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Environmental Sustainability of Food Consumption in Asia

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Abstract: This study assesses the environmental sustainability of food consumption in Thailand, India, China, Japan, and Saudi Arabia by using a life cycle assessment. These five Asian countries were selected according to the differences in surface area, population density, GDP, and food consumption patterns. The data were obtained from Food and Agriculture Organization food balance sheets, Ecoinvent 3.4 and Agri-footprint 4.0 databases, and scientific publications. The environmental impact categories chosen were global warming, terrestrial acidification, eutrophication, eco-toxicity, human toxicity, and fossil resource scarcity. The impact assessment was carried out by using the ReCiPe2006 v1.1 method. Based on the analysis, the highest environmental impacts for all categories (except eutrophication) were from the food consumption in China, followed by the consumption in Japan, Saudi Arabia, Thailand, and India. The major contributors to these impacts were meat, cereals, and animal products. Meat was the highest contributor in all countries except India, because of low meat consumption in India. A calorie intake analysis was also conducted, which showed reductions in environmental impacts by shifting towards calorie-adequate and non-environmentally intensive diets in Thailand, China, Japan, and Saudi Arabia. Therefore, a reduction in the consumption of meat, cereals, and animal products could therefore enhance the environmental sustainability of food consumption.

Keywords: LCA; food consumption patterns; sustainable consumption; sustainable diet; Asian dietary patterns

1. Introduction

The growing human population, expanding urbanization, and increasing environmental concerns stress the need for sustainable consumption and production [1]. Food production and consumption is one of the major contributors to environmental impacts, as globally, agriculture and food production has contributed to over 25% of total greenhouse gas emissions, yielded the largest share of land and water use, and caused significant eutrophication and acidification [2–4]. Food consumption and dietary choices directly influence food production systems and their related environmental sustainability. Therefore, it is imperative to comprehensively analyze them in depth and identify how the impacts can be mitigated. Environmental impacts of food consumption have been assessed by various tools, such as life cycle assessment (LCA), input–output models, carbon footprint, and ecological footprint [5–9]. Many studies have concluded that meat products (beef, pork, poultry, and fish) had the highest environmental impacts, while fruits and vegetables yielded lower impacts [4,5,8,10]. Therefore, shifts towards healthier diets with less meat and more vegetables are generally recommended. LCA studies on comparative consumption patterns under different production systems in different countries have also been undertaken, in order to enhance environmental sustainability of food consumption at the national and regional levels [5,7,8,10]. Nevertheless, most research accounted only for European diets, and the assessment of Asian diets is very rare. Since considerable differences in diet patterns can have significant implications in environmental impacts, specific studies for Asian countries are required in order to come up with sustainable consumption solutions applicable in the Asian context. Therefore, the main aims of this study are to assess the environmental impacts of food consumption in five selected Asian countries, identify major food groups responsible for different environmental impacts, compare the impacts of consumption among the countries analyzed, and recommend how an increase in environmental sustainability of food consumption in Asia could be attained. The results of the study will provide a country-comparative analysis on the impacts of food consumption through different impacts categories, insights on the major stressors to the environment related to food consumption in each country, and quantitative analysis on various diet scenarios to identify environmentally friendly diets. Together with further studies related to diet and nutrition, the results can be used to provide recommendations for the mitigation of impacts through shifts to healthier and more environmentally friendly diets in Asia.

2. Materials and Methods

LCA methodology based on ISO 14040 and ISO 14044 [11,12] was applied in this research to assess the environmental impacts of food consumption in Asia from a cradle-to-gate perspective. The five Asian countries selected for this assessment were Thailand, India, China, Japan, and Saudi Arabia. The demographic characteristics of each country in 2013, according to the data from World Bank [13–18], are shown in Table 1.

Table 1. Various parameters for the studied countries [13–18].

No.	Parameters	Countries				
		Thailand	**India**	**China**	**Japan**	**Saudi Arabia**
1	Population (thousands)	68,143	1,279,000	1,357,000	127,445	29,944
2	Surface area (sq. km)	513,120	3,287,260	9,562,950	377,962	2,149,690
3	Urbanized population (% of total)	47.94%	32%	53.17%	92.49%	82.72%
4	Population density (people per sq. km)	133.38	430.03	144.58	349.59	13.93
5	GDP (billion US$)	420.53	1,857	9,607	5,156	746.65
6	GDP per capita (US$)	15,293	5,251	12,368	38,974	51,265

The countries were chosen on the basis of variations in the different demographic characteristics, such as percentage of urbanized population, population density, and gross domestic product (GDP) per capita, as shown in Table 1. Therefore, these countries were chosen expecting that variation in country characteristics as such would also bring variations in their consumption patterns.

For the LCA of food consumption patterns of each country, a functional unit (FU) was defined. The FU for the study was defined as food consumption in kilograms per capita per year for each country, as annual and daily intake are appropriate FU choices for food item and diet comparison [7]. The foreground data as food consumption patterns were estimated from the food balance sheets provided by the Food and Agriculture Organization (FAO), with the representative year of 2013—the most recent fiscal year [19]. The FAO food balance sheets have also been used for estimating national and regional diets in previous studies [6,10]. The food balance sheets classify food into a total of ninety-four food items which are categorized into several groups. For each of these food items, data related to domestic supply quantity, export quantity, fat supply quantity, feed quantity and food quantity are available in the balance sheets. For this study, data related to food quantity is taken as foreground data and is defined as the total amount of food available for human consumption, which includes the food item in question as well as any other commodity derived from it [19].

The background data, life cycle inventory data of each food item, were obtained from Ecoinvent 3.4 and Agri-footprint 4.0 databases [20,21] and supplemented by peer-reviewed scientific publications.

The classification of each commodity into aggregated food items was done primarily on the basis of the FAO classification, but modified in accordance to existing articles regarding food consumption [22]. Based on this, the food items were classified into twelve "food groups":

1. Cereals, which consist of wheat, rice, barley, maize, rye, oats, and sorghum, and all other products derived from it. Millet, buckwheat, canary seeds, and bran were aggregated into rice, due to lack of inventory data;
2. Root vegetables, which consist of cassava and potatoes. Sweet potatoes, yams, and other tubers were also aggregated into potatoes;
3. Legumes, nuts, and oilseeds, which consist of beans, pulses (broad beans, horse beans, chick peas, cow peas, pigeon peas, Bambara beans, vetches, lupins, pulses, sesame seeds and other oilcrops), peas, nuts, soybeans, ground nuts, sunflower seeds, rapeseed (aggregated with mustard seed), coconuts, and olives. Beans and pulses were aggregated into a single food item, due to lack of inventory data;
4. Oils, which consist of soybean, groundnut, cottonseed, palm kernel, palm, coconut, rice bran, and maize germ oils. Sesame seed oil, olive oil, and oil derived from other sources were grouped with soybean oil;
5. Vegetables, which consist of tomatoes and products, onions, aubergine, cabbage, and carrots. Leafy vegetables, such as lettuce spinach, cauliflower, were grouped into cabbages. "Other vegetables" from the FAO balance sheets were distributed evenly into these five items;
6. Fruits, which consist of oranges and mandarins, citrus fruits (lemons, limes, and their products), banana and plantains, apples, pineapples, dates, grapes, and their corresponding products. "Other fruits" from the FAO balance sheets were distributed evenly into these seven items
7. Coffee and tea, which consists of coffee, tea, and their corresponding products. Cocoa is grouped into coffee, due to lack of inventory data;
8. Meat, which consists of bovine, mutton and goat, pig, and poultry meat. Offals and meat from horse, ass, mule, camel, snail, rabbit, and other rodents are aggregated into bovine meat
9. Fish and seafood, where fish, crustaceans, cephalopods, Mollusca, and other aquatic plants and animals are aggregated together;
10. Animal products, which consists of butter and ghee, cream, raw animal fats (including fish body oil, and fish liver oil), eggs, and milk;
11. Sugar and confectionary, which consists of sugarcane and sugar. Sugar (non-centrifugal), sugar (raw equivalent), sugar from sugarcane, sweeteners, and honey are aggregated into sugar;
12. Alcoholic beverages, which consists of wine and beer. Other fermented alcoholic drinks are aggregated into beer.

The aggregated food groups for each country are shown in Table 2. The detailed table for foreground and background data is given in Table S1 in the Supplementary Materials.

Apart from the LCA of food consumption in the selected countries, the study also adopts scenario analyses that compare the base diet scenario of each country with various consumption patterns integrating diet reduction options from different food groups that are the most important contributors to different environmental impact categories. This ensures an understanding of best diet reduction scenarios for each country, in order to decrease the environmental impacts of food consumption. The scenarios developed from the initial base case scenario results are explained in detail in the forthcoming section.

This assessment considers both attributional and consequential LCA (ALCA and CLCA, respectively) modeling approaches, but the main modeling choice is ALCA. The ALCA and CLCA modeling approaches are defined, respectively, as a "system modelling approach in which inputs and outputs are attributed to the functional unit of a product system by linking and/or partitioning the unit processes of the system according to a normative rule" and a "system modelling approach in which activities in a product system, are linked so that activities are included in the product system to the extent that they are expected to change as a consequence of a change in demand for the functional unit" [23].

The LCA software and life cycle impact assessment (LCIA) method applied in this assessment are Simapro 8.5.0.0 (PRé Consultants bv, Amersfoort, The Netherlands) and ReCiPe 2016 v1.01 [24], respectively. Six environmental impact categories previously addressed in existing LCA studies on food consumption (see Supplementary Materials), and the ones considered in this study are global warming potential (GWP), terrestrial acidification potential (ACP), marine eutrophication potential (EUP), eco-toxicity potential (ETP), human toxicity potential (HTP), and fossil resource scarcity (FRS). ETP is taken as the sum of terrestrial eco-toxicity, marine eco-toxicity, and freshwater eco-toxicity. Human toxicity is taken as the sum of human non-carcinogenic toxicity and human carcinogenic toxicity.

Table 2. Per capita consumption of twelve food groups for each country (modified from fiscal year 2013 [19]).

No.	Food Group	Per Capita Consumption (kg/Capita-Year)				
		Thailand	India	China	Japan	Saudi Arabia
1	Cereals	136	148	150	115	154
2	Root Vegetables	23	31	68	31	24
3	Legumes, nuts, and oilseeds	17	24	12	12	11
4	Oils	8	9	7	15	20
5	Vegetables	52	89	348	102	105
6	Fruits	103	56	94	53	92
7	Coffee and tea	2	1	1	6	6
8	Meat	30	4	65	52	68
9	Fish and seafood	26	5	45	50	13
10	Animal products	42	90	54	93	94
11	Sugar and confectionery	101	33	7	27	32
12	Alcoholic beverages	41	2	45	47	0
	TOTAL	581	492	896	603	618
	Total calorie intake (kcal/capita-day)	2785	2454	3112	2747	3255

3. Results and Discussion

3.1. Food Consumption Patterns

The food consumption patterns for each country, aggregated into twelve food groups, along with total average calorie intake per capita per day is shown in Table 2.

As shown in the table above, the diet patterns are considerably different for each country. For example, the consumption of sugar and confectionary ranges from 1% to 17%, and the supply for vegetables ranges from 9% to 39% out of total food consumed per capita per year in Thailand and China, respectively. In addition, the consumption of meat in India is much less than all the other countries studied, while in Saudi Arabia, there is no consumption of alcoholic beverages. The per capita consumption of calories per day shows that the highest consumption amount is 3255 kcal in Saudi Arabia, followed by China, Thailand, Japan, and India.

It is important to mention on the outset that the amount of vegetables supplied for China has an unusually high value. A study that used nationally representative data from the 2013 China Chronic Disease Surveillance survey contradicts this value, by stating that the national average for vegetable consumed per capita in one day is 350.6 grams per day, resulting in a yearly consumption of only 127.9 kg per capita in one year [25]. Therefore, the consumption amount of vegetables used here, i.e., 348 kg per capita per year, could be grossly overestimated. This overestimation reflects the inaccuracy of the data derived from the FAO food balance sheets.

3.2. Environmental Impacts of Asian Food Consumption Patterns

Life cycle environmental impacts of annual food consumption per capita in Thailand, India, China, Japan, and Saudi Arabia are presented in Figure 1. In order to understand the intensity of impacts from different food groups classified in the study, the impacts per kilogram of each food group was modelled, and their contribution relative to each other were calculated, and is shown in Figure 2. The detailed results can be found in Supplementary Materials.

Based on the LCA of food consumption in the five countries illustrated in Figure 1, the consumption in China yields the highest environmental impacts for all impact categories except marine eutrophication (Figure 1c), where Saudi Arabia has the highest impact. Both the amount and types of food consumed in different countries are the main causes of the differences in environmental impacts. China not only has the highest amount of food consumption, but also has high consumption of food groups, such as meat and animal products, that cause high impacts (see Table 2 and Figure 2). Similarly, India shows the lowest impacts in all categories except human toxicity (Figure 1e), in which Thailand had the lowest value. India has the lowest amount of food consumption, and the types of food groups consumed, such as cereals, fruits, and vegetables, have low impacts (see Table 2 and Figure 2). The analysis shows similar trends of environmental impacts for other countries as well, where, in almost all the impact categories, Thailand and India exhibit low impacts compared to Japan and Saudi Arabia. For almost all the impact categories for all the countries, meat and cereals are found to be the most significant contributors. The impacts of meat in India are insignificant in all impact categories, with meat contributing to only 1%–7% of the total impact. This is attributed to the fact that meat consumption in India is very low (<1% of total diet). For China, since the estimation of vegetables consumed were very excessive (39% of total consumption in China), they are also one of the major contributors in all impact categories.

For GWP, meat and cereals are the chief contributors in all the countries, with meat contributing to as high as 571 kg CO_2 eq (40%) in China. Meat consumption contributes to more than 25% in all countries except India for GWP. Cereals are the highest contributor to GWP in Thailand, contributing to 234 kg CO_2 eq (29% of total GWP). Cereals also rank in the top three contributors that contribute more than 15% in all countries. Vegetables in India and China also fall under the top three contributors for GWP, contributing to 15% and 23% of total emissions, respectively. Similarly, meat has the highest impact in all countries (except India) for terrestrial acidification, with contributions ranging from 36% in Thailand to 50% in Japan. For India, Japan, and Saudi Arabia, animal products also have high contributions, being one of the top three contributors for GWP, ACP, EUP, and ETP for all three countries. The consumption of milk in these countries is high (18%, 15%, and 15% in India, Japan, and Saudi Arabia respectively, as compared to only 7% and 6% in Thailand and China, respectively); as a result, the impacts these countries produce are also high.

Cereals are the dominating food group for all the impact categories, and are ranked as one of the top three contributors in all countries for GWP, ACP, EUP, ETP, and FRS. Although the impacts of meat are very pronounced in most impact categories, cereals are the most consistent food group, affecting almost all categories for all countries. The main reason for this is that the amounts of cereal consumption in all five countries are very high (17% in China to 30% in India).

For human toxicity, legumes, nuts, and oilseeds are ranked as the highest contributor in all countries, with values ranging from 255 kg 1,4-DCB (1,4 dichlorobenzene) in Saudi Arabia (36% of total impact) to 100 kg 1,4-DCB (24% of total impact) in Thailand. This is because legumes, nuts, and oilseeds have the highest HTP impact intensity compared with other food groups (see Figure 2). The main contribution to HTP by this food group (legumes, nuts, and oilseeds) was from the almond production process. The high emissions in water and soil of metals like cadmium, chromium, copper, lead, nickel, zinc, and especially mercury in the production of almonds were the major factors causing HTP.

For Thailand, alcoholic beverages are also significant for GWP, ETP, HTP, and FRS, with contributions amounting to 9%, 13%, and 16% of the total impact, respectively.

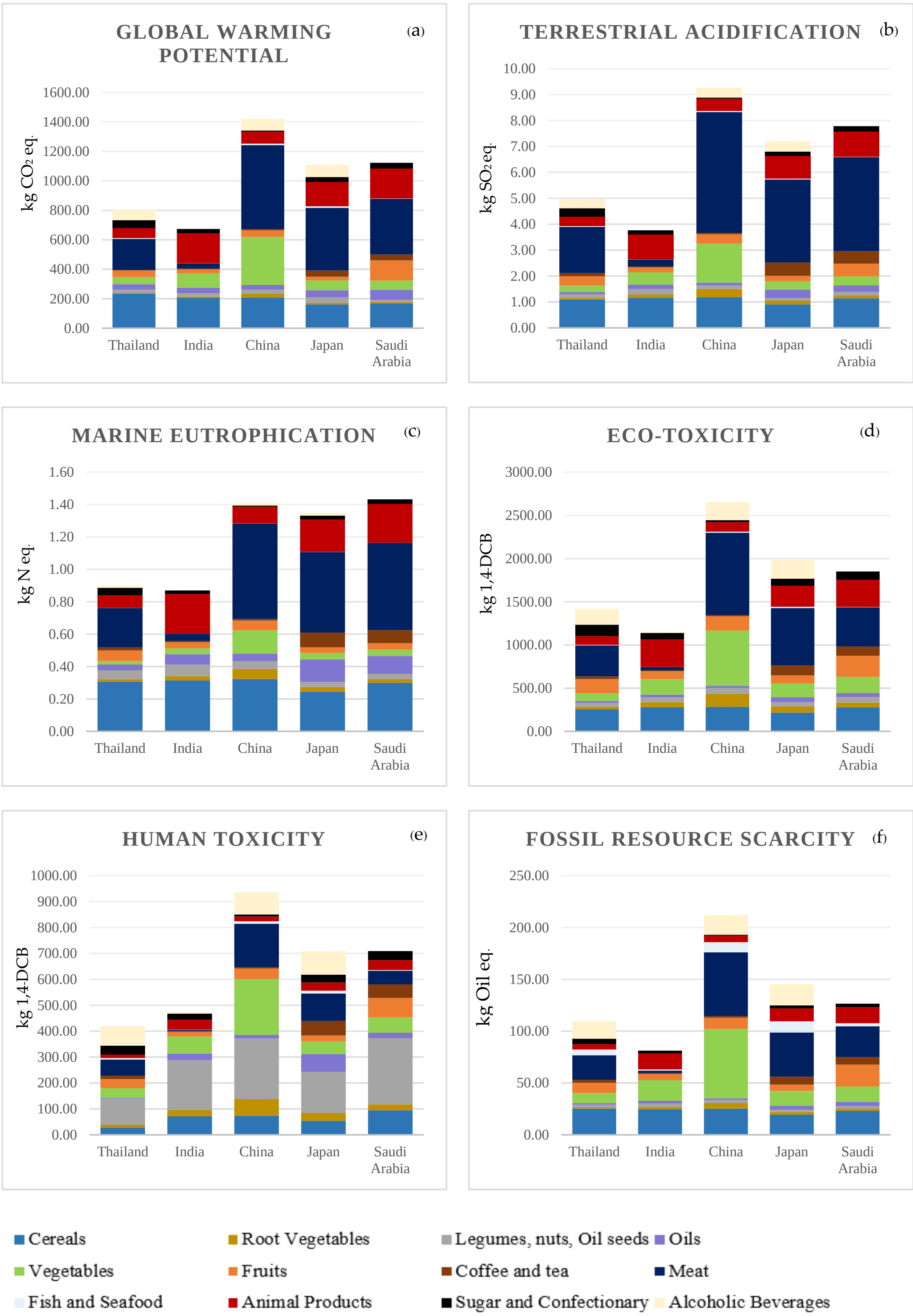

Figure 1. Comparison of life cycle environmental impacts of food consumption disaggregated by twelve food groups for six chosen impact categories, viz. (**a**) Global warming potential, (**b**) Terrestrial acidification, (**c**) Marine eutrophication, (**d**) Eco-toxicity, (**e**) Human toxicity and (**f**) Fossil resource scarcity.

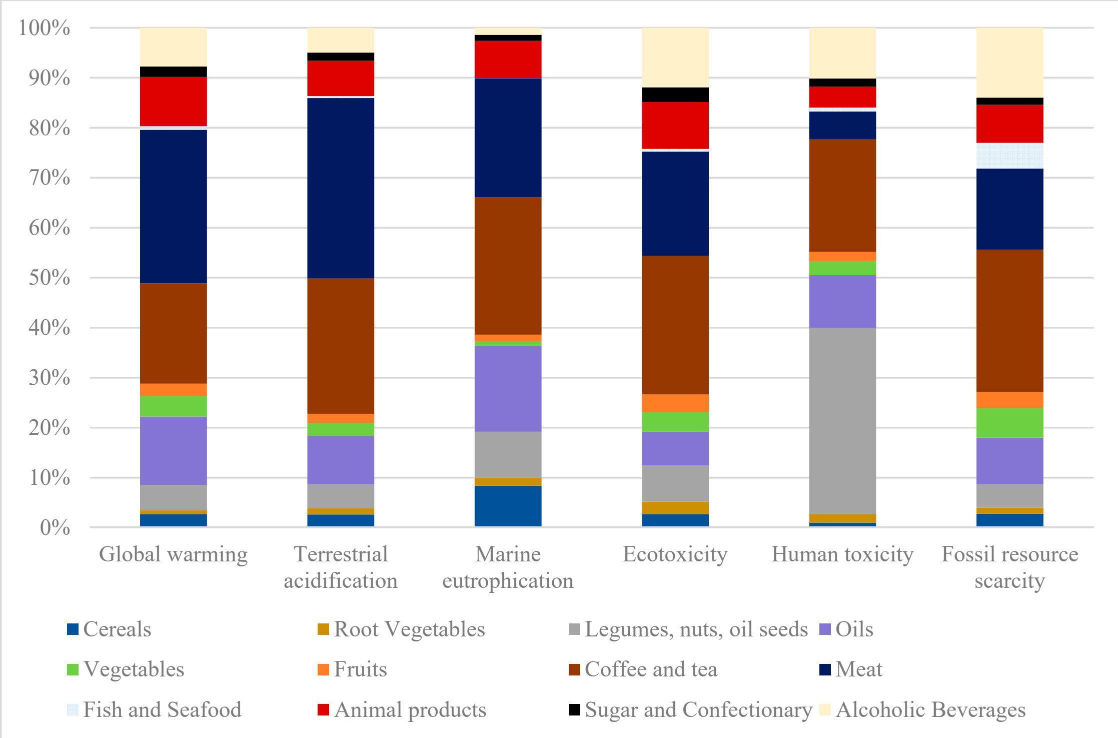

Figure 2. Life cycle environmental impact intensity per 1 kg of each food group. The impacts are illustrated as relative percentages of each food group.

Looking at Figures 1 and 2, the total impacts from each food group in each country depend on the intensity of impact (i.e., the impact produced by 1 kg of the food group) and the amount of the food group consumed. For example, although the impact intensity of oils and coffee and tea is very high in all the studied impact categories, they are not seen as significantly contributing to impacts in Asian diets, because this food group does not have a big proportion in those Asian diets (maximum of 1%). Conversely, although the impact intensity of cereals is not significant, they are found to be one of the major contributors to the impact categories, because large portions of the diets in all countries are composed of cereals (17% in China to 30% in India).

As pointed out earlier, China has highest impacts in all impact categories except marine eutrophication, where Saudi Arabia has the highest value. Looking at Table 2 and Figure 2, Saudi Arabia has higher consumption of cereals, oils, coffee, meat, and animal products in its diet (341 kg per capita)—five significant contributors to marine eutrophication—compared to China (278 kg per capita), which is why Saudi Arabia yields higher overall impacts in marine eutrophication than China. Similarly, India has the lowest impacts in all categories except human toxicity, in which Thailand has the lowest value because India has a higher consumption of legumes, nuts, and oilseeds—a major contributor to human toxicity (24 kg per capita)—compared to Thailand (17 kg per capita).

3.3. *Environmental Impacts of Food Consumption and Calorie Intake Analysis*

Referring to Table 2 and comparing the per capita calorie intake per day and food intake per year, it shows that the average calorie intake per person exceeds the Food and Agriculture Organization (FAO) benchmark adequate calorie intake of 2500 kcal/capita/day [26] for all countries except India. Calorie intakes were significantly higher in China and Saudi Arabia, which shows opportunities for improvement towards environmental impacts by reducing consumption to a calorie-adequate diet.

Based on the results and the benchmark adequate calorie intake, twelve scenarios are developed in order to ascertain which type of dietary shift would lead to better environmental benefits. The study considers dietary shifts for Thailand, China, Japan, and Saudi Arabia that will lead to a calorie intake of exactly 2500 kcal per capita. India is excluded from this comparative analysis, because India's kcal consumption per capita is lower than the benchmark value. It should be mentioned that the actual adequate energy requirements for an average person in different countries are different from the FAO benchmark, since the demography and population structure in these countries are substantially different. Twelve scenarios described in Table 3 represent three impact reduction options: (1) overall proportionate reduction of each food group, (2) reduction in animal product consumption only, and (3) reduction in cereals consumption.

Table 3. Description of scenarios to reduce calorie intake to the standard benchmark value.

Scenarios	Description
TH1_Overall reduction	This scenario adjusts the total calorie intake of the food consumption pattern in Thailand (TH) from 2785 to 2500 kcal/capita/day by reducing overall consumption of each food group by 10%.
TH2_ Animal product reduction	This scenario adjusts the total calorie intake of the food consumption pattern in Thailand from 2785 to 2500 kcal/capita/day by reducing meat and animal product consumption by 80%.
TH3_Cereal reduction	This scenario adjusts the total calorie intake of the food consumption pattern in Thailand from 2785 to 2500 kcal/capita/day by reducing cereal consumption by 22%.
CN1_Overall reduction	This scenario adjusts the total calorie intake of the food consumption pattern in China (CN) from 3112 to 2500 kcal/capita/day by reducing overall consumption of each food group by 20%.
CN2_ Animal product reduction	This scenario adjusts the total calorie intake of the food consumption pattern in China from 3112 to 2500 kcal/capita/day by reducing meat and animal product consumption by 40%.
CN3_Cereal reduction	This scenario adjusts the total calorie intake of the food consumption pattern in China from 3112 to 2500 kcal/capita/day by reducing cereal consumption by 17%.
JP1_Overall reduction	This scenario adjusts the total calorie intake of the food consumption pattern in Japan (JP) from 2747 to 2500 kcal/capita/day by reducing overall consumption of each food group by 9%.
JP2_Animal product reduction	This scenario adjusts the total calorie intake of the food consumption pattern in Japan from 2747 to 2500 kcal/capita/day by reducing meat and animal consumption by 52%.
JP3_Cereal reduction	This scenario adjusts the total calorie intake of the food consumption pattern in Japan from 2747 to 2500 kcal/capita/day by reducing cereal consumption by 25%.
SA1_Overall reduction	This scenario adjusts the total calorie intake of the food consumption pattern in Saudi Arabia (SA) from 3255 to 2500 kcal/capita/day by reducing overall consumption of each food group by 23%.
SA2_Animal product reduction	This scenario adjusts the total calorie intake of the food consumption pattern in Saudi Arabia from 3255 to 2500 kcal/capita/day by reducing meat and animal consumption by 55%.
SA3_Cereal reduction	This scenario adjusts the total calorie intake of the food consumption pattern in Saudi Arabia from 3255 to 2500 kcal/capita/day by reducing cereal consumption by 20%.

All developed impact reduction scenarios could generally reduce all impact categories, due to the proportional reduction in the amounts of the food groups consumed. The reduction percentages for each impact category when comparing the base case scenario (the reference situation without the reduction options) with the twelve scenarios described above are shown in Figure 3.

Figure 3. Percentage reductions in the impact categories for each scenario. (**a**) Global warming potential, (**b**) Terrestrial acidification, (**c**) Marine eutrophication, (**d**) Eco-toxicity, (**e**) Human toxicity and (**f**) Fossil resource scarcity.

The animal product reduction scenarios (TH2, JP2, and SA2) would be the most favorable options for dietary shifts for all countries except China, with reductions in the GWP, for example, amounting to

39%, 31%, and 36% in Thailand, Japan, and Saudi Arabia respectively. For China, the overall reduction scenario (CN1) shows more effectiveness in reducing impacts than the animal product reduction (CN2). This is mainly because of the huge proportion of food consumed being vegetables (39%) in China, in comparison to other countries. Therefore, the adoption of overall food reduction would show better results in China, and the reduction of animal product consumption in Thailand, Japan, and Saudi Arabia would be favorable. The overall reduction scenarios in Thailand, Japan, and Saudi Arabia (TH1, JP1, and SA1, respectively) also show reasonably reduced impacts, with GWP reductions amounting to 10%, 9%, and 23% in Thailand, Japan, and Saudi Arabia, respectively. The reduction in cereals consumption has the least comparative benefits, with impact reductions of only 2%–4% for the GWP. Reduction in cereals consumption affects the ETP and HTP reductions, amounting to as high as 30% for ETP and 15% for HTP in Thailand.

3.4. Environmental Impacts of Food Consumption under Different Modeling Choices

Table 4 shows the results of attributional LCA (ALCA) and consequential LCA (CLCA) for each country. ALCA and CLCA modeling choices result in different impact values, since the affected unit processes are different. However, the main findings in this comparative study could be similarly drawn. The food consumption in China has the highest environmental impacts for all impact categories (except marine eutrophication), while the food consumption in India yields the lowest impacts for all impact categories (except human toxicity).

Table 4. Attributional life cycle assessment (ALCA) and consequential life cycle assessment (CLCA) of food consumption in the studied Asian countries.

Attributional Life Cycle Assessment (ALCA)						
Impact Category	**Unit**	**Thailand**	**India**	**China**	**Japan**	**Saudi Arabia**
Global warming	kg CO_2 eq	811.44	675.96	1420.55	1109.13	1122.47
Terrestrial acidification	kg SO_2 eq	4.96	3.79	9.27	7.21	7.78
Marine eutrophication	kg N eq	0.91	0.87	1.41	1.35	1.44
Eco-toxicity	kg 1,4-DCB	1417.67	1147.77	2651.19	1987.24	1850.08
Human toxicity	kg 1,4-DCB	419.20	471.71	935.56	708.82	709.11
Fossil resource scarcity	kg oil eq	109.78	82.07	212.14	145.22	126.52
Consequential Life Cycle Assessment (CLCA)						
Impact Category	**Unit**	**Thailand**	**India**	**China**	**Japan**	**Saudi Arabia**
Global warming	kg CO_2 eq	685.14	552.60	1032.11	884.10	814.53
Terrestrial acidification	kg SO_2 eq	3.72	3.40	5.89	5.58	5.24
Marine eutrophication	kg N eq	0.89	0.98	1.23	1.23	1.38
Eco-toxicity	kg 1,4-DCB	1690.26	1373.50	2928.53	2221.32	1908.94
Human toxicity	kg 1,4-DCB	145.46	442.45	622.33	500.53	696.92
Fossil resource scarcity	kg oil eq	93.01	56.85	170.15	130.74	92.90

3.5. Policy Recommendations toward Sustainable Food Consumption in Asia

By looking at the intensity of the impacts of food groups to impact categories, the composition of diets, and various scenarios to change diets to adequate consumption levels, the most effective way to reduce impacts is found to be through the reduction in the consumption of meat and other animal products. This is chiefly attributed to the fact that the life cycle impacts of meat production are highly intensive, and that cutting down excess meat consumption provides the best option for drastically reducing the environmental impacts caused by it. Furthermore, maintaining a diet to recommended levels through cut-downs in overall consumption also shows good promise towards a consumption pattern that is friendlier to the environment, and at the same time is beneficial for citizens. However, nutrition should also be an additional parameter factored in the study, which can give better information on diets that are nutritionally adequate and environmentally friendly. This can be a prospective future research that can stem from this study.

Efforts have already been made in several Asian countries that have opted to adopt policies that tackle environmental problems through the consumption side. The government of China developed the Chinese Dietary Guidelines (CDGs) to guide individuals and policy makers to achieve healthier and sustainable food consumption and production, including a reduction in the consumption of meat [27]. The review specifically suggests citizens to consume plenty of vegetables, milk, and soybeans, with daily vegetable intake to be in the range of 300–500 grams, and consume appropriate amounts of fish, poultry, eggs, and lean meat for protein. A study relating the effects of following the CDGs evaluated the environmental benefits of the shift of the Chinese population from their current diet to the CDGs, and reported a decrease in greenhouse gases (GHGs) emissions by 1.65 million tons per year, which is a huge incentive for the government of China to implement policies that influence this individual diet shift [28].

However, tackling the environmental problems of food through the consumption side should also be accompanied by policies that incentivize and inform the people about benefits of healthier and less intensive diets. As such, several Asian countries have provided mandates to agencies in order to promote sustainable food consumption, chiefly through educational campaigns and changing consumer behavior towards sustainable consumption. For example, Japan has established a group on Consumer Citizenship for Sustainable Consumption in the Japanese Cabinet Office to promote responsible food consumption. Similarly, the Korean Presidential Committee on Green Growth established a Green Lifestyle for Sustainable Development team that focused on education for green growth [29]. They evaluated 11 policies related to sustainable consumption in Asia, and concluded that in order to involve more individuals in sustainable diet shifts, policies should be focused on consumer education, while social and political systems should be supportive, and also should facilitate individuals' voluntary participation towards a shift in sustainable diets. Therefore, quantitative research that focuses on different diet scenarios and the environmental impacts they imply should be supported by the qualitative research mentioned above, which details how this reduction on consumption could be achieved in the long term, in order to come up with policies that direct individuals in making healthier and environmentally friendlier decisions regarding the food they consume.

It is also necessary to focus on reduction of impacts on the production side. For example, impact categories in this study related to freshwater and marine eutrophication, as well as fossil resource scarcity, is largely attributed to the use of chemical fertilizers in agriculture. Recognizing the harmful effects of extensive chemical fertilizer use, Asian countries have started setting out policies to address this issue as well. For example, China announced new policies and plans to reduce environmental impacts from agriculture by limiting the use of chemical fertilizers in 2015, As such, its plan was to cap the total fertilizer use by 2020, and obtain a zero agricultural discharge by 2030 [30]. Similarly, in response to the effects of intensive agriculture, the government of Thailand also developed sustainable agriculture policies in its National Economic and Social Development Plan (NESDP), whose chief aim was to encourage crop diversification, discourage the use of inorganic fertilizers and pesticides, and promote organic agriculture [31].

Therefore, policies that address the shortcomings on both the production and the consumption side, and which are backed up by country-specific research, are required to improve the sustainability of food in Asian countries.

4. Conclusions

This study assesses the environmental sustainability of food consumption in five different Asian countries. The results show that the environmental impacts of food consumption primarily depend on two characteristics of diet patterns: the amount of food consumed and the types of food groups in the diet. The highest environmental impacts are found in China, and the lowest in India; the primary sources of environmental impacts from Asian diets are meat, cereals and animal products, although meat was not a significant contributor to India. Relating the environmental impacts with major contributors, and with calorie intake per capita per day in each country, the study recognizes two viable options regarding the reduction of impacts from the consumption side: shifting to a calorie-adequate diet, i.e., reducing calorie intake to 2500 kcal/capita/day; and by shifting towards diets that are less environmentally damaging, i.e., in this case, substituting the nutrition obtained from food groups with high environmental impacts, such as animal products, and meat. These changes in dietary patterns should be reinforced by policies that guide citizens in making informed decisions about the food they consume in terms of their health and the environmental impacts they produce. Furthermore, polices should also focus on reducing the impacts of food on the production side, in order to achieve food systems that are more sustainable.

Supplementary Materials: The following supplementary materials are available online at http://www.mdpi.com/2071-1050/11/20/5749/s1: Table S1: Data of per capita food consumption for each country and dataset used; Table S2: Life cycle inventory used for one kilogram of fish and seafood, Table S3: Life cycle inventory used for one liter of wine; Table S4: Life cycle inventory used for one liter of Beer; Table S5: Identified literature that uses the LCA approach to evaluate environmental impacts of food consumption; Table S6: Results of ALCA for the diet patterns of each country; Table S7: Result of CLCA for the diet patterns of each country; Table S8: Result of LCA for a diet with 1 kg of each food item; Table S9: Results of LCA for food consumption of Thailand; Table S10: Results of LCA for food consumption of India; Table S11: Results of LCA for food consumption of China; Table S12: Results of LCA for food consumption of Japan; Table S13: Results of LCA for food consumption of Saudi Arabia.

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