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RESEARCH ARTICLE

Investigating food insecurity, health and environment-related factors, and agricultural commercialization in Southwestern Nigeria: evidence from smallholder farming households

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Abstract
Hunger and food insecurity remained some of the serious challenges facing our world in present time with great concerns from Sub-Saharan Africa especially countries like Nigeria. This study investigates food insecurity (FI), health and environment-related factors, and agricultural commercialization among smallholder farm households. This study was conducted in Southwestern Nigeria utilizing cross-sectional survey data from 352 farm households and employed multi-stage sampling procedure. The household FI levels was determined using food insecurity access scale (HFIAS), crop commercialization index (CCI) was used to compute each household's CCI (four levels), while ordered logit model was used to analyse factors influencing FI. Health and environment-related factors' access were assessed across each FI category. The results indicated that about 13% of cassava farm households are non-participant in the marketing of their produce. The findings revealed that less than 20%, 30%. and 40% of households in all four FI categories had access to piped water, improved toilet facilities, and electricity respectively. The ordered logit regression analysis indicated that age, gender, education level, farm experience, nonfarm income, and ownership of motorcycle significantly influencing FI in the study areas. Therefore, this study stressed the implementation of policy actions capable of promoting rural infrastructure development that will lead to increased agricultural production, marketing, and improved quality of life of rural dwellers.

Keywords Rural farm households · Household food insecurity access scale (HFIAS) · Crop commercialization index (CCI) · Food security · Malnutrition · SDG 2

Introduction

Food insecurity and hunger are among the daunting challenges facing many nations of the world with grave concerns from Africa especially the sub-Saharan Africa (SSA) (Otekunrin et al. 2020a, 2021a). In recent estimates, the number of people experiencing hunger globally witnessed a surge in 2020 owing to the devastating effect of COVID-19. The report revealed that about 720–811 million people globally experienced hunger, while 118 million additional persons experienced hunger in 2020 compared to 2019 (FAO et al. 2021). African region had the highest percent (21.0%) of the population experiencing hunger in 2020, others include Latin America and the Caribbean (LAC) (9.1%) and Asia (9.0%). Owing to the emergence of COVID-19, global food insecurity rose from about 23% in 2014 to unprecedented 30% in 2020, reflecting the obvious situation that about one in three persons lack unhindered access to food in 2020 (FAO et al. 2021; Otekunrin and Otekunrin 2021a; Otekunrin et al. 2021a, b). Close to 928 million people globally face severe food insecurity while nearly additional 148 million persons experienced severe food insecurity in 2020 compared to 2019 making many nations off track towards achieving Zero Hunger target (SDG 2) in 2030 (FAO et al. 2021).

Hunger and food insecurity have become endemic in the African region (excluding the North African countries) (Ayinde et al. 2020; Otekunrin et al. 2019a, b; Otekunrin et al. 2020b). Majority of the countries in the region fall

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between middle and lower food security score levels in the 2021 Global Food Security Index (GFSI), with thirty-two countries from Africa. There were one hundred and thirteen countries captured in the 2021 report (Economist Impact 2021). Seventy percent of countries (7/10) in the category of worst performer are African countries reflecting serious food insecurity concerns in the Africa. In the report (2012–2021 GFSI scores) of the African countries, the scores from North Africa were among the best in Africa, while four countries (Malawi, Sudan, Mozambique and Burundi) were among the worst performers (Economist Impact 2021). Table 1 also reveals that Nigeria was ranked 97th and 20th in the 2021 GFSI in the world and in Africa respectively. However, 2021 Global Hunger Index (GHI) report revealed that Nigeria's GHI score was 28.3 (serious category), ranking 103rd among 116 ranked countries while percent undernourished population rose from 8.9% in 2000 to 14.6% in 2021 indicating that the country is not on the path of achieving SDG 2 target by 2030 (von Grebmer et al. 2021).

In the past, agricultural commercialization (AgriCom) in Africa is tantamount to large-scale farming involving cash crops (Martey et al. 2012). However, this has changed in recent time as these cash crops which are usually rain-fed and adversely affected by the harsh weather conditions. This has led to a reduction in annual harvest of the crops and hence, calls for pragmatic crop diversification programs (Martey et al. 2012; Obisesan, 2012; Opondo et al. 2017; Otekunrin et al. 2021c). Recently, food crops such as cassava

Table 1 GFSI score in 10 years (2012–2021) African countries

		GFSI score (0.0–100.0)										
Rank G/A	African country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	10-year change
54/1	Algeria	53.2	51.3	57.4	58.2	62.9	63.5	63.3	63.7	61.6	63.9	+10.7
55/2	Tunisia	60.0	57.7	58.4	59.2	59.8	63.2	62.2	61.8	60.2	62.7	+2.7
57/3	Morocco	54.1	54.8	55.7	58.4	57.8	58.2	62.0	59.2	62.1	62.5	+8.4
62/4	Egypt	58.9	58.5	59.5	62.4	59.8	58.0	57.0	61.3	59.8	60.8	+1.9
70/5	South Africa	55.8	56.3	56.8	59.5	63.4	60.0	61.6	59.4	58.0	57.8	+2.0
74/6	Botswana	53.7	53.8	53.4	53.4	54.0	53.7	54.7	56.1	56.1	55.5	+1.8
76/7	Mali	46.6	48.7	49.9	50.4	48.5	49.9	52.7	53.1	52.7	54.5	+7.9
82/8	Ghana	48.8	50.4	50.5	51.9	50.7	52.8	53.5	52.9	52.8	52.0	+3.2
85/9	Burkina Faso	40.4	42.7	43.1	44.1	43.9	46.3	48.1	49.3	46.8	48.1	+7.7
86/10	Cote d'Ivoire	43.8	44.3	43.8	47.1	44.4	46.8	49.7	50.3	50.4	48.0	+4.2
86/10	Tanzania	34.7	36.3	40.0	38.8	44.5	45.6	43.1	45.3	47.7	48.0	+13.3
88/12	Niger	40.4	40.8	40.4	43.3	46.4	44.8	48.3	49.8	49.9	47.6	+7.2
89/13	Senegal	41.4	42.6	45.9	48.1	48.7	46.7	48.5	48.1	45.5	47.4	+6.0
90/14	Kenya	38.3	40.5	43.4	43.6	43.2	45.9	45.3	48.6	46.7	46.8	+8.5
92/15	Cameroon	44.2	41.4	42.1	46.4	45.4	45.2	46.2	44.4	43.9	45.5	+1.3
93/16	Benin	39.9	40.3	41.8	45.2	45.8	46.4	45.4	45.4	46.1	45.2	+5.3
94/17	Togo	39.0	39.6	42.0	43.8	38.4	45.4	44.3	46.2	45.7	44.2	+5.2
95/18	Uganda	40.3	42.3	46.7	47.9	46.5	46.3	40.8	43.7	43.2	43.9	+3.6
96/19	Guinea	34.7	36.0	39.8	41.6	38.5	40.0	40.4	40.6	42.8	43.0	+8.3
97/20	Nigeria	39.0	41.1	39.5	40.9	42.4	41.9	40.5	42.6	41.2	41.3	+2.3
98/21	Angola	40.1	40.9	38.5	40.2	38.4	38.1	39.1	40.6	41.7	41.1	+1.0
99/22	Chad	33.2	32.3	35.9	39.0	39.2	39.9	40.2	43.8	41.7	40.6	+7.4
100/23	Madagascar	36.7	38.3	38.6	38.7	39.0	36.8	35.9	35.1	38.0	40.4	+3.7
101/24	Rwanda	43.6	39.9	42.5	44.2	42.6	37.4	38.8	43.7	45.2	40.3	−3.3
103/25	Congo Dem. Rep	32.3	34.8	34.6	35.1	34.3	35.4	32.8	38.0	38.1	39.1	+6.8
104/26	Sierra Leone	33.8	35.2	41.7	43.1	40.7	38.0	33.9	36.6	39.8	38.1	+4.3
105/27	Zambia	38.2	41.4	40.5	40.1	42.3	38.0	41.9	41.1	38.9	38.0	−0.2
108/28	Ethiopia	33.7	35.4	41.6	42.1	41.9	44.5	41.3	41.5	36.7	37.6	+3.9
10,929	Malawi	39.5	33.9	35.3	36.9	36.3	35.4	39.5	40.0	39.1	37.3	−2.2
110/30	Sudan	34.7	33.4	36.0	36.8	39.1	40.7	38.9	39.3	36.4	37.1	+2.4
111/31	Mozambique	37.7	43.0	42.5	41.6	39.8	36.3	37.3	41.7	37.2	35.9	−1.8
113/32	Burundi	39.2	38.7	38.8	41.4	42.7	41.5	31.1	37.2	38.0	34.7	−4.5

Source: Author's compilation from GFSI scores (2012–2021), Economist Group 2021; Rank G/A = Global/Africa rank

and sorghum are being supported for their drought-resistance and other attributes which make them suitable as food security crops in the Africa (Martey et al. 2012; Obisesan, 2012; Opondo et al. 2017). According to APRA (2018) and cited by Otekunrin et al. (2021c), that AgriCom stems from agricultural activities that hang on the market for the sale of produce and for the purchase of production inputs. In addition, AgriCom refers to increased market transactions for benefiting in the gains of specialization (Carletto et al. 2017; Opondo et al. 2017; Otekunrin et al. 2019c, 2021c). AgriCom may be viewed in two aspects: the output-side of production (market of agricultural produce) and the input-side of production (purchased inputs) (Carletto et al. 2017; Otekunrin et al. 2021c).

Moreover, it is evident that infrastructure development (especially environment and health-related) mostly in the rural areas in Africa (Nigeria inclusive) will tend to support agricultural commercialization. In addition, infrastructure development in Africa is pivotal to the economic growth, human capital development, and promotion of quality of life of the people especially in the rural settings (AfDB 2020). Owing to the recent population spike in Africa coupled with the United Nations (UN) projection of the continent's population increase from 1.3 billion in 2019 to 2.4 billion in 2050 and understanding that most of the increase is projected to come from SSA (UNDESA, 2019; OECD/ACET 2020). It is expedient that in order to cope with the ever-increasing demand for unhindered access to quality food, there is a need for the African countries (Nigeria inclusive) to scale up infrastructure development especially in the rural areas to match the demand of ever-increasing population in the region mainly in the aspects of production capacity, labour participation, and food security (OECD/ACET 2020). Where rural environment and health-related infrastructure such as good rood network, uninterrupted power supply, healthcare facilities, and access to safe drinking water and improved toilet facilities are available and functioning properly, will promote an enabling environment for smallholder farmers to thrive, leading to increased production and marketing of agricultural produce. The availability and adequate functioning of these rural infrastructure tend to promote increased income for farming households and improve quality of life of the rural households.

Cassava (*Manihot esculenta Crantz*) is commonly referred to as twemty-first century staple crop for most smallholder farmers globally (especially in Africa). It is counted among the most commonly grown root crop and also as be referred to as food security crop in most developing economies (Otekunrin and Sawicka 2019; Otekunrin et al. 2021c). Cassava can survive in areas with uncertain rainfall pattern where other crops may not be successfully cultivated in such areas and that is why cassava is commonly referred to as "drought-tolerant crop" (Otekunrin and Sawicka 2019; Otunba-Payne 2020; Otekunrin et al. 2021c). According to FAO statistical database (FAOSTAT), global cassava production stands at 303.6 million tons, while Nigeria had the highest total production (ranked 1st) in the world in 2019. In terms of global cassava producer ranking, Nigeria is followed by Democratic Republic of Congo, Thailand, and Ghana (2nd, 3rd, and 4th respectively). The cassava production in Africa reached 192 million and is recognized as the largest cassava growing region, while Nigeria retained the top spot as the highest producer of the crop in Africa and globally with about 59 million tons and 19.50% share of world total production in 2019 (FAOSTAT 2021; Otekunrin et al. 2021c). Cassava in believed to be one of the most valued crop both by production and consumption in Nigeria (Otekunrin and Sawicka 2019; SAHEL, 2016; Samuel et al. 2019; Otekunrin et al. 2021c). Ninety percent of cassava produce are consumed as food in the country but nearly 10% is utilized for industrial consumption with less than 1% cassava export opportunity (Otekunrin and Sawicka 2019; Otekunrin et al. 2021c).

Empirical studies have examined the prevalence and determinants of food insecurity among farming and non-farming households making use of both primary and secondary data sources in Nigeria (Akerele et al. 2013; Agbola 2014; Ahmed et al. 2015; Ibrahim et al. 2016; Ogunniyi et al. 2021; Obayelu et al. 2021; Otekunrin et al. 2021a). However, few empirical studies in Nigeria (Obayelu and Oyekola 2018; Oparinde et al. 2020; Obayelu et al. 2021; Otekunrin et al. 2021a) and other parts of the world have accessed the prevalence of household food insecurity using Household Food Insecurity Access Scale (HFIAS) approach (Pakravan-Charvadeh et al. 2020; Nour and Abdalla 2021; Samim et al. 2021; Otekunrin et al. 2021c; Otekunrin 2021). More so, some other empirical studies have investigated the associations between food insecurity status (using HFIAS) and socioeconomic-related indicators in Iran and household vulnerability to food insecurity during COVID-19 lockdown in Iran also using HFIAS approach (Pakravan-Charvadeh et al. 2021a, 2021b). These studies did not have any link to agricultural commercialization among farming households. However, previous studies have equally examined the effect of AgriCom on household poverty in Oyo state, Nigeria (Hussayn et al. 2020), and the effect of AgriCom on nutrition outcomes of children in Nigeria and other nations in Africa (Okezie and Nwosu 2007; Carletto et al. 2017; Otekunrin et al. 2021c). In addition, studies by Bolarinwa et al. (2020) examined relative effect of agricultural commercialization on household food security in Rwanda, while Oparinde et al. (2020) investigated agricultural commercialization and food security nexus among maize farmers in Ondo state, Nigeria. Studies on food insecurity, agricultural commercialization, and rural infrastructure development are currently scarce. This study is the first to investigate household food

insecurity, health and environmental-related factors, and agricultural commercialization in rural Nigeria. This study seeks to expand research frontier on food insecurity, agricultural commercialization, and health and environment-related infrastructure development literature in Nigeria and other part of the world. This study therefore seeks to investigate household food insecurity, health and environment-related factors, and agricultural commercialization among cassava farming households in Nigeria.

Research methodology

The study area

Nigeria is unarguably the 7th most populous nation in the world. As reported in Worldometer data, the current population of Nigeria (7 December 2021) is 213,425,147 people indicating 2.69% of total world population (Worldometer 2021). Southwestern Nigeria is one of the six geopolitical zones of Nigeria with a total land mass of 923,768 km^2 (Maps of World 2021; Otekunrin et al. 2021c). Nigeria has more than 250 ethnic groups but Hausa, Igbo, and Yoruba remained the predominant ethnic groups and national languages. He study was carried out in Oyo and Ogun states, Southwestern Nigeria. The region lies between latitude 9° 4.9199[l] N and longitude 8° 4.9199[l] E (find lattitude and longitude 2021; Otekunrin et al. 2021c). The capital of Ogun state is Abeokuta, and the state lies between latitude N 6° 54.59[l] and longitude E 3° 15.5018[l], and covers an area of 16,980.55 km^2 (Otekunrin et al. 2021c). It is covered by rainforest with wooden savanna in the northwest. Ibadan is the capital of Oyo state and lies between latitude N 8° 7.174[l] and longitude E 3° 25.1732[l] and covering an area of 24,454 km^2 (find lattitude and longitude 2021; Otekunrin et al. 2021c).

Study area, data collection, and sampling procedure

The study carried out in rural Ogun and Oyo states, Southwestern Nigeria. Multi-stage sampling procedure was used for the study. Firstly, random sampling of 2 states from 6 states in South-West was carried out. Secondly, five local government areas (LGAs) from Oyo state and three LGAs from Ogun state were randomly selected. Thirdly, a total of twenty-four villages were selected randomly from the LGAs. Fourthly, sixteen cassava farm households were randomly selected making a total of three hundred and eighty-four households (384). The data collection was carried out using structured questionnaire that include HFIAS module, the household socioeconomic factors, food and expenditure variables, rural health and environment-related factors (infrastructure), and other germane information. However, thirty-two (32) questionnaires (resulting in 352 respondents) were unusable for data analysis due to incomplete information from the respondents.

Food access measurement through HFIAS

Household food insecurity access scale (HFIAS) module can be used in determining household ability to access food, food choices, and other important household food (Coates et al. 2007; Jones et al. 2013; Otekunrin et al. 2021a). HFIAS module uses questionnaire that has nine incidence questions that reflect a steadily rising level of food insecurity, and nine recurrence-of-condition questions that are asked as a follow-up to each incidence question to determine how habitually the condition occurred (Table 2). The recurrence-of-condition question will have to be skipped only if the household head been interviewed confirm that the condition narrated in the follow-up question did not happen in the last 4 weeks (Coates et al. 2007; Otekunrin et al. 2021a). The food insecurity levels of the households in the two investigated through HFIAS (Coates et al. 2007). The HFIAS was developed by Food and Nutrition Technical Assistance Project (FANTA) which formulated a set of questions referred to as HFIAS Generic Questions that are already in use in many countries. The questions examine food insecurity at household level and used in classifying households from food secure to severely food insecure (Coates et al. 2007; Obayelu and Oyekola 2018; Obayelu et al. 2021; Samim et al. 2021; Nour and Abdalla 2021; Otekunrin et al. 2021a). All questions are asked within 4 weeks recall period. Firstly, the household head is asked an incidence question to determine if the situation really occurred 4 weeks period (yes or no). If it is affirmatively "yes," then, a recurrence-of-situation question is further asked to affirm if the condition occurred rarely (1–2 times), occasionally (3–10 times), or repeatedly (more than 10 times) in last 4 weeks (Coates et al. 2007).

Table 2 HFIAS questions

No	Occurrence questions
1(a)	Did you bother about not having food?
2(a)	Did you consume food you did not like?
3(a)	Did you eat one type of food often?
4(a)	Did you eat food you did not want to eat?
5(a)	Did you cut down size of meals?
6(a)	Did you skip some meals in a day?
7(a)	Did not have food to eat?
8(a)	Did you sleep with empty stomach?
9(a)	Did you go a whole day without food?

Adapted from Coates et al. (2007)

The HFIA prevalence is one of the indicators of HFIAS module that can be used in computing HFI. HFIA prevalence was used in this study because it is the only indicator that categorizes households into 4 distinct groups of food insecurity (FI) such as (i) food secure, (ii) mildly food insecure, (iii) moderately food insecure, and (iv) severely food insecure (Coates et al. 2007; Otekunrin et al. 2021a). However, following Coates et al. (2007), a HFIA group variable was computed for each household by giving a code for the FI class. The recurrence-of-situation was coded as 0 for all cases where the answer to the corresponding incidence question was "no" (i.e., if Q1 = 0 then Q1a = 0, if Q2 = 0 then Q2a = 0, etc.) before giving the FI category codes (Coates et al. 2007; Otekunrin et al. 2021a). The 4 FI categories was obtained following the formula as indicated by Coates et al. (2007) and Otekunrin et al. (2021a) to ensure that households are classified based on their most severe condition(s). In this study, the HFIA prevalence formulas (Coates et al. 2007; Otekunrin et al. 2021a) were used in determining the FI level of households in the study areas.

Estimating agricultural commercialization levels

The AgriCom levels of farm households in the two states were estimated using Crop commercialization Index (CCI) by Strasberg et al. 1999; Carletto et al. 2017; Otekunrin et al. 2021c defined as:

$$\mathrm{CCI}_i = \frac{\text{Gross value of crop sale}_{hhi,\text{yearj}}}{\text{Gross value of all crop production}_{\text{hhi, year}j}} \times 100 \quad (1)$$

We have hh_i is the ith household in year j.

The commercialization levels of farm households can be presented by as completely subsistence household (CCI = 0) to totally commercialized (CCI = 100). The crop sold ratio is used as proxy for CCI levels (Shively and Sununtnasuk 2015; Otekunrin et al. 2021c).

The farm households were grouped on basis of their commercialization levels. Non-participating households (non-sellers) in marketing cassava roots were categorized as zero commercialization level (CCI 1 = 0.0%) while participating households (sellers) are grouped as low commercialization level (CCI 2 = 1.00–49.9%), medium–high commercialization level (CCI 3 = 50.0–75.9%), and very high commercialization level (CCI 4 = 76.0–100.0%) levels (Otekunrin and Otekunrin 2021b; Otekunrin et al. 2021c).

Modelling the determinants of FI

In determining factors influencing FI among cassava farm households in the study areas, this research employed multivariate ordered logit model (OLM). The OLM is employed when the regressand has > 2 categories and the values of each category have sequential pattern in which a category is greater in value than the than the next (Torres-Reyna 2014; Otekunrin et al. 2021a). The FI levels in the study areas are in 4 categories (food secure, mild, moderate and severe FI) as specified in Coates et al. (2007) and Otekunrin et al. (2021a). Empirically, OLM and ordered probit models are commonly employed in determining ordinal survey data (Greene 2012; Obayelu 2012; Obayelu and Oyekola 2018; Cordero-Ahiman et al. 2020; Samim et al. 2021; Obayelu et al. 2021; Otekunrin et al. 2021a). It was argued that using anyone of the two models is basically on the purpose of choice and convenience (Long and Long 1997; Samim et al. 2021; Otekunrin et al. 2021a).

The logit coefficients are usually in log-odds unit and cannot be given ordinary least-square interpretation; it is expected that marginal effects should be used to determine changes in the probability of FI results as regards regressors (Booroah 2002; Obayelu 2012; Otekunrin et al. 2021a). The positive marginal effect estimate for a category suggests an increase in such variable will also increase the probability of belonging to such category, while negative estimates reduces the likelihood of belonging to that category (Booroah 2002; Obayelu 2012; Otekunrin et al. 2021a, c).

In this model, the observed ordinal variable is given as Y and it is a function of another variable y^* not measured. The y^* has various threshold points as specified in Long and Long (1997) and Greene (2012); the Eq. (1) is given as follows:

$$y_i^* = x_i' \beta + \varepsilon_i \quad (2)$$

where y_i^* is the hidden variable of the FI levels of the farm household i, x'_i is a vector of explanatory variables describing farming household i, β is a vector of parameters to be estimated, and ε_i is a random error term which follows a standard normal distribution. Following Coates et al. (2007) and Otekunrin et al. (2021a), FI is grouped into 4 outcomes: (1) food secure, (2) mildly food insecure, (3) moderately food insecure, and (4) severely food insecure.

Choice rule:

$$y_i = \begin{cases} 1 \quad if\ y_i^* \le \mu_1 (food\ secure) \\ 2 \quad if\ \mu_1 \le y_i^* \le \mu_2 (\text{mildly food insecure}) \\ 3 \quad if\ \mu_2 \le y_i^* \le \mu_3 (\text{moderately food insecure}) \\ 4 \quad if\ y_i^* > \mu_3 (\text{severely food insecure}) \end{cases} \quad (3)$$

The μ_1 to μ_3 are cut-off points to be determined for the FI categories (Otekunrin et al. 2021a).

Results and discussion

Exploring cassava farming households' food insecurity levels

The household heads' responses to HFIAS' nine occurrence questions depicting the FI situations of cassava farm households in the study areas are presented in Table 3. The results indicated that 14.8%, 15.1%, 15.6%, and 14.2% of the households in the two states did not experience questions 1–4 while 17.9%, 25.3%, 43.5%, 66.8%, and 90.9% of the household heads answered "No" to 5–9 questions. The other cassava farming household heads answered affirmatively (saying "yes") to HFIAS nine-question as indicated in Table 4. In addition, the results revealed a continuous rise in percent of households that responded "no" to the questions, while there was a downward trend in percentage of households that answered "yes" to the HFIAS nine-questions in 30 days recall period. However, Table 4 presents only cassava farming households that answered "yes" to all the nine HFIAS occurrence questions while indicating total numbers of households based on their reply to the recurrence of the conditions. Based on households' feedbacks, Table 5 reveals that 3.7% and 17.1% out of 136 and 164 households affirmed that they experienced worrying about not having enough food (Q1a) infrequently, while 16.9% and 37.8%, and 79.4% and 45.1% of the households confirmed that Q1a happened sometimes and frequently in rural Ogun and Oyo states respectively. However, only 7.5% and 12.4% out of 132 and 170 cassava farming households who responded that they seldom eat food they did not want to eat (Q4a), while 33.3% and 58.8%, and 59.1% and 28.8% of the households affirmed that they experienced food insecurity situations a times and repeatedly in rural Ogun and Oyo states respectively. Table 5 also indicates that 13.2% and 11.3% out of 121 and 142 farm families in the two states affirmed that skipping

Table 3 Farm households' occurrence of FI conditions in rural Ogun and Oyo states

	Ogun ($n=141$)		Oyo ($n=211$)		Pooled ($n=352$)	
	No	**Yes**	**No**	**Yes**	**No**	**Yes**
Question	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)
Q1	5 (3.55)	136 (96.45)	47 (22.27)	164 (77.73	52 (14.77)	300 (85.23)
Q2	6 (4.26)	135 (95.74)	47 (22.27)	164 (77.73	53 (15.06)	299 (84.94)
Q3	6 (4.26)	135 (95.74)	49 (23.22)	162 (76.78)	55 (15.63)	297 (84.38)
Q4	9 (6.38)	132 (93.61)	41 (19.43)	170 (80.57)	50 (14.20)	302 (85.80)
Q5	11 (7.80)	130 (92.20)	52 (24.64)	159 (75.36)	63 (17.90)	289 (82.10)
Q6	20 (14.18)	121 (85.82)	69 (32.70)	142 (67.30)	89 (25.28)	263 (74.72)
Q7	41 (29.08)	100 (70.92)	112 (53.08)	99 (46.92)	153 (43.47)	199 (56.53)
Q8	81 (57.45)	60 (42.55)	154 (72.99)	57 (27.01)	235 (66.76)	117 (33.24)
Q9	124 (87.94)	17 (12.06)	196 (92.89)	15 (7.11)	320 (90.91)	32 (9.09)

Source: Field survey, 2020

Table 4 Farm households' recurrence of FI conditions in rural Ogun and Oyo states

	Recurrence-of-condition				Recurrence-of-condition			
	Ogun state ($n=141$)				Oyo state ($n=211$)			
Question	**Rarely**	**Sometimes**	**Often**	**Total**	**Rarely**	**Sometimes**	**Often**	**Total**
	Freq (%)	Freq (%)	Freq (%)	Freq	Freq (%)	Freq (%)	Freq (%)	Freq
1a	5 (3.68)	23 (16.91)	108 (79.41)	136	28 (17.07)	62 (37.80)	74 (45.12)	164
2a	7 (5.19)	27 (20.00)	10 (74.81)	135	28 (17.07)	76 (46.34)	60 (36.59)	164
3a	12 (8.89)	32 (23.70)	91 (67.41)	135	13 (8.02)	88 (54.32)	61 (37.65)	162
4a	10 (7.58)	44 (33.3)	78 (59.09)	132	21 (12.35)	100 (58.82)	49 (28.82)	170
5a	14 (10.77)	60 (46.15)	56 (43.08)	130	23 (14.47)	84 (52.83)	52 (32.70)	159
6a	16 (13.22)	59 (48.76)	46 (38.02)	121	16 (11.27)	81 (57.04)	45 (31.69)	142
7a	43 (43.00)	33 (33.00)	24 (24.00)	100	29 (29.29)	48 (48.48)	22 (22.22)	99
8a	30 (50.00)	15 (25.00)	15 (25.00)	60	18 (31.58)	25 (43.86)	14 (24.56)	57
9a	14 (82.35)	2 (11.76)	1 (5.88)	17	11 (73.33)	3 (20.00)	1 (6.67)	15

Source: Field survey, 2020

Table 5 Socioeconomic factors of farm households across FI category

	Food Secure ($n=32$)	Mild FI ($n=17$)	Moderate FI ($n=86$)	Severe FI ($n=217$)	Total ($n=352$)
	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)
Age of household head (years)					
≤40	4 (12.5)	2 (11.8)	8 (9.3)	37 (17.1)	51 (14.5)
41–50	13 (40.6)	8 (47.1)	40 (46.5)	79 (36.4)	140 (39.8)
51–60	11 (34.4)	3 (17.6)	14 (16.3)	67 (30.9)	95 (27.0)
>60	4 (12.5)	4 (23.5)	24 (27.9)	34 (15.7)	66 (18.8)
Gender					
Male household heads	26 (81.3)	13 (76.5)	60 (69.8)	125 (57.6)	224 (63.6)
Female household heads	6 (18.8)	4 (23.5)	26 (30.2)	92 (42.4)	128 (36.4)
Marital Status					
Married/Co-habiting	31 (96.9)	16 (94.1)	71 (82.6)	187 (86.2)	305 (86.6)
Single/separated/widow(er)	1 (3.1)	1 (5.9)	15 (17.4)	30 (13.8)	47 (13.4)
Education level (years)					
No formal education	7 (21.9)	3 (17.6)	17 (19.8)	29 (13.4)	56 (15.9)
Primary	12 (37.5)	12 (70.6)	46 (53.5)	118 (54.4)	188 (53.4)
Secondary	9 (28.1)	2 (11.8)	22 (25.6)	61 (28.1)	94 (26.7)
Tertiary	4 (12.5)	-	1 (1.2)	9 (4.1)	14 (4.0)
Household size (persons)					
≤5	15 (46.9)	10 (58.8)	36 (41.9)	99 (45.6)	160 (45.5)
6–10	16 (50.0)	5 (29.4)	44 (51.2)	107 (49.3)	172 (48.9)
>10	1 (3.1)	2 (11.8)	6 (7.0)	11 (5.1)	20 (5.7)
Membership of cooperative					
Yes	7 (21.9)	1 (5.9)	19 (22.1)	80 (36.9)	107 (30.4)
No	25 (78.1)	16 (94.1)	67 (77.9)	137 (63.1)	245 (69.6)
Food expenditure (Naira)					
≤₦10,000	4 (12.5)	4 (23.5)	8 (9.3)	15 (6.9)	31 (8.8)
₦11,000–₦20,000	18 (56.3)	8 (47.1)	46 (53.5)	107 (49.3)	179 (50.9)
₦21,000–₦30,000	4 (12.5)	3 (17.6)	18 (20.9)	74 (34.1)	99 (28.1)
>₦30,000	6 (18.8)	2 (11.8)	14 (16.3)	21 (9.7)	43 (12.2)
Ownership of motorcycle					
Yes	15 (46.9)	5 (29.4)	49 (57.0)	137 (63.1)	206 (58.5)
No	17 (53.1)	12 (70.6)	37 (43.0)	80 (36.9)	146 (41.5)

Source: field survey data, 2020

some meals (Q6a) happened infrequently, while 48.8% and 57.0%, and 38.0% and 31.7% of the households sometimes or frequently experienced the food insecurity condition (Q6a) within 30 days recall period in rural Ogun and Oyo states respectively. Furthermore, results in Table 4 equally indicated that most (82.4% and 73.3%) of the farming households in the two states responded that they seldom go 24 h without finding something eat, revealing cassava farm families in the two states usually eat something, although the food may be monotonous and of low diet quality which is common in developing economies (Willett et al. 2019; Otekunrin and Otekunrin 2021a).

However, following the methods of computing HFIA level and HFIA prevalence (HFIAP) as given above, the prevalence of FI among farm families in the two states was determined and presented in Fig. 1. Further, Fig. 1 indicates that out of 352 total sampled smallholder cassava farming households (Ogun, 141 and Oyo, 211), only 9.1% (32) were food secure while varying food insecurity categories include mildly food insecure, 4.8% (17); moderately food insecure, 24.4% (86); and severely food insecure, 61.7% (217). The results revealed that majority (90.9%) of the cassava farm households in the two states were experiencing varying categories FI. This finding was different

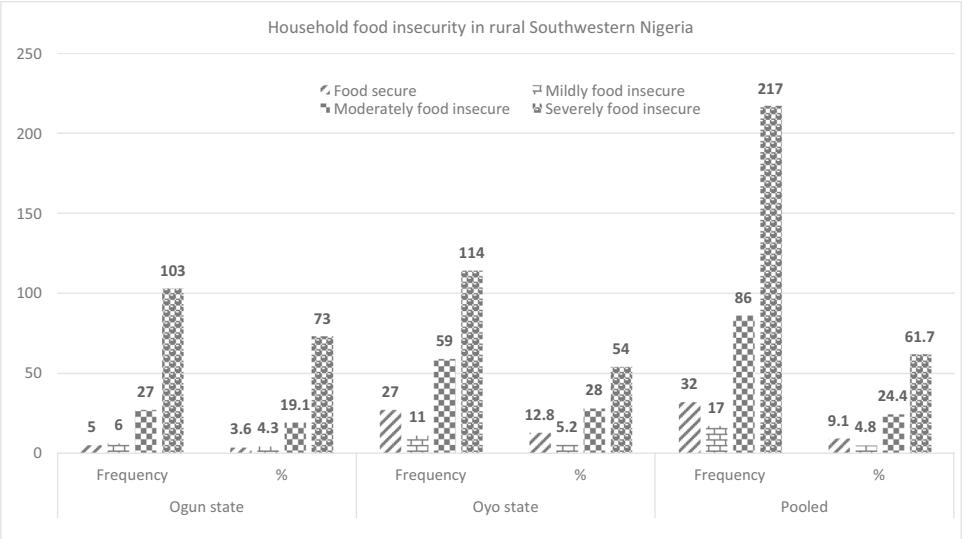

Fig. 1 FI categories in Ogun and Oyo states. Source: author's graph from field survey data

from Samim et al. (2021) who found that 66.8% of farming households in Takhar region of Afghanistan were FS using the same HFIAS approach. However, based on 320 food insecurity households in both Ogun and Oyo states (Fig. 1), about 61% (217) of the households were SFI, while about 5% (17) and 24% (86) of the households were mildly and moderately insecure respectively in 4 weeks. This finding was also corroborated by Obayelu and Oyekola (2018) who reported food insecurity prevalence of 80.9% among urban slum households in Ibadan, Nigeria.

Socioeconomic factors of farm households across FI levels

The socioeconomic factors of farm households in the two states across FI levels are presented in Table 5. The result indicated that farm household heads' age-group 41–50 years had the highest percent of the three varying FI categories among all age-group categories. This revealed that > 60 years household heads are more likely to experience moderate to severe FI due to limited resources as a result of old age which may lower overall agricultural production (Quddus and Bauer 2014; Obayelu et al. 2021; Otekunrin et al. 2021a). Further, male household heads are more food secure than female household heads in the study areas. Also, concerning FI levels, 76.5%, 69.8%, and 57.6% of male-headed households experienced varying FI categories from mildly to severe FI respectively, while 30.2% and 42.4% of female-headed households experienced moderate and severe FI respectively. Male household heads experienced higher FI levels than female headed farm households. This is rather contrary to the a priori expectation where women are cumbered with many responsibilities in the home, from caring for the children to many other duties which may lead to little engagement in farm operations. This result is contrary to Ahmed et al. (2015) and Obayelu et al. (2021) who found increased FI in female-headed households.

Furthermore, Table 5 indicates that 94.1%, 82.6%, and 86.2% of the married household heads were experiencing moderate to severe FI. Surprisingly, 96.9% of them (married household heads) are food secure. This may be connected to the fact that being married or co-habiting is likely to make the household more food secure especially when the couples are both actively engaged in economic activities, coupled with other members of the households engaged in income-generating activities that may lead to increased productivity and income for the family (Yusuf et al. 2015; Obayelu et al. 2021). In addition, prevalence of moderate to severe FI was highest in households with primary school level of education (70.6%, 53.5%, and 54.4% respectively). However, 64.8 and 64.3% with secondary and tertiary level of education respectively were experiencing severe FI within the 30-day recall period. This result suggested that high educational attainment of the household heads may not be responsible for reduced FI in farm families owing to the fact that only 4.0% of households had tertiary level of education with 64.3% severe FI. The results also indicated that 45.6% and 49.3% of the households with ≤ 5 and 6–10 members experienced severe FI. This finding revealed that severe FI was common in households with ≤ 5 and 6–10 members. In contrary to this result, Ogunniyi et al. (2021) reported about 6% FI among farmers with 0–5 members. Further, 94.1%, 77.95, and 63.1% of non-cooperative households are experiencing mildly, moderate, and severe FI respectively. Likewise, farm households that spent between 11,000 (US $30.96) and 20,000 (US $61.92) were most mild (47.1%), moderate (53.5%), and severe FI (49.3%) as regard food expenditure. This is likely to happen when food expenditure is very low, no thanks to the bad economic reality in Nigeria. About 59% of the household heads are having motorcycle to ease their

transportation within and outside the community. The results found that majority (57.0% and 63.2%) of household heads that owned motorbikes are still experiencing moderate and severe FI respectively.

Farm-related factors of households across FI levels

The farm-level factors of farm households in the two states across FI category are presented in Table 6. The size of farmland is an important factor in determining the commercialization opportunities in any agricultural enterprises. However, Table 6 reveals that farm households with ≤ 1.0 ha had the highest percent (41%) of households that are food severe, while 47% and 44% with less than a hectare are experiencing mildly and severe food insecurity respectively. Those cultivating on 1–2 ha of farmland were found to be experiencing moderate FI. When farm size increases, it is a common believed that it will lead to rise in food production that may likely to lead to reduction in food insecurity prevalence among farming households (Ahmed et al. 2015; Obayelu et al. 2021). Table 6 also indicates that majority (47.1%, 41.9%, and 44.7%) of the household having ≤ 10 years of farm experience suffered varying levels of FI.

However, 46.9% of households with about 20 years farm experience are the most food secure. In addition, 46.9% of households with farm income of 51,000 to 100,000 were the most food secure. Likewise, 38.7% of households having farm income of 51,000 to 100,000 were found to have highest level of severe FI. It is worthy to note that the possibility of households having more farm income and

Table 6 Farm-related factors of households across FI category

	Food secure ($n=32$)	Mild FI ($n=17$)	Moderate FI ($n=86$)	Severe FI ($n=217$)	Total ($n=352$)
	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)
Farm size (ha)					
Less than 1.00	13 (40.6)	8 (47.1)	30 (34.9)	95 (43.8)	146 (41.5)
1.01–2.00	9 (28.1)	5 (29.4)	31 (36.0)	73 (33.6)	118 (33.5)
2.01–3.00	8 (25.0)	3 (17.6)	13 (15.1)	39(18.0)	63 (17.9)
> 3.00	2 (6.3)	1 (5.9)	12 (14.0)	10 (4.6)	25 (7.1)
Farm experience (years)					
≤ 10	10 (31.3)	8 (47.1)	36 (41.9)	97 (44.7)	151 (42.9)
11–20	15 (46.9)	6 (35.3)	33 (38.4)	72 (33.2)	126 (35.8)
21–30	5 (15.6)	3 (17.6)	8 (9.3)	34 (15.7)	50 (14.2)
> 30	2 (6.3)	0 (0.0)	9 (10.5)	14 (6.5)	25 (7.1)
Farm income (Naira)					
≤ ₦50,000	9 (28.1)	2 (11.8)	19 (22.1)	45 (20.7)	75 (21.3)
₦51,000–₦100,000	15 (46.9)	5 (29.4)	23 (26.7)	67 (30.9)	110 (31.3)
₦101,000–₦200,000	6 (18.8)	7 (41.2)	40 (46.5)	84 (38.7)	137 (38.9)
> ₦200,000	2 (6.3)	3 (17.6)	4 (4.7)	21 (9.7)	30 (8.5)
Nonfarm income (Naira)					
≤ ₦50,000	7 (21.9)	5 (29.4)	18 (20.9)	59 (27.2)	89 (25.3)
₦51,000–₦100,000	12 (37.5)	8 (47.1)	59 (68.6)	121 (55.8)	200 (56.8)
> ₦100,000	13 (40.6)	4 (23.5)	9 (10.5)	37 (17.1)	63 (17.9)
Transport cost (Naira)					
≤ ₦2000	3 (9.4)	2 (11.8)	16 (18.6)	36 (16.6)	57 (16.2)
₦2100–₦4000	19 (59.4)	12 (70.6)	53 (61.6)	130 (59.9)	214 (60.8)
> ₦4000	10 (31.3)	3 (17.6)	17 (19.8)	51 (23.5)	81 (23.0)
Extension service					
Have access	7 (21.9)	3 (17.6)	21 (24.4)	93 (42.9)	124 (35.2)
No access	25 (78.1)	14 (82.4)	65 (75.6)	124 (57.1)	228 (64.8)

Source: Field survey data, 2020

still experiencing FI. The majority of the revenue received from sales of farm produce were ploughed back to the farm business while very small percent of the revenue was expended on food that can improve the diet quality and make households more food secure (Otekunrin et al. 2021a). However, household heads who spend between 2100 and 4000 were found to be most mildly (70.6%), moderately (61.6%), and severe food insecure (59.9%), while households with no access to extension service suffer varying levels of FI than those having access to extension service.

The CCI levels of farm households

This section reports the CCI levels of farm households in the two states. The CCI of each cassava farm household was computed as specified in the CCI equation. About 9% and 16% of cassava farm households were non-participant in the marketing of their produce (zero commercialization, CCI I) in Ogun and Oyo states respectively. This result revealed that 86.9% (306 out of 352) of all farm households in Ogun and Oyo participated actively in the sale of cassava roots in the market. About 30% (105) of the household heads had CCI between 50.0 and 75.0% (CCI II) in Ogun (31.2%) and Oyo (28.9%) states, while about 40% (141) of them had CCI > 75% (CCI IV) in Ogun (49.6%) and Oyo (33.6%) states.

Assessing FI categories across farm households' CCI levels

The FI categories across smallholder farm households' CCI levels in the two states are presented in Table 7. The very-high CCI (CCI IV) had the highest (53.1%) percent of households that are food secure, while low CCI level (CCI II) had the lowest (9.4%) percent of food secure households within 30-day recall period. This result indicated that about half (17) of the total number (32) of the households that are food secure belonged to very-high CCI households. This may be connected to the fact that very-high CCI households had the highest percent (47.6%) among CCI I-IV households that participated actively in the sale of their cassava roots in the market.

Furthermore, out of 217 severe FI cassava commercialization households, very-high CCI level households also had the highest percent (37.3%) of level of severe food

Table 7 Assessing food insecurity categories across farm households' CCI levels

CCI level	Households' food access Category ($n = 352$)				
	Food secure	Mild FI	Moderate FI	Severe FI	Pooled
	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)
Zero level	6 (18.8)	4 (23.5)	9 (10.5)	27 (12.4)	46 (13.1)
Low level	3 (9.4)	1 (5.9)	12 (14.0)	44 (20.3)	60 (17.0)
Medium–high level	6 (18.8)	3 (17.6)	31 (36.0)	65 (30.0)	105 (29.8)
Very-high level	17 (53.1)	9 (52.9)	34 (39.5)	81 (37.3)	141 (40.1)
Total	32 (100)	17 (100)	86 (100)	217 (100)	352 (100)

Source: Field Survey, 2020

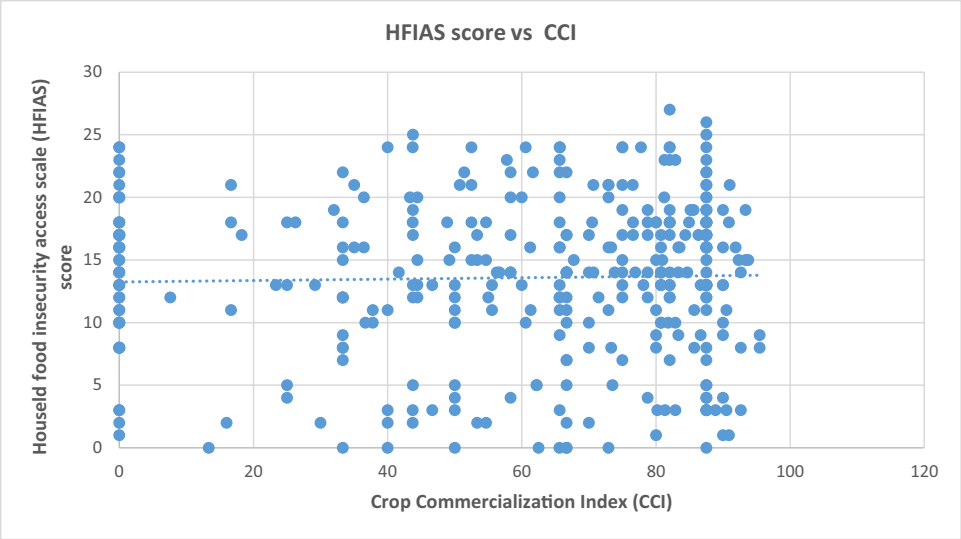

Fig. 2 Scatter plot showing the association between HFIAS score and CCI. Source: Author's graph, field survey data 2020

insecurity, while zero, low, and medium–high CCI level households had 12.4%, 20.3%, and 30.0% levels of severe FI. The results in Table 7 indicated that very-high CCI level households had highest level of food deprivation in all the four CCI levels when compared with other CCI households in the study areas within 30-day recall period.

From Fig. 2, the relationship between CCI and HFIAS score showed that there is "very weak" positive relationship between CCI and HFIAS score (basis for the food insecurity categories) of the farm households with correlation coefficient $r = 0.0268$. This association reveals that as CCI level increases, food insecurity (food deprivation) may progressively go up. This corroborated the findings in Table 7 that medium–high and very-high CCI level households (CCI III & VI) were found to have higher percent of moderate to severe FI. This revealed that belonging to high CCI households (CCI III–IV) may not necessarily mean households having unhindered access to food that can improve their nutrition and health status. This may happen if most of the revenue realized from the sale of cassava produce were again ploughed back into cassava farming enterprise without conscious effort by the household heads to purchase food items or produce some crops for home consumption (Otekunrin et al. 2021a).

However, detailed description of farm households' FI categories vis-à-vis their CCI levels in rural Ogun and Oyo states is presented in Table 8. This result presented the two states assessment of the cassava farming households' food insecurity categories according to individual CCI levels. The results revealed that out of 46 (pooled) zero CCI level (non-sellers) households, 34 belonged to Oyo state, while 12 were from Ogun state. From Ogun state zero commercialization households, no households were found to be food secure or mildly food insecure, while 75% (9) households were experiencing severe FI. Similar in Oyo state, 52.9% (18) of the zero commercialization households were experiencing severe FI. The results also showed that severe FI is prevalent in farm households belonging to CCI I in the study

Table 8 Description of cassava farming households' food insecurity categories across CCI levels

CCI levels			State		Pooled ($n = 352$)
			Ogun ($n = 141$)	**Oyo ($n = 211$)**	
			Frequency (%)	**Frequency (%)**	**Frequency (%)**
Zero level (non-seller) (CCI I)	**Food insecurity category**	Food secure	-	6 (17.6)	6 (13.0)
		Mildly food insecure	-	4 (11.8)	4 (8.7)
		Moderately food insecure	3 (25.0)	6 (17.6)	9 (19.6)
		Severely food insecure	9 (75.0)	18 (52.9)	27 (58.7)
	Total		12 (100)	34 (100)	46 (100)
Low level (CCI II)	**Food insecurity category**	Food secure	-	3 (6.7)	3 (5.0)
		Mildly food insecure	1 (6.7)	-	1 (1.7)
		Moderately food insecure	1 (6.7)	11 (24.4)	12 (20.0)
		Severely food insecure	13 (86.7)	31 (68.9)	44 (73.3
	Total		15 (100)	45 (100)	60 (100)
Medium–high level (CCI III)	**Food insecurity category**	Food secure	3 (6.8)	3 (4.9)	6 (5.7)
		Mildly food insecure	2 (4.5)	1 (1.6)	3 (2.9)
		Moderately food insecure	12 (27.3)	19 (31.1)	31 (29.5)
		Severely food insecure	27 (61.4)	38 (62.3)	65 (61.9)
	Total		44 (100)	61 (100)	105 (100)
Very high level (CCI IV)	**Food insecurity category**	Food secure	2 (2.9)	15 (21.1)	17 (12.1)
		Mildly food insecure	3 (4.3)	6 (8.5)	9 (6.4)
		Moderately food insecure	11 (15.7)	23 (32.4)	34 (24.1)
		Severely food insecure	54 (77.1)	27 (38.0)	81 (57.4)
	Total		70 (100)	71 (100)	141 (100)
CCI (1–IV)	**Food insecurity category**	Food secure	5 (3.5)	27 (12.8)	32 (9.1)
		Mildly food insecure	6 (4.3)	11 (5.2)	17 (4.8)
		Moderately food insecure	27 (19.1)	59 (28.0)	86 (24.4)
		Severely food insecure	103 (73.0)	114 (54.0)	217 (61.6)
	Total		141 (100)	211 (100)	352 (100)

Source: Computed from field survey data, 2020

areas. The result corroborated the findings of Ochieng et al. (2015) and Olanrewaju (2016) that commercialization has robust and positive effect on food security status of farming households in Central Africa and Southwestern Nigeria respectively. In low commercialization households with 60 households in both Ogun (13) and Oyo (31) states, no household was found to be food secure in Ogun state, while 86.7% of the households were reported to be experiencing severe FI. In Oyo state, just 6.7% of the households were found to be food secure, while 68.9% were experiencing severe FI. The results indicated that severe food deprivation existed among the low commercialization (CCI II) households with majority (73.3%) of the total sampled households reported to be severe FI in 4 weeks recall period.

Moreover, only 5.7% of CCI III households in the two states (Ogun, 6.8%; Oyo, 4.9%) were found to be food secure from 105 total commercialization households. In CCI III households, 27.3% and 61.4% in Ogun and 31.1% and 62.3% in Oyo state were experiencing moderate to severe FI respectively. In addition, under CCI IV households, only 12.1% (17) were FS including 2.7% (2) and 21.1% (15) in Ogun and Oyo states respectively. The result indicated that Ogun state had higher percent (77.1%) of severe FI CCI VI households when compared to that of Oyo state (38.0%) CCI IV households. About 57.4% (81) of total CCI IV households (141) were found to be severe FI, implying serious challenge of food deprivation in the CCI level households. Out of the 352 cassava commercialization households (CCI 1-IV), only 32 (9.1%) households were food secure, while 17 (4.8%), 86 (24.4%), and 217 (61.6%) were experiencing mildly to severe FI respectively. From Table 8, it revealed the prevalence of food deprivation in smallholder farm households in the two states. The study found that both less commercialized (CCI II) and highly commercialized (CCI III-IV) farm households experienced varying levels of FI.

Distribution of farming households' health and environment-related factors across FI category

The distribution of cassava farming households' health and environment-related factors (HEF) across food insecurity category is presented in Tables 9–13. Among the HEF considered are (1) access to electricity, (2) access to nutrition-related knowledge, (3) access to improved toilet, (4) access to safe drinking water, and (5) access to healthcare service in the two states. Table 9 reveals the level of electricity of cassava farming households across FI categories in the two states. The result indicated that 24 (75%) out of 32 households did not have access to electricity implying that only 14.8% had access to electricity in Oyo state, while 80% were in Ogun state. In severe FI households, 65% had access to electricity in Ogun state, while 32.5% make use of electricity in Oyo state. More so, both mildly and moderately food insecure households recorded the lowest access to electricity (23%) across the FI categories in the two states (Ogun and Oyo). Comparatively, Oyo state recorded higher percent (79.6%) of households with no access to electricity when compared to that of Ogun state with 34.0%. This result indicated that in the two states, less than 40% (38.6%) of farm households in all four food FI levels had access to electricity. This results was corroborated by the report of Africa's electricity index (AEI) which showed that Nigeria's AEI was abysmally low (1.95/100 in 2003; 2.72/100

Table 9 Distribution of farming households' access to electricity across FI category

Food insecurity category	Access to electricity	State		Pooled ($n=352$)
		Ogun ($n=141$)	**Oyo ($n=211$)**	
		Frequency (%)	**Frequency (%)**	**Frequency (%)**
Food secure	Have access	4 (80.0)	4 (14.8)	8 (25.0)
	No access	1 (20.0)	23 (85.2)	24 (75.0)
	Total	**5 (100)**	**27 (100)**	**32 (100)**
Mildly FI	Have access	4 (66.7)	0 (0.0)	4 (23.5)
	No access	2 (33.3)	11 (100)	13 (76.5)
	Total	**6 (100)**	**11 (100)**	**17 (100)**
Moderate FI	Have access	18 (66.7)	2 (3.4)	20 (23.3)
	No access	9 (33.3)	57 (96.6)	66 (76.7)
	Total	**27 (100)**	**59 (100)**	**86 (100)**
Severe FI	Have access	67 (65.0)	37 (32.5)	104 (47.9)
	No access	36 (35.0)	77 (67.5)	113 (52.1)
	Total	**103 (100)**	**114 (100)**	**217 (100)**
Total	Have access	93 (66.0)	43 (20.4)	136 (38.6)
	No access	48 (34.0)	168 (79.6)	216 (61.4)
	Total	**141 (100)**	**211 (100)**	**352 (100)**

Source: Field Survey, 2020

in 2020) when compared to other African counterparts (AfDB 2013; AfDB 2020; Otekunrin et al. 2021c). However, this results also revealed that access to electricity among cassava farm households in rural Oyo state was lower (20.4%) than the national average (38.9%) of rural households connected to the national grid as reported in 2018 NDHS (NPC and ICF 2019). This implies that many households will not have access to electricity which is crucial to farmers' increased production and processing of agricultural produce and can promote healthy living of rural households (NPC and ICF 2019; AfDB 2020; Otekunrin et al. 2021a).

The distribution of cassava farm households' nutrition-related knowledge across FI levels in the two states is presented in Table 10. The question was mostly directed to women in the household who were saddled with responsible of preparing food for the household. The respondents were asked on their exposure to nutrition-based knowledge usually facilitated by like extension officers or other non-governmental organizations or those garnered through listening to health and nutrition programs on radio or television. Table 10 shows that 81.3% of the food secure category had not undergone or had access to any nutrition-related knowledge where 85.2% households in Oyo state did not have nutrition-related knowledge. Considering all the four food insecurity categories in rural Ogun and Oyo states, 81.0% of the households (Ogun, 71.6%; Oyo, 87.2%) did not have access to such nutrition-related knowledge within 30-day recall period prior to this survey exercise. The results indicated that with adequate nutritional knowledge among farm households (especially food secure households), food, and nutrition security will improve. This result was corroborated by Fadare et al. (2019) and Otekunrin et al. (2021a) who reported low level of mothers' nutrition-based knowledge in rural households in Nigeria. This result was contrary to other studies from other developing economies who found positive relationship between mothers' education attainment and children nutrition (Abuya et al. 2011; Rakotonirainy et al. 2018; Custodio et al. 2019).

Access to improved toilet among farm households across FI categories in the two states is presented in Table 11. The results indicated that 75.0% farm households who were food secure did not have access to improved toilet in the study areas. None of the mild FI and 96.6% of moderate FI households had improved toilet access in rural Oyo state while not less than 50% of households in all the four FI categories in Ogun state were with no access to improved toilet facilities. Considering Oyo and Ogun states across the four FI categories, about 71% of households were with no access to improved toilet facilities. This finding is lower (29.3% access) when compare to the national average (39.1%) reported in 2018 NDHS (NPC and ICF 2019). Recently, Nigeria was ranked second in open defecation globally with not less than 38 million population practicing open defecation (UNICEF 2021; Otekunrin et al. 2021a). Open defecation in any settings (rural or urban) tends to increase the incidence of malnutrition and diarrheal disease especially among children (UNICEF 2021; Omotayo et al. 2021; Otekunrin et al. 2021a).

However, piped water access by farm households across FI categories in the study areas is presented in Table 12. The

Table 10 Distribution of farm households' nutrition knowledge across FI category

Food insecurity category	Nutrition-related knowledge	State		Pooled ($n=352$)
		Ogun ($n=141$)	**Oyo ($n=211$)**	
		Frequency (%)	**Frequency (%)**	**Frequency (%)**
Food secure	Have nutrition-related knowledge	2 (40.0)	4 (14.8)	6 (18.8)
	No nutrition-related knowledge	3 (60.0)	23 (85.2)	26 (81.3)
	Total	**5 (100)**	**27 (100)**	**32 (100)**
Mildly FI	Have nutrition-related knowledge	2 (33.3)	0 (0.0)	2 (11.8)
	No nutrition-related knowledge	4 (66.7)	11 (100.0)	15 (88.2)
	Total	**6 (100)**	**11 (100)**	**17 (100)**
Moderate FI	Have nutrition-related knowledge	9 (33.3)	2 (3.4)	11 (12.8)
	No nutrition-related knowledge	18 (66.7)	57 (96.6)	75 (87.2)
	Total	**27 (100)**	**59 (100)**	**86 (100)**
Severe FI	Have nutrition-related knowledge	27 (26.2)	21 (18.4)	48 (22.1)
	No nutrition-related knowledge	76 (73.8)	93 (81.6)	169 (77.9)
	Total	**103 (100)**	**114 (100)**	**217 (100)**
Total	Have nutrition-related knowledge	40 (28.4)	27 (12.8)	67 (19.0)
	No nutrition-related knowledge	101 (71.6)	184 (87.2)	285 (81.0)
	Total	**141 (100)**	**211 (100)**	**352 (100)**

Source: Field Survey, 2020

Table 11 Distribution of farm households' improved toilet access across FI category

Food insecurity category	Access to improved toilet	State		Pooled ($n=352$)
		Ogun ($n=141$)	**Oyo ($n=211$)**	
		Frequency (%)	**Frequency (%)**	**Frequency (%)**
Food secure	Have access	4 (80.0)	4 (14.8)	8 (25.0)
	No access	1 (20.0)	23 (85.2)	24 (75.0)
	Total	**5 (100)**	**27 (100)**	**32 (100)**
Mildly FI	Have access	3 (50.0)	0 (0.0)	3 (17.6)
	No access	3 (50.0)	11 (100.0)	14 (82.4)
	Total	**6 (100)**	**11 (100)**	**17 (100)**
Moderate FI	Have access	11 (40.7)	2 (3.4)	13 (15.1)
	No access	16 (59.3)	57 (96.6)	73 (84.9)
	Total	**27 (100)**	**59 (100)**	**86 (100)**
Severe FI	Have access	47 (45.6)	32 (28.1)	79 (36.4)
	No access	56 (54.4)	82 (71.9)	138 (63.6)
	Total	**103 (100)**	**114 (100)**	**217 (100)**
Total	Have access	65 (46.1)	38 (18.0)	103 (29.3)
	No access	76 (53.9)	173 (82.0)	249 (70.7)
	Total	**141 (100)**	**211 (100)**	**352 (100)**

Field Survey, 2020

Table 12 Distribution of farm households' piped water access across FI category

Food insecurity category	Access to piped water	State		Pooled ($n=352$)
		Ogun ($n=141$)	**Oyo ($n=211$)**	
		Frequency (%)	**Frequency (%)**	**Frequency (%)**
Food secure	Have access	1 (20.0)	3 (11.1)	4 (12.5)
	No access	4 (80.0)	24 (88.9)	28 (87.5)
	Total	**5 (100)**	**27 (100)**	**32 (100)**
Mildly FI	Have access	1 (16.7)	0 (0.0)	1 (5.9)
	No access	5 (83.3)	11 (100.0)	16 (94.1)
	Total	**6 (100)**	**11 (100)**	**17 (100)**
Moderate FI	Have access	10 (37.0)	0 (0.0)	10 (11.6)
	No access	17 (63.0)	59 (100.0)	76 (88.4)
	Total	**27 (100)**	**59 (100)**	**86 (100)**
Severe FI	Have access	31 (30.1)	5 (4.4)	36 (16.6)
	No access	72 (69.9)	109 (95.6)	181 (83.4)
	Total	**103 (100)**	**114 (100)**	**217 (100)**
Total	Have access	43 (30.5)	8 (3.8)	51 (14.5)
	No access	98 (69.5)	203 (96.2)	301 (85.5)
	Total	**141 (100)**	**211 (100)**	**352 (100)**

Field Survey, 2020

findings indicated that above 80% of households that are food secure, moderate, and severe food insecure were with no access to safe drinking water, while > 90% of households experiencing mild FI in the study areas were with no access to piped water. Considering all FI categories of the farm households, 3.8% in Oyo state had access to piped water, while 30.5% had access to safe drinking water in Ogun state. This is unsatisfactorily low when compared to the national average of 58.4% as reported by Nigeria (DHS) in 2018 for rural household access to safe drinking water in Nigeria (NPC and ICF 2019). More so, just like lack of improved toilet facilities, inadequate water and safe drinking water equally increase the incidence of open defecation in Nigeria, with the report from United Nations Children's Fund (UNICEF) who ranked Nigeria second in open defecation globally with 38 million people engaged in open defecation with West and

Table 13 Distribution of farm households' healthcare access across FI category

Food insecurity category	Access to healthcare service	State		Pooled ($n=352$)
		Ogun ($n=141$)	**Oyo ($n=211$)**	
		Frequency (%)	**Frequency (%)**	**Frequency (%)**
Food secure	Have access	4 (80.0)	11 (40.7)	15 (46.9)
	No access	1 (20.0)	16 (59.3)	17 (53.1)
	Total	**5 (100)**	**27 (100)**	**32 (100)**
Mildly FI	Have access	5 (83.3)	2 (18.2)	7 (41.2)
	No access	1 (16.7)	9 (81.8)	10 (58.8)
	Total	**6 (100)**	**11 (100)**	**17 (100)**
Moderate FI	Have access	24 (88.9)	18 (30.5)	42 (48.8)
	No access	3 (11.1)	41 (69.5)	44 (51.2)
	Total	**27 (100)**	**59 (100)**	**86 (100)**
Severe FI	Have access	81 (78.6)	57 (50.0)	138 (63.6)
	No access	22 (21.4)	57 (50.0)	79 (36.4)
	Total	**103 (100)**	**114 (100)**	**217 (100)**
Total	Have access	114 (80.9)	88 (41.7)	202 (57.4)
	No access	27 (19.1)	123 (58.3)	150 (42.6)
	Total	**141 (100)**	**211 (100)**	**352 (100)**

Field Survey, 2020

Central Africa accounting for 24% of open defecation globally (UNICEF 2021; Otekunrin et al. 2021c). This unhygienic and unhealthy practice negatively impacted nutrition and healthy living of household members and diarrheal disease prevalence mostly among young children (UNICEF 2021; Otekunrin et al. 2021c). This finding is contrary to study carried out in South Africa where 45% access to safe drinking in rural households was reported in 2019 (Omotayo et al. 2021).

Farm households' access to healthcare service across FI categories in the two states is presented in Table 13. About 47% of the farming households belonging to food secure category in the study areas (Ogun, 80%; Oyo, 41%) had access to healthcare service. Highest level (63.6%) of access to healthcare service was recorded in households experiencing severe FI when compared to all other FI categories in the study areas (Ogun, 79%; Oyo, 50%). The results in Table 13 also revealed access to healthcare service in Ogun state is higher (80.9%) than that of Oyo state (41.7%) across all the four food insecurity categories indicating better healthcare service delivery among rural cassava farming households in Ogun state. This result indicated access to functional healthcare service in rural Ogun state as pivotal to farm households' increased productivity and good health of farm households and other members of rural settings (Otekunrin et al. 2021a).

Determinants of cassava farm households' food insecurity

The drivers of FI among farm households in the two states are shown in Table 14. The HFIA prevalence was ordered, and the categories were significant ($P<0.01$). The threshold value depicting the FI levels, μ_1, μ_2, and μ_3, revealed that ranked levels (Knight et al. 2005; Obayelu et al. 2021; Otekunrin et al. 2021a). The regressand is the FI levels as mentioned above. The predicted probabilities of $Y=1$ or the marginal effects were estimated which measured changes in the probability of FI values in relation to a change in the regressors. Table 14 reveals the results of the OLM and the marginal effects of each of the regressors on the likelihood of HFIA prevalence categories. The statistical significance of the coefficients and the marginal effects are discussed as follows. Age, gender, level of education, farm size, farm experience, nonfarm income, and access to extension service were the explanatory variables that had significantly influenced FI levels of farm households in the study areas.

When the age of household head go up by a year, the likelihood of farm households being food secure experience mild or moderate FI increases. Comparatively, 1-year rise in household head's age brings down the probability of cassava farm households experiencing severe FI by 0.91%. This indicated that as the household heads grow older, the likelihood of being food secure increases and probability of experiencing severe FI reduces. In contrary, Omonona and Agoi (2007) and Obayelu et al. (2021) reported increase in age may likely reduce household heads being food secure.

However, a unit increase in male-headed cassava farming households raises the probability of households experiencing food security, mild or moderate FI. Similarly, an additional increased in male-headed household reduces the likelihood of experiencing severe FI. This finding was consistent with that of Omonona and Agoi (2007) and Obayelu (2012) but rather was in contrast with the work of Paddy (2003) who

Table 14 Determinants of cassava farming households' food insecurity

		Food secure	Mild FI	Moderate FI	Severe FI
Variable	**Coefficients**	***dy/dx***	***dy/dx***	***dy/dx***	***dy/dx***
Age	−0.0391***	0.0025***	0.0014**	0.0052**	−0.0091***
	(0.0144)	(0.0009)	(0.0006)	(0.0021)	(0.0033)
+Gender	−0.5594**	0.0338**	0.0184**	0.0743**	−0.1265**
	(0.2604)	(0.0144)	(0.0087)	(0.0355)	(0.0557)
+Marital status	−0.3375	0.0195	0.0108	0.0452	−0.0754
	(0.3247)	(0.0172)	(0.0100)	(0.0431)	(0.0695)
Household size	0.0433	−0.0028	−0.0015	−0.0058	0.0101
	(0.0466)	(0.0031)	(0.0017)	(0.0062)	(0.0108)
Year of schooling	−0.0744**	0.0048*	0.0108*	0.0099**	−0.0173**
	(0.0364)	(0.0025)	(0.0100)	(0.0050)	(0.0084)
Farm size	−0.2011	0.0129	0.0069	0.0269	−0.0467
	(0.1256)	(0.0079)	(0.0044)	(0.0175)	(0.0290)
Farm experience	0.0287*	−0.0018**	−0.0010*	−0.0038*	0.0067*
	(0.0151)	(0.0009)	(0.0006)	(0.0021)	(0.0035)
Farm income	1.37e−06	−8.78e−08	−4.73e−08	−1.83e−07	3.18e−07
	(1.59e−06)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Nonfarm income	−4.20e−06***	2.69e−07**	1.45e−07**	5.61e−07**	−9.76e−07***
	(1.59e−06)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
+Membership of cooperative	0.5180	−0.0306	−0.0168	−0.0689	0.1163
	(0.5105)	(0.0273)	(0.0166)	(0.0671)	(0.1097)
Food expenditure	0.000013	−8.60e−07	−4.64e−07	−1.79e−06	3.12e−06
	(0.00002)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
+Access to extension service	0.8584*	−0.0502*	−0.0274*	−0.1123*	0.1900*
	(0.4891)	(0.0279)	(0.0144)	(0.0622)	(0.1008)
Transport cost	−0.00008	5.05e−06	2.72e−06	0.00001	−0.00002
	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
+Own motorcycle	0.6981***	−0.0476**	−0.0250**	−0.0906***	0.1632***
	(0.2619)	(0.0197)	(0.0113)	(0.0339)	(0.0603)
Crop sold ratio	−0.0046	0.0003	0.0002	0.0006	−0.0011
	(0.0045)	(0.0003)	(0.0002)	(0.0006)	(0.0010)
/cut1	−4.9590				
	(0.8946)				
/cut2	−4.4352				
	(0.8808)				
/cut3	−2.9002				
	(0.8537)				

(+) is dummy variable from 0 to 1. ***Significance at 1% level. **Significance at 5% level. *Significance at 10% level. Figures in parentheses are robust standard errors. Number of observation = 352, log pseudo likelihood = −329.22532, Wald chi^2 (15) = 36.29, probability > chi^2 = 0.0016, pseudo R^2 = 0.0711

reported that the female counterparts are more food secure in Uganda.

In addition, when the year of schooling of cassava farm household head go up by a year, the probability of household being food secure, mildly or moderately food insecure, go up by 0.5, 1.1, or 1.0% respectively. In addition, 1-year rise in level of education of household head bring down the probability of the households experiencing severe FI by 2%. This indicated that as the level of education of household head go up, the probability of being food secure increases and less likely the household is experiencing severe FI. This result implies that higher level of education increases the likelihood of being FS and reduces severe food insecurity because it has positive influence on the production and nutrition-related decisions of the households (Olagunju et al. 2019; Ogunniyi et al. 2021; Obayelu et al. 2021; Otekunrin et al. 2021a).

Furthermore, the results (Table 14) indicated that CCI levels (proxied by crop sold ratio) did not have significant effect on household food insecurity in the study areas. This revealed that the level of cassava commercialization (Zero to Very-High CCI) may not necessarily influence food insecurity status of the farming households. This finding was corroborated by result in Fig. 2 where a very weak association was found between HFIAS score and CCI levels.

However, if the farming experience of cassava farm household head go up by a year, the probability of the households being food secure and experiencing mildly or moderate FI go down by 0.0018, 0.0010, or 0.0038 units respectively. In contrary, when farm experience goes up by 1 year, probability of the household experiencing severe FI increases by 0.67%. This results indicated that as the household heads advance in year of farming experience (as reflected in age increment), the less likely they are food secure and the more likely they experience severe FI. This may be connected to the fact that as cassava farm household heads advance in age, the strength to engage in agricultural activities reduces which portends lower production capacity and consequently reduces income which may expose them to food insecurity (Omonona and Agoi 2007; Obayelu et al. 2021; Otekunrin et al. 2021a).

The results also revealed that when nonfarm income goes up by one naira, the probability of household being food secure, experiencing mild or moderate FI increases, while the same increase in nonfarm income brings down the probability of the households experiencing severe FI. This shows the importance of nonfarm income sources in cassava farming or in any other agricultural enterprises in promoting multiple revenue sources capable of improving revenue base of the farming households and reducing the prevalence of severe food insecurity especially in rural settings. In contrary, Nkomoki et al. (2019) posited that increase in nonfarm income reduces the probability of the households being food secure in Zambia.

In sharp contrast to a priori expectation, increase in access to extension service by cassava farm household head increases severe food insecurity. A unit increase to extension service (through the extension officers) reduces the probability of households being food secure, experiencing mild or moderate FI by 5.0%, 2.7%, or 11.2% respectively. This result may be connected to the fact that only few (35.2%) farm household heads were privileged to experience extension officers visiting their cassava farms and enjoying the benefits of the services rendered, while majority (64.8%) of the farm household heads did not benefit from the services of the extension officers in several farming seasons (Otekunrin et al. 2021a). The ownership of motorcycle among cassava farm household heads negatively influenced the food insecurity status in the study areas. A unit increase in motorcycle ownership reduces the probability of the households being food secure, experiencing mild or moderate FI by 4.8%, 2.5%, and 9.1% respectively. In addition, a unit increase in household heads' motorcycle ownership increases the likelihood of the households experiencing severe food insecurity by 19.0%. This finding is rather contrary to a priori expectation in that the more cassava farm household heads own motorbikes, the better their means of transportation. This may be connected to the fact that over 50% (58.5%) of the cassava farm household heads did not have motorbike or vehicle to ease their transportation and this may consequently increase the levels of food insecurity among them.

Conclusion and recommendations

The findings on FI status of farm households in the two states revealed that 9.1% were found to be food secure, while 90.9% experienced varying levels of FI (mild, 4.8%; moderate, 24.4%; severe, 61.6%) within 30-day recall period when the survey was carried out. About 13% of the cassava farm households were non-participant in the sale of cassava roots (CCI I) in the last cropping season, while 87% of farming households participated actively in the sales of cassava roots with varying degree of cassava commercialization levels (CCI II, 17.0%; CCI III, 29.8%; CCI IV, 40.1%). With respect to the access to health and environment-related factors across FI categories of cassava farm households in the two states, access to electricity, piped water, and improved toilet were below 40% and lower than the national average (NPC and ICF 2019). The study also showed the existence of very weak positive relationship between CCI and HFIAS score of the cassava farm households which indicated that as CCI levels of farm households increases, food insecurity (food deprivation) among them may increase accordingly. Based on the foregoing, this study emphasized that relevant stakeholders (both government and non-government organizations) should assist in the provision of rural infrastructure facilities such as improved toilet facilities, piped water, and massive rural electrification. However, proper nutrition-sensitive intervention programs should be implemented in the rural communities to promote better nutrition knowledge and high-quality diets among farm households and enhance agricultural production, marketing, and improve quality of life of rural households.

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

Declarations

Ethical approval and consent to participate The study was approved by the Department of Agricultural Economics and Farm Management Review Board of Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria. In addition, the Oyo State Ethics Review Committee of the Ministry of Health, Department of Planning, Research and Statistics approved this study with Reference Number: AD13/479/4420[A]. Informed consent was obtained from the respondents before the survey was carried out and respondent data are fully anonymized.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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