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ORIGINAL PAPER

Dietary transitions in Indonesia: the case of urban, rural, and forested areas

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Abstract

This study examines food consumption patterns in Indonesia across urban, rural, and forested areas with varying levels of tree cover loss (TCL). Using household food consumption data from the National Socio-economic Survey in 2008 and 2017, and data from the Global Forest Watch website, we identify differences in food consumption patterns in urban, rural, and forested areas with high and low TCL. The results indicate a dietary transition is occurring in Indonesia, characterized by increased consumption of wheat, chicken, fish, sugar-sweetened beverages, processed, ultra-processed, and ready-to-eat foods, and a decline in the consumption of green leafy vegetables and fresh legumes across all area categories. Diet quality is declining in all area categories, however, urban areas showed the most accelerated decline, with declining dietary diversity, decreasing consumption of healthy foods, while increasing consumption of less healthy foods and the highest consumption of ultra-processed foods. Furthermore, foods consumed more in urban (vs. rural) and high-TCL (vs. low-TCL) areas, such as wheat, broiler chicken, dairy, and packaged foods, are associated with modern diets and sourced from farther away, indicating accelerated modernization and delocalization of diets. Conversely, foods consumed more in rural and low-TCL areas, such as traditional staple foods, free-range eggs, and dark green leafy vegetables, are considered more locally sourced and traditional. We conclude that dietary transitions occur across all regions, but the modernization of diets is more accelerated in urban and high-TCL areas. Given the mixed health consequences of modern diets, policies should anticipate negative impacts while preserving positive aspects.

Keywords Dietary transition · Rural–urban · Tree cover loss · Indonesia · Food consumption · Modern diet

1 Background

Worldwide, dietary patterns are changing, characterized by a higher intake of animal-source foods, fats and sweets, and less fiber. This shift is widely known as the dietary transition, sometimes referred to as the modernization of diets. Modern diets are typically high in fat, added sugar, animal-source foods, refined carbohydrates, and low in fresh vegetables, legumes, and coarse grains (Popkin, 2006; Popkin et al., 2012). Modern diets are also linked to multiple processing stages involving modern food processing machinery (Monteiro et al., 2019). Many of the foods associated with modern diets in Asia are sourced from subnational, national, and international trade (Baker & Friel, 2016). Popkin et al. (2012) describe a modern dietary transition and its associated health implications as a global pandemic in low- and middle-income countries (LMIC). However, while a dietary transition is a generally accepted phenomenon in LMICs, it

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has not been comprehensively studied in Indonesia, one of the largest LMICs in Asia.

As the world's largest archipelagic nation, Indonesia is comprised of 17,001 islands, spread across 514 regencies in 37 provinces (Statistics Indonesia, 2023a). Many of its diverse regions boast their own unique dietary and culinary traditions (Nurhasan et al., 2022). A nationally representative study showed that there was a shift in dietary preferences of Indonesians towards 'Western food' among people who moved to Jakarta, the capital city, but not in the general population (Colozza & Avendano, 2019). Another study showed that children and adolescents living in urban areas in Indonesia more frequently consumed sugar-sweetened beverages and foods, caffeinated soft drinks, energy drinks, fatty fried foods, refined carbohydrates, and preserved meats than those who lived in rural areas (Nurwanti et al., 2019). A study in West Sumatra suggested that people still retain their preference for traditional diets; however, consumption of sugar and vegetable oils is increasing due to increasing purchasing power (Lipoeto et al., 2004). Similarly, Pawera et al. (2020) found in the same region that traditional foods are still preferred over western foods, although there is rising availability and consumption of sweets and fatty foods. In West Papua Province, a recent study found that a dietary transition is happening towards higher consumption of rice, broiler chicken, tofu, tempeh, along with ultra-processed foods, and foods consumed away from home (Nurhasan et al., 2022). Thus, the current evidence seems to point towards similar changes across different populations in different geographies but does not provide an overall picture of what is happening in the country. Moreover, most of the studies also rely on consumption frequency and expenditures rather than directly on quantities of foods consumed which is a more accurate method of measurement to assess dietary changes.

The specific patterns of dietary transitions differ globally based on geography and socio-economic factors (Kandala & Stranges, 2014; Quintero-Lesmes & Herran, 2019). Urban populations tend to consume more calories with a lower proportion of these calories coming from cereals, carbohydrates, and fats. Urban populations also consume more protein, especially meat and have a higher prevalence of overweight among children in 55 of 80 low-income countries (Hawkes et al., 2017). Evidence from Tanzania shows that moving to urban from rural areas changed the composition of diets significantly in that country but did not increase total calorie intake (Cockx et al., 2019). Evidence from India suggests that rural-to-urban migration can have both positive impacts, such as higher consumption of fruits and vegetables, and negative impacts, such as increased consumption of energy and fat (Bowen et al., 2011). Although less studied, some evidence shows that landscape changes can also result in dietary changes (Broegaard et al., 2017; Ickowitz et al., 2021). Rasolofoson et al. (2018) found that forests were positively associated with several aspects of children's diets in a sample from 27 developing countries. Another study suggests that the replacement of more natural landscapes with cultivated ones can result in loss of wild foods, while the replacement of polycultural landscapes with monocultures can reduce agrobiodiversity impacting the diversity of diets (Ickowitz et al., 2019; Mehraban & Ickowitz, 2021). Herforth and Ahmed (2015) note that changes in livelihood activities can affect the time allocated to food production for people who heavily depend on nearby food sources, particularly those living in forested regions (Rowland et al., 2022). This can result in less time allocated to gathering, hunting, or preparing traditional meals, with impacts on food security and nutrition.

Indonesia's landscapes are distinguished by extensive forest cover, accounting for more than half of the country's land area. Consequently, forests can play important roles in local food systems (Ickowitz et al., 2016) with forest foods contributing substantially to dietary adequacy in forest-adjacent communities (Rowland et al., 2017). In some areas with high forest cover, such as in Central Kalimantan Province, local people recognize forests as a 'free supermarket' (Tempo, 2020). Wild products are not exclusively collected by those living in remote rural areas. In West Papua Province, even residents near urban centers frequently visit forests to collect wood fuel and food (Nurhasan et al., 2022). However, this pattern varies by context. For instance, among the Punan indigenous people in East Kalimantan, Indonesia, a study observed less reliance on forest resources for dietary needs as the proximity to urban areas increased (Dounias et al., 2007). Despite their important contributions to foods, landscape changes involving reductions in forest cover are sometimes considered necessary for development and food security (Ministry of Environment and Forestry, 2020). Between 2008 and 2017, Indonesia lost 16.9 million hectares of tree cover, 37 percent of which occurred in primary forests (Turubanova et al., 2018). Efforts by the Indonesian government towards sustainable forest management led to a reduction in primary forest loss by 2021, reflecting progress in forest conservation (Weisse & Goldman, 2022). As forests are also important for direct food acquisition and indirect food provisioning ecosystem services to forest-adjacent people (HLPE, 2017), it is important to assess the impact of deforestation on the food security and nutrition of people living in areas where this is occurring.

From a food and nutrition perspective, dietary transitions can be problematic as modern diets are linked to overweight, obesity (Popkin & Ng, 2021; Popkin et al., 2012), and noncommunicable diseases (Malik & Hu, 2019). Evidence from the Indonesian Basic Health Study (RISKESDAS) 2018 shows that the frequency of consumption of fatty food, food with preservatives, seasoned food, and soft drinks have significant influence on non-communicable diseases (NCDs) among people aged 15–54 in Indonesia (Arifin et al., 2022). In the three decades, from 1990 to 2016, disability adjusted life-years (DALYs) at birth in Indonesia increased about 8.0 years (95% UI 7.3–8.8), from 63.6 years (63.2–64.0) to 71.7 years (71.0–72.3), while total DALY lost from NCD also increased (Mboi et al., 2018). The significant increase of DALYs lost in the three decades was mainly from diabetes (157.1%), ischemic heart disease (113.9%), and lung cancer (113.1%) (Directorate General of Disease Prevention & Control, 2020).

Modernization involves a shift from local autonomy to dependence on a global system of resource allocation and political power, which is characterized by pervasive delocalization (Pelto & Vargas, 1992). This means that food, energy, and services that were once available locally are now transformed into commodities exchanged in markets, often sourced from regions outside the local area. Pelto and Vargas (1992) uses the term *delocalization* to describe this shift, and refer to the definition of *delocalization* by Poggie and Lynch (1974), as “a chain of complex events that result when food, energy, and services that had formerly been provided within the local setting are transformed into market exchange commodities, with the bulk of these originating from sources outside the local region” (p. 363). At an individual and household level, *delocalization* means that an increasing portion of the daily diet comes from distant places usually through commercial channels (Pelto & Pelto, 1983). It is important to distinguish between *delocalization* and modernization in the context of Indonesia. The term ‘modern foods’ does not have a uniform meaning across all regions of Indonesia due to the country’s diversity and size. Therefore, the association of certain foods with modernity can originate from their production and consumption patterns in regions that are more economically developed, and not necessarily ‘Western foods’ that are normally described as modern. For example, in West Papua, Indonesia, there has been a transition from traditional staple foods such as sago (and tubers) to rice, which is the main staple food in Java and Sumatra, Indonesia (Nurhasan et al., 2022). Whether or not rice can be categorized as part of a modern diet in Indonesia may be arguable; however, because rice is historically not widely consumed nor cultivated in West Papua province, the increased consumption of rice can definitely be considered as part of a process of *delocalization* of the Papuan diet.

Given the considerable diversity in diets across Indonesia, patterns of dietary transition can vary significantly from one region to another. Moreover, there is a scarcity of studies examining dietary changes in forested areas of Indonesia, which are particularly relevant given the substantial changes in the natural environment of these regions over the past decades. Therefore, the research questions that this study seeks to answer are: How have food consumption patterns in Indonesia’s urban and rural areas, as well as in forested areas with high and low tree cover loss (TCL), changed from 2008 to 2017, and what are the comparative patterns in each of those years? To address these questions, the study analyzes dietary transition from two perspectives: 1) the *modernization of diets*, defining modern diets as those high in fat, added sugar, animal-source foods, refined carbohydrates, ultra-processed foods and low in fresh vegetables, legumes, and coarse grains; and 2) *delocalization of diets* defining delocalized diets as those that rely on foods sourced from outside the region where it is consumed.

2 Methods

Using two rounds of weekly household food consumption data from the National Socio-Economic Survey (Survey Sosial Ekonomi Nasional (SUSENAS) 2008 (Statistics Indonesia, 2008) and 2017 (Statistics Indonesia, 2017), we explored differences in food consumption patterns between people living in urban and rural, and in high-TCL and low-TCL areas. The unit of analysis used was regency (*kabupaten*), because the sampling design of the SUSENAS surveys is representative to this level. These data are limited to the food procured (purchased and produced) by households for food consumption, but do not include recall of intake for individual household members.

To compare differences in food consumption in urban and rural areas, we used categories of urban and rural areas in Indonesia based on data from SUSENAS 2008 and 2017 (Statistics Indonesia, 2008, 2017). To compare differences in food consumption in forested areas, we examined food consumption in rural areas with the highest natural forest cover in Indonesia based on forest cover data from 2010. We selected 2010 as the baseline due to the availability of datasets on forest extent indicators as reported by the Global Forest Watch website (Hansen et al., 2013). Among the most forested regencies, we then selected 50 regencies characterized by high tree cover loss and 50 regencies characterized by low tree cover loss occurring between 2008 and 2017 from the dataset. This period was selected to align with our socio-economic data from SUSENAS and to offer a temporal analysis of TCL. By examining TCL over nearly a decade, we aimed to capture significant trends that could potentially impact food consumption patterns in these areas. For high and low tree cover loss data, we focused on households in rural areas of the regencies as we believe that these are the households most likely to be impacted by changes in forest food systems. The rural areas with high tree cover loss are designated as high-TCL areas, while those with low tree cover loss are referred to as low-TCL areas.

To understand the dietary patterns in 2008 and 2017, and the differences in these patterns between areas, we regrouped foods listed in the SUSENAS 2008 and 2017 datasets and analyzed them for each year and area category (urban, rural, high-TCL, and low-TCL). Our analysis aimed to assess changes in diets, in ways that could indicate the origins of the foods and changes in diet quality, measured with various indicators.

1) General changes (measured as percent change) in food consumption patterns over time assessed by regrouping the SUSENAS food list based on the FAO guidelines for household and individual dietary diversity (Kennedy et al., 2013) as presented in Supplementary Table A1. The daily per capita consumption data is obtained by dividing the household consumption amount by the number of household members, regardless of age and gender.
2) Changes in diet quality are measured with the below indicators:

a) Changes in household access to diverse foods over time were assessed using the Household Dietary Diversity Score (HDDS). We based our food groups on the 12 food groups in the FAO guidelines (Kennedy et al., 2013). SUSENAS data has been used for HDDS assessment in previous studies like Nurhasan et al. (2022). Similarly, Mehraban and Ickowitz (2021) used seven-day household food consumption data from the Indonesian Family Life Survey (IFLS) to construct a HDDS. Fongar et al. (2019) showed that HDDS based on household level seven-day food recall data can be used as a proxy for aspects of individual dietary quality.
b) Changes in household consumption of healthy and less healthy foods over time were assessed using the Global Dietary Recommendation (GDR) score. This score merges two subcomponents: GDR-Healthy (a positive value based on recommendations for healthy food consumption) and GDR-Limit (a negative value based on recommendations for limiting certain foods, here also referred to as 'less healthy' foods). These reflect global recommendations for consumption of healthy and 'less healthy' foods respectively (Herforth et al., 2020). The GDR score has been validated against the diet quality standard (HDI-2020) as an index of WHO global dietary recommendations for chronic disease prevention. A lower Total GDR score, lower GDR-Healthy score, and higher GDR-Limit score indicate poorer diet quality (Wang et al., 2022).
c) Changes in individual consumption of ultra-processed foods were assessed using the NOVA classification system. This system categorizes food into four groups based on their level of processing: fresh and minimally processed foods (Group 1); processed culinary ingredients (Group 2); processed foods (Group 3); and ultra-processed foods (Group 4) (Monteiro et al., 2019). Changes in the consumption levels of different food groups can indicate shifts in the composition of modern diets. An increase or decrease in the consumption of ultra-processed foods (UPF) can reflect broader trends in dietary habits, such as the incorporation of more processed and convenience foods and a shift away from traditional eating patterns.
d) Changes in the consumption of ready-to-eat foods were assessed using the Classification of Individual Consumption According to Purpose (COICOP) Division 11 (United Nations, 2018). COICOP is an internationally recognized system for classifying household expenditures, providing a framework for categorizing goods and services based on their purpose. COICOP Division 11 encompasses services provided by restaurants, cafés, and similar establishments.
e) Macronutrient intake was assessed by calculating the total energy/calories (kcal), protein (grams), fat (grams), and carbohydrate (kcal) content of the consumed food. The macronutrient content of each food consumed was provided by the SUSENAS dataset.

For each of these indicators, we reported the average quantity of food consumed, intake or scores from food consumption within a year in these categories. Additionally, we analyzed the differences in consumption between years and areas, along with the statistical significance of these differences based on a two-sample independent t-test.

3) The relative food consumption pattern in urban vs. rural and high-TCL vs. low-TCL areas was assessed by running a series of regressions with the quantity of foods from the relevant food groups or the food quality scores as the dependent variables. The control variables included non-food expenditures (used as a proxy for income), household size, province, and area categories (urban/rural or high-TCL/low-TCL). We report the coefficients, standard errors, and significance levels for the area categories and non-food expenditures.

3 Results

3.1 The Selected Regencies

For the national samples, we included all urban and rural regencies existing in 2008 and 2017. For the 2008 data, the study included 101,240 households in urban areas and 181,147 in rural areas. For the 2017 data, it included 127,690 households in urban areas and 169,586 in rural areas. For the sample of forested areas, we identified 100 forested regencies in Indonesia, comprising 50 regencies with

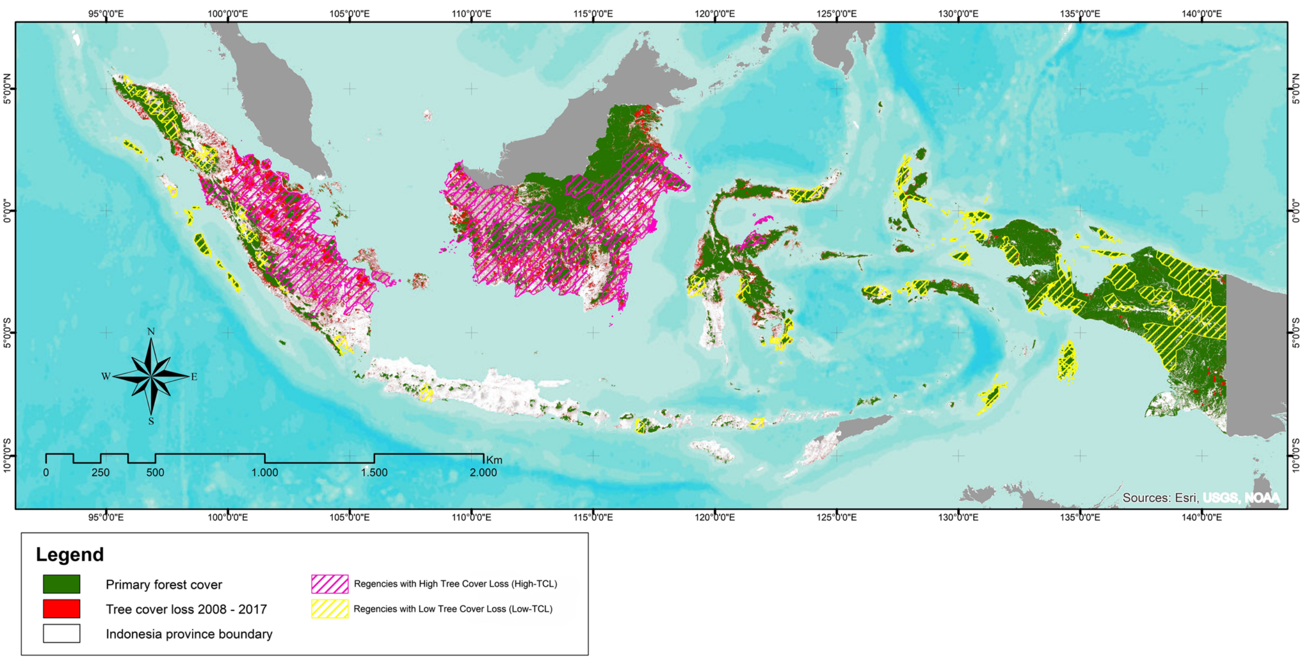

Fig. 1 Map of the selected regencies. *Note:* The primary forest cover data in Indonesia are from Margono et al. (2014) and tree cover loss data from Hansen et al. (2013) and Turubanova et al. (2018) which were accessed through the Global Forest Watch website

high tree cover loss (high-TCL) and 50 with low tree cover loss (low-TCL). For the 2008 data, the study included 24,814 households in rural high-TCL regencies and 19,990 in rural low-TCL regencies. For the 2017 data, it included 21,278 households in rural high-TCL regencies and 18,288 in rural low-TCL regencies. Figure 1 depicts these regencies, differentiated by their deforestation patterns from 2008 to 2017. The map shows Indonesian territory in white, forest cover in 2010 in green, and areas of tree cover loss from 2008–2017 in red. Tree cover is defined as areas with a canopy density greater than 30% (Hansen et al., 2013). Regencies in the high-TCL category are outlined in pink, while those in the low-TCL category are marked with yellow lines. For a complete list of the regencies under each category, refer to Supplementary Table A2.

3.2 Trends in food consumption patterns 2008–2017

Analysis of food consumption trends from 2008 to 2017 reveals that all area categories (urban, rural, high-TCL, and low-TCL) experienced an increase in the consumption of processed-preserved-prepared-outside home (POH) meat, snacks & crackers, organ meat, liquid dairy, fresh avian meat,[1] sugar-sweetened beverages, vitamin A-rich fruits, processed legumes, other vitamin A-rich vegetables, wheat-based staples, fresh fish and other aquatic animals (OAA), edible fats, and spices. Conversely, there was a decrease in the consumption of rice-based staples, dark green leafy vegetables, fresh legumes and nuts, sugar, preserved fish OAA, salt, beverage ingredients, and 'other' fresh meat in these categories. Figure 2 illustrates the trends in food group consumption in urban and rural areas (2a) and in high- and low-TCL areas (2b). The detailed values of average food consumption amounts (mean ± SD) are listed in Supplementary Table A3 for urban and rural areas, and in Supplementary Table A4 for high-TCL and low-TCL areas.

Between 2008 and 2017, there was an increase in total calorie intake across all area categories, with the exception of low-TCL areas. In urban areas, this increase in calorie intake was particularly pronounced, rising from 1,917 kcal to 2,143 kcal. This significant rise is attributed to the increasing trend in the consumption of all macronutrients. Conversely, in low-TCL areas, the total calorie intake remained relatively unchanged. This stability is due to a slight-yet-significant increase in protein and fat intake, counterbalanced by a decrease in carbohydrate intake. In rural and high-TCL areas, a similar pattern was observed with a decrease in carbohydrate intake. The increase in total calorie intake in these areas was driven by increased intake of fats and proteins. Figure 3 illustrates these changes in macronutrient intake.

Between 2008 and 2017 in Indonesia, the analysis showed a consistent increase in HDDS for both 12 and 7 food groups across all area categories, except urban (Fig. 4a).

[1] The term 'avian' is used here to include both domesticated and non-domesticated birds.

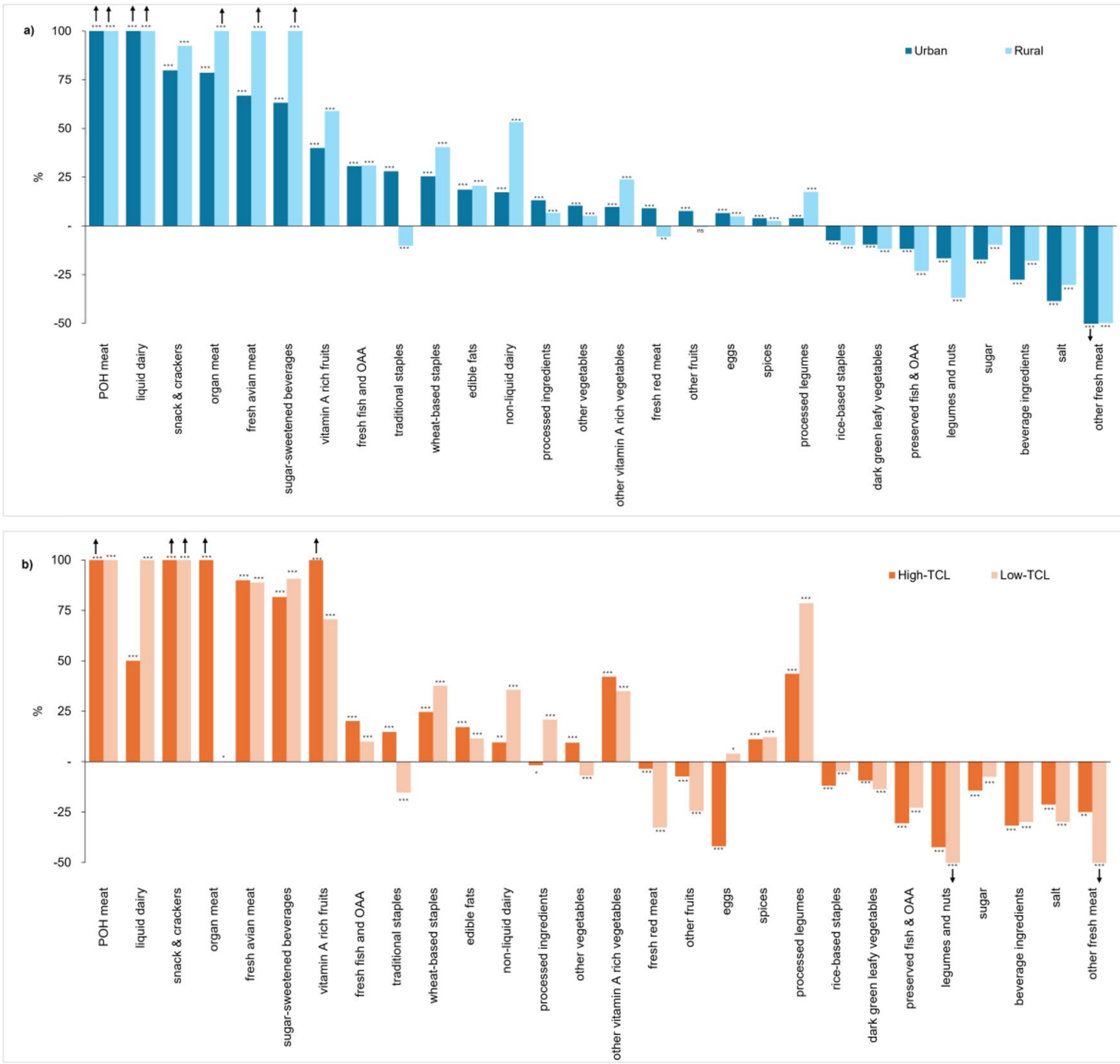

Fig. 2 National food consumption trends in urban and rural areas (**a**) and in high-TCL and low-TCL areas (**b**) from 2008 to 2017. *Notes:* Measured as percent change (%). Abbreviations used in the figure; TCL for tree cover loss; OAA for other aquatic animals; POH for processed-preserved-prepared-outside-home;—ns stands for not statistically significant. To ensure balanced proportions in the presentation of the bars, we limited the highest percent change to a maximum of 100% and a minimum of -50%. Bars representing changes higher than 100% and lower than -50% were as follows: POH meat in urban (268%) and rural areas (446%), as well as in high-TCL area (627%); liquid dairies in urban (168%) and rural areas (120%); snacks & crackers in high- and low-TCL areas consecutively (118%, 117%); organ meat in rural (175%) and in high-TCL areas (160%); sugar-sweetened beverages and fresh avian meat in rural area consecutively (102%, 101%); vitamin A-rich fruits in high-TCL area (104%); legumes and nuts in low-TCL areas (-59%); and other fresh meat in urban (-100%) and low-TCL areas (-60%), consecutively. Statistically significant difference *** $P<0.001$; ** at $0.001 \leq P \leq 0.01$; and * at $0.01 < P \leq 0.05$

GDR-Healthy score also decreases in urban areas, from 4.6 to 4.3, while all the other area categories saw an increase, trends that are also depicted in Fig. 4a. GDR-Limit scores rose in both urban and rural areas, from 4.5 to 5.1 and 3.8 to 5, respectively, contributing to a decrease in Total GDR scores in these regions, as shown in the same figure. Additionally, Fig. 4b illustrates a universal and significant shift towards higher consumption of processed and ultra-processed foods under NOVA 3 and 4 categories, along with a marked increase in ready-to-eat food intake across all area categories.

3.3 Comparing within year relative food consumption patterns in urban vs. rural with patterns in high-TCL vs. low-TCL areas

In addition to analyzing food consumption trends within area categories from 2008 to 2017, we also investigated the patterns arising from the amounts of food consumed in urban vs. rural areas, and in high-TCL vs. low-TCL areas, during the same period. We use information from Figs. 4 and 5 to illustrate the difference between area categories in diet quality indicators

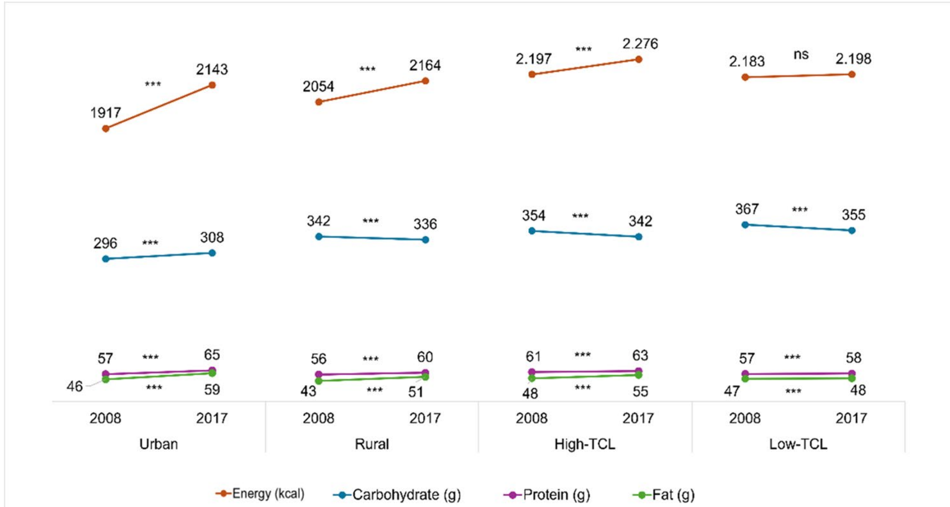

Fig. 3 Macronutrient intake in all areas observed in 2008 and 2017, based on total calories/energy (**a**), carbohydrate (**b**), protein (**c**), and fat (**d**) content of food consumed. *Notes:* Abbreviations used in the figure: TCL for Tree Cover Loss. Statistically significant difference *** $P<0.001$; ** at $0.001 \le P \le 0.01$; and * at $0.01 < P \le 0.05$

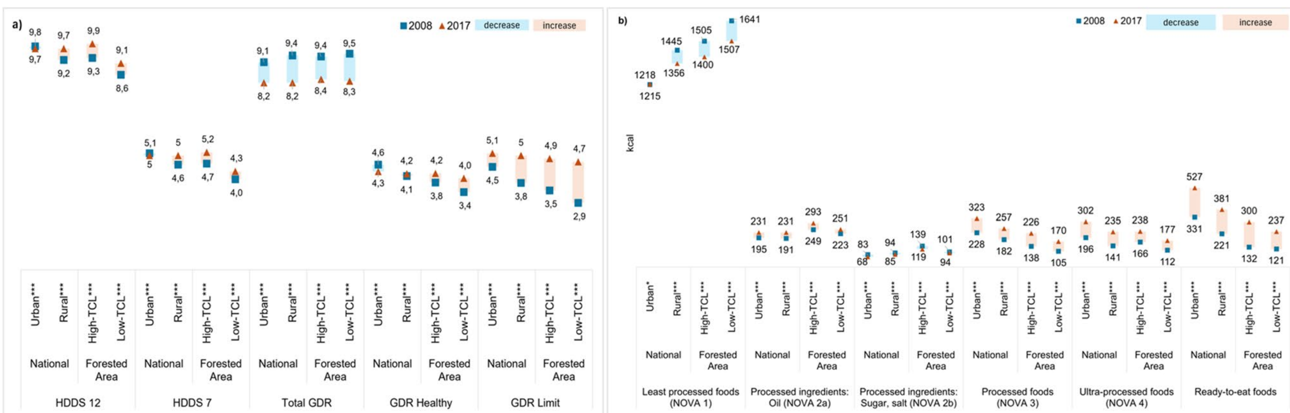

Fig. 4 Diet quality indicators in all areas observed in 2008 and 2017, based on Household Dietary Diversity Score (HDDS) and Global Dietary Recommendation (GDR) (**a**), and NOVA Classification (**b**). *Notes:* Abbreviations used in the figure: HDDS for Household Dietary Diversity Score, GDR for Global Dietary Recommendation, TCL for Tree Cover Loss. HDDS 12 includes cereals, tubers, vegetables, fruits, meats, eggs, fish, legumes, dairy, oils and fats, spice-condiments and beverages ingredients, sweets (including ultra-processed foods and ready-to-eat foods); HDDS 7 includes vegetables, fruits, meats, eggs, fish, legumes, dairy (excluding ultra-processed foods). GDR-Healthy includes dark green leafy vegetables, vitamin A-rich orange vegetables, roots and tubers, other vegetables, vitamin A-rich fruits, citrus fruits, other fruits, legumes, nuts and seeds, whole grains; GDR-Limit includes sugar-sweetened beverages, baked grain-based sweets, other sweets, salty packaged snacks, unprocessed red meat, processed meat, deep-fried foods, food from fast-food restaurants or instant noodles; Total GDR score is the sum of GDR-Healthy and GDR-Limit, with the addition of 9 scores at the end of the calculation. Statistically significant difference *** $P<0.001$; ** at $0.001 \le P \le 0.01$; and * at $0.01 < P \le 0.05$

and food consumption, while Table 1 and Supplementary Table A7 present the results from regression models.

For both 2008 and 2017, the average per capita daily consumption of processed foods, ultra-processed foods, and ready-to-eat foods contributed more calories in urban areas than in rural areas, and in high-TCL areas than in low- TCL areas. In contrast, the average per capita daily consumption of least processed foods contributed more calories in rural areas than in urban areas, and in low-TCL areas than in high-TCL areas (see Fig. 4b). After controlling for non-food expenditures, province, and household size, this pattern remains consistent for urban versus rural areas but loses significance in forested areas (see Table 1 and Supplementary Table A7). Additionally, non-food expenditures are positively associated with the consumption of these foods in all areas, suggesting that independent of geographical location (urban vs. rural, high-TCL vs. low-TCL), higher income also increases the consumption of processed, ultra-processed, and ready-to-eat foods in Indonesia.

In 2008 and 2017, average scores of HDDS and GDR-Healthy were higher in urban than in rural areas, and in

Table 1 Results from regression models: Each row represents a model for quantities consumed of different food groups or diet quality indicators for 2008 and 2017-coefficients with standard errors in parentheses[1–7]

No	Dep Variables: Food groups and Diet quality indicators	Independent Variables			
		Area categories[3]		Non-food expenditures[4]	
		National	Forested areas	National	Forested areas
A. Foods which are consumed more in urban vs. rural areas and in high-TCL vs. low-TCL areas in 2008					
1	Wheat-based staples	4.06***(0.09)	8.97***(0.75)	2.22***(0.03)	5.18***(0.15)
2	Fresh fish and OAA	5.73***(0.23)	8.07***(2.13)	6.27***(0.09)	10.85***(0.42)
3	Fresh avian meat	2.74***(0.08)	5.20***(0.71)	2.97***(0.03)	5.21***(0.14)
4	Eggs	5.73***(0.13)	3.92**(1.47)	2.58***(0.05)	6.23***(0.29)
5	Layer's eggs	6.00***(0.13)	6.81***(1.47)	2.21***(0.05)	5.77***(0.29)
6	Processed legumes	7.17***(0.17)	13.69***(1.01)	2.18***(0.07)	4.57***(0.2)
7	Snacks & crackers	5.95***(0.16)	20.06***(0.97)	3.00***(0.06)	7.09***(0.19)
8	Processed ingredients	0.43***(0.03)	2.89***(0.19)	0.53***(0.01)	0.93***(0.04)
9	Sugar-sweetened beverages	15.20***(0.33)	37.25***(2.2)	9.34***(0.13)	18.18***(0.44)
10	Energy from fat	8.43***(0.86)	79.86***(7.18)	38.07***(0.33)	70.14***(1.42)
11	NOVA 3 (moderately processed)	35.95***(0.65)	33.25***(3.77)	14.95***(0.25)	28.51***(0.75)
12	NOVA 4 (ultra-processed foods)	41.56***(0.61)	67.12***(4.19)	24.75***(0.23)	43.27***(0.83)
13	RTE (ready-to-eat foods)	102.93***(1.24)	79.78***(5.44)	26.55***(0.47)	41.70***(1.08)
14	GDR healthy score	0.25***(0.01)	0.55***(0.04)	0.20***(0.00)	0.40***(0.01)
15	GDR limit score	0.43***(0.01)	0.44***(0.05)	0.18***(0.00)	0.38***(0.01)
16	HDDS 12[1]	0.26***(0.01)	0.48***(0.05)	0.22***(0.00)	0.42***(0.01)
17	HDDS 7[2]	0.25***(0.00)	0.50***(0.04)	0.15***(0.00)	0.32***(0.01)
B. Foods which are consumed more in rural vs. urban areas and in low-TCL vs. high-TCL areas in 2008					
1	Traditional staples	–31.95***(0.48)	–39.85***(5.70)	–2.62***(0.18)	–12.15***(1.13)
2	Preserved fish and OAA	–3.23***(0.05)	–8.63***(0.44)	–0.09***(0.02)	0.13(0.09)
3	Fresh red meat	–0.32***(0.05)	–3.82***(0.56)	1.02***(0.02)	1.10***(0.11)
4	Free-range-eggs	–0.31***(0.02)	–0.48***(0.13)	0.12***(0.01)	0.12***(0.03)
5	Edible fats	–0.32***(0.08)	–6.93***(0.67)	1.87***(0.03)	3.67***(0.13)
6	Salt	–1.05***(0.02)	–0.72***(0.12)	0.00(0.01)	0.00(0.02)
7	NOVA 2a (edible oil)	–2.36***(0.59)	–50.65***(4.77)	12.63***(0.23)	25.89***(0.95)
C. Foods which are consumed more in urban vs. rural areas and in high-TCL vs. low-TCL areas in 2017					
1	Wheat-based staples	1.95***(0.09)	10.17***(0.84)	1.05***(0.02)	1.92***(0.08)
2	Fresh avian meat	2.88***(0.10)	2.77**(0.95)	1.73***(0.02)	2.71***(0.08)
3	Layer's eggs	3.59***(0.07)	1.95***(0.54)	0.66***(0.01)	1.21***(0.05)
4	Processed legumes	4.53***(0.17)	9.34***(1.17)	0.82***(0.03)	2.08***(0.1)
5	Processed ingredients	0.57***(0.03)	1.76***(0.19)	0.27***(0.00)	0.45***(0.02)
6	Snacks & crackers	4.9***(0.19)	11.89***(1.52)	1.62***(0.04)	3.96***(0.14)
7	Sugar-sweetened beverages	9.34***(0.37)	36.23***(2.82)	4.60***(0.07)	8.47***(0.25)
8	Energy from fat	22.44***(0.81)	34.92***(6.92)	19.86***(0.15)	32.09***(0.62)
9	NOVA 3 (moderately processed)	47.13***(0.71)	12.98*(5.15)	10.2***(0.13)	17.49***(0.46)
10	NOVA 4 (ultra-processed foods)	36.78***(0.70)	41.41***(5.44)	12.97***(0.13)	19.11***(0.48)
11	RTE (ready-to-eat foods)	124.07***(1.40)	52.35***(8.53)	16.97***(0.26)	27.57***(0.76)
D. Foods which are consumed more in rural vs. urban areas and in low-TCL vs. high-TCL areas in 2017					
1	Rice-based staples	–32.63***(0.37)	–12.40***(3.50)	–0.63***(0.07)	1.70***(0.31)
2	Traditional staples	–24.3***(0.45)	–16.33**(5.26)	–0.03(0.08)	–1.06*(0.47)
3	Preserved fish and OAA	–2.08***(0.04)	–10.39***(0.38)	–0.00(0.01)	0.14***(0.03)
4	Fresh red meat	–0.53***(0.04)	–4.96***(0.43)	0.55***(0.01)	0.53***(0.04)
5	Free-range-eggs	–0.19***(0.01)	–0.45***(0.11)	0.07***(0.00)	0.05***(0.01)
6	Dark green leafy vegetables	–5.73***(0.17)	–8.48***(1.59)	0.28***(0.03)	0.62***(0.14)
7	Other vegetables	–9.75***(0.33)	–13.46***(2.71)	2.71***(0.06)	4.87***(0.24)

Table 1 (continued)

No	Dep Variables: Food groups and Diet quality indicators	Independent Variables			
		Area categories[3]		Non-food expenditures[4]	
		National	Forested areas	National	Forested areas
8	Edible fats	–0.81***(0.09)	–5.64***(0.74)	0.91***(0.02)	1.53***(0.07)
9	Salt	–0.85***(0.01)	–0.72***(0.11)	–0.01***(0.00)	0.02*(0.01)
10	NOVA 2a (edible oil)	–6.55***(0.61)	–40.91***(5.31)	5.97***(0.11)	10.77***(0.47)
E. Foods with partially significant patterns across urban vs. rural and high-TCL vs. low-TCL areas in 2008					
1	Preserved POH meat	1.53***(0.03)	0.40(0.23)	0.8***(0.01)	0.68***(0.05)
2	Organ meat	0.59***(0.02)	0.10(0.13)	0.28***(0.01)	0.34***(0.03)
3	Liquid dairy	0.59***(0.05)	0.21(0.17)	0.78***(0.02)	0.18***(0.03)
4	Rice-based staple	–43.35***(0.45)	–0.28(3.83)	–1.61***(0.17)	4.61***(0.76)
5	Other fresh meat	–0.18***(0.03)	–0.01(0.26)	0.06***(0.01)	0.13**(0.05)
6	Sugar	–3.09***(0.09)	–1.09(0.78)	1.05***(0.03)	2.75***(0.15)
7	NOVA 2b (sugar, salt)	–11.39***(0.33)	–3.95(2.83)	3.85***(0.12)	10.07***(0.56)
F. Foods with partially significant patterns across urban vs. rural and high-TCL vs. low-TCL areas in 2017					
1	Fresh fish and OAA	4.24***(0.22)	2.69(2.10)	3.45***(0.04)	4.66***(0.19)
2	Preserved POH meat	3.09***(0.07)	0.48(0.51)	0.89***(0.01)	0.96***(0.05)
3	Organ meat	0.58***(0.03)	0.36(0.19)	0.17***(0.00)	0.19***(0.02)
4	Eggs	3.69***(0.07)	0.66(0.57)	0.87***(0.01)	1.50***(0.05)
5	Liquid dairy	1.34***(0.06)	0.05(0.21)	0.83***(0.01)	0.17***(0.02)
6	Other fresh meat	–0.16***(0.02)	–0.39(0.21)	0.01(0.00)	0.04(0.02)
7	NOVA 1 (least processed)	–153.86***(1.70)	–10.52(15.55)	16.9***(0.31)	33.33***(1.39)
8	GDR final score	–0.06***(0.01)	–0.04(0.06)	–0.00(0.00)	0.01(0.01)

high-TCL than in low-TCL areas. Although urban and high-TCL areas had higher Healthy GDR scores, they also had worse limit GDR scores compared to rural and low-TCL areas, leading to a comparable total GDR score for all area categories (see Fig. 4a). When controlling for non-food expenditures and household size, rural areas had a higher total GDR score, with no significant difference between high and low TCL areas in 2017 (see Table 1 and supplementary Table A7). The results from the regression analysis indicate that this pattern was consistent in 2008, with non-food expenditure positively associated with HDDS and both GDR-Healthy and limit scores. However, this pattern shifted in 2017 when people in rural areas exhibited higher HDDS, GDR-Healthy, and worse limit scores than those in urban areas (see Table 1 and Supplementary Table A7). In forested areas in both 2008 and 2017, being in high-TCL areas was associated with higher HDDS, GDR Healthy, and GDR Limit scores than in low-TCL areas, albeit with a diminishing influence of non-food expenditure from 2008 to 2017 (Table 1 and Supplementary Table A7).

In Fig. 5, the average food consumption patterns across various area categories for the years 2008 (a) and 2017 (b) are presented. For both years under study, a notable pattern emerges in both urban and high-TCL areas. In the top one-third of the figures, the dark blue bars representing urban areas and the dark orange bars representing high-TCL areas are consistently longer than their counterparts, the light blue (rural) and light orange (low-TCL) bars. This indicates higher levels of food consumption in urban and high-TCL areas compared to rural and low-TCL areas. The middle one-third of the figures shows food groups whose consumption shows a reverse trend in urban and high-TCL areas. Here, the longer bars are light blue and light orange, suggesting higher food consumption in rural and low-TCL areas compared to urban and high-TCL areas. The lower third of the figures displays food consumption patterns that do not exhibit a similar trend.

Further insights are gained from Table 1, where a series of regression analyses were conducted, with the amount of food consumed as the outcome variable controlling for non-food expenditures (serving as a proxy for income), household size, and province. The beta coefficients from this analysis show consistent trends for 45 food groups for both urban vs. rural and high- vs. low-TCL comparisons, being either both positive or both negative in 2008 and 2017. Table 1 indicates that the consumption of most foods and food classification scores increase with non-food expenditure, except for traditional staples in 2008 for both area categories. In 2017, the influence and statistical significance of non-food expenditure

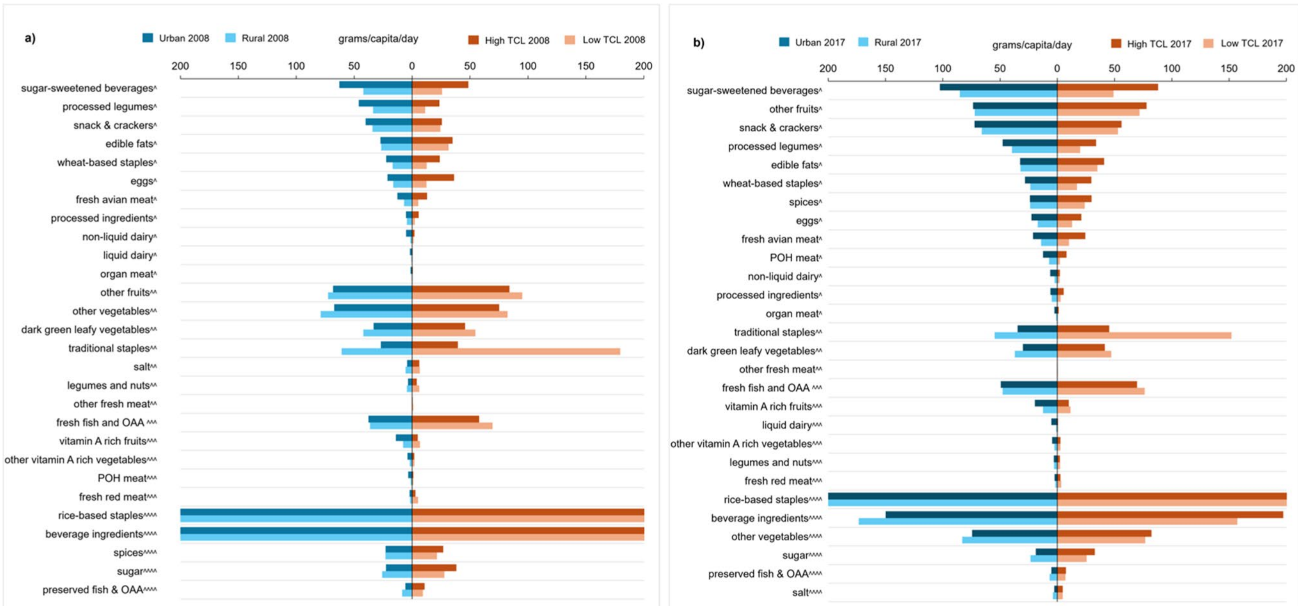

Fig. 5 Amount of food consumed (grams/capita/day) in urban–rural and high-low TCL differences in the year 2008 (**a**) and 2017 (**b**). *Notes:* Abbreviations used in the figure: TCL for Tree Cover Loss; OAA for other aquatic animals; POH for processed-preserved-prepared-outside-home. The bars in the figures display the amount of food consumed (grams/ capita/ day) in urban (dark blue), rural (light blue), high-TCL (dark orange), and low-TCL (light orange). Symbol ^ showing same pattern between urban (vs. rural) and high-TCL (vs. low-TCL); ^more in urban and high-TCL; ^^more in rural and low-TCL; ^^^more in urban and low-TCL; ^^^^more in rural and high-TCL

on the consumption of traditional staples diminished both nationally and in forested areas; nonetheless, consumption remained higher in rural and low-TCL areas. The national consumption of rice-based staples in 2008 and 2017, preserved fish and OAA in 2008, and salt in 2017 were also negatively associated with non-food expenditure; however, the same association was not observed in forested areas. Detailed household expenditures (mean ± SD) in rural and urban areas are shown in Supplementary Table A5, while those in high- and low-TCL areas are presented in Supplementary Table A6.

4 Discussion

Our analysis shows that Indonesia's urban and rural, as well as high- and low-TCL areas, universally experienced increased consumption of processed and ultra-processed foods, food prepared away from home, wheat-based staples, total animal-source foods, fats, snacks and crackers, sugar-sweetened beverages, total energy, protein and fat, and decreased consumption of dark green leafy vegetables, fresh legumes and nuts and fresh and minimally processed foods. This trend follows the general changes in dietary patterns seen all over the world, where consumption of refined carbohydrates, added sweeteners, edible oils, and animal-source foods increased, and consumption of legumes, vegetables and fruits decreased (Popkin, 2004, 2015). There is an upward trend in HDDS and Healthy GDR scores across all areas except urban areas. Moreover, total GDR scores decreased universally, primarily due to the increased consumption of 'less healthy' or 'limit' foods across all areas. This decline is notable in urban areas, where there was a marked decrease in the consumption of healthy foods and an increase in 'limit' food consumption. Overall, this suggests a decline in diet quality and an increased risk of non-communicable diseases all over Indonesia, especially in urban areas.

Apart from the temporal trend towards diet modernization, the comparison of the relative amounts of food consumed in urban versus rural areas and in high-TCL versus low-TCL regions highlights a distinct pattern: certain foods are more consumed in high-TCL areas, which are also more prevalent in urban areas in both 2008 and 2017. These foods include wheat-based staples, fresh avian meat, layer's eggs, processed legumes, processed ingredients, caloric snacks, sugar-sweetened beverages, moderately processed foods, ultra-processed foods, ready-to-eat foods, and foods that contributes to energy from fat. The consumption of these foods increases with higher income levels (inferred from non-food expenditures) and are higher in urban areas (than in rural areas) and high-TCL areas (than low-TCL areas). Conversely, we observed that certain foods are consumed more in low-TCL areas (compared to high-TCL areas), and similarly, more in rural areas (than in urban areas) in both 2008 and 2017. These foods are traditional staples, preserved fish and OAA, fresh red meat, free-range eggs, edible fats and oil, and salt. Most of the foods that are consumed more in urban (than rural) and high-TCL (than low-TCL) areas are associated with modern diets, and below we discuss the implications of these findings for Indonesia.

4.1 Foods consumed more in urban (vs. rural) and high-TCL (vs. Low-TCL) are associated with modern and delocalized diets

Processed ingredients, caloric snacks, sugar-sweetened beverages, fatty foods, and processed and ultra-processed foods, along with ready-to-eat foods, are typical of modern diets (Popkin et al., 2012). While many of such foods are highly associated with delocalization of diets, the next section explains how in the Indonesian context, the consumption of wheat-based staples, fresh avian meat, layer's eggs, and processed legumes, are also associated with delocalized diets in Indonesia.

4.1.1 Wheat-based staple foods

Consumption of wheat-based staples in Indonesia is positively associated with area categories; consumption is higher in urban (vs. rural) and high-TCL (vs. low-TCL) areas, consistent across both years studied. Wheat-based staple consumption is also positively associated with non-food expenditure, indicating that those with higher incomes tend to consume more wheat-based staple foods. High consumption of wheat-based foods in Indonesia reflects delocalized food systems, given that wheat is entirely imported. The introduction of wheat as part of a 1969 U.S. economic cooperation package led to its preference over locally available flour for various cuisines, despite Indonesia's unsuitability for wheat cultivation. This has resulted in Indonesia becoming one of the largest importers of wheat from the U.S. (Subejo, 2013).

Outside Java, many Indonesians traditionally consumed (and some still consume) sago, especially in regions like Kalimantan, Papua, Maluku, and Sumatra (Bintoro et al., 2018; Wardis, 2014). Even in Java, historically known for rice production, locals included cassava and corn in their diets (Jesica et al., 2017; Purwidiani, 2017). The significantly lower consumption of traditional staple foods in urban (vs. rural) and high-TCL (vs. low-TCL) areas in both years points to a more pronounced delocalization of diets in these areas. Interestingly, in 2008, higher non-food expenditure was associated with lower consumption of traditional staple foods nationally and in forested areas, suggesting higher traditional staple food consumption among low-income households. However, by 2017, this association was no longer statistically significant at the national level, likely due to the dramatic decrease in sago consumption in rural areas, and increase in corn and tubers consumption in urban areas. The decrease in sago consumption in rural areas is likely due to its reduced use as a staple food, while the increase in corn and tubers consumption in urban areas is likely due to their increased use as snacks, such as cassava crackers and sweet corn with cheese and condensed milk, a distinction that is not differentiated in the SUSENAS data. In forested areas, the association of non-food expenditure with traditional staple consumption also lessened, though it remained statistically significant. It should be noted that 25 out of the 50 low-TCL regencies are located in heavily forested areas of Maluku, Papua, and East Nusa Tenggara, known for retaining traditional staple foods. Therefore, it appears that staple food consumption in urban and high-TCL areas is more modern and delocalized compared to rural and low-TCL areas, which maintained a higher consumption of traditional staples.

4.1.2 Fresh avian meats and layer's eggs

The higher consumption of fresh avian meat and eggs in urban (vs. rural) and high-TCL (vs. low-TCL) areas is primarily from broiler chicken and layer's eggs. The regression results show that in Indonesia this consumption pattern is positively associated with non-food expenditures and is more prevalent in urban and high-TCL areas, a trend consistent over both years studied. Indonesia ranks fourth globally in broiler chicken production, with almost 70% of this production concentrated in Java (Statistics Indonesia, 2019). Similarly, 60% of the country's layer's egg production is based in Java (Statistics Indonesia, 2023b). Notably, only one Java regency is classified as a low-TCL area, with none in the high-TCL category. This centralization in broiler chicken and layer's egg production suggests that higher consumption in urban and high-TCL areas is indicative of better access to delocalized diets. People in these areas likely have improved access to food transported from Java or other food production centers, compared to those in rural and low-TCL areas. Consistent with this, Putra et al. (2020) found that urban residents have higher consumption of eggs, milk, and meat, likely due to better market access to livestock products.

Interestingly, the consumption of eggs from free-range or local chickens, known locally as 'ayam kampung', shows an opposite pattern. These chickens are predominantly raised by small-scale farmers in a traditional free-range environment. In support of these local breeds, the Indonesian government issued Presidential Regulation No. 44 in 2016, which restricts the farming of local breed chickens to small, medium, and micro enterprises, as well as cooperatives (Hadi et al., 2021). In contrast to other trends, rural and low-TCL areas consume more eggs from free-range or local chickens than urban and high-TCL areas. This trend supports our previous conclusion that the higher consumption of layer's eggs and broiler chicken in certain areas indicates a shift towards more delocalized diets. It also aligns with the observed decrease in the consumption of eggs from free-range or local chickens, highlighting a significant change in dietary patterns.

4.1.3 Processed legumes (tofu and tempeh)

Similar to broiler chicken and layer's eggs, processed legumes are consumed more in urban (vs. rural) and high-TCL (vs. low-TCL) areas, and this consumption pattern is positively associated with higher income. In Indonesia, the most consumed legumes are tofu and tempeh, both made from fermented and processed soybeans. Soybean is the third most important crop in Indonesia, after rice and maize (Harsono et al., 2021). Tofu and tempeh are considered the most important plant-based proteins in Indonesia, as they are typically more affordable than animal-source foods, especially in Java (Harsono et al., 2021). Historically, the majority of tofu and tempeh consumers have been in Java, where tempeh originates and where most tempeh and tofu factories are located (Shurtleff & Aoyagi, 2007). The higher consumption of tofu and tempeh outside of Java can be seen as part of the process of delocalization of diets, especially in heavily forested areas of eastern Indonesia. Reports indicate that about 65% of soy is imported (Ningrum et al., 2018), with some estimates even higher, exceeding 80% (Harsono et al., 2021). Therefore, the consumption of tempeh and tofu outside of Java marks the expansion of non-local food, as regions selected for high-TCL and low-TCL were predominantly outside of Java (only one out of 100 selected forested regencies is in Java). This expansion could be influenced by trans-migrants (Wirawan et al., 2018), who relocated to various places in Indonesia from Java. Studies have shown that tempeh and tofu consumption outside Java is dominated by, but not exclusive to, the trans-migrant population (Widati et al., 2019). The significantly higher consumption of processed legumes in urban and high-TCL areas, compared to rural and low-TCL areas, in both years can be interpreted as a shift towards the delocalization of diets.

4.2 Implication of dietary transition to food security and nutrition in Indonesia

Dietary transitions are often described by nutritionists as having negative consequences (Popkin, 2012; Pressler et al., 2022). In the context of Indonesia, however, dietary transition encompasses a mix of both positive and negative aspects.

4.2.1 The 'silver lining' of modern diets for Indonesia

The modernization of diets is characterized by an increase in energy, fat, and protein consumption, which is especially beneficial in Indonesian regions where these nutrients have historically been low. In 2008, average energy intake in all area categories fell below adequate levels, and protein intake reached adequacy only in high-TCL areas. Fat intake in all areas was also very low. By 2017, there was a significant improvement, with average energy and protein intake in all areas meeting the adequacy levels of 2,100 kcal for energy and 57 g for protein, as per MoH 2019 guidelines. While our study did not specifically evaluate macronutrient intake with respect to age and sex, it's important to note that the World Health Organization (WHO) advises that most adults should ensure adequate energy intake and essential fatty acids, as well as support the absorption of fat-soluble vitamins, by having a total fat intake that constitutes at least 15–20% of their total energy consumption. Additionally, they recommend limiting fat intake to 30% to reduce the risk of unhealthy weight gain (WHO, 2023). This recommendation was met across all area categories in 2017.

Inadequate energy intake can lead to both immediate and long-term health consequences. Acute energy deficiency manifests in the short term as weight loss, changes in body composition, and reductions in basal metabolic rate and physical activity, as described in studies by Kurpad et al. (2005). Chronic energy deficiency, a long-term condition, involves adaptations to reduced caloric intake, such as decreased total energy expenditure, often linked to smaller body size and reduced physical activity. These adaptations can be subtle and gradual, not necessarily resulting in immediate weight loss. Therefore, the observed increase in calorie, protein, and fat intake in modern diets, while presenting its own challenges, especially in urban areas where there is an increasing trend towards over-consumption, is a significant step towards addressing the nutritional deficiencies that have been prevalent in various Indonesian communities.

Increased consumption of broiler chicken and layer's eggs in urban and high-TCL areas, although a phenomenon associated with the delocalization of diets, could also be viewed as positive from the perspective of food security and nutrition, along with the increased animal-source foods consumption in all area categories. The consumption of animal-source foods, including broiler chicken and layer's eggs, is positively associated with human health outcomes in low- and middle-income countries (LMICs) due to their high nutrient content. These foods provide a range of essential amino acids, fatty acids, and micronutrients that play a crucial role in child growth and adult metabolism (Allen, 2013). Studies have shown that animal-source foods, particularly red meat, fish, and chicken, contain high levels of preformed vitamin A (retinol), vitamins B12, D and E, riboflavin, calcium, iron, and zinc, which are better absorbed by the human body compared to those from plant sources (Allen, 2013). The lack of consumption of animal-source foods has been associated with stunting and wasting (Darapheak et al., 2013). Children who consume a higher proportion of energy from animal-source foods have been found to be taller, heavier, and have better cognitive performances compared to those with lower intake (Allen, 2013; Headey et al., 2018). Mustafa et al. (2020) found stunted and at-risk-of- stunting children who were given milk, egg and multiple micronutrient powder had better length-for-age *z* scores. Stunting and wasting in Indonesia are still considered high. Almost one-third of Indonesian children under-five are stunted and one in ten children under-five are wasted (Ministry of Health, 2019). Improving consumption of animal-source foods is one of the important objectives of the stunting programs conducted by the Indonesian government (BKKBN, 2022; Ministry of Health, 2023). As such, from a health perspective, increased consumption of fish, chicken and dairy is positive.

4.2.2 The trade-offs of modern diets

The dietary transition in Indonesia has been characterized by a decrease in the consumption of nutrient-dense foods like fresh legumes, nuts, and dark green leafy vegetables. Legumes, in particular, are known for their high protein content, unsaturated fatty acids, fiber, and phytochemicals (Ros, 2010; Albuquerque et al., 2020), and have been associated with reduced risks of NCDs and obesity (Martini et al., 2021). Despite Indonesia's rich variety of legumes (Ministry of Environment and Forestry, 2006), their consumption, apart from processed soy products like tofu and tempeh, remains low. Promoting local legumes and nuts can benefit food security, nutrition, and biodiversity conservation (Djaafar & Marwati, 2019).

Concurrently, there has been a significant increase in the intake of processed and ultra-processed foods, including ready-to-eat options. In all area categories, there has been a significant increase in the intake of sugar-sweetened and salted processed foods and beverages ingredients, but consumption was higher in urban and high-TCL areas in both years. The observed increase in the consumption of these food groups is consistent with findings from Nurwanti et al. (2019). In their nationally representative study in Indonesia, it was found that children and adolescents living in urban areas consumed sugar-sweetened beverages and foods, caffeinated soft drinks, energy drinks, fatty fried foods, refined carbohydrates, and preserved meats more frequently than those in rural areas. The rise in ultra-processed and ready-to-eat foods undermines the reliability of reduced sugar and salt usage in home-prepared foods as an overall intake indicator. The Total Diet Survey in 2014 revealed that a notable percentage of Indonesians consumed excessive sugar and sodium (Ministry of Health, 2014), contributing to the country's high NCD burden. The "Isi Piringku" campaign aims to promote healthier eating habits, but the increasing consumption of processed foods challenges these efforts. Furthermore, the analysis based on the NOVA classification reveals a higher consumption of processed and ultra-processed foods in urban and high-TCL areas. While food processing is essential for enhancing shelf life and edibility (Weaver et al., 2014), the consumption of ultra-processed foods is linked to negative health outcomes (Pagliai et al., 2021). Thus, the modernization of diets can be seen as a double-edged sword, providing both benefits and potential harm.

The impact of increasing consumption of food eaten away from home, often linked to non-communicable diseases (NCDs) in high-income countries, is not so straightforward in some Asian countries such as Vietnam (Harris et al., 2020). Likewise, traditional food vendors in Indonesia, offering freshly prepared meals, are a vital part of the food landscape (Aprilianti & Amanta, 2020; Vermeulen et al., 2019). Vietnam, a neighboring country to Indonesia, is a good example of a country that has been relatively successful in avoiding some of the problems associated with the dietary transition and is one of the few countries globally that has not experienced a soaring obesity rate. In Vietnam, traditional food vendors typically offer diverse, healthy, affordable, convenient, varied, and nutritious options. A significant portion of the consumption of vegetables, meat, and grains is categorized under food eaten away from home; thus, they are not visible from the household food consumption list (Harris et al., 2020). However, Vietnam has a lower presence of international fast-food chains compared to Indonesia (Baker & Friel, 2016). In Indonesia, some local food vendors, especially those in urban areas, compete with the transnational fast-food sector, often pushing them to offer similar products at cheaper prices (Nurdiansyah, 2019).

Creative adaptations of government regulations, such as Indonesia's Ministry of Health Regulation No. 30 of 2013 on the inclusion of sugar, salt, and fat content as well as health messages on processed food and fast foods (Ministry of Health, 2013), require business owners to include information on the sugar, salt, and fat content of their products. However, this regulation only applies to large-scale vendors with more than 250 outlets, offering little incentive for many smaller-scale food vendors to provide healthier options. The growing trend of consuming ready-to-eat foods in Indonesia could be an opportunity to promote healthier diets, or it could lead to significant health risks. Effectively managing and regulating traditional and modern food vendors of various scales could be a strategic entry point to capitalize on the opportunity for promoting healthier diets and reducing health risks.

4.2.3 Dietary transitions and diet quality indicators

The improvement in dietary diversity, as indicated by HDDS scores, persisted in rural areas, including the forested low and high TCL areas, even when the scoring method was adjusted to exclude less healthy foods. HDDS, serving as a proxy for the variety of nutrients available, along with GDR-Healthy scores, which reflect global recommendations on health-protective foods, showed a significant shift in their association with non-food expenditures and income over the years. By 2017, higher HDDS and GDR-Healthy scores were more prevalent in rural (than urban) and high-TCL (than low-TCL) areas, with the influence of income on diet quality becoming negligible or even negative at the national level. This shift in dietary patterns is further elucidated when examining the GDR-Limit scores, which reflect recommendations on dietary components to limit. In 2008, higher consumption of less healthy diets was associated with urban and high-TCL areas and was strongly linked to income. By 2017, this pattern had shifted, with rural areas showing higher consumption of less healthy foods, and the association with income turning insignificant. In forested areas, while less healthy food consumption remained higher in high-TCL areas, income became negatively associated. This evolution in dietary patterns underscores the complexity of dietary transitions in Indonesia and highlights the need for targeted nutritional policies that address these nuanced changes, suggesting that higher income does not always equate to better diet quality but can also lead to increased consumption of less healthy foods, influenced by various factors including geographical location.

4.3 Limitations of the study

This study has several limitations. First, it is observational, implying that causality cannot be established, and only associations between geographical areas and dietary patterns and trends can be described. Second, the SUSENAS surveys primarily capture household-level food consumption and do not provide individual-level information or account for age and sex differences within households. Therefore, the data are not used as an actual intake reference but as reference values for comparing between the years 2008 and 2017, and between high-TCL and low-TCL areas. Additionally, in the regression analysis, we could not perform a panel data analysis since the respondents of the survey in 2008 and 2017 were different. We also lack data on mothers' education and the gender of the head of the household, which are potentially important determinants of food consumption and diet quality. Lastly, cultural, and geographical factors in certain regions may influence dietary patterns and confound the results in low tree cover loss areas. For example, there are more regencies in the low-TCL category located in Papua Province, West Papua Province, East Nusa Tenggara, Maluku, and Sumatra regions bordering the Indian Ocean, and there are more regencies of the high-TCL group located in Kalimantan and Sumatra. Despite these limitations, our study provides valuable insights into the complex dynamics of dietary transition in Indonesia's diverse landscapes. It is the first to investigate this phenomenon using nationally representative quantitative data on food consumption over nearly a decade across different contexts, employing various diet quality indicators and including aspects of locality (distance to food sources).

5 Conclusion

Our analysis reveals that from 2008 to 2017, Indonesia experienced significant shifts in food consumption patterns across urban and rural areas, as well as in regions with varying degrees of tree cover loss. In all area categories, diet quality, as indicated by Total GDR scores, was declining. All areas saw an increase in the consumption of less healthy foods, with urban areas experiencing a decrease in healthy food consumption, while rural and forested areas saw an increase in healthy food consumption. HDDS scores could not show the nuance of healthy and less healthy (limit) food consumption but similarly indicated an improvement in dietary diversity in rural and forested areas and a worsening in urban areas, as shown by the Healthy GDR scores. All area categories saw a marked increase in the consumption of processed, ultra-processed and ready-to-eat foods, wheat-based staples, broiler chicken and fish, and sugar-sweetened beverages. There was also a decline in the consumption of nutrient-dense foods like green leafy vegetables and fresh legumes. These trends indicate a move towards more modern diets in all the categories we observed. The modernization of diets in Indonesia is a double-edged sword, with the positive health effects of increased consumption of animal-source foods and the negative impacts of increased consumption of processed, ultra-processed, caloric, and ready-to-eat foods.

The comparison of the relative amounts of food consumed in urban versus rural areas and in high-TCL versus low-TCL regions within the same year found that foods consumed more in urban (vs. rural) and high-TCL (vs. low-TCL) areas are associated with modern and delocalized diets. These foods include wheat-based staples, fresh avian meat, layer's eggs, processed legumes, processed ingredients, caloric snacks, sugar-sweetened beverages, processed foods, ultra-processed foods, ready-to-eat foods, and foods that contributes to energy from fat. While dietary diversity in urban areas was higher than in rural areas, and similarly, regions with high-TCL had higher dietary diversity than low-TCL (as measured by HDDS and Healthy GDR scores), this was also accompanied by higher consumption of less healthy foods (as shown in higher scores of GDR Limit and NOVA 4). In contrast, rural and low-TCL areas, despite having lower dietary diversity initially, showed less pronounced shifts towards unhealthy dietary patterns. These findings underscore that while all areas exhibited some forms of dietary transition, different areas in Indonesia with different food system contexts experienced dietary transition differently. The diverse specific patterns we found in this study highlight the need for targeted nutritional policies and interventions that balance the benefits of modern dietary practices with the preservation of traditional, nutrient-rich food consumption. Future research should focus on the long-term health outcomes of these dietary transitions and explore sustainable strategies to promote healthy eating habits across diverse Indonesian landscapes.

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Author's contribution Mulia Nurhasan contributed to the design of the study, led the analysis, and led the drafting process. Desy Leo Ariesta and Mia Mustika Hutria Utami contributed in data analysis and drafting process. Mochamad Fahim and Nia Aprillyana contributed in design of the study and initial data analysis. Agus Muhamad Maulana contributed in cartographing the map and data analysis. Amy Ickowitz substantially contributed in the design of the study, drafting process and monitored the quality of the study. All authors read and approved the final manuscript.

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Data availability All data used in this study are secondary. The datasets presented in this article are not readily available because they were obtained from Statistics Indonesia under agreement that it was used only for the purpose of relevant research by the institution. More information regarding susenas data collection can be found here https://pst.bps.go.id/.

Declarations

Research involving human participants and/or animals Not applicable

Informed consent Not applicable

Competing interests The authors declare that the research was conducted in the absence of organization or entity with any financial or non-financial interest that could be construed as a potential conflict of interest.

References

Albuquerque, T. G., Nunes, M. A., Bessada, S. M., Costa, H. S., & Oliveira, M. B. P. (2020). Biologically active and health promoting food components of nuts, oilseeds, fruits, vegetables, cereals, and legumes. In Pico, Y. (Ed), *Chemical analysis of food*: *Techniques and Applications* (2nd ed., pp. 609–656) Academic Press.

Allen, L. (2013). Comparing the value of protein sources for maternal and child nutrition. *Food and Nutrition Bulletin, 34*(2), 263–266. https://doi.org/10.1177/156482651303400223

Aprilianti, I., & Amanta, F. (2020). Promoting food safety in Indonesia's online food delivery services. *CIPS: Center for Indonesian Policy Studies*, *September*, 1–34. https://doi.org/10.13140/RG.2.2.29722.67524

Arifin, H., Chou, K.-R., Ibrahim, K., Fitri, S. U. R., Pradipta, R. O., Rias, Y. A., Sitorus, N., Wiratama, B. S., Setiawan, A., Setyowati, S., Kuswanto, H., Mediarti, D., Rosnani, R., Sulistini, R., & Pahria, T. (2022). Analysis of modifiable, non-modifiable, and physiological risk factors of non-communicable diseases in Indonesia: Evidence from the 2018 Indonesian basic health research. *Journal of Multidisciplinary Healthcare, 15*, 2203–2221. https://doi.org/10.2147/JMDH.S382191

Baker, P., & Friel, S. (2016). Food systems transformations, ultra-processed food markets and the nutrition transition in Asia. *Globalization and Health*, *12*(1). https://doi.org/10.1186/s12992-016-0223-3

Bintoro, M. H., Nurulhaq, M. I., Pratama, A. J., Ahmad, F., & Ayulia, L. (2018). Growing area of sago palm and its environment. In H. Ehara, Y. Toyoda, & D. V Johnson (Eds.), *Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods* (pp. 17–29). Springer Open. Retrieved October 18, 2022. https://library.oapen.org/bitstream/handle/20.500.12657/27725/1002281.pdf?sequence=1#page=41

BKKBN. (2022). *BKKBN dan Kemenparekraf jalin kerjasama ciptakan produk protein hewani untuk cegah stunting*. Badan Kependudukan Dan Keluarga Berencana Nasional. Retrieved February 17, 2023, from https://www.bkkbn.go.id/berita-bkkbn-dan-kemenparekraf-jalin-kerjasama-ciptakan-produk-protein-hewani-untuk-cegah-stunting

Bowen, L., Ebrahim, S., de Stavola, B., Ness, A., Kinra, S., Bharathi, A. V., Prabhakaran, D., & Reddy, K. S. (2011). Dietary intake and rural-urban migration in India: A cross-sectional study. *PLoS ONE*, *6*(6). https://doi.org/10.1371/journal.pone.0014822

Broegaard, R. B., Rasmussen, L. V., Dawson, N., Mertz, O., Vongvisouk, T., & Grogan, K. (2017). Wild food collection and nutrition under commercial agriculture expansion in agriculture-forest landscapes. *Forest Policy and Economics, 84*, 92–101. https://doi.org/10.1016/j.forpol.2016.12.012

Cockx, L., Colen, L., De Weerdt, J., Gomez, Y., Paloma, S. (2019). Urbanization as a driver of changing food demand in Africa: Evidence from rural-urban migration in Tanzania. In *European Commision*. https://doi.org/10.2760/515064

Colozza, D., & Avendano, M. (2019). Urbanisation, dietary change and traditional food practices in Indonesia: A longitudinal analysis. *Social Science and Medicine*, *233*. https://doi.org/10.1016/j.socscimed.2019.06.007

Darapheak, C., Takano, T., Kizuki, M., Nakamura, K., & Seino, K. (2013). Consumption of animal source foods and dietary diversity reduce stunting in children in Cambodia. *International Archives of Medicine*, *6*(1). https://doi.org/10.1186/1755-7682-6-29

Directorate General of Disease Prevention and Control. (2020). Rencana aksi program (P2P) tahun 2020–2024. In *Ministry of Health*. Retrieved February 8, 2023. https://e-renggar.kemkes.go.id/file_performance/1-465827-01-3tahunan-178.pdf

Djaafar, T. F., & Marwati, T. (2019). Indonesia local beans and its benefit as functional food. *Journal of Food Technology and Food Chemistry, 2*(1), 105.

Dounias, E., Selzner, A., Koizumi, M., & Levang, P. (2007). From sago to rice, from forest to town: The consequences of sedentarization for the nutritional ecology of Punan former hunter-gatherers of Borneo. *Food and Nutrition Bulletin, 28*(2_suppl2), S294–S302.

Fongar, A., Gödecke, T., Aseta, A., & Qaim, M. (2019). How well do different dietary and nutrition assessment tools match? Insights from rural Kenya. *Public Health Nutrition, 22*(3), 391–403. https://doi.org/10.1017/S1368980018002756

Hadi, R. F., Suprayogi, W. P. S., Handayanta, E., Sudiyono, S., Hanifa, A., & Widyawati, S. D. (2021). Peningkatan produktivitas usaha budidaya ayam kampung UKM putra budi Kecamatan Mojolaban Kabupaten Sukoharjo. *PRIMA: Journal of Community Empowering and Services, 5*(2), 118–126.

Hansen, M. C., Potapov, P., Moore, R., Hancher, M., Turubanova, S., Tyukavina, A., Thau, D., Stehman, S., Goetz, S., Loveland, T., Kommareddy, A., Egorov, A., Chini, L., Justice, C. O., & Townshend, J. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science, 342*, 850–853. https://doi.org/10.1126/science.1244693

Harris, J., Nguyen, P. H., Tran, L. M., & Huynh, P. N. (2020). Nutrition transition in Vietnam: Changing food supply, food prices, household expenditure, diet and nutrition outcomes. *Food Security*, *12*(5). https://doi.org/10.1007/s12571-020-01096-x

Harsono, A., Harnowo, D., Ginting, E., & Elisabeth, D. A. A. (2021). Soybean in Indonesia: Current status, challenges and opportunities to achieve self-sufficiency. In Jimenez-Lopez J. C & Clemente, A. (Eds.). *Legumes Research-Volume 1*. IntechOpen. https://doi.org/10.5772/intechopen.94734

Hawkes, C., Harris, J., & Gillespie, S. (2017). Changing diets: Urbanization and the nutrition transition. In *2017 Global food policy report* (p. 34–41). International Food Policy Research Institute. https://doi.org/10.2499/9780896292529

Headey, D., Hirvonen, K., & Hoddinott, J. (2018). Animal sourced foods and child stunting. *American Journal of Agricultural Economics, 100*(5), 1302–1319. https://doi.org/10.1093/ajae/aay053

Herforth, A., & Ahmed, S. (2015). The food environment, its effects on dietary consumption, and potential for measurement within agriculture-nutrition interventions. *Food Security, 7*(3), 505–520. https://doi.org/10.1007/s12571-015-0455-8

Herforth, A. W., Wiesmann, D., Martínez-Steele, E., Andrade, G., & Monteiro, C. A. (2020). Community and global nutrition introducing a suite of low-burden diet quality indicators that reflect healthy diet patterns at population level. *Current Developments in Nutrition, 4*(12), 1–14. https://doi.org/10.1093/CDN/NZAA168

HLPE. (2017). Sustainable forestry for food security and nutrition: A report by the high level panel of experts on food security and nutrition. FAO. Retrieved February 8, 2022. https://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE_Reports/HLPE-Report-11_EN.pdf

Ickowitz, A., Rowland, D., Powell, B., Salim, M. A., & Sunderland, T. (2016). Forests, trees, and micronutrient-rich food consumption in Indonesia. *PLoS ONE, 11*(5), e0154139. https://doi.org/10.1371/journal.pone.0154139

Ickowitz, A., Powell, B., Rowland, D., Jones, A., & Sunderland, T. (2019). Agricultural intensification, dietary diversity, and markets in the global food security narrative. *Global Food Security, 20*(February 2018), 9–16. https://doi.org/10.1016/j.gfs.2018.11.002

Ickowitz, A., Powell, B., Rasmussen, L. V., & Rhemtulla, J. (2021). Editorial: Impacts of tropical landscape change on human diet and local food systems. *Frontiers in Sustainable Food Systems, 5*(January), 1–3. https://doi.org/10.3389/fsufs.2021.645241

Jesica, C., Cansa, E., Fidelia, J., Irwan, J., & Yosua, W. (2017). Gaplek, tiwul and gatot as staple food in Javanese barren area. *International Journal of History, 7*(4), 1–6. https://doi.org/10.24247/ijhrdec20171

Kandala, N. B., & Stranges, S. (2014). Geographic variation of overweight and obesity among women in Nigeria: A case for nutritional transition in Sub-Saharan Africa. *PLoS One*, *9*(6). https://doi.org/10.1371/journal.pone.0101103

Kennedy, G., Ballard, T., & Dop, M. (2013). Guidelines for measuring household and individual dietary diversity. In *Fao*. FAO. 613.2KEN.

Kurpad, A., Muthayya, S., & Vaz, M. (2005). Consequences of inadequate food energy and negative energy balance in humans. *Public Health Nutrition, 8*(7a), 1053–1076. https://doi.org/10.1079/phn2005796

Lipoeto, N. I., Wattanapenpaiboon, N., Malik, A., & Wahlqvist, M. L. (2004). The nutrition transition in West Sumatra, Indonesia. *Asia Pacific Journal of Clinical Nutrition, 13*(3), 312–316.

Malik, V. S., & Hu, F. B. (2019). Sugar-sweetened beverages and cardiometabolic health: An update of the evidence. *Nutrients*, *11*(1840), 1–17. https://doi.org/10.3390/nu11081840

Margono, B. A., Potapov, P. V., Turubanova, S., Stolle, F., & Hansen, M. C. (2014). Primary forest cover loss in Indonesia over 2000–2012. *Nature Climate Change, 4*(8), 730–735. https://doi.org/10.1038/nclimate2277

Martini, D., Godos, J., Marventano, S., Tieri, M., Ghelfi, F., Titta, L., Lafranconi, A., et al. (2021). Nut and legume consumption and human health: An umbrella review of observational studies. *International Journal of Food Sciences and Nutrition, 72*(7), 871–878. https://doi.org/10.1080/09637486.2021.1880554

Mboi, N., Murty Surbakti, I., Trihandini, I., Elyazar, I., Houston Smith, K., Bahjuri Ali, P., Kosen, S., Flemons, K., Ray, S. E., Cao, J., Glenn, S. D., Miller-Petrie, M. K., Mooney, M. D., Ried, J. L., Nur Anggraini Ningrum, D., Idris, F., Siregar, K. N., Harimurti, P., Bernstein, R. S., … Hay, S. I. (2018). On the road to universal health care in Indonesia, 1990–2016: A systematic analysis for the Global Burden of Disease Study 2016. *The Lancet*, *392*(10147). https://doi.org/10.1016/S0140-6736(18)30595-6

Mehraban, N., & Ickowitz, A. (2021). Dietary diversity of rural Indonesian households declines over time with agricultural production diversity even as incomes rise. *Global Food Security, 28*, 100502. https://doi.org/10.1016/j.gfs.2021.100502

Ministry of Environment and Forestry. (2006). Status lingkungan hidup Indonesia. In E. B. Walujo (Ed.), *Kongres Ilmu Pengetahuan X, 8–10 November 2011* (Keanekarag). Lembaga Ilmu Pengetahuan Indonesia. Retrieved February 8, 2022. http://www.opi.lipi.go.id/data/1228964432/%0Adata/13086710321320841770.makalah.pdf

Ministry of Environment and Forestry. (2020). Penjelasan KLHK tentang penyediaan kawasan hutan untuk pembangunan food estate. *Ministry of Environment and Forestry*. Retrieved February 8, 2022. http://ppid.menlhk.go.id/berita/siaran-pers/5711/penjelasan-klhk-tentang-penyediaan-kawasan-hutan-untuk-pembangunan-food-estate#:~:text=Terbitnya Peraturan Menteri Lingkungan Hidup,merupakan program strategis nasional dalam.

Ministry of Health. (2013). Minister of Health regulation number 30 year 2013 concerning inclusion of information on content of sugar, salt, and fat as well as health messages for processed foods and ready-to-eat foods (Patent No. 30). In *Ministry of Health,* (No. 30). Retrieved February 8, 2022. https://peraturan.bpk.go.id/Home/Details/172111/permenkes-no-30-tahun-2013

Ministry of Health. (2014). Studi diet total: Survei konsumsi makanan individu Indonesia 2014. Jakarta: Health Research and Development Agency. Retrieved Febuary 8, 2022. https://repository.badankebijakan.kemkes.go.id/id/eprint/4741/1/Laporan_SDT2014.pdf

Ministry of Health. (2019). Laporan nasional RISKESDAS tahun 2018. Jakarta: Health Research and Development Agency. Accessed August 21, 2021, from https://labdata.litbang.kemkes.go.id/images/download/laporan/RKD/2018/Laporan_Nasional_RKD2018_FINAL.pdf

Ministry of Health. (2023). *Protein hewani cegah stunting*. Ministry of Health. Retrieved February 17, 2023, from https://promkes.kemkes.go.id/protein-hewani-cegah-stunting

Monteiro, C. A., Cannon, G., Lawrence, M., Costa Louzada, M. L., & Machado, P. P. (2019). *Ultra-processed foods, diet quality, and health using the NOVA classification system*. FAO. https://openknowledge.fao.org/server/api/core/bitstreams/5277b379-0acb-4d97-a6a3-602774104629/content

Mustafa M., Alam, M. A., Das, S., Fahim, S. M., Hossain, M. S., Petri, W. A., Ashorn, P., Ashorn, U., & Ahmed, T. (2020). Daily supplementation with egg, cow milk, and multiple micronutrients increases linear growth of young children with short stature. *Journal of Nutrition*, *150*(2), 394–403. https://doi.org/10.1093/jn/nxz253

Ningrum, I. H., Irianto, H., & Riptanti, E. W. (2018). Analysis of soybean production and import trends and its import factors in Indonesia. *IOP Conference Series: Earth and Environmental Science*, *142*(1). https://doi.org/10.1088/1755-1315/142/1/012059

Nurdiansyah, R. (2019). *Budaya Pola Konsumsi Makanan Cepat Saji dalam Kehidupan Remaja Jakarta (Studi Kasus: Franchise KFC)* [Bachelor's thesis]. FISIP UIN Jakarta.

Nurhasan, M., Maulana, A. M., Ariesta, D. L., Usfar, A. A., Napitupulu, L., Rouw, A., Hurulean, F., Hapsari, A., Heatubun, C. D., & Ickowitz, A. (2022). Toward a sustainable food system in West Papua, Indonesia: Exploring the links between dietary transition, food security, and forests. *Frontiers in Sustainable Food Systems, 5*(March), 1–20. https://doi.org/10.3389/fsufs.2021.789186

Nurwanti, E., Hadi, H., Chang, J.-S., Paramashati, B. A., & Gittelson, J. (2019). Rural – urban differences in dietary behavior and obesity: Result of the RISKESDAS study in 10–18 year old Indonesian children and adolescent. *Nutrients*, *11*(2813), 1–14. https://doi.org/10.3390/nu11112813

Pagliai, G., Dinu, M., Madarena, M. P., Bonaccio, M., Iacoviello, L., & Sofi, F. (2021). Consumption of ultra-processed foods and health status: A systematic review and meta-analysis. *British Journal of Nutrition, 125*(3), 308–318. https://doi.org/10.1017/S0007114520002688

Pawera, L., Khomsan, A., Zuhud, E. A. M., Hunter, D., Ickowitz, A., & Polesny, Z. (2020). Wild food plants and trends in their use: From knowledge and perceptions to drivers of change in West Sumatra, Indonesia. *Foods, 9*(9). https://doi.org/10.3390/foods9091240

Pelto, G. H., & Pelto, P. J. (1983). Diet and delocalization: Dietary changes since 1750. *The Journal of Interdisciplinary History, 14*(2), 507–528. https://doi.org/10.2307/203719

Pelto, G. H., & Vargas, L. A. (1992). Introduction: Dietary change and nutrition. *Ecology of Food and Nutrition, 27*(3–4), 159–161. https://doi.org/10.1080/03670244.1992.9991241

Poggie, J., & Lynch, R. (1974). *Rethinking modernization: Anthropological perspectives*. Praeger.

Popkin, B. M. (2004). The nutrition transition: An overview of world patterns of change. *Nutrition Reviews*, *62*(7 II). https://doi.org/10.1111/j.1753-4887.2004.tb00084.x

Popkin, B. M. (2006). Global nutrition dynamics: The world is shifting rapidly toward a diet linked with noncommunicable diseases. *American Journal of Clinical Nutrition, 84*(2), 289–298. https://doi.org/10.1093/ajcn/84.2.289

Popkin, B. M., Adair, L. S., & Ng, S. W. (2012). Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition Reviews, 70*(1), 3–21. https://doi.org/10.1111/j.1753-4887.2011.00456.x

Popkin, B. M. (2015). Nutrition transition and the global diabetes epidemic. *Current Diabetes Reports*, *15*(9). https://doi.org/10.1007/s11892-015-0631-4

Popkin, B. M., & Ng, S. W. (2021). The nutrition transition to a stage of high obesity and noncommunicable disease prevalence dominated by ultra-processed foods is not inevitable. *Obesity Reviews, 23*(1), 1–18. https://doi.org/10.1111/obr.13366

Pressler, M., Devinsky, J., Duster, M., Lee, J. H., Glick, C. S., Wiener, S., ... & Devinsky, O. (2022). Dietary transitions and health outcomes in four populations–Systematic Review. *Frontiers in Nutrition*, 9, 748305. https://doi.org/10.3389/fnut.2022.748305

Purwidiani, N. (2017). Non-rice staple food patterns in Indonesia. *1st International Conference on Social, Applied Science and Technology in Home Economics (ICONHOMECS 2017)*, 241–244. https://doi.org/10.2991/iconhomecs-17.2018.55

Putra, A. S., Tong, G., & Pribadi, D. O. (2020). Food security challenges in rapidly urbanizing developing countries: Insight from Indonesia. *Sustainability (Switzerland), 12*(22), 1–18. https://doi.org/10.3390/su12229550

Quintero-Lesmes, D. C., & Herran, O. F. (2019). Food changes and geography: Dietary transition in Colombia. *Annals of Global Health*, *85*(1). https://doi.org/10.5334/aogh.1643

Rasolofoson, R. A., Hanauer, M. M., Pappinen, A., Fisher, B., & Ricketts, T. H. (2018). Impacts of forests on children's diet in rural areas across 27 developing countries. *Science Advances, 4*(8), 1–10. https://doi.org/10.1126/sciadv.aat2853

Ros, E. (2010). Health benefits of nut consumption. *Nutrients, 2*(7), 652–682. https://doi.org/10.3390/nu2070652

Rowland, D., Ickowitz, A., Powell, B., Nasi, R., & Sunderland, T. (2017). Forest foods and healthy diets: Quantifying the contributions. *Environmental Conservation, 44*(2), 102–114. https://doi.org/10.1017/S0376892916000151

Rowland, D., Zanello, G., Waliyo, E., & Ickowitz, A. (2022). Oil palm and gendered time use: A mixed-methods case study from West Kalimantan. *Indonesia. Forest Policy and Economics, 137*, 102682. https://doi.org/10.1016/j.forpol.2021.102682

Shurtleff, W., & Aoyagi, A. (2007). History of tempeh. In *The History of Traditional Fermented Soyfoods* (p. 85). Soyinfo Center. Retrieved November 14, 2022. http://www.luk.staff.ugm.ac.id/itd/artikel/Shurtleff-Aoyagi-HistoryOfTempeh.pdf

Statistics Indonesia. (2008). *Data susenas blok 41 2008* [Data set]. Statistics Indonesia.

Statistics Indonesia. (2017). *Data susenas blok 41 42 43 2017* [Data set]. Statistics Indonesia.

Statistics Indonesia. (2019). *Produksi daging ayam ras pedaging menurut Provinsi (Ton), 2017–2019*. Statistics Indonesia. Retrieved January 29, 2023, from https://www.bps.go.id/indicator/24/488/2/produksi-daging-ayam-ras-pedaging-menurut-provinsi.html
Statistics Indonesia. (2023a). *Luas daerah dan jumlah pulau menurut provinsi.* Statistics Indonesia. Retrieved November 26, 2023, from https://www.bps.go.id/id/indicator/153/1110/1/luas-daerah-dan-jumlah-pulau-menurut-provinsi.html
Statistics Indonesia. (2023b). *Produksi Telur Ayam Petelur menurut Provinsi (Ton), 2021–2022*. Statistics Indonesia. Retrieved January 08, 2024, from Produksi Telur Ayam Petelur menurut Provinsi (Ton), 2021–2022.
Subejo. (2013). *Indonesia caught in wheat trap*. The Jakarta Post. Retrieved May 27, 2023. https://www.thejakartapost.com/news/2013/07/11/indonesia-caught-wheat-trap.html
Tempo. (2020). *Hutan itu supermarketnya orang Dayak*. Tempo. Retreived January 7, 2024, from https://majalah.tempo.co/read/selingan/161590/pangalangok-jilah-pemimpin-pasukan-merah-dayak-perusak-hutan-dibiarkan-di-mana-keadilan
Turubanova, S., Potapov, P., Tyukavina, A., & Hansen, M. (2018). Ongoing primary forest loss in Brazil, Democratic Republic of the Congo, and Indonesia. In *Environmental Research Letters* (Vol. 13). IOP Publishing. https://doi.org/10.1088/1748-9326/aacd1c
United Nations. (2018). Classification of Individual Consumption According to Purpose (COICOP) 2018. In *United Nations* (Issue 99). Retrieved October 9, 2022. https://unstats.un.org/unsd/classifications/unsdclassifications/COICOP_2018_-_pre-edited_white_cover_version_-_2018-12-26.pdf
Vermeulen, S., Wellesley, L., Singh, S., Agustina, R., Izwardy, D., & Saminarsih, D. (2019). *Healthy diets from sustainable production: Indonesia*. Retrieved June 18, 2022. https://www.chathamhouse.org/sites/default/files/2020-12/2019-01-24-healthy-diets-sustainable-production.pdf
Wang, H., Herforth, A. W., Xi, B., & Zou, Z. (2022). Validation of the diet quality questionnaire in Chinese children and adolescents and relationship with pediatric overweight and obesity. *Nutrients, 14*(17), 3551. https://doi.org/10.3390/nu14173551
Wardis, G. (2014). Gaplek, tiwul and gatot as staple food in Javanese barren area. *South Pacific Study, 34*(2), 99–116.
Weaver, C. M., Dwyer, J., Fulgoni, V. L., 3rd., King, J. C., Leveille, G. A., MacDonald, R. S., Ordovas, J., & Schnakenberg, D. (2014). Processed foods: Contributions to nutrition. *American Journal of Clinical Nutrition, 99*(6), 1525–1542. https://doi.org/10.3945/ajcn.114.089284
Weisse, M., & Goldman, L. (2022). Kehilangan hutan tetap tinggi di tahun 2021. *Global Forest Watch*. Retrieved March 18, 2023, from https://www.globalforestwatch.org/blog/id/data-and-research/data-kehilangan-tutupan-pohon-global-2021/
Widati, A., Darwanto, D., Masyhuri, M., & Waluyati, L. (2019). The different pattern of food consumption between local farmers and transmigrant farmers in the border area of Papua, Indonesia. *Journal of Food and Nutrition Research, 7*, 506–513. https://doi.org/10.12691/jfnr-7-7-4
Wirawan, N. N., Purwestri, R. C., Fahmi, I., Jati, I. R. A. P., Kariuki, L. W., Barati, Z., Hartung, J., Lusiana, B., & Biesalski, H. K. (2018). Food consumption and dietary diversity of women in transmigrant area Buol, Central Sulawesi and original location Demak, Central Java, Indonesia. *Malaysian Journal of Nutrition, 24*(4), 587–596.
World Health Organization. (2023). Total fat intake for the prevention of unhealthy weight gain in adults and children: WHO guideline. Geneva: World Health Organization. Licence: CC BY-NC-SA 3.0 IGO. Retrieved December 30, 2023. https://iris.who.int/bitstream/handle/10665/370421/9789240073654-eng.pdf?sequence=1

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