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ORIGINAL ARTICLE

Longitudinal analysis of home food production and food sharing behavior in Japan: multiple benefits of local food systems and the recent impact of the COVID-19 pandemic

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Abstract

Home food production and sharing (home consumption) make up a local community-based food system that has become a custom closely tied to people's daily life and culture across Japan. In this study, nationwide questionnaire surveys were conducted in 2015 and 2021 to investigate the status and trends of non-commercial home food consumption in Japan. We were also able to evaluate the effects of the COVID-19 pandemic, which commenced at the beginning of 2020 in Japan. It was found that a wide variety of foods and many different species of food are part of home consumption. In addition, the amount of home production and the amount shared with close neighbors and friends via social networks is higher in agricultural areas than in urban areas. The amount of home production was slightly higher and the amount shared with others slightly lower in 2021 compared with 2015, suggesting that COVID-19 may have limited the sharing activities that also connect people. Meanwhile, the majority of respondents who were directly asked about the effects of the COVID-19 pandemic in the survey in 2021 answered "no change", suggesting a resilient system even under the pressures of the pandemic. Moreover, there has been an uptake in home food production and sharing amongst younger generations, men, and people living in urban areas. These customs and lifestyles are embedded in Japanese culture, helping to produce a sustainable and resilient food system. This home consumption system has the potential to contribute to various global challenges in the form of nature-based solutions which help meet the targets of the sustainable development goals, in particular a reduction in greenhouse gas emissions, and the promotion of health, well-being and social relations. We discuss future research challenges for a more resource-efficient, inclusive, and sustainable growth model that includes home consumption.

Keywords Ecosystem services · Provisioning services · Gifting · Homegarden · Self-consumption · Health

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Introduction

Food systems and their provision have long provided important ecosystem and health services in addition to calories (Pretty and Bharucha 2018; Dasgupta 2021). However, in recent decades, the management of food systems, from production to distribution and consumption, has become one of the most critical contemporary global challenges, particularly in relation to the climate crisis, biodiversity loss, soil degradation, deterioration of water quality, and an increased availability and consumption of unhealthy food (Rockström et al. 2020; IPCC 2022). It is reported that 25% of greenhouse gas (GHG) emissions arise from agriculture and land use (IPCC 2022), and modern industrialized food systems with high content of ultra-processed foods (UPFs) contribute to diet-related chronic disease (Monteiro et al. 2019). While food supply chains are becoming increasingly globalized

due to the expansion of international trade and marketing of food, the importance of local food production and consumption with a short supply chain has been demonstrated to be a key component of the transition towards more sustainable food systems (King et al. 2014; Plieninger et al. 2018), promoting human health with better quality and healthier foods (Lang and Rayner 2012; iPES Food 2021).

Besides food's core nutritional value in supporting human life, numerous ways of framing food have been identified, which is food as not only a commodity but also as a human right, commons, identity, culture, security, and as a link to nature (Cantarero 2013; Lang 2020; SAPEA 2020; García-Martín et al. 2022). From these multifaceted perspectives, the re-embedding of food production in local contexts has also received growing attention (Penker 2006; Fendrychová and Jehlička 2018). Local food systems play a vital role in people's daily lives comprised of three elements in addition to purchase: home or community production, gathering from the wild, and sharing/gifting. In these systems, foods are consumed on a small local scale without commercial transactions, and within networks of households, close neighbors, friends, and relatives. This direct use of local ecosystem services contributes to human well-being and local sustainability by maintaining agrobiodiversity (Huai and Hamilton 2009), access to fresh food and nutritional balance (Galhena et al. 2013; Tatebayashi et al. 2019), food stocks in case of emergencies and disasters (Saito et al. 2015), traditional dishes and regional characteristics (Koda et al. 2004), as well as social relations through sharing (Kamiyama et al. 2016; Saito 2019; Pretty et al. 2020). In light of these considerations, there is increased interest in the importance of local food production and consumption systems that are not subject to commercial transactions.

When managed sustainably according to local rules and norms, such practices without commercial transactions, that is embedded in local food systems, can be understood as a time-tested local strategy to address social, ecological, economic, and health challenges, in other words, as nature-based solutions (NbS) (Miralles-Wilhelm 2021). Cabral et al. (2017) studying urban gardens have shown that in addition to functioning as green infrastructure, participation in gardens promotes health and well-being, a sense of place, cultural identity, and social cohesion, which are important for societies to adapt to various changes as nature-based solutions. For example, a community garden initiative to grow food to share in public spaces for free harvesting that began in Todmorden, England, is helping to restore local food production systems, change behavior toward the environment, and create more resilient cities, and is now spreading around the world (Paull 2013). Sharma et al. (2022) conducted a literature review on homegardens and indicated that homegardens are an important strategy for achieving the sustainable development goals (SDGs) (United Nations 2015).

Local, non-commercial food systems are prevalent worldwide as customs not limited to farm products, but also include fruit, forest foods and wild plants, mushrooms and meats, and marine products such as fish and algae (Befu 1968; Nolien 2012; Jehlička and Daněk, 2017; Bharucha and Pretty 2010; Saito and Shibata 2012; Gnechten et al. 2020). For example, Bharucha and Pretty (2010) investigated the uses of wild foods (plants and animals) by agricultural and forager communities in 22 countries of Asia and Africa and found that the mean use of wild foods is 90–100 species per location. Jehlička and Daněk (2017) conducted a large-scale survey in the Czech Republic to investigate the home production and sharing of home-grown foods and found that home production and received gifts combined account for about 40 percent of total household consumption in the case of fruit, vegetable, potato and eggs. However, these customary types of food consumption are rarely recorded in national or international time-series statistical data, and the targeted food, area, survey period, and other parameters (e.g. respondents' residential area, age etc.) considered in these studies have been limited.

Satoyama is a term applied in Japan to socio-ecological production landscapes that embrace the richness and interconnectedness of human culture and local ecosystems, and these occupy some 40% of Japan's total land area (Duraiappa et al. 2012). These mosaic landscapes are constructed of ecosystems—secondary forests, farmlands, paddies, irrigation ponds, and grasslands—along with human settlements that have been managed to produce bundles of ecosystem services for human well-being (Duraiappa et al. 2012; Berkes 2020). The social relationship of giving and receiving food is closely related to the maintenance of traditions and culture (Nakazawa et al. 2014; Saito and Kamiyama 2016). For example, the giving and receiving of food was the basis of mutual relations that have long been important not only in daily life but also in the conduct of special events like local weddings, funerals, and traditional religious rituals, and at the same time, home-grown and gathered foods were served and shared as traditional dishes at such occasions (Nakazawa et al. 2014). In addition, the multifaceted health benefits of home/community gardens have been demonstrated in recent years, such as lowering body mass index (BMI) and blood pressure, and treating chronic diseases like obesity through promotion of physical activity and healthy eating (George et al. 2015). Japan is one of only two (the other is the Republic of Korea) high per capita GDP countries worldwide that has been able to maintain national obesity levels at less than 5% since 1990 (Global Obesity Observatory 2022). Obesity was uncommon prior to 1990 but since then, in the USA it has grown from 6 to > 35% of the population, and in Europe from 3–5% to 15–30%. Therefore, using Japan as a case study to examine the state of home production and consumption, which has multifaceted benefits, will help us

understand the potential of local food systems as NbS to tackle global challenges.

Many communities in Japan are dependent on local and sustainable food systems and relationships. However, these face serious social challenges arising from a declining birthrate, the aging population, and rural depopulation. It has been suggested that the spread of modern food systems will cause further major changes in food consumption behavior, and that home production and sharing behavior may decline even more in the future (Kamiyama et al. 2014). At the same time, the COVID-19 pandemic, which commenced in February 2020 in Japan, became a new challenge to local food systems. It is well-understood that the pandemic has had a fundamental impact on daily lives and lifestyles. One outcome was that the management of kitchen gardens (home production) began to assume greater importance, especially in urban areas, from the viewpoint of food security, nutrition intake, and healthy living for people in voluntary self-isolation (Sofo and Sofo 2020; Lal 2020), leading to a notable increase in the frequency of gardening following the onset of the pandemic (Corley et al. 2021). While activity related to home production and gathering, which occurs close to home, continues to be viable even during a pandemic, sharing that involves interaction between people may decline because of voluntary self-isolation. Therefore, a quantitative understanding of the conditions and changes in home consumption over recent years may play an important role in helping to ensure the sustainability and resilience of local communities and ecosystems.

In January 2015, we conducted a nationwide online questionnaire survey in Japan to investigate the state of home consumption of food. In this study, "home consumption" was a collective term that referred to the consumption of home produced/gathered food and received/shared food which was produced/gathered in other households. The subsequent study in 2021 was designed to provide a quantitative understanding of changes in the intervening six years, with a particular focus on the impacts of the COVID-19 pandemic. An online questionnaire survey was conducted in 2021 using the same questions, scale, and sampling conditions as in 2015. To consider the effects of the COVID-19 pandemic, we added specific questions concerning the effects of the pandemic on home production, gathering, and food sharing behavior.

Methods

Questionnaire survey

In January 2015, we conducted a nationwide online questionnaire survey of adults aged 20 and over. The online questionnaire survey was performed by Macromill, Inc., a major online research company with some 10 million people registered as potential respondents throughout Japan. There were no limitations regarding the occupations and household structures of respondents, and the survey was designed to ensure no gender and age bias. Furthermore, the primary classification of national agricultural area type defined by the Ministry of Agriculture, Forestry and Fisheries at a municipal level was used to limit spatial bias. This classification is based on the basic conditions that define the structure of regional agriculture, dividing agricultural areas into four categories: urban areas, flatland agricultural areas, intermediate agricultural areas, and mountainous agricultural areas. The company system randomly selects potential respondents under settings that avoid biases, constantly monitors response rates, and distributes the questionnaires to the potential respondents online in a sequential manner to reach the target number of responses. The willing recipients complete the questionnaire online. The distribution is terminated when the target number of responses is approached.

This questionnaire survey is regarding the relationship between individual lifestyles and ecosystem services. In the 2015 study, two questions related to the home consumption of food were extracted and analyzed (Table 1). In Question 1, assuming that the amount of food comprising meals in one year is 100%, respondents were asked to provide the ratios of "(1) food produced and gathered in the household (cultivated and wild foods)," "(2) food received and shared from and by other people, such as neighbors, friends, and relatives," and "(3) purchased food" for each food category (grains [rice], vegetables, fruits, fish and algae, mushrooms, edible wild plants and meat) to obtain relative values. We asked about these ratios on an annual basis using the same approach as in the previous study (Kamiyama et al. 2016), since these ratios have been found to vary seasonally, influenced by the specific harvest time of each food (Tatebayashi et al. 2019), and questions on an annual basis are relatively easy for respondents to answer. In Question 2, respondents were required to provide answers regarding the number of food species produced at home and received from other people with reference to the food categories introduced in Question 1. Thus, Question 2 collectively considers food produced at home and received from other people within the domain of home consumption.

In February 2021, we conducted a subsequent online questionnaire survey regarding the relationship between people's lifestyles and ecosystem services using the same survey company, targets, scale, and conditions as the 2015 survey. From this survey, we extracted and analyzed six key questions: two related to home consumption of food (also used in the 2015 survey), and four (Questions 3–6) related to the effects of the COVID-19 pandemic (Table 1), which explicitly addressed changes in home production

Table 1 Online questionnaire survey content

Common questions from the 2015 and 2021 surveys (1–2)	
Question 1	Assuming that the overall amount of the foods you eat is 100%, what is the ratio of "food produced and gathered in the household (cultivated and wild foods)", "food received and shared from and by other people, such as neighbors, friends, and relatives," and "purchased food"? Consider your diet during the last year, and choose the most applicable answer for each of the following categories: grains (rice), vegetables, fruits, fish/algae, mushrooms, edible wild plants, and wild meat 【Options (One answer)】 [0%], [Approximately 20%], [Approximately 40%], [Approximately 60%], [Approximately 80%], and [100%]
Question 2	This question is for those who answered that they practiced "home production and gathering" and "receiving and sharing" to a certain extent (excluding 0%) in Question 1. Please tell us about the number of food species that you usually produce/gather, or receive/share, excluding those that you purchase. Please answer for each of the categories 【Options (One answer)】 [1–5 species], [6–10 species], [11–15 species], [16–20 species], [21–25 species] [26–30 species], [31–35 species], [36–40 species], and [41 species or more]
Questions in the 2021 survey (3–6)	
Question 3	This question is for those who answered that they practiced "home production and gathering" and "receiving and sharing" to a certain extent (excluding 0%) in Question 1 Prior to the onset of the COVID-19 pandemic in February 2020, did you practice home production such as growing crops in rice fields, and vegetable gardens at home, catching fish and harvesting algae from the sea and rivers, gathering wild plants and mushrooms, or hunting wild meat in forests? 【Options (One answer)】 [No (I started home production of vegetables after the onset of the COVID-19 pandemic etc.)] [Yes]
Question 4	This question is for those who answered that they "practiced home production and gathering prior to the onset of the COVID-19 pandemic" in Question 3. How has your home production and gathering behavior changed in comparison to your behavior before the onset of the pandemic? Please state the "volume of home-produced/gathered food", "species of home-produced/gathered food", and "time spent on home production/gathering" 【Options (One answer)】 [Significantly decreased], [Decreased], [Unchanged], [Increased], and [Significantly increased]
Question 5	This question is for those who answered that they practiced "receiving and sharing" to a certain extent (excluding 0%) in Question 1 Did you receive or share any food from or by other people before the onset of the COVID-19 pandemic? 【Options (One answer)】 [No (I stated receiving vegetables from my neighbors after the onset of the COVID-19 pandemic, etc.)] [Yes]
Question 6	This question is for those who answered that they "received or shared food prior to the onset of the COVID-19 pandemic" in Question 5 How did the receiving or sharing of food change after the onset of the COVID-19 pandemic? Please describe the "volume of food received/shared," "number of received/shared species," "frequency of receiving/sharing," and "number of receiving/sharing partners." 【Options (One answer)】 [Significantly decreased], [Decreased], [Unchanged], [Increased], and [Significantly increased]

and food sharing behavior since the onset of the pandemic in February 2020. Additionally, respondents were asked about the presence or absence of home production and sharing behaviors, with reference to the volume and nature of home production and time spent on home production and the volume, nature, and frequency of sharing activity, as well as the changes in the number of sharing partners.

Analysis

Using the analysis software R, we investigated factors that influence the actual state of home consumption. Multiple regression analysis was performed using a generalized linear model (GLM) with the following as dependent variables: ratio of home produced food, received food, and purchased food in one's diet (Question 1); number of food species

consumed at home (Question 2); presence or absence of home production and sharing before and after the COVID-19 pandemic (Questions 3 and 5); and specific changes in home production and sharing behavior before and after the onset of the COVID-19 pandemic (Questions 4 and 6). For the analysis, the ratio of each option (0, 0.2, 0.4, 0.6, 0.8, and 1) in Question 1, the median of each option (3, 8, 13, 18, 23, 27, 33, 38, 43) in Question 2, values converted to 0/1 data in Questions 3 and 5, and scored values of the interval scales in Questions 4 and 6 were used. In the model for home consumption and the number of food species, the explanatory variables were gender, age, primary classification of national agricultural area type, and survey year of the respondents. Regarding home consumption and sharing before and after the onset of the COVID-19 pandemic, the explanatory variables were gender, age, and primary classification of national agricultural area type, excluding the survey year.

Results

A total of 1586 and 1548 responses were collected in 2015 over a six-day period from January 8 to 13 and in 2021 over a three-day period from February 15 to 17, respectively.

Overall trend of home consumption in the ratio and in the number of species

Figure 1 shows overall home consumption in the ratio and the number of species across both the 2015 and 2021 data. The average ratios (in percentage) of home-produced and received foods in one year's diet were, respectively, as follows: 10% and 19% for rice, 11% and 16% for vegetables, 4% and 15% for fruits, and 3% and 7% for fish and algae, 2% and 5% for mushrooms, 6% and 8% for edible wild plants, and 0.4% and 4% for wild meat (Fig. 1a). In terms of overall home-consumed food species (i.e., food species produced and received) across both the 2015 and 2021 data, the average number of species was highest in the category of vegetables at 6.2 species, followed by fish and algae at 4.5 species, fruits and mushrooms at 3.9 species, edible wild plants at 3.8 species, and wild meat at 3.0 species (Fig. 1b).

Effects of attributes of respondents to home consumption

Table 2 shows the results of the multiple regression analysis of attributes of respondents that explain the ratio of home-produced food, ratio of food received from relatives, and the ratio of purchased food in one year's diet. Figure 2 shows the response results with average values, focusing on the national agricultural area type classification and survey year. Regardless of the year of the survey, older respondents generally had a higher ratio of home-produced foods than younger respondents (significant in the case of vegetables, fruits, and edible wild plants); additionally, men were found to have a lower ratio of received food than women (significant in the case of rice, vegetables, and fruits). In agricultural areas, the ratios for home-produced foods and received foods were significantly higher, and the ratio of purchased food was significantly lower in almost all food categories, than in urban areas. With regard to the survey year, the ratio

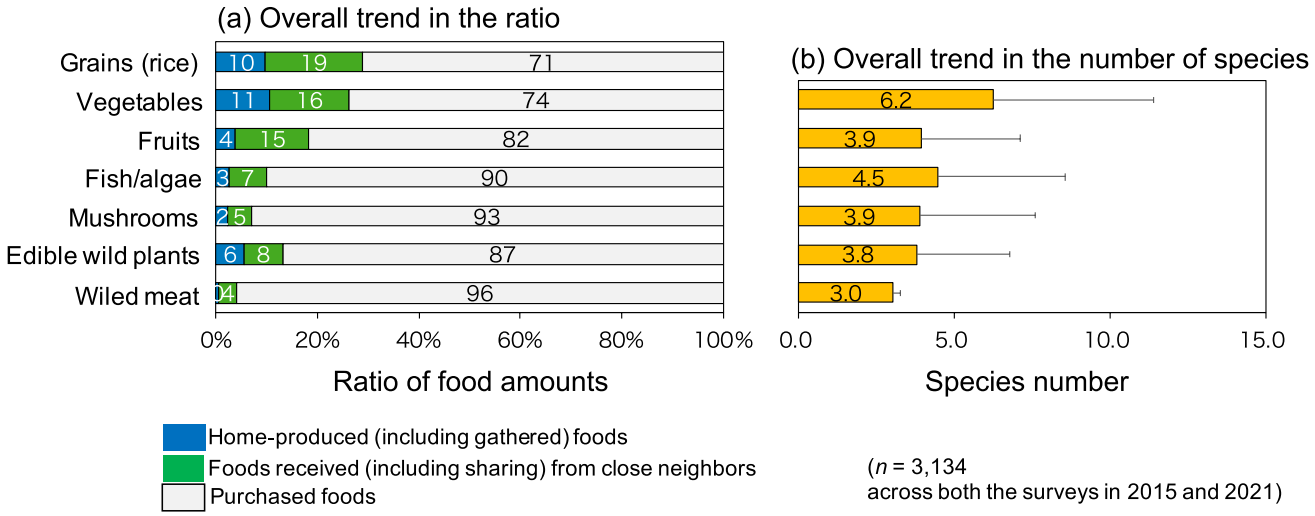

Fig. 1 The overall home consumption in the ratio (**a**) and the number of species (**b**) across both the 2015 and 2021 data ($n=3134$). In (**a**), the average value of the ratio of home-produced (including gathered) foods, foods received (including sharing) from close neighbors, friends and relatives, and purchased foods in the diet during a single year is shown by food categories. The numbers in the graph indicate the mean values of ratio (**a**) and species number (**b**) respectively

Table 2 Results of multiple regression analysis by a generalized linear model with the ratio of home consumption in the diet as the dependent variable

	Grains (rice) Estimate	Vegetables Estimate	Fruits Estimate	Fish/algae Estimate	Mushrooms Estimate	Edible wild plants Estimate	Wild meat Estimate
Ratio of home-produced/gathered foods							
(Intercept)	−2.77***	−3.52***	−5.05***	−4.40***	−5.48***	−4.88***	−7.81***
Gender: men (compared with women)	0.10	−0.09	0.21	0.25	0.32	0.03	0.58
Age	−0.02**	0.01*	0.02*	−0.01	0.01	0.01*	0.01
Area type: Flatland agricultural area (compared with urban)	1.35***	1.11***	0.84**	1.13**	0.87	1.06**	1.07
Area type: Intermediate agricultural area (compared with urban)	1.05***	0.97***	0.82**	0.91*	1.21*	1.41***	1.42
Area type: Mountain agricultural area (compared with urban)	0.85***	0.93***	0.76*	1.42***	1.59***	1.63***	1.51
Survey year: 2021 (Compared with 2015)	0.66***	0.27*	0.36	0.22	0.48	0.32	0.57
Ratio of foods received from neighbors (including sharing)							
(Intercept)	−0.30	−1.60***	−1.55***	−2.62***	−4.07***	−3.10***	−3.02***
Gender: Men (compared with women)	−0.25*	−0.23*	−0.26*	−0.10	0.21	0.00	0.03
Age	−0.02***	0.00	−0.01	−0.01	0.01	0.00	−0.01
Area type: Flatland agricultural area (compared with urban)	0.08	0.45**	0.33*	0.48*	0.59	0.64*	0.09
Area type: Intermediate agricultural area (compared with urban)	0.23	0.42**	0.40**	0.73**	0.79**	0.94***	0.18
Area type: Mountain agricultural area (compared with urban)	0.15	0.41**	0.29	0.86***	1.15***	1.14***	0.54*
Survey year: 2021 (Compared with 2015)	−0.44***	−0.22*	−0.21*	−0.17	−0.18	−0.16	−0.23
Ratio of purchased foods							
(Intercept)	0.17	1.59***	1.61***	2.50***	3.97***	3.12***	3.18***
Gender: Men (compared with women)	0.13	0.19*	0.12	0.02	−0.23	−0.02	−0.11
Age	0.02***	0.00	0.00	0.01	−0.01	0.00	0.01
Area type: Flatland agricultural area (compared with urban)	−0.60***	−0.79***	−0.41**	−0.68**	−0.71**	−0.83***	−0.13
Area type: Intermediate agricultural area (compared with urban)	−0.54***	−0.69***	−0.47***	−0.81***	−0.97***	−1.17***	−0.25
Area type: Mountain agricultural area (compared with urban)	−0.40***	−0.67***	−0.32*	−1.06***	−1.35***	−1.41***	−0.62*
Survey year: 2021 (Compared with 2015)	0.04	0.00	−0.04	0.05	−0.05	−0.07	0.11

About the ratio of home-produced (including gathered) foods, foods received (including sharing) from close neighbors (including friends and relatives), and purchased foods, the ratios of grains (rice), vegetables, fruits, fish/algae, mushrooms, edible wild plants, and wild meat were set as dependent variables, and sex, age, national agricultural area type classification, and survey year were set as the explanatory variables. The explanation of the effect of each explanatory variable is enclosed in parentheses in the table. The probability distribution is a binomial distribution, and the link function is a logit function. The significance levels are as follows: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

of home-produced foods was higher in the 2021 survey in almost all food categories, while the proportion of received foods tended to decrease (significantly rice, vegetables, and fruits). However, there was no change in the ratio of purchases compared to the 2015 survey.

Table 3 shows the results of the multiple regression analysis of attributes of respondents that explain the number of food species consumed at home. Compared to urban areas, flatland agricultural areas and intermediate agricultural areas had a significantly high number of home-consumed vegetable species. Additionally, men tended to answer a lower number of species of vegetables and a higher number of species of fish and algae, mushrooms, and edible wild plants than women. Apart from this, no particular tendencies were observed, and no changes were observed between survey years.

Home production and sharing behavior before and after the onset of the COVID-19 pandemic

Table 4 shows the results of the multiple regression analysis indicating changes in home production before and after the

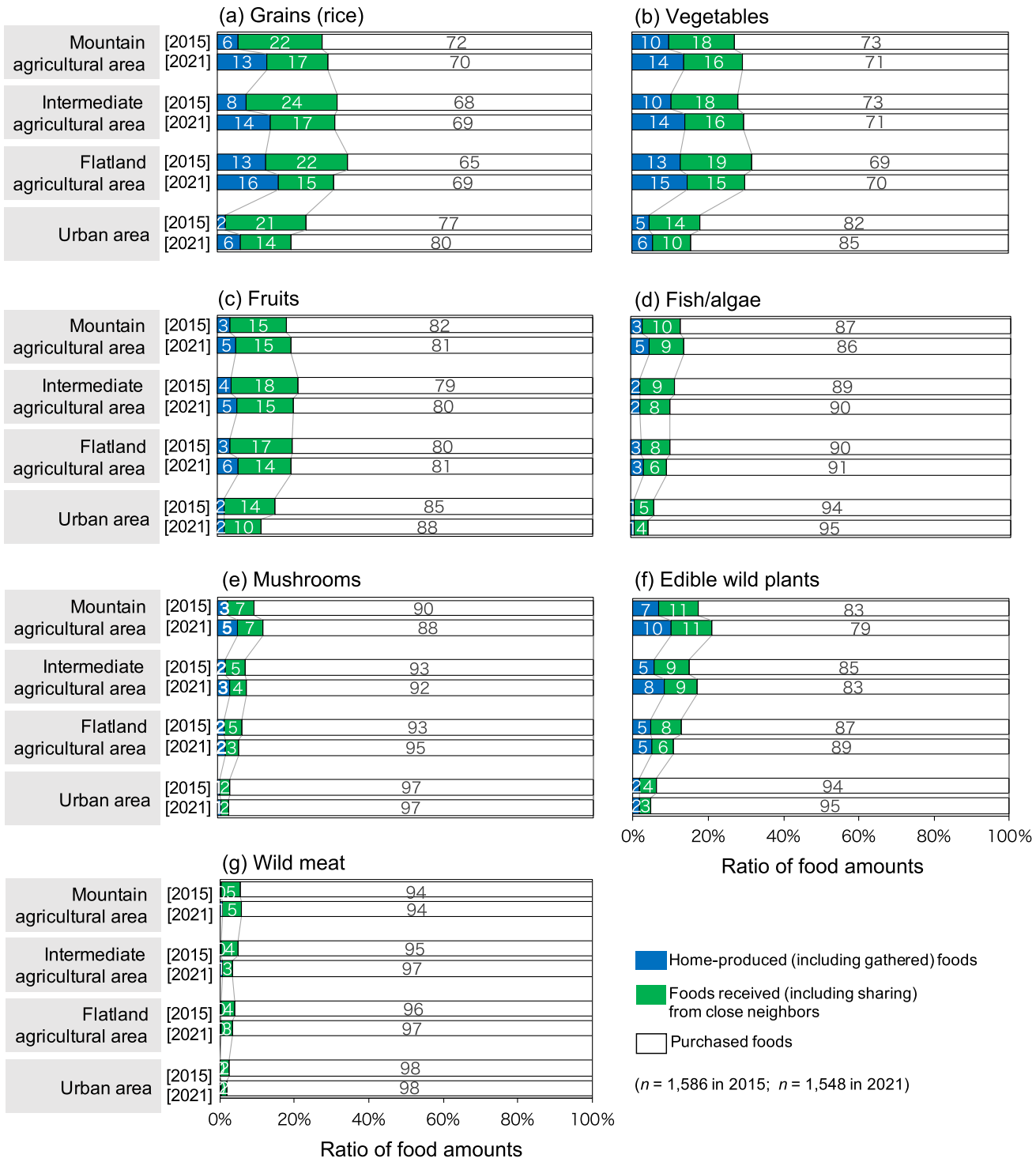

Fig. 2 Ratios of home consumption in overall diet in the years 2015 ($n=1586$) and 2021 ($n=1548$). The average value of the ratio of home-produced (including gathered) foods, foods received (including sharing) from close neighbors, friends and relatives, and purchased foods in the diet during a single year is shown by the following: food category (**a**–**f**); national agricultural area type classification of the Ministry of Agriculture, Forestry and Fisheries (mountainous agricultural area, intermediate agricultural area, flatland agricultural area, and urban area); and survey year (2015 and 2021). The numbers in the graph indicate the ratio values

Table 3 Multiple regression analysis results by a generalized linear model with the number of home-consumed foods as the dependent variable

Number of home comsumed food	Vegetables	Fruits	Fish/algae	Mushrooms	Edible wild plants	Wild meats
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
(Intercept)	6.03***	4.26***	4.79***	4.51***	4.13***	4.46***
Gender: Men (compared with women)	−0.87***	0.27	0.93***	0.63*	0.62**	1.15**
Age	0.01	−0.01	−0.02	−0.01	−0.01	−0.02
Area type: Flatland agricultual area (compared with urban)	0.67*	−0.07	0.03	−0.17	−0.03	−0.15
Area type: Intermediate agricultual area (compared with urban)	0.66*	−0.06	−0.27	−0.52	−0.31	−0.08
Area type: Mountain agricultual area (compared with urban)	0.32	−0.03	−0.05	−0.69	−0.24	−0.33
Survey year: 2021 (Compared with 2015)	−0.37	−0.16	0.00	0.25	−0.07	0.16

About the number of home-consumed foods (home-produced/gathered or received/shared food), the number of species of vegetables, fruits, fish/algae, mushrooms, and edible wild plants was set as the dependent variable, and gender, age, national agricultural area type classification, and survey year were set as explanatory variables. The explanation of the effect of each explanatory variable is enclosed in parentheses in the table. The probability distribution is gamma distribution. The significance levels are as follows: *p < 0.05, **p < 0.01, ***p < 0.001

Table 4 Results of multiple regression analysis using a generalized linear model with changes in home production and sharing behavior before and after the onset of the COVID-19 pandemic as dependent variables

Home production/gathering	Whether the respondent practiced home production/gathering prior to the pandemic	Changes in home production/gathering after the pandemic		
		Volume	Number of species	Time to spend
	Estimate	Estimate	Estimate	Estimate
(Intercept)	−0.27	1.30	0.50	0.58
Gender: Men (compared with women)	0.03	0.06	−0.02	−0.05
Age	0.02*	−0.20	0.00	0.00
Area type: Flatland agricultural area (compared with urban)	0.54*	0.09	0.09	0.00
Area type: Intermediate agricultural area (compared with urban)	0.63**	−0.05	0.03	−0.05
Area type: Mountain agricultural area (compared with urban)	0.92***	−0.01	0.04	0.01
Receiving/sharing	**Whether the respondent practiced receiving/sharing prior to the pandemic**	**Changes in receiving/sharing after the pandemic**		
		Volume	Number of species	Frequency	Number of partners
	Estimate	Estimate	Estimate	Estimate	Estimate
(Intercept)	0.84*	0.30	0.31	0.19	0.24
Gender: Men (compared with women)	−0.37*	0.07	0.02	0.06	0.05
Age	0.02*	0.00	0.00	0.00	0.00
Area type: Flatland agricultural area (compared with urban)	0.11	−0.01	−0.02	−0.02	0.04
Area type: Intermediate agricultural area (compared with urban)	0.13	−0.02	−0.03	−0.01	0.03
Area type: Mountain agricultural area (compared with urban)	0.44	0.02	0.00	0.03	0.05

Dependent variable was whether the respondent practiced home production (including gathering) and receiving (including sharing) prior to the pandemic. If they practiced these behaviors, dependent variables were the volume of home-produced/gathered foods, the number of home-produced/gathered species, the time spent on home production/gathering, the amount of food received/shared, the number of received/shared species, the frequency of receiving/sharing, and the increase/decrease in the number of receiving/sharing partners. The explanatory variables were gender, age, and national agricultural area type classification. The explanation of the effect of each explanatory variable is enclosed in parentheses in the table. The probability distribution is a binomial distribution, and the link function is a logit function. The significance levels are as follows: *p < 0.05, **p < 0.01, ***p < 0.001

onset of the COVID-19 pandemic, the presence or absence of sharing behavior, and attributes of the respondents that explain specific changes (Table 4). Even before the pandemic, many older adults and people living in agricultural areas practiced home production and sharing, while many younger people, men, and residents of urban areas started to practice these behaviors after the onset of the pandemic. Figure 3 shows the presence or absence of home production and sharing before and after the onset of the COVID-19 pandemic. Of the respondents currently practicing home production in urban areas, 36% were found to have started home production since the pandemic (Fig. 3a). With regard to sharing, 20% of the respondents currently practicing sharing in urban areas started to do so since the pandemic (Fig. 3b).

No obvious differences were observed in terms of gender, age, and residential area regarding changes in home consumption behavior and sharing behavior (e.g., volume, number of food species) before and after the onset of the pandemic (Table 4). Figure 4 shows the overall tendencies and changes in home-production and sharing behavior after the onset of the pandemic (as compared to before). The majority of the respondents answered that there was no change in the nature of both home production and sharing. However, in the case of home production, the proportion of people who answered "increased" with regard to the volume, number of food species, and time spent on food production exceeded the proportion of people who answered “decreased” (by 2 times). In terms of sharing, the proportion of people who answered “decreased” with regard to the volume, number of food species, frequency, and number of people sharing food exceeded the proportion of people who answered “increased” (by 2–3 times).

Discussion

This study found that home consumption (consumption of home produced/gathered food and received/shared food which was produced/gathered in other households without commercial transaction) was practiced to a certain extent in Japan, with a wide variety of foods and many different species of food. This study is the first report to investigate the actual situation of home consumption on a national scale in Japan aiming to detect any long-term changes. Across both the 2015 and 2021 surveys, as shown in Fig. 1, the average ratios for home consumption (i.e., the sum of home-produced food and shared food) were as follows: 29% for rice, 26% for vegetables, 18% for fruits, and 10% for fish and algae, 7% for mushrooms, 13% for edible wild plants, and 4% for wild meat, assuming that the amount of food comprising meals in one year is 100%. Since we conducted online questionnaire surveys, it is possible that the responses were limited to those who have good access to the Internet and are accustomed to answering online questionnaires. Nevertheless, the fact that we were able to efficiently sample a large number of potential respondents owned by a major online research company, without gender, age, or spatial bias (as evenly as possible from urban to rural areas), would have contributed greatly to efficiently analyzing and understanding the actual status and trends of home consumption in Japan.

Contribution to GHG emissions and transportation cost reduction

The results suggest that such Japanese customs and lifestyles of home consumption may already be an effective means to overcome several global challenges. In terms of GHG emissions, home consumption generally does not involve food transportation (at least for the consumption of rice, vegetables and fruits harvested from home rice fields and gardens), and so emissions resulting from transportation of home-grown foods are assumed to be low. The same goes for sharing with neighbors, and families and friends living nearby. Regarding food categories, the consumption of wild meat (meat not produced from industrial livestock raised under intensive agricultural conditions) is expected to be particularly effective in terms of reducing GHG emissions (Nunes et al. 2021), despite survey results showing that only a small amount of wild meat is consumed. On the other hand, it should be noted that other activities may not necessarily contribute to reducing GHG emissions, including sending foods via courier services across country to families living in other prefectures, (Kamiyama et al. 2014) or gathering/hunting wild foods in coastal/mountainous areas that are only accessible by car (Coley et al. 2009). Further research may be needed to understand to what extent the home production and sharing behaviors contribute to GHG emission reductions overall.

At the same time, it is important to address the problem of Japan’s significantly high food miles (total amount of food transported x distance). This is related to the ratio of imported food compared with other developed countries, leading to a significantly low self-sufficiency rate at the national scale (Ministry of Agriculture, Forestry and Fisheries 2022; Shimada and Fujimori 2022). Given this situation, “local production for local consumption” has become even more important in Japan recently (Yokohari 2012; Hara et al. 2013; Tsuchiya et al. 2021). Such indicators, however, are calculated on a market basis, and the uncertain situation with regards to home consumption is not reflected in these calculations. In the future, it will be necessary to deepen our understanding of the customs and lifestyles surrounding home consumption and to take these aspects of home consumption into account

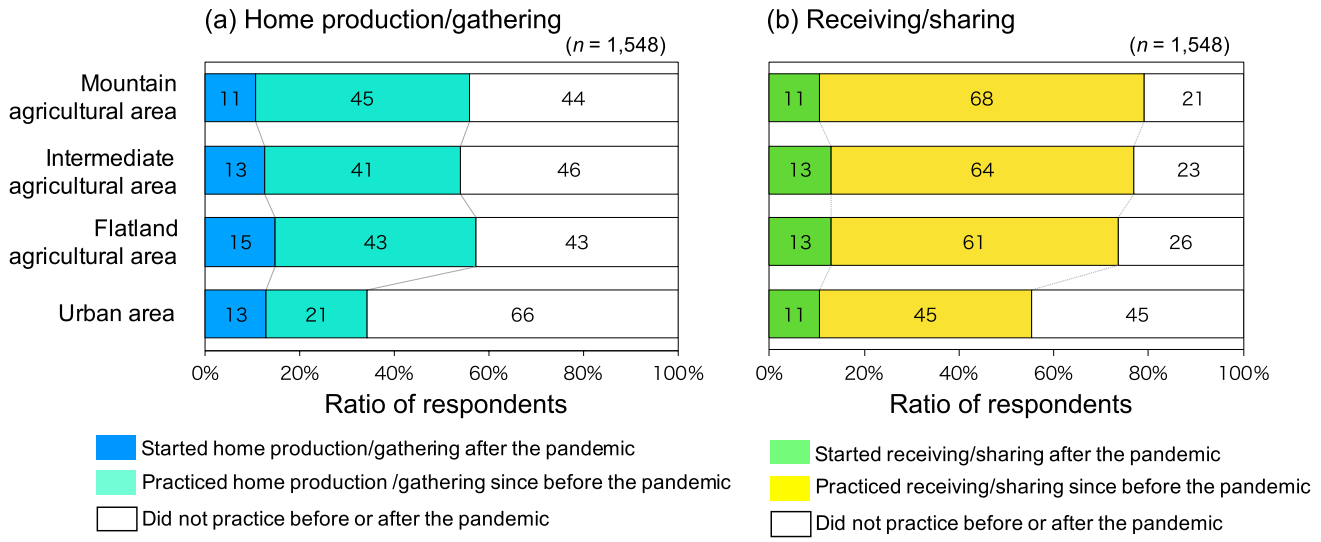

Fig. 3 Presence or absence of **a** home production/gathering and **b** receiving/sharing before and after the onset of the COVID-19 pandemic, which was asked in the survey conducted in 2021 ($n=1548$). This figure shows the ratio of people who answered "started home production/gathering following the onset of the pandemic," "practiced home production/gathering prior to the onset of the pandemic," and "did not practice home production/gathering before or after the pandemic" in (**a**); in addition to those who answered "started receiving/sharing after the pandemic," "practiced receiving/sharing since before the pandemic," and "did not practice receiving/sharing before or after the pandemic" in (**b**) in terms of the national agricultural area type classification by the Ministry of Agriculture, Forestry and Fisheries (mountain agricultural area, intermediate agricultural area, flatland agricultural area, and urban area). The numbers in the graph show the number of respondents. In the question, the reference point of "after the onset of the pandemic" is February 2020

in the calculations, which enables us to balance between commercial and non- commercial foods and in turn will contribute to building a sustainable society that combines a sustainable localized food system.

Contribution to physical health

The situation of home consumption revealed through this study has also provided important insights into people's health. Recently, the consumption of harmful ultra-processed foods (UPFs) (Monteiro et al. 2019) has been increasing, but this study shows that more home-produced

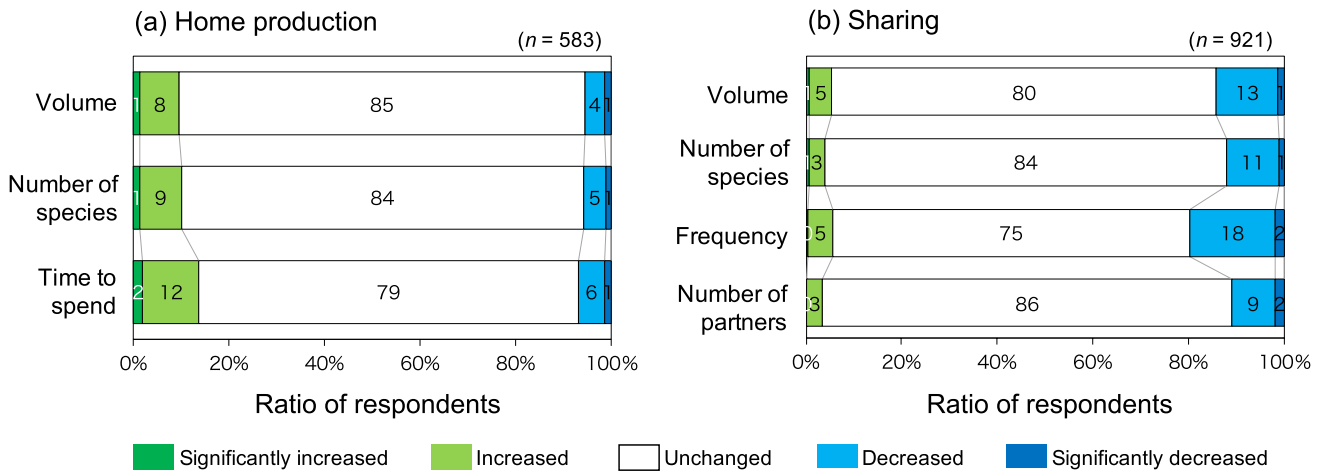

Fig. 4 Changes in **a** home production/gathering and **b** receiving/sharing behavior after the pandemic compared to before the pandemic. The figure shows post-pandemic changes in terms of **a** the volume of home production/gathering, number of home-produced/gathered species, and time spent on home production/gathering; and **b** the volume of food received/shared, number of received/shared species, frequency of receiving/sharing, and the number of receiving/sharing partners, targeting **a** respondents who have been practicing home production/gathering ($n=583$) and **b** receiving/sharing ($n=921$) prior to the pandemic, the ratio of respondents. The numbers in the graph show the number of respondents. In the question, the reference point f "after the onset of the pandemic" is February 2020

fresh foods are consumed in rural agricultural areas, which could be understood that UPF consumption might be kept low in rural Japan. In addition, there are major health benefits to be gained due to the wide variety of nutrients in home-produced fresh foods and gathered wild foods (Łuczaj et al. 2013; Tatebayashi et al. 2019). Although a clear relationship between health and home consumption cannot be determined from this study, previous studies have shown that homegardens have health-promoting effects such as obesity prevention due to physical activity and healthy eating (George et al. 2015). Thus, the relationship between home consumption and health in Japan would be worth examining in the future.

Suffering from obesity can potentially affect people's health and can cause a range of medically/physically/mentally straining conditions. Using the Global Burden of Disease Study (GBD) 2017, ai et al. (2020) analyzed global deaths and disability-adjusted life years (DALYs) attributable to high BMI in 195 countries and territories. It showed that the age-standardized rate of high-BMI-related DALYs in Japan was 538.2 DALYs (per 100,000 people) in 2017, while the global average was 1816.9 DALYs. Compared with other countries, for example, the same rates were 2355.1 DALYs per 100,000 population in the United States, where overall health and environmental costs come to US$2.1 trillion annually including US$360 million to tackle obesity and another US$600 million for other diet-related non-communicable diseases (The Rockefeller Foundation 2021). This suggests that medical costs to tackle obesity are significantly lower in Japan. Past studies have reported that the Japanese traditional diet, often characterized by high consumption of rice, fish, and soybean products and low consumption of animal fat and meat, can contribute to healthy and sustainable diets (Koga et al. 2017; Gabriel et al. 2018). In addition, OECD (2019) reports that the impact of obesity on the wider economy beyond health expenditure (e.g. mortality, early retirement, absenteeism, unemployment etc.) is between 0.5 and 1.6% of GDP, which carries considerable costs for society, so the Japanese diet and dietary lifestyle supported by the custom of home consumption may be a useful model case for other countries with high economic burden associated with diet-related chronic disease.

Contribution to cultural and social aspects

The results showed that the proportion of food received from others for home consumption was also high, indicating that people are consuming locally-produced food not only through home production but also through relationships with local people (i.e. neighbors, friends, and relatives). From the viewpoint of anthropology, social relationships forged through the sharing or gifting of natural resources (i.e. ecosystem services) have played an essential role in social integration, maintenance of tradition, lifestyles, and culture (Price 1975; Nolin 2012; Widlok 2017). Befu (1968) summarized the anthropological importance of gift-giving in Japan and reported that pervasive practices—for example, sharing agricultural crops with neighbors and relatives—are embedded in social structures and principles of reciprocity. Stryamets et al. (2015) showed that the tradition of wild plant gathering also has a positive influence on social relations. Kamiyama et al. (2016) investigated home production and sharing at the community level and found that households with a larger sharing network tend to have a higher amount of home consumption and have a higher number of food species. As such, these relationships via home-produced food can be regarded as indicators of social capital at the individual level (Kamiyama et al. 2020). The sharing of locally-produced food for home consumption revealed on a national scale in this study suggests that part of the local, non-commercial food system is generally supported by social relations and reciprocal relationships in Japan. In other words, social networks and sustainability in local communities will be maintained partly by promoting and preserving the custom of sharing home-produced food.

The amount of home-produced and received food, as well as the number of species of food, were generally found to be higher in agricultural areas generally known as *Satoyama* than in urban areas (Table 2, Fig. 2), which is consistent with previous studies in Japan (Kamiyama et al. 2014, 2020) and other countries (Smith 2002; Morton et al. 2008; Jehlička and Daněk, 2017). Smith (2002) compared the production and exchange of home-grown food in two sites in Slovakia and found that households in provincial cities buy fewer market potatoes, vegetables, and fruits than households in the capital do. Smith (2002) attributed these findings to longstanding practices and not to economic necessity. Jehlička and Daněk (2017) investigated home production and sharing in rural areas in the Czech Republic and concluded that these practices were sustainable alternative food networks driven by a desire for fresh and healthy food, fulfilling personal hobbies, and the development of enjoyable social ties. In addition, in Japan's Satoyama, it is known that indigenous dishes served not only in everyday life but also in local events such as weddings, funerals, and traditional religious rituals, are longstanding traditions grounded in the diversity of indigenous home-produced foods (Noto Regional Association for GIAHS Promotion and Cooperation 2010; Nakazawa et al. 2014). It can be understood that the greater varieties and quantities of home-produced and shared foods in agricultural areas indicated in this study align with longstanding customs

connecting people and nature in *Satoyama* where diverse ecosystem services and human well-being are produced.

Changes between surveys in 2015 and 2021, and the impact of the COVID-19 pandemic

In the six-year period between 2015 and 2021, there was no nationwide change in home consumption (covering home production, gathering, and sharing). Previous studies predicted that there is likely to be a decline in home consumption behavior that does not involve market transactions due to various social factors, such as the declining birthrate and aging population, depopulation, and changes in consumption behavior (Kamiyama et al. 2014). However, despite no obvious decline, both surveys indicate that it is older people who tend to engage in home consumption. Therefore, this trend is likely to decline in the long term, if no efforts to sustain it are implemented.

Additionally, according to the 2021 survey, the volume of home production generally increased, and the volume of sharing decreased compared to 2015. This tendency is consistent with the result obtained from a question in this study that directly inquired about the effects of the COVID-19 pandemic on home production (as shown in Fig. 4). In terms of volume, the number of food species, and time spent on home production, the number of respondents who answered "increased" exceeded those who answered “decreased”. Furthermore, with regard to the volume, nature, and frequency of sharing and the number of sharing partners, the number of respondents who answered "decreased" exceeded those who answered “increased”. It is not clear from this study what factors might have affected the results in drawing a comparison between 2015 and 2021, but when considered together with the results in Fig. 4, it is possible that the changes from 2015 to 2021 (i.e., an increase in home production and decrease in the amount of sharing) could be traced to the onset of the pandemic. However, it should be noted that the majority of respondents who were directly asked about the effects of the COVID-19 pandemic on home production and sharing behavior (Fig. 4) answered “no change”, thereby indicating that home consumption is a resilient system that is not significantly affected even by a major pandemic.

Although the amount of home-produced and received food, as well as the number of species of food, were generally found to be higher in agricultural areas than in urban areas, the findings also suggest that the COVID-19 pandemic may have provided an opportunity for younger people, men, and residents of urban areas who have not practiced home production or sharing in the past, to start engaging in such activities (Fig. 3). These people, who either had no knowledge of these practices or could not allocate the requisite time and effort to food sharing and home production, have started to engage in these activities due to increased time spent at home as a result of voluntary self-isolation (Mullins et al. 2021). In addition to the importance of urban agricultural production which has been demonstrated from the perspective of food security, practices such as the use of municipal farms, allotment gardens and tools to share farms/gardens and produced food can contribute to maintaining social relationships in urban areas through food production and sharing. Indeed, it is reported that urban homegardens can build resilience among households by increasing food security, individual empowerment, social relations, resistance to marginalization, community development, production of cultural identity, ecological processes and biodiversity, and conservation (Taylor and Lovell 2014). Creating diverse home production and sharing styles outside of agricultural areas in the future will require a mechanism to establish and promote these practices in urban areas so that they become an integral part of the daily lives of residents, rather than a temporary habit developed as a result of self-isolation during the COVID-19 pandemic.

Ways forward

The practices and challenges related to home food consumption will make a considerable contribution to SDGs (United Nations 2015): specifically, first, they contribute to SDG 2 “End hunger, achieve food security and improve nutrition and promote sustainable agriculture”, and particularly Target 2.4 “ensure sustainable food production systems and implement resilient agricultural practices (…) that help maintain ecosystems, that strengthen capacity for adaptation to climate change (…) and that progressively improve land and soil quality”. At the same time, we have described in the previous paragraphs the multiple benefits of home food consumption including gathering from the wild and sharing/gifting, such as reducing GHG emissions, and maintaining physical health, traditional and regional characteristics, and social relations as a resilient system even under a major pandemic. Considering these benefits, home food consumption can also contribute to access to safe and nutritious food (Targets 2.1 and 2.2), maintenance of the genetic diversity and traditional knowledge (Target 2.5), sustainable development and lifestyles in harmony with nature (Target 12.8), strengthening resilience and adaptive capacity to climate-related hazards and natural disasters, and carbon sequestration potential (Targets 13.1 and 13.2), biodiversity conservation (Target 15.5), and concepts of food sovereignty (Target 16.7). Therefore, we can conclude that home production and sharing behavior may play a critical role in promoting the transition from a resource-intensive growth model towards a more resource-efficient, inclusive, and sustainable growth model.

To promote and preserve the traditional Japanese diet supported by the custom of home production and food sharing as an inclusive and sustainable local food system, it might be necessary to redefine the Japanese diet in terms of home production and food sharing, and at the same time to develop subsystems, and activate these subsystems as a mechanism for resilience (Saito and Kamiyama 2016). For example, Kim et al. (2016) clearly defined the traditional Korean diet by clarifying the fundamental principles of what kind of combinations of dishes and cooking methods are used to serve the traditional diet, and by evaluating health-promoting effects and elements of tradition, custom, and culture that are involved not only in the raw ingredients but also in the diet. In terms of food sharing, there was a case study conducted in Hachijo Island, Japan, whereby a mechanism was proposed to strengthen the stockpiling system in case of emergencies and at the same time reduce the environmental and economic burden by jointly owning and using communal freezers in the village instead of freezers in individual households to stock home-produced food (Saito et al. 2015). Through such efforts, home consumption of food as NbS could facilitate new decentralized governance structures for food and lead to the development of local food strategies with citizen participation that emphasize food embedded in local contexts and needs (Miralles-Wilhelm 2021). It will also be important to assess and examine mechanisms that might enable home consumption following the pandemic and any new emergencies that may arise in the future (Bisoffi et al. 2021). Although previous case studies at the local scale suggested that social capital, which includes food sharing, contributes to sustainable community development and improvement of community resilience (Saito et al. 2019), it is also true that various measures to prevent the spread of infection following the onset of the COVID-19 pandemic have limited people's interaction and ability to use shared spaces and items. At the same time, viewing the pandemic as an opportunity (Bisoffi et al. 2021) it may be necessary to re-think and re-value the local food system with a focus on the importance of home consumption and resilience in emergencies.

Conclusion

The management of food systems, including food production, distribution, and consumption, is widely recognized as one of the most critical global challenges facing humankind today. Local food production and consumption on a relatively small spatial scale with a short supply chain has been demonstrated as a sustainable food system. In this study, we focused on home production and the sharing of home-produced foods with local networks in Japan, without involving market transactions, and conducted nationwide online questionnaire surveys in 2015 and 2021 to investigate the actual state of home consumption (i.e., consumption of home produced/gathered food and received/shared food which was produced/gathered in other households) and any changes that occurred in the intervening six years. In addition, we evaluated the COVID-19 pandemic, which started at the beginning of 2020 in Japan, to see if it had any effects on home production and sharing behaviors. This is the first study to investigate the actual situation of home consumption on a national scale in Japan, with the aim of detecting any long-term changes. It was found that home consumption was practiced to a certain extent in Japan, with a wide variety of foods and many different species of food, and that this situation has not changed greatly over time even under the COVID-19 pandemic. The findings suggest that such customs and lifestyles of home consumption embedded in the local food system in Japan can be understood as a sustainable and resilient system, with the potential to solve various global challenges as nature-based solutions, helping to meet the targets of the SDGs. In particular, home consumption may contribute to a reduction in GHG emissions due to the minimal transportation required. Home consumption also supports the Japanese traditional diet, by promoting a healthy lifestyle through the consumption of fresh and healthy food. This may contribute to the low incidences of non-communicable diseases and low public and personal medical costs in Japan. Furthermore, through food sharing (i.e. giving and/or receiving food), social capital can be created, providing an additional benefit for individuals and local communities. Going forward, it will be necessary to develop the custom of home production and food sharing as a subsystem and activate this as a mechanism for change both in cities and rural areas. At the same time, a quantification method should be developed and standardized to evaluate the multiple benefits of home consumption. This will enable international comparisons and application outside Japan, thereby promoting transitions from a resource-intensive growth model towards a more resource-efficient, inclusive, and sustainable growth model.

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Data availability The data that support the findings of this study are available from the corresponding author upon request.

Declarations

Conflict of interest The authors have no conflicts of interests/competing interests to declare relevant to this article's content.

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