

## Determinants of food loss and waste behaviour among farming households in southwestern Nigeria

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Received: August 2025

Published: March 2026

DOI: [https://doi.org/10.53936/afjare.2026.21\(1\).3](https://doi.org/10.53936/afjare.2026.21(1).3)

### Abstract

*This study examines determinants of food loss and waste behaviour among farming households in western Nigeria. Stratified and systematic random sampling was used to select 300 cases of primary data collected in two periods of late and early rain, respectively. Data were analysed using the food*

*loss and waste (FLW) index and simultaneous equation model. The FLW index was 0.48, with food loss at 0.18 and food waste at 0.3. The simultaneous regression results revealed the drivers of food loss/waste to be household size, education, dependency ratio and non-expenses on food. A 10% increase in food expenses enhances FLW by 0.89% for the food poor and by 0.49% in the moderately food non-poor. Transition households experiencing food security had a strong correlation with low FLW. As income generation declines over time, food-secure households experience an increase in food insecurity and FLW. Thus, we recommend a policy on FLW reduction and a more varied occupational structure that can add value to labour time for reasonable income support.*

**Key words:** panel data, post-harvest loss, FLW index, simultaneous-equation model, household food security, Nigerian agriculture

## 1. Introduction

In the context of the food security nexus, one of the primary sustainability issues that requires immediate attention is food loss and waste (Skawińska & Zalewski 2022; Boiteau & Pingali 2023; Schneider *et al.* 2024; Olabode *et al.* 2025). Policymakers, researchers, businesses and civil society organisations have made food loss and waste a top priority in recent years, both globally and specifically in developing nations such as Nigeria (Akerle *et al.* 2017; Boiteau & Pingali 2023). Food security and food loss or waste are related (Cattaneo *et al.* 2021; Cafiero *et al.* 2024). Achieving zero food loss and waste are part of the strategy to end hunger and overcome the Zero Hunger Challenge (United Nations Environment Programme [UNEP] 2021; Rosegrant *et al.* 2024). Therefore, among other things, preventing or minimising food loss and waste would be necessary to achieve zero hunger. A thorough understanding of the causal relationship between food loss and waste and the food security nexus is necessary (Hossain *et al.* 2023). Food loss and waste is a worldwide problem that is currently receiving more attention due to issues with food security and associated environmental concerns (Rosegrant *et al.* 2024).

Consumer behaviour has been examined in household food waste studies in an effort to explain food security, poverty and household food waste behaviours (Qi *et al.* 2021). Reports from the Food and Agriculture Organization of the United Nations ([FAO] 2019) and HLPE (2020) indicate the need to reduce food loss and waste, which is firmly embedded in the 2030 Agenda for Sustainable Development. These reports deduced that food loss and waste reduction are considered important for improving food security and nutrition, promoting environmental sustainability and lowering production costs. However, efforts to reduce food loss and waste will only be effective if informed by a solid understanding of the problem. While in alignment with the global SDG 12.3 goals on food loss/waste, Target 12.3, the percentage of food lost globally after harvest on farms, in transport and storage and at the wholesale and processing levels is usually attributed to structural inadequacies in the countries. Food loss and waste have been identified in the literature as a recurring problem in developing countries, yet little is documented (Wang *et al.* 2021; Apeti & Edoh 2024). This continued increase in food insecurity, which is focused more on low-level subsistence than was achieved 20 or 30 years ago, should raise serious concerns. This is the justification for conducting the current study.

Food ‘loss’ occurs before it reaches the consumer due to problems related to the stages of production, storage, processing and distribution (Caitlin *et al.* 2025). However, food that is fit for consumption but is purposefully prohibited from entering the selling or consumption stages is referred to as ‘waste’ (Pérez-Escamilla *et al.* 2024; Thorsen *et al.* 2024). This distinction highlights the need for targeted interventions at various points in the food supply chain to reduce both loss and waste in the food-security nexus (Ahmed *et al.* 2024). This study aimed to assess the factors influencing food loss and waste (FLW) in the food-security nexus among farming households in southwest Nigeria and identify

strategies for its reduction. Thus, knowing the relationship between food loss/waste and food security can improve micro-policy for household-level food waste reduction (Anderson *et al.* 2023). By implementing targeted strategies that address the root causes of food waste, policymakers can enhance food availability and accessibility (Siderius *et al.* 2024). Nigeria grapples with a significant food loss and waste challenge, with approximately 40% of its total food production lost annually (FAO 2025.). The 2025 FAO report indicated that 33.2 million Nigerians were expected to be acutely food insecure during the June-August lean season in 2025, with nearly 1.8 million in an emergency situation. The southwestern region is not the primary focus of the most urgent food insecurity concerns, but it is still affected by about 5.4% post-harvest annual losses. Hence, there is a need to build up resilience in the face of the prevalence of FLW in this region. The study is structured as follows: Section 1 contains the introduction, and Section 2 provides the theoretical framework, which served as the study's driving force. The study's methodology is covered in Section 3, followed by the results and discussion in Section 4, while Section 5 concludes the study.

## 2. Theoretical framework

According to Campoy-Muñoz *et al.* (2017), the most frequently cited connection between food waste and food security is an implicit one. The number of hungry people worldwide is listed after the amount of food wasted worldwide, but food loss cannot be calculated at the micro-level other than at the macro level (Corrado & Palumbo 2022; Zahidi *et al.* 2024). The FAO (2024) estimated that approximately 1.3 billion tons of edible food are lost or wasted annually worldwide. This staggering figure highlights the urgent need for systemic changes in food production, distribution and consumption patterns. Addressing this issue not only requires innovative solutions, but also a collective commitment from individuals, businesses and governments to reduce food waste at every stage of the supply chain. Wealthy households buy and cook more than they actually need, which ultimately leads to more food waste, while food-insecure households are thought to be more concerned about the financial volatility of food prices, which influences them to buy food ingredients in bulk. Because most foods are not consumed in time, this results in food waste (Dhar *et al.* 2024). Therefore, from the perspective of econometric estimation, it is necessary to ascertain the relationship between consumer attitudes and behaviours that result in food loss and waste. Understanding these dynamics can help develop targeted interventions aimed at reducing food waste, particularly among vulnerable populations. This can be achieved by promoting better purchasing practices and efficient food storage/usage strategies (Montalvo *et al.* 2024).

## 3. Methodology

### 3.1 Study area

One of Nigeria's six main regions is the southwest. The states in the southwestern region are Lagos, Oyo, Ogun, Ondo, Osun and Ekiti. Three states – Lagos, Ogun and Ondo – were randomly chosen from the six states in southwest Nigeria. Ondo State is primarily an agricultural state with plenty of job opportunities in both the public and private sectors. Moreover, the state has a reputation for being conservative when it comes to FLW. Ogun State is a commercial and agricultural town, where FLW is prevalent, although under control in certain areas. On the other hand, FLW is visible in Lagos, the region's commercial centre and a multicultural city.

### 3.2 Sampling techniques

The sampling frame adopted for this study was obtained from the agricultural development programmes (ADP) of each respective location. In each of the respective ADP zones, 1 600 registered

farmers were sampled (sampling frame) (Table 1). The study adopted stratified random sampling to select four rural/semi-urban local government areas (LGAs) in each state, giving a total of 12 LGAs. These four LGAs were randomly selected based on information sourced from the Nigeria Bureau of Statistics (NBS 2023). Systematic random sampling was used to select 40 households from each of the selected 12 rural/semi-urban communities. Thus, a total of 160 households per state (selection of the 160 households per state is a result of the 10% taken from the sampling frame of each of the selected state), and 480 households in all, were selected during the first round of data collection (Table 1). This took place from October 2022 to February 2023, when two visits were made per month (first week of the month and last week of the month), giving a total of 10 visits for data enumeration regarding the identified households. The same methodology was used for the second round of data collection, from March to July 2023. On visiting the same households during the second round of data collection, only 300 households' data were useful for data analysis. The unused data of the other 180 households had incomplete information, missing data in the questionnaire that could not provide sufficient information for data analysis, and respondents who had relocated and could not be traced. The information was collected through the use of piloted interview schedules/questionnaires. Food price data were obtained from community market surveys. Both primary and secondary data were used for this study. Based on the specific nature of the data requirement for this study, panel data were adopted and they were collected at two times over a period of ten months (October 2022 to July 2023).

**Table 1: Distribution of the selection procedure and sample size from the sampling frame**

State	Zones (75%)	LGAs/blocks (75%)	Cells/towns (50%)	Registered contact farmers/Sampling frame	10% selection of the registered contact farmers
Ondo	Zone 1				
	Akure South	Akure South	Akure	200	20
			Oda Road	200	20
	Owo	Owo	Owo	200	20
			Ipele	200	20
	Irele	Irele	Irele	200	20
			Sabomi	200	20
	Zone III				
	Idanre	Idanre/Ileoluji	Idanre	200	20
			Ileoluji	200	20
Lagos	Badagry	Badagry	Gayingbo	200	20
			Iworo	200	20
	Epe	Epe	Araga	200	20
			Igboye	200	20
	Ikorodu	Ikorodu	Agbowo	200	20
			Igbodu	200	20
	Mushin	Mushin	Ojuiwoye	200	20
			Isolo	200	20
Ogun	Ijebu	Odogbolu	Odogbolu	200	20
		Ijebu ode	Ijebu	200	20
	Remo	Ikenne	Ikenne	200	20
		Sagamu	Sagamu	200	20
	Egba	Abeokuta north	Abeokuta	200	20
		Ewekoro	Ewekoro	200	20
	Yewa	Yewa south	Ayetoro	200	20
		Ado odo/Ota	Ota	200	20
		<b>Total</b>		<b>480</b>	

Source: Registered arable crop farmers from the agricultural development programme (ADP) list, 2023

Primary data were collected with the aid of a well-structured and tested questionnaire, administered to farming households in the area of study. Secondary data came from the Central Bank of Nigeria and the National Bureau of Statistics. Food consumption and FLW information/data were collected on an individual basis from the households. Magnitudes of daily food intake were collected for each member of the household, using a 48-hour recall method. Thus, daily food intake quantities for each individual in the household and FLW were collected twice in the month of March and also twice in the month of November. The analysis reported here was based on per capita daily food consumption averaged over the 10 months of data collection. This is designed to reduce measurement errors in food consumption by smoothing day-to-day fluctuations in food intake. These quantities were then converted into kilogram units. Income and expenditure information as well as FLW data were obtained on a fortnightly basis for a period of ten months.

### 3.3 Econometric estimation of food insecurity transition

A household is considered food secure if all of its members have access to enough safe, nourishing food to sustain an active and healthy lifestyle (Bayliss-Smith 2020; Hellegers 2022). This definition emphasises not only the quantity of food available, but also its quality (Aregawi *et al.* 2024). The food security nexus is a dynamic issue rather than a static one (Zasada *et al.* 2019; Santeramo 2021; Giles *et al.* 2024). Thus, using the Markov chain model as a framework, this study investigated the transition to food security using food loss and waste as the drivers. To fit the study's objectives, the Markov chain theory and methodology used by Baulch and McCulloch (1998) and Nord *et al.* (1999) were modified to fit the scope of the study.

In order to comprehend the correlates and causes of movement into and out of food insecurity, the Markov chain model was used to investigate the dynamics of food security. The number of households in and out of a food-secure situation during a specific time period, broken down by their food-security status, is displayed in the food-insecurity transition matrix. This matrix provides valuable insights into patterns of food security, revealing how various factors influence households' transitions between secure and insecure status. By analysing these transitions, researchers can identify key determinants that may contribute to improving food security interventions. As a result, it is simple to determine how many households have experienced food insecurity or not, as well as how many people have fled or fallen into it. The likelihood of entering and leaving between the two periods can then be computed from the matrix. In order to obtain the transition probability matrix displayed in Equation (1), the items in the transition matrix above were transformed into probability values of entering and leaving a situation of food insecurity. Each item was then divided by the corresponding row total.

The Markov food insecurity transition matrix can be derived as follows:

$$\begin{pmatrix} F_{11} & F_{12} & F_{13} \\ F_{21} & F_{22} & F_{23} \\ F_{31} & F_{32} & F_{33} \end{pmatrix} \quad (1)$$

The vector of initial probability  $P_H(0)$  is obtained by dividing each column total by the grand total. Thereafter, the proportion of households that will be in each category in the subsequent periods can be known by using the following equation:

$$P_H(T) = P_H(0)P^T, \quad (2)$$

where T is the time period in years.

Long-term equilibrium ( $Le$ ) would be derived from:

$$LeP_H = Le, \quad (3)$$

As

$$(Le_1 Le_2 Le_3) = \begin{pmatrix} F_{11} & F_{12} & F_{13} \\ F_{21} & F_{22} & F_{23} \\ F_{31} & F_{32} & F_{33} \end{pmatrix} = (Le_1 Le_2 Le_3) \quad (4)$$

The solution to the above matrix produced  $Le_1$ ,  $Le_2$  and  $Le_3$ , which are the proportion of households that will be food secure, moderately food insecure and core food insecure at the equilibrium, respectively.  $Le_1$  is the equilibrium state for core food secure;  $Le_2$  the equilibrium state for moderate food insecure and  $Le_3$  the equilibrium state for food secure. From Table 2, the simple probability of entry and exit of the food (in)secure are then derived. To obtain the food-secure/insecure households, a food-secure/insecure line will be constructed to delineate the food secure and insecure status of the households.

**Table 2: First-order Markov model of food insecurity transition**

Period I – early rain	Period II – late rain			Total
	Core food insecurity	Moderate food insecurity	Food security	
Core food insecurity	CFIS	MFIS	FS	
Moderate food insecurity	CFIS	MFIS	FS	
Food security	CFIS	MFIS	FS	
<b>Total</b>				<b>300</b>

Notes: CFIS = core food insecurity; MFIS = moderate food insecurity; FS = food security

The study used the following specific steps in the delineation of food secure/insecure households (Greer & Thorbecke 1986):

1. The value of food ( $VF_{hj}^*$ ) consumed by each household, which is equal to the sum of the value of purchased food ( $Vh_{hj}^*$ ) and the value of own production consumed ( $Ch_{hj}^*$ ), was determined by:

$$VF_{hj}^* = Vh_{hj}^* + Ch_{hj}^*, \quad (5)$$

where  $Vh_{hj}^*$  is deduced as

$$Vh_{hj}^* = \sum Q_{ij} Ph_{ij}, \quad (6)$$

where  $Vh_{hj}^*$  is the value of purchased food consumed by the  $j$ th household;  $Q_{ij}$  is the quantity of the  $i$ th food item purchased by the  $j$ th household; and  $Ph_{ij}$  is the local price paid by the  $j$ th household for the  $i$ th food item. The value of own output or food consumed by the household,  $Gh_{ij}$ , is the product of own production (including gifts) ( $OP_i$ ) and local prices ( $P_{xi}$ ). The quantity,  $OP_{ij}$ , is the imputed value of consumption:

$$Gh_{ij}^* = \sum OP_{ij} Ph_{ij} \quad (7)$$

2. The adult equivalent  $H_j$  for each household was proxied by the household size.

3.  $VFh_j^*$  was deduced by

$$VFh_j^* = \frac{VFh_{ij}^*}{H_j}, \quad (8)$$

where  $VFh_j^*$  is the total value of food consumed by the  $j$ th household;  $H_j$  is the adult equivalent for the  $j$ th household, and  $VFh_{ij}^*$  is the total value of food consumed per adult equivalent units.

4. The different types and quantities of foods consumed by the different households were converted to calories ( $Ca_j$ ) using the calorie equivalents.

5. A regression model was fitted to estimate parameters to determine the food insecurity threshold (line):

$$\ln Tfx_j = a + bCa_j, \quad (9)$$

where  $Tfx_j$  is the total food expenditure per adult equivalent by household  $j$ ;  $Ca_j$  the total calorie consumption per adult equivalent by household  $j$ , and  $a$  and  $b$  are the parameters to be estimated.

6. The food poverty line,  $Z$  (which is the estimated cost of acquiring the calorie recommended daily allowance (RDA)) was estimated as:

$$Z = Le^{a+bRe}, \quad (10)$$

where  $Z$  is the food insufficiency threshold (line) and the recommended daily allowance of calories per adult equivalent, of 2 350 (Schubert, 1994).

7. The classifications of various measures of food insufficiency households ( $Ph_\alpha$ ) were computed using the formula of Foster *et al.* (1984):

$$Ph_\alpha = \frac{1}{N} \sum_{i=1}^{Qh} \left( \frac{Z - Y_i}{Z} \right)^\alpha, \quad (11)$$

where  $Z$  is the food insecurity line;  $Y_i$  is food expenditure measured in Naira ( $N$ ) $_i$  ( $i = 1, 2, \dots, q$ );  $q$  is the number of households below the food insecurity line (food poverty households);  $N$  is the total number of sampled households; and  $\alpha$  are the parameters of the Foster Greer and Thorbecke index ( $Ph_\alpha$ ).  $\alpha \geq 0$ , and it can take three values, of 0, 1 and 2. These values give rise to different implications. This formula was therefore used to decompose the farming households into classes of food-security/food-insecurity status.

### 3.4 Calculation of food loss and waste

The value of food lost or wasted annually at the global level is estimated at US\$1 trillion (Montalvo *et al.* 2024). Yet reliable numbers on specific numbers of wastage are absent. Food is lost or wasted throughout various stages of the food supply chain. During agricultural production, crops and harvest can become damaged or spoiled, animals may die due to diseases, fish may be discarded during fishing and milk could be lost due to cattle diseases (Zahidi *et al.* 2024).

The mass balance method designed by Caldeira *et al.* (2019) was used in this research. This method calculates the amount of FLW as the difference between inputs and outputs of food, their stock

variations, and weight changes during the process (Hartikainen *et al.* 2018). This method presents several advantages, as it allows calculating the FLW of liquid and solid food at each stage of the food supply chain (FSC). Moreover, the data required are often easily accessible and readily available, e.g., in national statistics (Endalew *et al.* 2015). For this research, the mass balance method was found to be appropriate. It covers the FSC worldwide, in all stages, and includes a wide range of food products. In addition, the amount of FLW estimated for each study area was associated with its level of food security, using the four clusters formed by the Global Food Security Index (GFSI) designed by The Economist Intelligence Unit. These clusters are ‘very good’, ‘good’, ‘moderate’ and ‘weak’, and a set of indicators calculates them based on four categories related to food security: affordability, availability, quality and safety, and natural resources and resilience. The GFSI is calculated for 113 countries, while FLW is estimated for 171; therefore, the rest of the countries were classified in a ‘without EUI index’ cluster. The accounting approach to estimate FLW is described in Figure 1. The following equations represent the estimation of FLW and pooling that was adopted for this study.

$$FLW_{xi} = \sum_{i=1}^n \delta A_{ij} x; \alpha B_{ij} x; \beta C_{ij} x; D\gamma_{ij} x; E\theta_{ijx}; \varepsilon \quad (12)$$

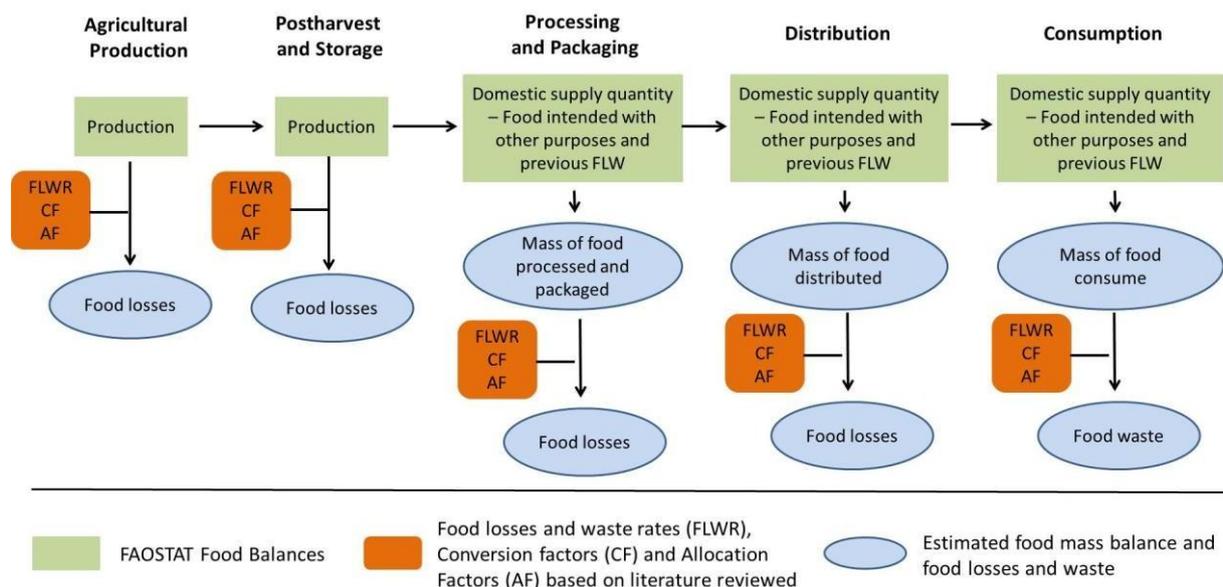
$$FLW_{xi} = a_0 + a_1 \delta A_{ij_1} + a_2 \alpha B_{ij_2} + a_3 \beta C_{ij_3} + a_4 D\gamma_{ij_4} + \dots + a_5 E\theta_{ij_5} + \varepsilon, \quad (13)$$

where

$$FLW_x = FLW_{xi} \quad (14)$$

and where

1.  $i$  is the food group: fruit, cereals, milk, fish and seafood, meat, eggs, starchy roots, oil crops, and vegetables;
2.  $j$  is the stage of the FSC: agricultural production, post-harvest, storage, processing and packaging, distribution and consumption;
3.  $k$  is the food insecurity status;
4.  $l$  is the level of food insecurity, categorised as chronic, moderate and good;
5.  $\delta A_{ij}$  is the domestic food supply quantity, which is the quantity of food available in the food group  $i$  in stage  $j$ ;
6.  $\alpha B_{ij}$  is the food loss and waste rate (FLWR) in the food group  $i$  in stage  $j$ , where  $k$  is defined as the ratio of food loss and waste to the total amount of food production;
7.  $\beta C_{ij}$  is the allocation factor in the food group  $i$  in stage  $j$ , where  $k$  is defined as the proportion of the food meant for human consumption;
8.  $D\gamma_{ij}$  is the conversion factor in the food group  $i$  in stage  $j$ , where  $k$  defines the proportion of edible food;
9.  $E\theta_{ijx}$  is the conversion factor in the food group  $i$  in stage  $j$ , where  $k$  defines the proportion of non-edible food;
10.  $FLW_{kl}$  is the food loss and waste in country  $k$  with the level  $l$  of security.



**Figure 1: Accounting approach to estimate FLW**

Source: FAO 2021

The mass balance method distinguishes between edible and non-edible food. Regarding FLW, quantification only considers edible food and discordance in the FLW estimation. Several causes contribute to decreased edible food mass in the FSC stages (Endalew *et al.* 2015). In this regard, food loss occurs at all stages except consumption, when food waste occurs (Harvey *et al.* 2019). Therefore, the FLW is calculated by multiplying the amount of food available at each step of the food chain (FLWR) by the conversion factors. Finally, the FLW considers the country’s level of food security. Thus, the following equation was used to calculate the per capita FLW:

$$FLW_{PC} = \frac{FLW_x}{Ph_n}, \tag{15}$$

where  $FLW_{PC}$  is the per capita food loss and waste, and  $Ph_n$  is the population/sample size (n).

### 3.5 Estimation techniques

The structural form equation adopted as a framework for this study is the simultaneous equation model. The use of the simultaneous model enables all the available information from the explanatory variables to be used in the equation as a single model (simultaneous model) (Gascón *et al.* 2022). The idea of this model is that FLW has a significant role in the food security nexus. The study deduced that the food insecurity gap (which serves as the percentage insecurity gap) as one of the dependent variables has an amended distribution as:

$$\text{The food insecurity gap (FISG}_i) = \left( \frac{Z - Y_i}{Z} \right), \tag{16}$$

where  $FISG_i$  (food insecurity gap) is the latent economic quantity of interest:

1. If  $Z > Y_i$ ,  $FISG_i$  is positive, this means that the household records a food spending level that is less than the food security threshold (line) and is regarded as falling into a situation of food insecurity; and

2. If  $Z < Y_i$ ,  $FISG_i$  is negative. It has a superior food spending level to the food insecurity line and is regarded as falling into a situation of food security.

The implication is that, for food insecure households, the  $FISG_i$ 's are positive, while for food secure households, they are negative. This situation calls for a simultaneous equation. Hence, in our model specification,  $FLW_{xi}$  is used as a dependent variable. Hence, the model is expressed as:

$$FLW_{xi} = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + \dots a_{20}X_{20} + \varepsilon, \quad (17)$$

where one of the  $X_i$  is  $FLW_{xi}$ , extracted from Equation (17) to Equation (18).

Hence, the estimating equation is:

$$FHi_j = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + \dots a_{20}FLW_{xi} + \varepsilon, \quad (18)$$

where  $FHi_j$  = food insecurity status,

$$FHi_j = 1, \text{ If } D_i > D_{0i}$$

$$FHi_j = 0, \text{ If } D_i < D_{0i} \dots 300.$$

The four categories of food insecurity transitions are provided below:

1.  $FH_{11} = 1$  if never food insecurity, 0 if otherwise;
2.  $FH_{12} = 1$  if gratifying food insecurity, 0 if otherwise;
3.  $FH_{13} = 1$  if exiting food insecurity, 0 if otherwise;
4.  $FH_{14} = 1$  if always food insecurity, 0 if otherwise;

$a$  = coefficients;  $\beta$  = vector of respective parameters;

$X_1 - X_{20}$  = independent variables, while  $\varepsilon$  = distributed error term.

The independent variables are socio-economic and demographic variables and are captured as:  $X_1$  = household size (number);  $X_2$  = level of education (years);  $X_3$  = age (years);  $X_4$  = marital status of household head;  $X_5$  = gender of household head;  $X_6$  = farming/fishing experience (Naira);  $X_7$  = hired labour (Naira);  $X_8$  = dependency ratio (No.);  $X_9$  = expenses on food (Naira);  $X_{10}$  = farming/fishing income (Naira);  $X_{11}$  = farm size (Ha);  $X_{12}$  = expenses on non-food items (Naira);  $X_{13}$  = expenses on inputs (Naira);  $X_{14}$  = non-farm rural activities income (Naira);  $X_{15}$  = income consumed outputs (Naira);  $X_{16}$  = access to extension facilities (dummy), if access = 1, otherwise = 0;  $X_{17}$  = access to credit facilities (dummy), if access = 1, otherwise = 0;  $X_{18}$  = market facilities (dummy), if access = 1, otherwise = 0;  $X_{19}$  = asset status (measured in Naira);  $X_{20}$  = estimates of  $FLW_{pc}$  (measured in Naira).

### 3.6 Simultaneous equation model

To establish linkages (or interactions) between  $FLW$  and the food insecurity transition nexus, the simultaneous equation model was adopted. The effects of  $FLW$  and the food insecurity transition nexus on agriculture and other variables of economic growth were examined by regression analysis, for which a two-stage methodology was used. This is necessary because the food insecurity transition

nexus and FLW are jointly dependent on similar household socio-economic variables (Gascón *et al.* 2022). Moreover, FLW has been used previously as the dependent variable in Equation (17). Hence, in Equation (18), FLW was then used as part of the independent variables that predicted the food insecurity transition nexus. The study therefore used the two-stage least squares (2SLS) estimation method. This calls for a test for model fitness, which was done through the use of the Durbin-Wu-Hausman to test for endogeneity, test for overidentification, and test for the likelihood ratio. These tests were used to assess the model's assumptions whether it can satisfy the parameters that are statistically significant or not. The study used the Stata (IBM) version 21 statistical package edition, which helped in estimating simultaneous equation models using two-stage least squares (2SLS) as the estimation technique. The use of 2SLS has the advantage of estimating all parameters of the structural equation in the model simultaneously (Gascón *et al.* 2022). The objective of using 2SLS is to facilitate the use of the ordinary least squares (OLS) method for each equation of the structural model.

### 3.7 Econometric estimation issues

Even though the structural equation presented in Equation (18) is theoretically valid, estimating the model by a single equation of the ordinary least squares (OLS) regression procedure would likely result in biased estimates of elasticity coefficients (Khalid *et al.* 2019). Theoretically, the share of both non-farm income and farm income are considered endogenous to the food insecurity model for two reasons. First, since the income variable used in this model is basically labour income (both for non-farm and farm income), its value is largely an outcome of labour supply choices. Second, reverse causality is a potential source of bias in the OLS estimate of the coefficients of food insecurity household model and income share. Furthermore, given the difficulty in getting accurate information on the income of individuals and households in developing countries, classical measurement error bias (or dwindling bias) may also be a very important source of bias in this modelling.

Therefore, a number of steps were taken to address the potential biases of the estimates of the insecurity status of farm-household income and non-farm income share elasticity. First, the study adopted the maximum likelihood estimates (MLE) method on the dependent variable. MLE was used to estimate population parameters from a random sample. Second, in order to reduce the classical measurement error bias, per capita income on food expenditure and income data were used. Also, the study engaged in multiple visits and 48-hour memory recall over the period of data collection (10 months). The instrumental variable of the two-stage least-squares estimation procedure furthermore was used to address the problems of bias due to measurement error, omitted variables and reverse causality. The robustness check of the instrumental variable was used as a variable to proxy data on all income sources comprising the non-farm and farm income variable. This variable is correlated with the endogenous regressor, but uncorrelated with the error in the structural equation.

## 4. Results and discussion

### 4.1 Preliminary statistics

The study revealed that the mean age in Lagos is 46.10, in Ogun is 47.86 and in Ondo is 47.27 (Table 3). This is an active age group that can support the adoption of progressive technology. The study also shows a fairly literate group, by whom information that is disseminated can easily be accessed and used appropriately. However, the dependency ratio in the study is 4, and this has implications for the resources of the households (Table 3). The average monthly income in Lagos is higher by 24% than Ogun state, at 23.3%, and 26.7% in Ondo state. Similarly, the sustenance allowance for food in Ogun state is higher by 3.32% than in Lagos, where it is 5.37%, and 4.42% in Ondo state. Moreover,

Table 3 indicates that monthly income was higher during the first round of data collection, with a differential of 30%. Allowances for food upkeep during the first round of data collection was higher than during the second round, with a differential of 1.2%. The study found that there was a significant contribution of non-farm income to household income during the second round of data collection, thus increasing the disposable income. Moreover, respondents from Ogun and Ondo state consumed more (15.5%) farm produce than Lagos households. Likewise, farm income was found to have increased by 10.01% during the second data collection; however, a decrease of 4% was recorded in Ogun and 4.85% in Ondo (Table 3). Thus, sustenance allowances were higher in Lagos, with a difference of 6.03%, and a difference of 6.46% in Ogun. There were no changes for Ondo state.

**Table 3: Fundamental statistics and variables that influenced food security status and the FLW transition matrix**

Selected household characteristics	Lagos		Ogun		Ondo		All groups	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	46.10	10.49	47.86	12.25	47.37	12.42	47.11	11.74
Household size	6.10	2.51	7.40	1.82	7.13	1.92	6.91	2.16
Dependency ratio	3.28	1.73	4.45	1.59	3.75	1.68	3.83	1.73
Educational level	3.29	0.87	2.56	0.61	2.74	0.79	2.86	0.82
Income (monthly) ₦ (1 <sup>st</sup> data collection)	394 040	155 363	301 070	118 478	211 750	57 221	302 286	138 858
Income (monthly) ₦ (2 <sup>nd</sup> data collection)	275 830	108 754	210 750	82 935	148 220	40 085	211 600	97 200
Expenses on food (₦) 1 <sup>st</sup> data collection (%)	126 090 (32.00)	97 160	106 343 (35.32)	37 913	65 759 (31.06)	38 857	96 732	44 434. -
Expenses on food (₦) 2 <sup>nd</sup> data collection (%)	104 810 (38.00)	41 327	80 085 (24.03)	31 515	56 325 (37.97)	15 221	80 408	36 936
Income monthly (farm) ₦ 1 <sup>st</sup> data collection (%)	36.40		55.38		72.26			
Non-farm income (%)	38.01		45.49		13.07			
Gifts income (%)	10.05		4.00		4.85			
Farm produce (income) (%) consumed at home (%)	15.54		11.00		9.82			
Income monthly (farm) ₦ 2 <sup>nd</sup> data collection (%)	31.82		43.62		63.06			
Non-farm income (%)	47.91		34.19		12.34			
Gifts income (%)	8.92		11.27		7.22			
Farm produce (income) (%) consumed at home (%)	11.35		10.92		17.38			

#### 4.2 Income distribution and differentials during the transition

The study deduced that income distribution played a significant role in food security and the FLW transition model. Table 4 reveals that there were more households in the low-income category, as the study indicated a differential of 46.43%. Others income categories are intermediate (19.01%) and the high-income category (33.67%) (Table 4). This income distribution and categorisation helped the study in generating a chain that aided the use of the Markov chain model that was used in the simulation of food security and the FLW transition matrix.

**Table 4: Income distribution and differentials during the transition**

Income category	1 <sup>st</sup> data collection (n)	2 <sup>nd</sup> data collection (n)	Differentials (%)
75 001 – 100 000	0	14	14.0
100 001 – 125 000	3	41	93.0
125 001 – 150 000	24	54	55.6
150 001 – 200 000	51	59	13.56
200 001 – 250 000	80	33	58.75
250 001 – 300 000	25	36	30.56
300 001 – 350 000	16	29	50.0
350 001 – 400 000	27	16	40.7
400 001 – 500 000	40	18	55.0
500 001- 1 000 000	34	0	34.0
<b>Summary:</b> Lower-income group (75 001 – 200 000): 46.43%			
Intermediate-income group (200 000 – 350 000): 19.01%			
High-income group (350 001 – 1 000 000): 33.67%			

Source: Authors' calculations

### 4.3 Food security status transition matrix from October 2022 to July 2023

The preliminary statistics of households' food security status and food expenses in Table 5 reveals that households spent ₦1 439.38 per person on daily food expenses during the first data collection, while the second data collection indicated daily food expenses of ₦1 020.81 per person. Hence, the study shows that food-secure households have larger food expenditures per capita than other groups (Table 5), and the minimum food spending needs per capita are relatively lower in the food-secure households. Therefore, the ratio of minimum food spending to usual food expenditure is around unity (0.94) for the food-secure household, but higher (1.37) for the food-insecure group (Table 5). This evidence indicates that the needs of households experiencing greater food insecurity are also expected to be significantly higher than their available resources. However, households' ability to manage resources may contribute to differences between food insecurity levels and vice versa. However, there might be other factors responsible for the food insecurity status of the household.

**Table 5: Food security status transition matrix from October 2022 – July 2023**

1 <sup>st</sup> data collection matrix (October 2022)	2 <sup>nd</sup> data collection matrix (July 2023)			Row (total)
	Food non-poor % (n)	Food poor (moderate) % (n)	Food poor % (n)	
Food non-poor % (n)	18.33 (55)	13.66 (41)	23.67 (71)	55.67 (167)
Food poor (moderate) % (n)	5.67 (17)	7.00 (21)	11.00 (33)	23.66 (71)
Food poor % (n)	7.67 (23)	4.33 (13)	8.67 (26)	20.67 (62)
Column (total)	31.67 (95)	24.99 (75)	43.34 (130)	

Source: Authors' calculations

The study examined seasonal variation in farming systems among smallholder farmers in southwestern Nigeria and its influence on food-secure households, and found that, during the on-farm period (harvesting season), 59.1% households were food secure, compared to 46% during the off-farm season (planting period). Hence, many households progressed into a food-secure status during the harvesting season, with a difference of 12.9%. The study therefore used probabilities to ascertain whether or not households moved into food security (non-poor) (Table 6). The results of this analysis revealed that the probability of households becoming food insecure, given that such households were food secure in the first period, was 0.23, and the probability of escaping food insecurity, given that such households were food non-poor, was 0.37. Similarly, the earlier methodological discussion

showed the relationship between entry and exit probabilities and the steady-state food-insufficient headcount using the Markov model (with the ratio of the entry into and exit from probabilities being equal to the ratio of the proportion of food insecure and food poor to food secure and food non-poor). Therefore, food-secure status had a dynamic nature, as evident in this study interpreted by the use of panel data. The results of the analysis reveal the importance of examining factors influencing entries into and exits from the food-secure (non-poor) situation.

**Table 6: Modest entry and exit probabilities**

Year (2022-2023)	Probability of experiencing FLW	Probability of exiting FLW	Households moving out of FLW	Headcount (%)
October	0.23	0.37	39.6	40.8
July	0.31	0.33	31.7	35.3

Source: Authors' calculation

Notes: N = 300; headcount is for the second data collection; FLW = food loss and waste

#### 4.4 Estimated FLW percentages for each food group at various stages of the food supply chain (FSC)

Evidence from Table 7 shows the various FLW for each food group at various stages of the food supply chain (FSC). Table 7 shows that food loss occurs mostly in tomatoes, mango and oil palm, at 43%, 31% and 31% respectively, which are losses at the agricultural production level. Similarly, high post-harvest handling food losses occur mostly in vegetables (26%), tomatoes (25%), peppers (21%) and plantain/bananas (18%). For processing and packaging FSC, more food losses occur in cassava (22.1%), plantain/banana (20%), cocoa (18%) and oil palm (16%) (Table 7). However, for the food waste FSC distribution category, more food waste was recorded for fresh tomatoes (31%) and processed peppers (21%), while processed vegetables (3.2%) and fresh yam (5.5%) were in the lowest category (Table 7).

**Table 7: Estimated FLW percentages for each food group at various stages of the food supply chain (FSC)**

Commodities	Agricultural production (%)	Post-harvest handling & storage	Processing & packaging	Distribution		Consumption	
				Fresh	Processed	Fresh	Processed
Cassava	17	15.1	22.1	25	8.9	2.5	4.5
Yam	12	8.5	7.2	5.5	4.8	6.0	4.1
Maize	14	11	10	9.1	5.1	4.8	5.6
Cowpea (bean)	19	12	5.0	6.0	4.5	2.5	2.0
Vegetable	20	26	2.5	8.1	3.2	14.3	10.5
Mango	31	10	08	17	11	18	12
Pineapple	8	15	12	8	5	6	6.4
Plantain/banana	12	18	20	11	8	7	5
Fruits	19	4	5.8	9.2	4.3	21	13.5
Tomatoes	43	25	13	31	18	21	08
Pepper	15	21	09	19	21	10	13
Oil Palm	31	10	16	23	12	12	06
Cocoa	21	11	18	19	12	3	2
Poultry	6	15	8	9.5	5.5	11.8	4.3

Source: Field survey, 2023

Overall, the study found that the levels of loss in tomatoes are extremely high, which calls for new measures at the level of tomato processing. The study also confirms that fruit are the food wasted the most in the study area, and therefore a national plan to reduce fruit waste is more necessary and urgent (Table 7). The study found that the high food losses recorded for tomatoes, fruits and vegetables at

the production stage are due to the inefficiency of the labour force on fruit farms and, to some extent, to poor agricultural practices and procedures.

#### 4.5 Food loss waste (FLW) and food security status transition matrix

The study examines the food loss waste (FLW) and food security status transition matrix in the study areas, and the results are presented in Table 8. The study reveals that the category of respondents who are food non-poor and with low FLW comprises 13.67% of the population. Similarly, respondents who are food poor and have a high FLW are 29.67% of the population (Table 8). Hence, this study established that there is a relationship between FLW and food security. A high FLW is common among the food poor, as 30% of the differentials were from food non-poor households.

**Table 8: The food loss waste (FLW) and food security status transition matrix**

Food loss waste (FLW) transition matrix	Food security status transition matrix			Row (total)
	Food non-poor % (n)	Food poor (moderate) % (n)	Food poor % (n)	
FLW low % (n)	13.67 (41)	7.67 (23)	9.00 (27)	30.33 (91)
FLW moderate % (n)	7.33 (22)	1.67 (05)	4.67 (14)	13.67 (41)
FLW high % (n)	10.67 (32)	15.67 (47)	29.67 (89)	56.00 (168)
Column (total)	31.67 (95)	24.99 (75)	43.34 (130)	

Source: Authors' calculations

#### 4.6 Determinants of food loss waste in food security nexus

Table 9 reveals that 13 of the 20 independent variables measured had significant coefficient values at different levels. Fundamental variables that significantly stimulate the food insecurity gap are as follows: household size, level of education (years), farming/fishing experience, hired labour, dependency ratio, expenses regarding food, farming/fishing income, expenses regarding non-food items, expenses on inputs, income from non-farm rural activities, market facilities, asset status, and estimates of FLW per capita (FLWpc). The explanatory variables that influence FLW are as follows: household size, level of education, dependency ratio, expenses relating to food, farming/fishing income, income from non-farm rural activities, market facilities and asset status. The study deduced that FLW and food insecurity are jointly determined by socio-economic variables. This therefore implies that the marginal effects of variables that measure well-being (food spending needs) differ among the households. This outcome hence can be a basis for forecasting the food security risk, particularly those in the moderate and core food-poor households. However, other studies have contended that poor households influenced by FLW can also enhance food insecurity (Cafiero *et al.* 2024; Schneider *et al.* 2024). The marginal effects predicting food insecurity and FLW results are presented in Table 9.

**Table 9: Determinants of FLW reduction practices among farming households**

Particulars (Variable)	Estimates	Standard errors	t-values
X <sub>1</sub> = household size (number)	0.043	0.0015	2.430**
X <sub>2</sub> = level of education (years)	0.004	0.001	4.873***
X <sub>3</sub> = age (years)	0.352	0.169	0.814
X <sub>4</sub> = marital status of household head	0.583	0.138	1.258
X <sub>5</sub> = sex of household head	0.818	0.205	0.913
X <sub>6</sub> = farming/fishing experience (Naira)	0.072	0.026	2.143*
X <sub>7</sub> = hired labour (Naira)	-0.053	0.019	-2.185*
X <sub>8</sub> = dependency ratio (no.)	-0.002	0.001	-5.823***
X <sub>9</sub> = expenses on food (Naira)	-0.018	0.011	-3.818***
X <sub>10</sub> = farming/fishing income (Naira)	0.013	0.010	2.281*
X <sub>11</sub> = farm size/fishing pond size (ha)	0.137	0.084	1.673
X <sub>12</sub> = expenses on non-food items (Naira)	0.037	0.016	3.015***
X <sub>13</sub> = expenses on inputs (Naira)	0.002	0.001	7.235***
X <sub>14</sub> = income from non-farm rural activities (Naira)	0.003		6.928***
X <sub>15</sub> = income from consumed outputs (Naira)	-0.081	0.025	0.813
X <sub>16</sub> = access to extension facilities (dummy), if access = 1, otherwise = 0	0.178	0.131	0.0738
X <sub>17</sub> = access to credit facilities (dummy), if access = 1, otherwise = 0	0.083	0.017	0.1878
X <sub>18</sub> = market facilities (dummy), if access = 1, otherwise = 0	0.002	0.001	4.836***
X <sub>19</sub> = asset status (measured in Naira)	0.073	0.026	2.328**
X <sub>20</sub> = Estimates of FLWpc (measured in Naira)	-0.004	0.001	-11.853***

Source: Computer-generated results.

Notes: \*\*\*, \*\* and \* indicate significance at the 1%, 5% and 10% level, respectively

### Model results of OLS estimates of the simultaneous equation model

Source	SS	Df	MS	Diagnostic
Model	224.819549	4	112.409794	No of observations = 3
Residual	144.797694	296	314.777896	F(4, 296) = 418.58
<b>Total</b>	<b>369.617243</b>	<b>300</b>		Prob. > f = 0.000
				R squared = 0.6079
				Adjusted R squared = 0.5836
				Root MSE = 1.7741

Notes: SS = sum of squares; Df = degrees of freedom; MS = mean of squares.

Source: Computer-generated results

The study established the link between the FLW and food security (food non-poor) nexus. The results of this analysis are presented in Table 10. Table 10 shows that the odds ratios (OR) of various independent variables and specified coefficients had direct marginal effects. Household size and income variables indicated a very strong influence of FLWs in the food security nexus. However, education, dependency ratio and income from secondary sources had significant variables across some categories. The study deduced that an additional increase of 10% in household size (X<sub>1</sub>) enhanced food poor by 0.73%, and led to an increase in moderately food poor by 0.18% and food non-poor by 0.07%. Similarly, the estimated marginal effects of a 10% increase in dependency ratio would enhance food poor by 0.7%, was not significant for the moderately food poor, but enhanced the food non-poor by 0.11%. Moreover, a 10% increase in farm/fish income would enhance the food poor by 0.28%, the moderate food poor by 0.12%, and the food non-poor by 0.48%. The estimated marginal effects of a 10% increase in food expenses led to an increase of 0.089% in the food non-poor and 0.049% in the moderately food non-poor. In addition, the effects of a 10% increase in the income consumed outputs (X<sub>15</sub>) had an opposite effect to that of an increase in minimum spending needs, particularly in the moderately food-poor and food-poor households. This result is consistent

with the findings of past studies (Kafa & Jaegler 2021; Cela *et al.* 2024). These studies argue that the marginal propensity of food marketable outputs consumed at home (that could have earned income) is higher than exchanging farm outputs for income. The marginal effects are of larger magnitude for the food-poor groups. This result suggests that income earned from the sales of marketable surplus outputs has a relatively larger effect on reducing the food-insecure situation among the core food insecure category. The contribution of non-farm income ( $X_{14}$ ) to food non-poor is significant at a 1% level. Therefore, evidence is being established here that more participation in non-farm activities leads to a likelihood of being in a situation of food non-poor and low FLW. The positive correlation indicates that they are affected in the same direction by random shocks. The results also show that household size ( $X_1$ ), dependency ratio ( $X_8$ ), income from consumed outputs ( $X_{15}$ ) and farming/fishing income ( $X_{10}$ ) influenced food insecurity positively, i.e. the higher these variables, the poorer the food insecure situation. It was deduced that a high dependency ratio ( $X_8$ ) is a key determinant of household economic stress, as the study found that a high dependency ratio ( $X_8$ ) was significantly correlated with high food waste. Households with many dependents (children and/or elderly) face a heavier financial burden, potentially leading to a high consumption of junk food and thus enhanced food waste. There is a need to educate household members on how to handle food waste, and how to reduce it by planning meals, storing food properly, and managing leftovers effectively.

**Table 10: Marginal effects of selected variables in the simultaneous equation model of FLW status**

Particulars (selected variables)	Estimates		
	FLW low (food non-poor)	FLW moderate (food poor)	FLW high (food poor)
Constant			
$X_1$ = household size (number)	0.07*	0.018**	0.031***
$X_2$ = level of education (years)	0.149***	0.012	0.023
$X_6$ = farming/fishing experience (Naira)	0.119**	0.372**	0.475*
$X_8$ = dependency ratio (no.)	0.018*	0.0341	0.697***
$X_9$ = expenses on food (Naira)	0.089*	0.049***	0.0019
$X_{10}$ = farming/fishing income (Naira)	0.18*	0.12*	0.28**
$X_{12}$ = expenses on non-food items (Naira)	0.013	0.09	-0.037***
$X_{14}$ = income from non-farm rural activities (Naira)	0.078*	0.024	0.022**
$X_{15}$ = income from consumed outputs (Naira)	0.0018	-0.0185	-0.0217
$X_{18}$ = market facilities (dummy), if access = 1, otherwise = 0	0.038*	0.0184	0.0241

Source: Computer-generated results

Notes: n = 300. \*\*\*, \*\* and \* indicate significance at 1%, 5% and 10%, respectively

#### 4.7 Hausman specification test (HST)

The Hausman specification test was conducted to test the simultaneity in the relationship between the FLW and food insecure status (food poor). The endogenous variables in the model, such as compounded household income (food insecure) and the FLW, were analysed individually in relation to the rest of the predetermined variables by using the ordinary least squares (OLS) method. The unstandardised predicted value and residuals were saved. Once this had been accomplished, another endogenous variable was created from the residuals and included in the analysis as an explanatory variable. If the t-value for this variable is statistically significant and greater than or equal to 2, then it can be concluded that there is simultaneity (Mills & Zandvakili 1997; Paudel 2004).

The following are the results after performing the Hausman specification test (HST).

$$\Delta V_t = 12.247 - 0.326\Delta G^* + 0.145\varepsilon^* \quad (19)$$

t - value            -5.147            2.17

$$\Delta G \{y(t)\} = 28.146 - 1.583\Delta t^* + 0.126\varepsilon^*, \quad (20)$$

t - value            -5.101 -1.583            2.46

where  $\Delta V_t$  = FLW reduction,  $\Delta G \{y(t)\}^*$  = estimated unstandardised predicted value of growth of real output from the reduced-form equation by OLS,  $\varepsilon^*$  = saved residual value while estimating the unstandardised predicted value of compounded LDI,  $\Delta G \{y(t)\}$  = computed household income,  $\Delta V_t^*$  = estimated unstandardised predicted value of compounded  $\Delta V_t$  from the reduced-form equation by OLS, and  $\varepsilon^*$  = saved residual value while estimating the unstandardised predicted value of compounded household income. These estimated coefficients of the  $\varepsilon^*$  variables are statistically significant and greater than 2 in both equations, implying that there is simultaneity between compounded changes in  $V_t$  and agricultural/economic growth. Equations 19 and 20 present the results from the reduced-form equation (as in  $\Delta G \{y(t)\}^*$  and  $\Delta V_t^*$ ), expressing the endogenous variables as functions of exogenous or predetermined variables only. Their parameters measure both the direct and indirect influence of the exogenous variables on the endogenous variables. These reduced-form parameters are composed entirely of structural parameters (Gascón *et al.* 2022). The reduced-form parameter is a combination of some of the structural parameters.

#### 4.8 Policy implications of the findings

The study found that FLW occurs across the entire food supply chain where higher rates of food loss (reduction in quantity or quality from production to distribution) are indicated. We therefore conclude that FLW was due to factors such as inadequate infrastructure and post-harvest handling. In contrast, developed countries, particularly those with high urbanisation, experience higher levels of food waste at the retail and consumer levels. This is often linked to consumer behaviour, aesthetic standards for produce, and overproduction (Thorsen *et al.* 2024). The study found that the levels of fruit waste were extremely high, which calls for new measures at the level of storage and processing, and a review of production and post-harvest handling. The study also confirms that vegetables are the food wasted the second most in the area of the study, and therefore a national plan to reduce vegetable waste is necessary and urgent. Past studies argued that the traditional preservation methods, such as fermentation, drying and smoking, are ancient techniques that play a crucial role in reducing food loss and sustaining cultural continuity (Ahmed *et al.* 2024). The results of the study's analysis indicate that farmers who adopted the use of preservatives/smoking/storage gave rise to a minimal FLW of 10%, compared to the 8.3% of the processing method. Hence, this traditional method of processing and storage enhanced FLW reduction and reinforced cultural identity and traditional knowledge. The cultural continuity of these traditional methods therefore represents resilience and generational knowledge of land and agricultural practices, as it allows communities to preserve a successful volume of agricultural commodities. Previous studies have indicated that traditional diets are linked to lower risks of chronic diseases like heart disease, diabetes and obesity. Reducing the waste of nutrient-rich, traditional foods like fruits, vegetables and fish protects the health of local populations.

The results of the econometrics indicated that the marginal propensity to consume food marketable outputs at home (that could have earned income) was higher than the exchange farm outputs for income. The marginal effects are of larger magnitude for the food-poor groups. Hence, income earned from the sales of marketable surplus outputs has a relatively larger effect in reducing the food-insecure situation among the core food insecure category. The contribution of non-farm income ( $X_{14}$ ) to food non-poor is significant, at a 1% level. Therefore, evidence is being established here that more participation in non-farm activities gives rise to the likelihood of these households being in a food

non-poor and low FLW situation. The positive correlation indicates that these two aspects are affected in the same direction by random shocks. The study revealed the extent of FLW, identify its causes and its influence on food security, economic well-being and environmental sustainability. Food loss and waste (FLW) studies in Nigeria are crucial for understanding and improving household food systems. Hence, policy that will strengthen the development and adoption of technologies like smart inventory management systems, energy-efficient processing and packaging solutions can also play a role in reducing food loss and waste. This suggests that policy that can influence increases in income can do the same to improve FLW reduction. Thus, the study's findings reveal that reducing FLW has a significant effect on food non-poor (low FLW). The results suggest that there is a curvilinear relationship between the course of FLW reduction and food security enhancement.

## 5. Conclusions

“Do food waste interventions hold the potential to make an effective contribution to the food security nexus?” was the question that the study attempted to answer. By examining the shift between food loss and waste reduction in the food-security relationship among farming households in southwestern Nigeria, the study provides an answer to this query. The study findings supported the notion that food waste is a major issue and hardship for households in southwestern Nigeria. According to the study, micro-scale food security circumstances may be directly and temporarily affected by initiatives to reduce FLW. Although the study is only a pilot study, these circumstances can have a substantial impact when incorporated into a larger value chain or food system approach. According to the study's findings, in certain situations food insecurity may also be largely caused by FLW. However, there is no one solution that can be used to reduce food waste in general. Reducing waste can help achieve the goal of improving food security, especially when it comes to increasing the food supply in a reasonably efficient manner, but additional steps will be required. This is especially true because efforts to reduce food waste typically concentrate on just one aspect of food security – food availability. Future research may address the relative undervaluation of access, utilisation and stability in waste interventions and related elements in the literature.

Using two seasons, this study introduced a novel way to investigate the relationship between food security status and FLW in transition. In order to explain the generation of food waste, a model was subsequently developed that integrated the transition to food insecurity with conventional consumer waste-related behaviours. But even though this paper adds something new to the discussion, there is still a lot to learn about this topic. This paper emphasises the incentives to reduce food loss and waste, as well as the significant connection between FLW reduction and the food security nexus. According to the study, there is still a high prevalence of food poverty among farming households in southwest Nigeria. Large household sizes, high dependant ratios, income-consumed outputs and non-food expenditure have all been found to contribute to factors of temporary food insecurity. Food security (not food poverty) is a feature of households with a reasonable size. The majority of families experiencing food insecurity are primarily farmers, with a high dependency ratio and low levels of education.

Households in transition experiencing food insecurity have a strong correlation with low FLW, income generation and seasonal fluctuations in the agricultural harvest. As income generation declines over time, food secure (or food non-poor) households experience an increase in food insecurity (FLW). Thus, a policy on FLW reduction, and a more varied occupational structure that can add value to labour time for reasonable income support, are recommended. In addition, compared to households in the food sufficiency class, food-insecure (food-poor) households spend less per person to meet their basic needs, have a higher rate of non-participation in non-farm activities, and thus experience a larger gap between their perceived (subjective) minimum food spending needs and

their available resources. Increases in educational attainment have a comparatively greater impact on altering the status of food insecurity, and the marginal effects of FLW and the degree of food insecurity are positively connected. The food security status of households and the FLW of the identified households were calculated simultaneously, and the results show a simultaneity. Therefore, policies that have an impact on income growth can also have an impact on FLW reduction. This result therefore shows that food non-poor (low FLW) households are significantly influenced by lowering FLW. The findings imply that the improvement of food security and the duration of the FLW reduction have a curvilinear relationship.

The study has provided a deeper understanding of FLW within the context of Nigeria's household food systems. The study also identified gaps in knowledge and research priorities to guide future research efforts in further addressing the challenges of food loss and waste in Nigeria's household food systems. This is essential for developing effective strategies to enhance food security, improve livelihoods and promote sustainable development. The findings of this study also revealed that understanding the FLW issue is important, and that it is necessary to move beyond simply quantifying loss to analysing its causes and potential solutions. Hence, there is a need for newer research to focus on specific commodities, regional differences and the effectiveness of interventions, including those addressing post-harvest handling, storage and processing, particularly in developing countries like Nigeria. Several studies now recognise the stark differences between food-producing and food-consuming regions, such as the north and south of Nigeria. This will help to tailor interventions to specific contexts, such as addressing conflict and infrastructure challenges in the north. A significant shift is towards understanding and addressing post-harvest losses, including those occurring during handling, storage and processing in the south. This is crucial in regions where these losses are particularly high, as highlighted in studies on sub-Saharan Africa. While global estimates of FLW are important, newer studies emphasise the need for localised solutions and interventions that consider the specific context of each region, as in Nigeria. There is growing recognition of the role of consumer behaviour and awareness in reducing food waste at the retail and household levels. In essence, recent studies on FLW in Nigeria and globally are moving beyond simple quantification to a more in-depth understanding of the issue, its causes, and potential solutions tailored to specific contexts.

## Acknowledgements

This study benefitted tremendously from the comments and contributions made during the presentation of the draft paper at the International Conference of Agricultural Economists (ICAEs), New Delhi, India, 2024. The funding by the Federal Government of Nigeria Tertiary Education Fund (TETFUND) is gratefully acknowledged.

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