.W., Key, T.J., Lorimer, J., Pierrehumbert, R.T., Scarborough, P., Springmann, M. & Jebb, S.A. 2018. Meat consumption, health and the environment. Science 361: eaam5324. https://doi.org/10.1126/science.aam5324

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S. M. & Toulmin, C. 2010. Food Security: The Challenge of Feeding 9 Billion People. Science 327: 812–818. https://doi.org/10.1126/science.1185383

Garnett, T., Mathewson, S., Angelides, P. & Borthwick, F. 2015. Policies and actions to shift eating patterns: What works? Food Climate Research Network, London. https://www.fcrn.org.uk/sites/default/files/fcrn_chatham_house_0.pdf.

IPCC 2019. Chapter 5: Food Security, Executive Summary. Climate Change and Land. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/srccl.

Kaljonen, M., Salo, M., Lyytimäki, J. & Furman, E. 2020. From isolated labels and nudges to sustained tinkering: assessing long-term changes in sustainable eating at a lunch restaurant. British Food Journal. https://doi.org/ 10.1108/BFJ-10-2019-0816.

Kaljonen, M., Peltola, T., Salo, M. & Furman, E. 2019. Attentive, speculative experimental research for sustainability transitions: an exploration in sustainable eating. Journal of Cleaner Production 206: 365–373. https://doi.org/10.1016/j.jclepro.2018.09.206

Knuuttila, M. & Vatanen, E. 2017. The importance of the food chain to the national economy and regions in Finland. Helsinki, Finland: Natural Resources Institute. (in Finnish). http://urn.fi/URN:NBN:fi-fe201705296939

Latvala, T. & Mikkola, E. 2020. Food consumption and consumer prices. In: Latvala, T., Väre, M. & Niemi, J. (eds.). Finnish agri-food sector outlook 2020. Natural resources and bioeconomy studies 33/2020: 9–14. (in Finnish). https://jukuri.luke.fi/handle/10024/545930.

Luke 2020. Economydoctor, total calculation of agriculture. Luke profitability bookkeeping results. April 27, 2020. www.luke.fi/economydoctor

Lawrence, M. & Friel, S. 2019. Healthy and Sustainable Food Systems. Routledge. https://doi.org/10.4324/9781351189033

Lehtonen, H. & Irz, X. 2013. Impacts of reducing red meat consumption on agricultural production in Finland. Agricultural and Food Science 22: 356–370. https://doi.org/10.23986/afsci.8007

Mason, P. & Lang, T. 2017. Sustainable Diets: How Ecological Nutrition Can Transform Consumption and the Food System. London: Routledge. https://doi.org/10.4324/9781315802930

Miller, R. & Blair, P. 2009. Input-Output Analysis: Foundations and Extensions. New York, USA: Cambridge University Press. https://doi.org/10.1017/CBO9780511626982

Niles, M. T., Ahuja, R., Barker, T., Esquivel, J., Gutterman, S., Heller, M. C., Mango, N., Portner, D., Raimond, R., Tirado, C. & Vermeulen, S. 2018. Climate change mitigation beyond agriculture: a review of food system opportunities and implications. Renewable Agriculture and Food Systems 33: 297–308. https://doi.org/10.1017/S1742170518000029

National Nutrition Council 2014. Nutrition and food recommendations 2014. The National Nutrition Council of Finland, Finnish Food Authority, Helsinki. (in Finnish).

Nordic Council of Ministers 2012. Nordic Nutrition Recommendations 2012. Nordic Council of Ministers, Copenhagen.

OECD 2020. Carbon leakage and agriculture: A literature review on emissions mitigation policies, COM/TAD/ENV/JWPTE(2020)5. Joint Working Party on Trade and Environment, Organisation for Economic Co-operation and Development (OECD), Paris.

Parsons, K., Hawkes, C. & Wells, R. 2019. What is the food system? A Food policy perspective. In: Rethinking Food Policy: A Fresh Approach to Policy and Practice. London: Centre for Food Policy. https://www.city.ac.uk/__data/assets/pdf_file/0008/471599/7643_Brief-2_What-is-the-food-system-A-food-policy-perspective_WEB_SP.pdf.

Röös, E., Carlsson, G., Ferawati, F., Hefni, M., Stephan, A., Tidåker, P. & Witthöft C. 2018. Less meat, more legumes: prospects and challenges in the transition toward sustainable diets in Sweden. Renewable Agriculture and Food Systems: 1–14. https://doi.org/10.1017/S1742170518000443

Reisch, L., Sunstein, C. & Gwozdz, W. 2017. Viewpoint: Beyond carrots and sticks: Europeans support health nudges. Food Policy 69: 1–10. https://doi.org/10.1016/j.foodpol.2017.01.007

Reisch, L., Eberle, U. & Lorek, S. 2013. Sustainable food consumption: an overview of contemporary issues and policies. Sustainability: Science, Practice and Policy 9: 7–25. https://doi.org/10.1080/15487733.2013.11908111

Ripple, W.J., Smith, P., Haberl, H., Montzka, S.A., McAlpine, C. & Boucher, D.H. 2014. Ruminants, climate change and climate policy. Nature Climate Change 4: 2–5. https://doi.org/10.1038/nclimate2081

Saarinen, M., Kaljonen, M., Niemi, J., Antikainen, R., Hakala, K., Hartikainen, H., Heikkinen, J., Joensuu, K., Lehtonen, H., Mattila, T., Nisonen, S., Ketoja, E., Knuuttila, M., Regina, K., Rikkonen, P., Seppälä, J. & Varho, V. 2019. Effects of dietary change and policy mix supporting the change: End report of the FoodMin project. Publication of the Finnish Government's assessment and research activities. (in Finnish).

Swinburn, B.A., Kraak, V.I., Allender, S., Atkins, V. J., Baker P. I., Bogard, J. R., Brinsden, H., Calvillo, A., De Schutter, O., Devarajan, R., Ezzati, M. Friel, S., Goenka, S., Hammond, R.A., Hastings, G., Hawkes, C., Herrero, M., Hovmand, P.S., Howden, M., Jaacks, L.M., Kapetanaki, A.B., Kasman, M., Kuhnlein, H.V., Kumanyika, S.K., Larijani, B., Lobstein, T., Long, M.W., Matsudo, V.K.R., Mills, S.D.H., Morgan, G., Morshed, A., Nece, P.M., Pan, A., Patterson, D.W., Sacks, G., Shekar, M., Simmons, G.L, Smit, W., Tootee, A., Vandevijvere, S., Waterlander, W.E., Wolfenden, L. & Dietz, W.H. 2019. The global syndemic of obesity, undernutrition, and climate change: The Lancet Commission report. The Lancet 393:791–846. https://doi.org/10.1016/S0140-6736(18)32822-8

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B.L., Lassaletta, L., de Vries, W., Vermeulen, S.J., Herrero, M., Carlson, K.M., Jonell, M., Troell, M., DeClerck, F., Gordon, L.J., Zurayk, R., Scarborough, P., Rayner, M., Loken, B., Fanzo, J., Godfray, H.C.J., Tilman, D., Rockström, J. & Willett, W. 2018. Options for keeping the food system within environmental limits. Nature 562: 519–525. https://doi.org/10.1038/s41586-018-0594-0

Thaler, R.H. & Sunstein, C.R. 2008. Nudge: Improving Decisions about Health, Wealth, and Happiness. New Haven, USA: Yale University Press. 293 p.

Valsta, L., Kaartinen, N., Tapanainen, H., Männistö, S. & Sääksjärvi, K. 2018. Nutrition in Finland - The National FinDiet 2017 Survey. THL Report 12/2018, Finnish Institute for Health and Welfare (THL). (in Finnish).

Vainio, A., Niva, M., Jallinoja, P. & Latvala, T. 2016. From Beef to Beans: Eating Motives and the Replacement of Animal Proteins with Plant Proteins among Finnish Consumers. Appetite 106: 92–100. https://doi.org/10.1016/j.appet.2016.03.002

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L.J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J.A., De Vries, W., Sibanda, L.M., Afshin, A., Chaudhary, A., Herrero, M., Agustina, R., Branca, F., Lartey, A., Fan, S., Crona, B., Fox, E., Bignet, V., Troell, M., Lindahl, T., Singh, S., Cornell, S.E., Reddy, K.S., Narain, S., Nishtar, S. & Murray, C.J.L. 2019. Food in the Anthropocene: The EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems. The Lancet 393: 447–92. https://doi.org/10.1016/S0140-6736(18)31788-4

Wirsenius, S., Hedenus, F. & Mohlin, K. 2011. Greenhouse gas taxes on animal food products: rationale, tax scheme and climate mitigation effects. Climatic Change 108: 159–184. https://doi.org/10.1007/s10584-010-9971-x