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Food insecurity, coping strategies, and resilience of agricultural cooperative members during COVID-19 in West Africa

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Abstract

Background Lockdown measures of COVID-19 have had different repercussions on the well-being of households in West Africa depending on their resilience capacity. This study compares the dynamic of households' food insecurity during COVID-19 pandemic according to their membership in different types of agricultural cooperatives in four West African countries, namely Ghana, Mali, Ivory Coast, and Senegal.

Methodology We used data collected from 1270 members of agricultural cooperatives and regression analyses, to understand the link between the nature of their cooperatives and the food insecurity dynamic of their household, while controlling for other sociodemographic characteristics. Cooperative were categorized either "active" or "poorly/not active" depending on their capacity to conduct initiatives that address the needs of their members, to maintain communication between leaders and members, the participation of members to decisions, and their possession of a good understanding of business management. Food insecurity is measured using the Food Insecurity Experience Scale (FIES) and the Coping Strategy Index (CSI). Respondents were asked to answer questions related to their food security status for the period before and during the pandemic.

Results The COVID-19 pandemic has adversely affected respondents' food security status. These effects varied according to the severity of sanitary measures implemented and to the dynamism of cooperatives. Households of poorly or not active cooperatives have experienced more food insecurity in Ivory Coast and Senegal than those who were members of active cooperatives; in Ghana the effects were significant but similar in both types of cooperatives. Members of both cooperatives in Mali appear to have been less affected than members in other countries. Furthermore, households of poorly/not active cooperatives have used more severe coping strategies in Ivory Coast, Ghana, and Senegal during the pandemic.

Conclusions Strong collaboration and support provided by cooperatives can contribute to increase the resilience capacity of their members to shocks such as the COVID-19 pandemic.

Keywords Agricultural cooperatives, COVID-19, Food security, Resilience, West Africa

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Background

Due to COVID-19 pandemic, several countries imposed nationwide, regional, or local lockdowns such as home quarantine, travel bans, curfews, closure of borders, businesses, or schools. Those lockdowns triggered consumer panic in some areas that resulted in food stockpiling, thus creating a shortage of basic commodities [1–4]. Studies have assessed the socioeconomic impacts of the pandemic on household living conditions. They have shown that the pandemic has led to increased unemployment, food insecurity, loss of income, and livelihoods [5, 6]. Studies have reported that the pandemic has increased the number of people experiencing extreme poverty and food insecurity, particularly in countries where many people are currently close to the poverty line [7–9]. Kansiime et al. [10] found that more than two-thirds of households surveyed have experienced a decline in their income because of COVID-19 and their food insecurity increased by 38% and 44% in Kenya and Uganda, respectively. In the Sundarbans region of West Bengal in India, authors found that household weekly income fell by US$ 13.5, an 88% drop from the long-term average with a further 63% reduction in remittances [11].

Worldwide, the pandemic and lockdown measures have significantly affected many food systems, particularly marketing of agricultural inputs and products, food processing, and employment along food value chains, all of which have exacerbated poverty and food insecurity [1, 7, 8, 12–20]. Although, studies underlined the disruption of food systems due to COVID-19 in many countries, some modern value chains showed more resilience in terms of ensuring food availability by, for example, co-pivoting on e-commerce [21] than traditional and transitory chains that dominate developing countries [1, 4, 18, 22–26]. In Senegal, COVID-19 disrupted both the modern and the traditional fruit and vegetable supply chains even though both have innovated to cope with the sanitary measures put in place [27]. To date, although the actual number of COVID-19 infections in Africa remains relatively low, concerns are about how the pandemic exacerbated food insecurity [28–30] particularly in the populations in Western Africa who are already facing hunger, malnutrition, and poverty [9, 31]. These effects will be felt differently according to the socioeconomic profile, with vulnerable groups such as women, young children, teenagers, and the elderly being particularly exposed [1, 9, 16, 26, 32, 33].

During a systemic shock such as the COVID-19 pandemic, resilience, *i.e.*, the capacity to bounce back from shock, becomes essential to protect smallholder farmers livelihoods [28, 29], and thus, response by cooperatives to the needs of their members could be an integral part to build resilience and to restore livelihoods offering some sort of social protection [34]. Indeed, smallholder farmers are often the poorest and the most vulnerable people with lower bargaining power, and cooperative membership has generally been seen as playing a role in reducing their exposure and vulnerability [35–37]. Cooperatives are often founded by persons sharing a common need to ensure the provision of products or services which the market, and/or the state, fails to provide them with [35, 38]. As COVID-19 brings new challenges worldwide, including for smallholder farmers [39], it is necessary for agricultural cooperatives, through the provision of products and services, to continue to support their members. In specific high-poverty countries like Nigeria in Western Africa, the support provided by agricultural cooperatives (distribution of food, free water, distribution of masks, deferral of payment of certain bills, etc.) to specific category of households like smallholder farmers living with pre-existing vulnerability to COVID-19 has improved the living conditions of household members, particularly those of women [40]. Thus, the restriction measures could have differentiated consequences on the living conditions of vulnerable households [4, 7, 40–42] depending on the capacity of their cooperative to provide first necessity services. Cooperatives are more or less active in providing products and services. Using empirical evidence and data from face-to-face household-level surveys, this study compares the food insecurity dynamic of agricultural cooperative members during COVID-19 pandemic, according to the level of dynamism of their cooperative. We focus on the link between cooperatives' dynamism, which refers to their capacity to continue providing services or needs of their members even during a shock, and the resilience of their members assessed through the degree of aggravation or not of their food insecurity. This study contributes to adding to the literature about resilience capacity of agricultural cooperatives members. The findings suggest that supporting collective actions through agricultural cooperatives could be a major driver for the resilience of vulnerable households. Understanding the role of active cooperatives in the resilience of these vulnerable group will provide evidence for designing targeted policies and interventions aimed at mitigating adverse effects of shocks such as the pandemic of COVID-19.

Conceptual framework

COVID-19 and the sanitary measures deployed to counter it have increased the relevance of the resilience concept and its measurement in terms of food security, for which the issues of shocks, vulnerability, and risk are critical [1, 43–47]. In the last two decades, resilience has emerged as a promising concept that can help societies become less vulnerable to shocks and stressors [1, 44, 46,

47]. Many definitions of resilience exist in the literature, but the common characteristic is that resilience refers to the capacities of households and communities to deal with adverse events in a way that does not negatively affect their long-term well-being and/or functioning [1, 45, 47]. Resilience is defined as the capacity that ensures stressors and shocks do not have long-lasting adverse development consequences [48, 49]. Because high exposure and vulnerability to shocks could prevent most poor people from accessing food, mainly due to lack of resources or infrastructure [47], cooperatives can be used as a shell to absorb some of the shocks. Resilience results, or emerges, from a combination of different properties or capacities such as coping strategies or adaptive capacity [50, 51]. Referring to resilience capability of cooperative, we analyze the resilience of households that are cooperative members in relation to their ability to access sufficient food in the face of the stressor/shock. To mitigate or counteract adverse effects of the shocks or stressors due to COVID-19, different resilience strategies are used by cooperatives. For example, in response to sanitary measures in Honduras, some cooperatives have deployed capacity building, sensitization, financial products such as grants or loans, input provisioning, and collective marketing strategies for their members [52].

Cooperative characteristics such as value driven, member owned, and democratically controlled, aim at fulfilling the needs of their members [53–56], are main drivers for resilience capacity. For example, the lack of resilience of cooperatives members in Southeast Africa during COVID-19 could be explained by many factors such as organizational immaturity, large membership size, elite control, and limited business orientation resulting from a general scarcity of management capital [28]. Cooperatives' focus on satisfying the needs of their members in a sustainable way has a critical impact on their resilience during crisis [34, 57]. The bond between cooperatives and members are strengthened in both directions: members support their cooperatives, and cooperatives support their members to get through the crisis [34, 58].

The characteristics of the cooperatives included in this study are presented in different diagnostic studies [59–63] carried out during two rural economic development projects aiming to improve the living conditions of smallholder farmers: program for the development of inclusive and sustainable model cooperatives (PROCED) in Ivory Coast, Ghana, and Senegal, and Agricultural and Rural Finance Project in Mali (FARM). These diagnoses led to the classification of cooperatives in two main categories: active cooperatives vs. poorly/not active cooperatives. Cooperatives were considered active when they fulfilled each of the following three criteria: (1) they conduct initiatives that address the needs of their members (e.g., training, members awareness, provision of affordable credit, maintaining marketing channel, collective marketing, collective inputs provisioning, etc.); in turn, members use and benefit from the services of the cooperative; (2) leaders maintain good communication with members through regular meetings, and a democratic group dynamic whereby members participate in decisions and orientations is implemented, and (3) they possess a good understanding of business management, they conduct their operations and provide relevant, consistent, and timely services. On the opposite, poorly/not active cooperatives included many inactive members who were registered but did not do business with it. They also included cooperatives whose leaders had troubles reaching out to members through frequent meetings and maintaining a relationship of trust with them. A poorly/not active cooperative could also encounter difficulties in its economic management, it could have struggled setting up services or might not have had the capacity to ensure the consistency of its operations.

Materials and methods

Areas of study

This study was conducted in six areas located in four West African countries: Korhogo and Abengourou in Ivory Coast, Bolgatanga in Ghana, Ségou and Baguinéda in Mali, and Casamance in Senegal. These areas correspond to localities where were conducted PROCED and FARM projects and were chosen accordingly as households were facing COVID-19 pandemic problematic, as elsewhere in the world. In the rest of the article, to simplify the writing, we will simply name the countries, although the analysis only concerns the regions in which the data were collected.

Table 1 presents the general characteristics of the six study areas. The areas are described using the multidimensional poverty index (MPI), the women empowerment index (WEI) [64–67], their main agricultural production, the stringency index (SI) in September–October 2020 (the 30 days before the survey) and in October–November 2020 (the survey period), the level of compliance from the population to the sanitary measures, and official cumulative number of COVID-19 cases and deaths until April 7, 2022. Table 1 shows that the six study areas have different levels of MPI, population from Abengourou and Bolgatanga being the least vulnerable to poverty, and population from the other areas are already experiencing poverty. In Ghana, the women parboilers are the most empowered women of all three countries where the WEI was calculated, meaning that these women can take decision about their production and manage their assets compared to the women in region where households grow cashew, cocoa, banana,

Table 1 Descriptive characteristics of the six study areas

Country	Study areas	MPI (OPHI)	WEI[e]	Production	SI[f] Sept–Oct 2020	SI[f] Oct–Nov 2020	Compliance to sanitary measures[g]	COVID-19 cumul active cases until 2022-04-07[h]	COVID-19 cumul deaths until 2022-04-07[g]
Ivory Coast	Korhogo	0.408[a]	0.404	Cashew	From 38 to 25	Stable at 25	Low	81,800	796
	Abengourou	0.214[a]	0.503	Cocoa					
Ghana	Bolgatanga	0.214[b]	0.739	Parboiled-Rice	Stable at 44	Stable at 39	Strong	161,034	1445
Senegal	Casamance	0.411[c]	0.642	Banana or Beekeeping	From 38 to 45	From 38 to 31	Higher in Kolda than Sédhiou or Ziguinchor	85,940	1965
Mali	Ségou	0.424[d]	–	Irrigated rice	From 47 to 38	Stable at 38	Low	30,526	729
	Baguinéda	0.353[d]	–	Irrigated rice/onion					

[a] [64]
[b] [65]
[c] [66]
[d] [67]
[e] [117]
[f] [68]
[g] Authors' compilation (2020)
[h] [118]

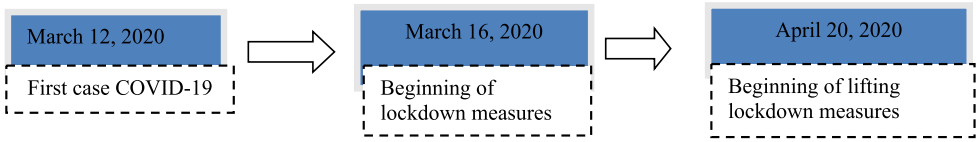
or irrigated rice, value chains that are traditionally dominated by men. Finally, the sanitary measures put in place by the government to limit the propagation of COVID-19 are evaluated by the Stringency Index[1] [30, 68] and the compliance level of these measures. The timeline of COVID-19' lockdown measures in the four countries is presented in Fig. 1. The first cases of COVID-19 have been detected in Senegal on March 2, 2020, with a beginning of first and partial lockdown measures on March 16, 2020. This start-up period of the first measures was similar in Ivory Coast and in Ghana. Mali was the country which implemented first lockdown measures before the arrival of the first cases of COVID-19.

Ghana is the country where the most severe measures, including mandatory quarantine of travelers entering the country, borders closing, and movement restrictions [69, 70], were continuously put in place from September to October 2020, with a stronger adhesion of the population. In Ivory Coast, the lockdown measures put in place such as borders controls, flights suspensions from affected countries, schools closing, borders closing, state of emergency declaration with movement restrictions, maquis and bars closing, and nationwide curfew[71] were not well respected by the population. Lockdown measures imposed in Senegal comprised travel restrictions, cruise ships bans, schools closing for three weeks, public gatherings bans for a month, and curfews [72]. However, within the Casamance region in Senegal, the government measures were more respected in Kolda than in Sédhiou and Ziguinchor. Finally, Mali was spared during the first wave of the disease, and as a result, the state's emergency measures were quickly relaxed, although these measures (social distance, public gatherings bans, suspension of flights from affected countries, schools and nightclubs closing, curfews) were not scrupulously respected by most of the population [73].

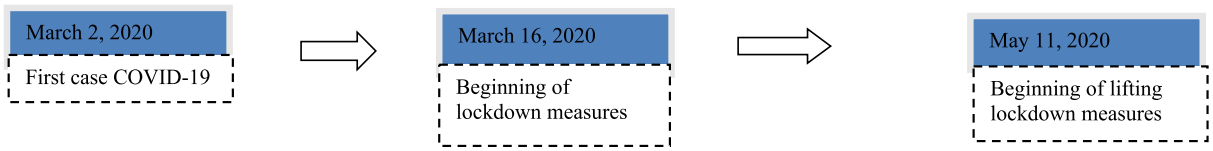
Sampling and data collection

The number of cooperatives chosen from each country (Table 2) depends mainly on the number of cooperatives supported by the two projects implemented (PROCED and FARM) in the targeted areas, membership size, and availability of members to participate in the survey. In Mali, the FARM project involves more cooperatives than the PROCED and they are also smaller in membership size. To reflect this difference, the number of cooperatives included in the Mali sample was therefore higher than in any other countries. In 2019–2020, PROCED and FARM project participants reached 32,177 and were distributed across the four countries as follows: 855 participants for Ivory Coast (57% of which were women), 935 for Ghana (68% women), 30,163 for Mali (49% women),

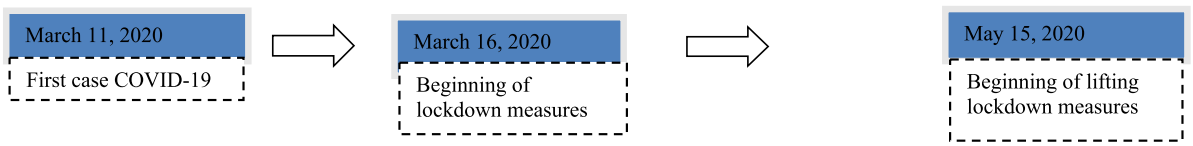
[1] The stringency index ranges between 0 and 100 and is a composite measure based on 9 indicators: school closures, workplace closures, cancellation of public events, restrictions on public gatherings, closures of public transport, stay-at-home requirements, public information campaigns, restrictions on internal movements, and international travel controls. While differences may exist across different sub-region of a country, the index reflects the response of the strictest sub-region of the country.



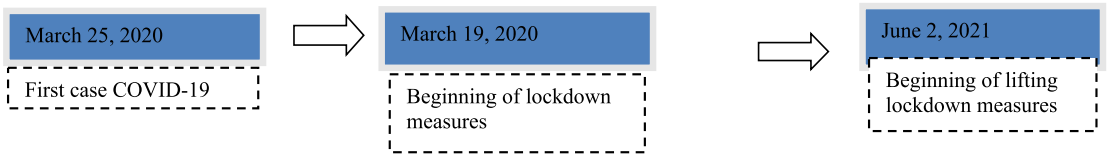
a. Timeline of COVID-19' lockdown measures in Ghana



b. Timeline of COVID-19' lockdown measures in Senegal



c. Timeline of COVID-19' lockdown measures in Ivory Coast



d. Timeline of COVID-19' lockdown measures in Mali

Fig. 1 Timeline of COVID-19' lockdown measures in Ghana, Senegal, Ivory Coast, and Mali. Source: Authors (2023)

Table 2 Sampling

Country	Expected sample	Active cooperatives			Poorly/not active cooperatives			Actual sample	% of women
		Number of cooperatives	Number of women in cooperative	Number of men in cooperative	Number of cooperatives	Number of women in cooperative	Number of men in cooperative		
Ghana	329	5	134	65	4	90	40	329	68
Ivory Coast	319	1	115	86	1	67	50	318	57
Mali	500	6	95	112	13	138	123	468	50
Senegal	155	1	39	39	1	38	39	155	50
Total	1303	13	383	302	19	333	252	1270	56

Source: Authors' calculation (2023)

and 224 for Senegal (49% women). The study sample was drawn using the stratification method. The stratification was done according to the relative numbers of individuals in active and poorly/not active cooperatives. A total of 1,270 persons were randomly selected from the participants of the two projects, 716 women, 554 men, 329 from Ghana, 318 from Ivory Coast, 468 from Mali, and 155 from Senegal; 685 were members of an active cooperative, 585 members of poorly/not active cooperatives (Table 2).

From October 7 till November 16, 2020, data were collected from the respondents about their food security

and coping strategies before and during the pandemic across the six targeted areas, as well as information about other socioeconomic and demographic characteristics. Respondents and interviewers complied with sanitary measures implemented by local authorities such as social distancing and wearing of masks. Whenever possible, not only the official member of the cooperative but also his or her spouse were interviewed to get a more complete and more accurate picture of the respondent's household. We used recall data on the food security status prior to the COVID-19 pandemic for each respondent. However, we are aware of the potential bias that this method can introduce into data collection and analysis. In our case, this issue was controlled by the fact that the interviewers were familiar with each of the interviewees, and, thanks to the implementation of the two projects (PROCED and FARM), interviewers were therefore able to provide respondents with sufficiently precise information to make it easier for them to recall their situation one year earlier (e.g., season, project activities that were ongoing at the time, various project-related highlights).

Table 3 presents the descriptive statistics for the demographic and socioeconomic characteristics of the respondents for the whole sample and according to the type of the cooperative. Briefly, the whole sampling contains 56% women vs 44% men; 4% of respondents are literate, 26% have reached primary school level, 11% of them have secondary or technical school level, and 1% have reached university or tertiary level; and 81% of respondents are plot owners. In this way, we can capture the difference in decision making and opportunity structure available to people educated at different levels as reported by authors [10, 74, 75]. Although plot size variation may influence extent of vulnerability [76], our database did not contain information about plot size, so we did not include this variable in our analysis. Furthermore, 72% of respondents have lost income due to COVID-19 vs 28% who did not lose income; 81% of them grow food crops vs 19% who grow cash crops. Finally, 85% of respondents declared agriculture as a main occupation, and the average age of respondents is 44.47 years. The respondent in the farming household, either the husband or the spouse, could have agriculture or other activities such as trade and handicrafts, as their main occupation, but farming is above all an integral part of their economic activities.

Resilience measurement

The resilience capacity of the members of cooperatives was assessed through (i) the dynamics of their food security between the period before and during the pandemic (using the Food Insecurity Experience Scale (FIES) survey module) [77, 78] and the (ii) dynamics of their coping strategies during the same two periods (using the Coping Strategy Index (CSI)) [79]. The smaller or null the increase of food security indicators like prevalence of moderate or severe food insecurity or CSI, the greater the resilience [80].

Prevalence of food insecurity analysis

The FIES is a survey module developed by the Food and Agriculture Organization (FAO) to measure the severity of food insecurity (FI) at household or individual level as a latent trait, conceptualized as the condition of not being able to freely access the food one needs to live a healthy, active, and dignified life [81–84]. However, the lack of a gold standard measure for essentially unobservable (*i.e.*, latent) attributes makes such a measure challenging. Fortunately, the application of statistical inference principles to FI measurement could legitimate conclusions drawn in terms of probability [85].

One of the unique contributions of the FIES survey module compared to similar methods for measuring FI is that, in addition to considering compromised quality and reduced food quantity, it also captures psychosocial elements associated with anxiety or uncertainty about obtaining sufficient food [82]. The innovation brought by the FIES survey module is its ability to use thresholds to classify and compare estimated prevalence rates at regional and global levels [82, 86]. The FIES measurement relies on people's direct responses to eight questions related to their access to adequate food (Table 4). Each of the eight FIES questions was asked with reference to the period during and before the COVID-19 pandemic. Here is an example using the first item (WORRIED). To collect information regarding the pandemic period, the question was asked as follows: *In the past 30 days, have you ever been worried about not having enough to eat, due to lack of money or other resources?* Similarly, to collect information regarding the period before the COVID-19 pandemic, the question was asked as follows: *At this time last year, were you ever worried about not having enough to eat, due to lack of money or other resources?* To ensure the gathering of timely and reliable information on food security, we adapted the FIES survey module to the current pandemic situation using the updated version of the FIES survey module [87]. Using statistical methods and the guidelines developed by the FAO, the answers to the eight questions of the FIES module are put together to calculate the food security indicators like the prevalence of moderate or severe food insecurity.

Each of the eight questions of the FIES module was asked to respondents in the surveyed households, with clear reference to each of the two time periods analyzed, *i.e.*, during and before the COVID-19 pandemic. Recall data were therefore used for the pre-pandemic

Table 3 Demographic and socioeconomic characteristics of the respondents ($N=1270$)

Variable	Ivory Coast			Ghana			Mali			Senegal			Total sample
	Active cooperative	Poorly/ Not active cooperative	Total	Active cooperative	Poorly/ Not active cooperative	Total	Active cooperative	Poorly/ Not active cooperative	Total	Active cooperative	Poorly/ Not active cooperative	Total	
Gender of respondent (1 if men and 0 if women)[a]													
Women	115 (63%)	67 (37%)	182 (100%)	134 (60%)	90 (40%)	224 (100%)	95 (41%)	138 (59%)	233 (100%)	39 (51%)	38 (49%)	77 (100%)	716 (56%)
Men	86 (63%)	50 (37%)	136 (100%)	65 (62%)	40 (38%)	105 (100%)	112 (48%)	123 (52%)	235 (100%)	39 (50%)	39 (50%)	78 (100%)	554 (44%)
Education level of respondent (1 = Yes, 0 if not)[a]													
Literate	0 (0%)	3 (100%)	3 (100%)	15 (44%)	19 (56%)	34 (100%)	41 (43%)	55 (57%)	96 (100%)	22 (54%)	19 (46%)	41 (100%)	174 (14%)
Primary level	63 (86%)	10 (14%)	73 (100%)	44 (72%)	17 (28%)	61 (100%)	78 (51%)	75 (49%)	153 (100%)	23 (58%)	17 (42%)	40 (100%)	327 (26%)
Secondary/ technical level	27 (77%)	8 (23%)	35 (100%)	15 (63%)	9 (37%)	24 (100%)	17 (40%)	26 (60%)	43 (100%)	9 (27%)	24 (73%)	33 (100%)	135 (11%)
University/ Tertiary level	2 (100%)	0 (0%)	2 (100%)	6 (100%)	0 (0%)	6 (100%)	0 (0%)	1 (100%)	1 (100%)	0 (0%)	5 (100%)	5 (100%)	14 (1%)
Plot ownership by respondent (1 if Yes, 0 if not)[a]													
No	68 (65%)	36 (35%)	104 (100%)	45 (67%)	22 (33%)	67 (100%)	16 (33%)	33 (67%)	49 (100%)	6 (26%)	17 (74%)	23 (100%)	243 (19%)
Yes	133 (62%)	81 (38%)	214 (100%)	154 (59%)	108 (41%)	262 (100%)	191 (46%)	228 (54%)	419 (100%)	72 (55%)	60 (45%)	132 (100%)	1027 (81%)
Loss of income due to COVID-19 from March to October 2020 by respondent[a]													
No	146 (75%)	49 (25%)	195 (100%)	29 (76%)	9 (24%)	38 (100%)	53 (47%)	60 (53%)	113 (100%)	4 (36%)	7 (64%)	11 (100%)	357 (28%)
Yes	55 (45%)	68 (55%)	123 (100%)	170 (58%)	121 (42%)	291 (100%)	154 (43%)	201 (57%)	355 (100%)	74 (51%)	70 (49%)	144 (100%)	913 (72%)
Type of crops usually grown by respondent[a]													
Cash crops	143 (63%)	83 (37%)	226 (100%)	1 (100%)	0 (0%)	1 (100%)	3 (43%)	4 (57%)	7 (100%)	1 (13%)	7 (87%)	8 (100%)	242 (19%)
Food crops	58 (63%)	34 (37%)	92 (100%)	198 (60%)	130 (40%)	328 (100%)	204 (44%)	257 (56%)	461 (100%)	77 (52%)	70 (48%)	147 (100%)	1028 (81%)
Agriculture as usually main occupation of respondent[a]													
No	8 (21%)	30 (79%)	38 (100%)	42 (61%)	27 (39%)	69 (100%)	13 (33%)	26 (67%)	39 (100%)	16 (37%)	27 (63%)	43 (100%)	189 (15%)
Yes	193 (69%)	87 (31%)	280 (100%)	157 (60%)	103 (40%)	260 (100%)	194 (45%)	235 (55%)	429 (100%)	62 (55%)	50 (45%)	112 (100%)	1081(85%)
Age of respondent (number of years)[b]													
Mean (standard deviation)	44.77 (12.86)	45.12 (12.90)	46.80 (13.0)	44.67 (12.98)	43.95 (12.38)	43.42 (12.00)	44.40 (12.92)	44.16 (12.75)	43.89 (12.93)	44.49 (12.93)	44.11 (12.60)	43.17 (12.54)	44.47 (12.80)

Source: Authors' calculation (2023)

[a] When variables are qualitative, we report frequencies with relative percentages in brackets

[b] When variables are quantitative, we report means with standard deviations in brackets

period. During data collection, respondents did not give extreme values (98: don't know, and 99: refused to answer) to each of the eight questions and we easily coded each response 0 or 1.

Dichotomous (Yes/No) responses to FIES questions provide sufficient information to construct a unidimensional measure using a Rasch model [82]. Because food security is itself an unobservable characteristic, it can only be measured by examining its observable manifestations. The Rasch model assumes that the position of a respondent r and items i can be located on the same unidimensional scale and postulates that the respondent's probability of answering "Yes" to item i is a linear function of the difference between the severity of food insecurity condition experienced by r and severity of item i. Scoring $x_{r.i}$ (response given by respondent r to point i) as 1 for "Yes" and 0 for "No" responses, we have

$$p \equiv \text{Prob}(x_{r.i} = 1) = \frac{e^{(a_r - b_i)}}{1 + e^{(a^r - b_i)}} \tag{1}$$

and then

$$\ln\left(\frac{p}{1-p}\right) = a_r - b_i, \tag{2}$$

where a_r is the measure of the level of food insecurity experienced by the respondents, and b_i is reflecting the severity associated with the experience captured by the different questions. The greatest advantage of the Rasch model is that the measures of individual severity (a_r) are linked monotonically to the raw score. Thus, the raw scores, that are the number of affirmed items, are a sufficient basis to represent the severity of food security of the respondents on an ordinal scale [86, 88].

An R package developed by FAO (https://CRAN.R-project.org/package=RM.weights) has been used to implement the Rasch model in this study. The package estimates the severity parameter by maximizing the conditional likelihood function of the raw score, and by using, in the estimation process, only cases with non-extreme response patterns. Respondent severity parameters are then estimated by maximizing the likelihood function given item parameters. The prevalence rates were calculated for each country, before and during COVID-19 according to the type of cooperative.

Coping strategies analysis

The CSI measures which actions people undertake when they do not have access to sufficient food. The CSI was indeed first developed to assess the food security situation in households [70, 79]. A coping strategy is an action carried out by households/individuals when shocks push them beyond the difficulties encountered in "normal" times. We used the CSI instead of the Reduced Coping Strategies Index (rCSI) to have a complete picture on all strategies used, including their degree of severity to cope with the pandemic. As reported [75], a single coping mechanism might not provide sufficient protection to a household faced with a COVID-19 shock that presents itself in multiple coinciding shocks. Therefore, households instead employ multiple coping mechanisms complimentarily. The index is a set of questions about the strategies adopted by households to cope with an inadequate food situation [89] and results in a simple numerical score [79]. The CSI is based on possible answers to a single question: "What do you do when you do not have enough food and you do not have the money to buy it?" In this study, 26 strategies, classified in four levels according to their severity, were identified (Table 5).

Each question regarding these 26 strategies was asked with reference to the period before and during the COVID-19 pandemic, to determine whether respondents used each of these strategies. For example, regarding the pandemic period, the following question was used: *In the past 30 days, did you have to use any of the following coping strategies because there was not enough food or money to buy food?* Then each of the 26 strategies was named and the respondent answered Yes or No. Similarly, to collect information regarding the period before the COVID-19 pandemic, the question was asked as follows: *At this time last year, did you have to use any of the following coping strategies because there was not enough food or money to buy food?*

The score for each individual coping strategy is calculated by multiplying its frequency and corresponding severity. The CSI score for each household is the sum of all individual scores and is calculated using Formula (3). A high CSI indicates a poor food security situation. The average CSI was calculated for each country, before and during the pandemic and according to the type of cooperative:

$$\begin{aligned} \text{CSI} = \sum &(\text{fCS1} \times \text{wCS1}) + (\text{fCS2} \times \text{wCS2}) \\ &+ \cdots + (\text{fCSn} \times \text{wCSn}), \end{aligned} \tag{3}$$

where

fCS was the frequency of coping strategy used over the last 30 days,

wCS was the degree of severity of coping strategy, and

1…n was the number of coping strategies (here $n = 26$).

Table 4 The FIES Survey Module (FIES-SM)[a]

Items	Questions	Possible responses
WORRIED	In the past 30 days, have you ever been worried about not having enough to eat, due to lack of money or other resources?	0 No 98 Don't know 1 Yes 99 Refused
HEALTHY	In the past 30 days, has it happened that you could not eat nutritious and healthy foods, due to lack of money or other resources?	0 No 98 Don't know 1 Yes 99 Refused
FEWFOOT	In the last 30 days, did you happen to eat almost always the same thing, due to lack of money or other resources?	0 No 98 Don't know 1 Yes 99 Refused
SKIPPED	In the past 30 days, have you ever had to skip a meal, due to lack of money or other resources?	0 No 98 Don't know 1 Yes 99 Refused
ATELESS	In the past 30 days, has it happened that you haven't eaten as much as you need, due to lack of money or other resources?	0 No 98 Don't know 1 Yes 99 Refused
RUNOUT	In the past 30 days, has it happened that there was nothing left to eat at home, due to lack of money or other resources?	0 No 98 Don't know 1 Yes 99 Refused
HUNGRY	In the past 30 days, have you been hungry but haven't eaten, due to lack of money or other resources?	0 No 98 Don't know 1 Yes 99 Refused
WHOLEDAY	In the past 30 days, did you happen to have nothing to eat all day, due to lack of money or other resources?	0 No 98 Don't Know 1 Yes 99 Refused

[a] Adapted from FAO[87]

Regression analysis to understand the link between the type of cooperative and resilience capacity of households

The severity of FI experienced by respondent i belonging to either an active or poorly/not active cooperative before and during COVID-19 was measured by the variation in the respondent's FIES raw score between the two periods:

$$\Delta RS_i = RS_{i\text{during}} - RS_{i\text{before}}. \tag{4}$$

If $\Delta RS_i > 0$, then the FI status of the respondent i has been deteriorated; if $\Delta RS_i < 0$, the FI status of the respondent i has been improved; and if $\Delta RS_i = 0$, the FI status of the respondent i remained stable.

The variation in coping strategies used by respondent i to deal with the FI experienced was measured accordingly as the difference between CSI during and CSI before like:

$$\Delta CSI_i = CSI_{i\text{during}} - CSI_{i\text{before}}. \tag{5}$$

If $\Delta CSI_i > 0$, then the coping strategies used were more frequent and/or more severe; if $\Delta CSI_i < 0$, the coping strategies used by respondents in response to COVID-19 were less severe/frequent; and if $\Delta CSI_i = 0$, then the coping strategies used remained stable.

We performed regression models to analyze the correlation between the type of cooperative to which the respondents belong, and the variation of their household's FI scores and coping strategies, while controlling for sociodemographic characteristics (age, education level, gender, occupation, etc., of members), their economic conditions (income, type of crop), and their geographical area of residence (Ivory Coast, Ghana, Mali, and Senegal). ΔRS_i and ΔCSI_i are then constructed as continuous dependent variables in the regression models:

$$\Delta RS_i = RS_{i\text{during}} - RS_{i\text{before}} = \alpha_0 + \alpha_j C_{ji} + \beta_i P_i + \sum\nolimits_i \alpha_i X_i + \sum\nolimits_i \gamma_i V_i + \varepsilon_i, \tag{6}$$

$$\Delta CSI_i = CSI_{i\text{during}} - CSI_{i\text{before}} = \alpha_0' + \alpha_j' C_{ji} + \beta_i' P_i + \sum\nolimits_i \alpha_i' X_i + \sum\nolimits_i \gamma_i' V_i + \varepsilon_i', \tag{7}$$

where $\alpha_0$and α_0' are constant terms to be estimated; $\alpha_j$andα_j' are coefficients associated to the type of cooperative C_{ji} (active or poorly/not active, respectively, coded 1 and 0) to which the interviewee i belongs; $\beta_i$andβ_i' are coefficients associated to the country P_i of respondents; $\alpha_i$andα_i' are coefficients related to sociodemographic characteristics X_i of respondents; γ_i and γ_i' are coefficients relative to economic conditions V_i of respondents; and ε_i and ε_i' are error terms. In Eqs. (6) and (7), $\alpha_j < 0$ and $\alpha_j' < 0$ mean, respectively, that respondents who are members of poorly/not active cooperatives have experienced a higher variation of FI and a higher variation of their coping strategies than members of active cooperatives.

We tested the endogeneity of the variable "type of cooperative," that could possibly be caused by variable measurement error, omitted variables bias, selection bias, and simultaneity or reverse causality [90, 91]. In our models, we suspected a measurement error for "type of cooperative" and omitted variables bias due to some relevant variables not being collected (*e.g.*, plot size,

Table 5 List of 26 coping strategies and severity levels used over the last 30 days[a]

Coping strategies	Degree of severity
1. Leave village to look for work	3
2. Sell household assets or good	2
3. Buy food on credit	2
4. Use savings	1
5. Borrow money	1
6. Sell a production good or a mean of transport	2
7. Reduce spending on health (including the purchase of drugs) and education	3
8. Take girls out of school	3
9. Take boys out of school	3
10. Sell house or land	4
11. Beg	4
12. Sell small animals (e.g., chickens)	2
13. Sell cattle	2
14. Sell last female from productive herd	2
15. Sell production at a lower price	2
16. Reduce working hours, fire, or do not hire salary workers	1
17. Send girls to look for work	3
18. Send boys to look for work	3
19. Reduce area cultivated	2
20. Reduce quantity or quality of inputs applied	1
21.Reduce quantity or quality of seeds used	1
22. Reduce portion of marketed production to have more for household consumption	1
23. Reduce portions of food to give it to others	3
24. Reduce portions of girls to give them to others	3
25. In your opinion, were there women in your community that monetized their sexual relations?	4
26. Marry one of your daughters	4

[a] Adapted from Maxwell and Caldwell [79]

household size, cooperative size, credit access, etc.). We used the instrumental variables (IV) approach as it allows to control for several sources of endogeneity [90, 92].

Since C_{ji} in Eqs. 6 and 7 depends onX_i, V_i, and$X_i\prime$(other variables), we introduce an unobserved latent variable C_{ji}^*, which determines whether $C_{ji} = 1$ or 0, and which can be written as follows:

$$C_{ji}^* = \pi_{1i}X_i + \pi_{2i}V_i + \pi_{3i}X_i\prime = \mu_i,$$

$$C_{ji} = \begin{cases} 1, & \text{if } C_{ji}^* \text{ is an active cooperative} \\ 0, & \text{otherwise} \end{cases}. \quad (8)$$

Errors (ε_i, μ_i) are assumed to be bivariate normal correlated with Var $(\varepsilon_i) = \sigma^2$, Var$(\mu_i) = 1$, and Cov $(\varepsilon_i, \mu_i) = \rho\sigma^2$. In Eqs. 6 and 7, the endogenous regressor "type of cooperative" is a binary variable and can be considered as a treatment indicator [93]. We applied the maximum likelihood (ML) estimator to perform regressions with endogenous treatment by using *etregress* command in STATA (16.1, StataCorp LLC, College Station, TX). However, the big challenge is to find a valid IV Z that satisfies the following three conditions: relevance, randomness, or exogeneity, and exclusion restriction [94–96]. The relevance condition means that cov(Z, X)$\neq$0. Exogeneity requires that cov(Z,ε_i)=0. The exclusion condition states that the IV must only influence the dependent variable (ΔRS_i and ΔCSI_i) via the type of cooperative, but neither directly nor via other channels [94]. We tried to find good/strong IVs among variables included in the models (see Table 3), but the pairwise correlations with the endogenous variable were weak, thus affecting the relevance criteria.

Therefore, we tried external IVs[2]. We finally found "Marketing channels disrupted by COVID-19" and the socio-cultural group "MANJACK" to be good/strong IVs, since they are weakly correlated with ΔRS_i and ΔCSI_i but

[2] An external IV is "external" to the dataset because it is not one of the variables included in the model but is rather an unrelated external factor that affects the endogenous explanatory variable [97].

correlated with "type of cooperative." Thus, our IVs meet the relevance and exclusion conditions required. "Marketing channels disrupted by COVID-19" is a binary variable that takes the value 1 if the marketing channel used by the cooperative members has been disrupted during the COVID-19 pandemic, 0 otherwise. "MANJACK" is a binary variable that refers to a socio-cultural group in Senegal. It takes 1 if the cooperative member is from this group, 0 otherwise. The pairwise correlations between "type of cooperative" and "Marketing channels disrupted by COVID-19" is − 0.23 for pooled data (model 1), − 0.35 for pooled data excluding from Mali (model 2), and − 0.68 for Ivory Coast (model 3). The correlation with "MANJACK" is − 0.30 for Senegal (model 5). The pairwise correlations between the outcome variable ΔRS_i and "Marketing channels disrupted by COVID-19" is, respectively, 0.10 for model 1, 0.17 for model 2, and 0.18 for model 3. The correlation with "MANJACK" is -0.19 for model 5. The pairwise correlations between the outcome variable ΔCSI_i and "Marketing channels disrupted by COVID-19" is, respectively, 0.17 for model 1, 0.14 for model 2, and 0.07 for model 3. The correlation with "MANJACK" is -0.06 for model 5.

Unlike poorly/not active cooperatives, the services provided by active cooperatives (such as cooperative's purchase of production from their members, the cooperative's diversity of contacts, and contracts with other value chain players) help mitigate the effect of shocks on the marketing of members' production, as highlighted in several studies [18, 29, 98] making their members more able to earn income or access food. In addition, households in certain socio-cultural groups such as "MANJACK" in Senegal are members exclusively of poorly/not active cooperatives, which prevents them from benefiting from services provided by active cooperative in the event of shocks. This may affect their ability to access income or food [99, 100]. However, for model 4 (Ghana), our efforts[3] to find good/strong IVs failed. Like Tran et al. [102], while recognizing the limitation of this approach, we used "type of cooperative" directly in the estimation and thus applied a simple OLS estimator.

Once the conditions for IVs validity had been checked, we performed an endogeneity test of the variable "type of cooperative" using the Wald test on the significance of the correlated disturbances ε_i and $\mu_i(\varepsilon_{i'}$ and μ_i, respectively). If the hypothesis H0: $\rho = 0$ is rejected, then there is endogeneity, and ML estimates are reported in Tables 8 and 9. Conversely, if the hypothesis H0: $\rho = 0$ is not rejected, there is no endogeneity. In the latter case, the OLS estimator is reported in Tables 8 and 9 because it is more efficient in terms of fit [90, 91, 96, 103].

[3] Including the use of Least Absolute Shrinkage Operator (LASSO) method for IV selection. Lasso is a boosting-based approach to select IV and estimates the first-stage regression coefficients via a shrinkage procedure [101].

Results

Descriptive statistics

Food insecurity before and during COVID-19

Table 6 shows an overall increase in prevalence of moderate or severe FI ($FI_{mod+sev}$) and in prevalence of severe FI (FI_{sev}) during the pandemic. In general, the $FI_{mod+sev}$ increased regardless of country or cooperative type. During the pandemic, the $FI_{mod+sev}$ was higher for households affiliated with poorly/not active cooperatives than for those of active cooperatives, except in Mali where the prevalence was lower in poor/not active cooperative (22.3%) compared to active cooperative (34%). The increase rate of $FI_{mod+sev}$ was very high in Ghana (+680%) and Ivory Coast (+434%), moderate in Senegal (+65%), and relatively low in Mali (+26%) for households members in poorly/not active cooperative. It should, however, be noted that the prevalence of $FI_{mod+sev}$ before COVID-19 was already very high for the regions under study in Senegal (46.17%) and relatively high in Mali (25.6%). In Mali, the relative stability of FI level, compared to the other countries, could be associated to the significantly lower numbers of cases officially reported and of the resulting rapid easing of sanitary measures. Furthermore, as already mentioned, these measures were not scrupulously respected by most of the population.

The FI_{sev} experienced by households shows a greater increase for poorly/not active cooperatives members compared to active cooperatives members in Ivory Coast (+498% vs+127%), Ghana (+721% vs+356%), and in Senegal (+87% vs − 8%). Our results also showed a decline in the FI_{sev} for members in both active and poorly/not active cooperatives in Mali and for members of active cooperative in Senegal.

CSI before and during COVID-19

Before the pandemic, in all countries except Ivory Coast, members of active cooperative deployed more severe coping strategies than members of poorly/not active cooperatives. During the COVID-19 pandemic, members of poorly/not active cooperatives deployed more severe coping strategies than members of active cooperatives in Ivory Coast and Ghana, whereas members of active cooperatives deployed more severe coping strategies in Mali and Senegal (Table 7). In Mali, there were no major changes in coping strategies used by members of active and poorly/not active cooperatives. The average CSI before and during the pandemic was similar, which supposes that members of cooperatives in Mali were less exposed to the pandemic's shock compared to the other

Table 6 Prevalence of food insecurity (FI) before and during COVID-19 according to the type of cooperative

Countries	Period	Prevalence of Moderate or Severe FI, $FI_{mod+sev}$ (%)				Prevalence of Severe FI, FI_{sev} (%)			
		Total	Active cooperative	Poorly/ not active cooperative	*Percentage point difference (*Poorly/*not active vs active cooperative*	Total	Active cooperative	Poorly/ not active cooperative	*Percentage point difference (*Poorly/*not active vs active cooperative*
Ivory Coast ($n=318$)	Before	11.34	10.47	13.73	3.26	3.59	2.97	4.81	1.84
	During	42	21.35	73.3	51.95	16.31	6.74	28.76	22.02
	Percentage point difference (during vs before)	*30.66*	*10.88*	*59.57*	48.69	*12.72*	*3.77*	*23.95*	20.18
Ghana ($n=329$)	Before	11.92	14.24	8.95	(5.29)	7.57	9.29	5.06	(4.23)
	During	67.68	69.01	69.77	0.76	42.03	42.35	41.55	(0.80)
	Percentage point difference (during vs before)	*55.76*	*54.77*	*60.82*	6.05	*34.46*	*33.06*	*36.49*	3.43
Mali ($n=468$)	Before	25.58	33.17	17.79	(15.38)	2.28	3.29	1.64	(1.65)
	During	28.53	33.74	22.39	(11.35)	2.34	2.55	0.98	(1.57)
	Percentage point difference (during vs before)	*2.95*	*0.57*	*4.6*	4.03	*0.06*	*(0.74)*	*(0.66)*	0.08
Senegal ($n=155$)	Before	46.17	54.6	45.5	(9.10)	11.5	32	14.6	(17.40)
	During	94.51	71.3	74.9	3.60	10.96	29.4	27.3	(2.10)
	Percentage point difference (during vs before)	*48.34*	*16.7*	*29.4*	12.70	*(0.54)*	*(2.6)*	*12.7*	15.30

Percentages are calculated using the sample of respondents by type of cooperative in each country

countries. This is consistent with the above-mentioned relatively constant FI measured in this country.

In Ivory Coast, prior to the pandemic, members of poorly/not active cooperatives were already in a more precarious situation than members of active cooperatives and had to adopt more severe coping strategies during the pandemic. As a result, the CSI average increased for poorly/not active cooperatives, whereas it remained stable for active cooperatives. However, in Ghana and Senegal, the CSI increased for both types of cooperatives; this increase was more pronounced for poorly/not active cooperatives than for active cooperatives.

The occurrence of coping strategies used, regardless of their severity degree (levels 1, 2, 3, and 4 reported in Table 5), has increased in average in both types of cooperatives, and particularly in poorly/not active cooperative during the pandemic. Although the use of coping strategies of levels 1 and 2 (e.g., reduction of food consumption, use of credit, selling assets or goods, etc.) are most frequent, respondents of poorly/not active cooperatives have also used more severe strategies of levels 3 and 4 (e.g., removing children from school to manage spending shortfalls, sending boy to look for jobs, reducing portions of food to give to others, etc.) in Ivory Coast, Ghana, and Senegal.

Regression models

Factors associated to the variation of the FIES' raw scores

Column 1 in Table 8 (ML regression including all countries) shows that four factors have significant effects on the FI of respondents in all four countries: type of cooperative, respondent's university/tertiary education level, agriculture as respondent's main occupation, and respondent's country. The type of the cooperative has a negative effect, indicating that members of poorly/not active cooperatives experienced a higher aggravation of their FI compared to active cooperatives members. The university/tertiary education level has a negative effect, indicating that respondents with this level of education are less food insecure than other respondents. The effects varied across countries: respondents in Ivory Coast, Ghana, and Senegal experienced a higher aggravation of FI compared to those living in Mali. The results were similar when excluding Mali from the model to take account of the fact that in this country, FI and CSI remained relatively stable (Column 2 in Table 8). Model 2 (Column 2) adds that respondents with primary education are more food insecure than others.

Columns 3, 4, and 5 in Table 8 show OLS regressions results for Ivory Coast and Ghana, and ML regression results for Senegal. Since the descriptive statistics showed

Table 7 Average CSI before and during COVID-19 according to the type of cooperative

Countries	Period	Active cooperatives	Poorly/not active cooperatives	Change in CSI (poorly/not active vs active cooperative)	*T* test (active–poorly/not cooperative)
Ivory Coast (*n* = 318)	Before	1.18	2.33	1.15	0.003***
	During	1.98	14.5	12.52	< 2.2e−16***
	Change in CSI (during vs before)	0.8	12.17	11.37	
Ghana (*n* = 329)	Before	4.73	3.02	− 1.71	0.004***
	During	17.62	24.33	6.71	0.000***
	Change in CSI (during vs before)	12.89	21.31	8.42	
Mali (*n* = 468)	Before	10.67	8.94	− 1.73	0.012**
	During	10.65	9.25	− 1.4	0.049**
	Change in CSI (during vs before)	− 0.02	0.31	0.33	
Senegal (*n* = 155)	Before	15.63	8.18	− 7.45	1.705e−06***
	During	19.77	14.55	− 5.22	3.34e−06***
	Change in CSI (during vs before)	4.14	6.37	2.23	

Percentages are calculated using the sample of respondents by type of cooperative in each country

*** Significant at 1%

** Significant at 5%

* Significant at 10%

little variation before and during the pandemic for the members of both types of cooperatives in Mali, there was no significant effects observed and the results are therefore not reported in Table 8.

Thus, when decomposing the analysis per country, the sign of the coefficient for the type of cooperative remains negative and significant in Ivory Coast, indicating that cooperative members have not experienced the same dynamic of their FI. In this country, members of poorly/not active cooperatives experienced a higher aggravation of their FI compared to members of active cooperatives. Furthermore, in Ivory Coast, respondents with university/tertiary education level are less food insecure than respondents with less education, and respondents with agriculture as main occupation experienced a greater deterioration in their FI.

In Ghana, although descriptive statistics showed a significant difference between these groups, when other covariables are controlled in the regression, such difference disappears. In Ghana, families of female respondents compared to males' respondents who lost income and who plant cash crops and respondents with agriculture as main occupation experienced a greater deterioration in their FI. In Senegal, older respondents and those who grow staple crops are the ones whose food security status has deteriorated.

Factors associated to the variation in the coping strategies used to address food insecurity

Table 9 presents the factors associated with the variation in the coping strategies during the COVID-19 pandemic, either in all four countries (Column 1), in all countries except Mali for the same reasons mentioned previously (Column 2) or in each of the remaining countries (Columns 3, 4, and 5). In all five regressions models, CSI scores for members of poorly/not active cooperatives increased more than that of members of active cooperatives (indicating a recourse to more severe coping strategies in the former group). Male respondents in Ivory Coast used more severe coping strategies than women. Households whose main occupation is agriculture have used more severe coping strategies than other when data are pooled (Columns 1 and 2). Although literate respondents used severe coping strategies particularly in Ghana (Columns 1, 2, and 4), these strategies were used less by respondents with a university education (Column 1). At last, respondents who lost income during the pandemic used severe coping strategy, particularly in Ghana (Columns 1, 2, and 4).

Discussion

Heterogeneous resilience capacity to COVID-19 pandemic according to cooperatives' type

In this study, we found that FI experienced by members of both types of active and poorly/not active cooperatives was aggravated during the pandemic. These results confirm the findings of previous studies indicating that the COVID-19 crisis tends to increase the proportion of households identified as moderately and severely food insecure [7, 10, 15, 31, 75, 98, 104]. However, the situation of individuals and their families has not evolved in quite the same way, depending on whether they are

Table 8 Factors associated to the variation of the FIES raw scores

Models	(1) All countries	(2) All countries excluding Mali	(3) Ivory Coast	(4) Ghana	(5) Senegal
Estimator	ML	ML	OLS	OLS	ML
Type of cooperative (1 if active cooperative, 0 if poorly/not active cooperative)	− 3.177** (− 7.34)	− 4.880*** (− 7.94)	− 3.632*** (− 10.15)	− 0.758 (− 1.58)	0.240 (0.44)
Gender of respondent (1 if men, 0 if women)	0.008 (0.05)	− 0.108 (− 0.37)	0.430 (1.11)	− 1.317** (− 2.64)	− 0.109 (− 0.22)
Education of respondent					
Literate level (Yes = 1, No = 0)	0.216 (0.95)	0.273 (0.62)	0.398 (0.17)	0.994 (1.69)	− 0.285 (− 0.47)
Primary level (Yes = 1, No = 0)	(0.84) 0.168	0.689* (2.06)	0.357 (0.98)	0.722 (1.10)	0.240 (0.39)
Secondary/technical level (Yes = 1, No = 0)	− 0.105 (− 0.41)	0.031 (0.08)	0.499 (1.17)	0.412 (0.47)	− 0.091 (− 0.14)
University/tertiary level (Yes = 1, No = 0)	− 2.320*** (− 3.48)	− 1.890* (− 2.17)	− 0.951** (− 2.94)	0.237 (0.21)	− 1.181 (− 1.12)
Plot ownership by respondent (1 if Yes, 0 if not)	0.094 (0.41)	− 0.006 (− 0.02)	− 0.462 (− 1.08)	− 0.598 (− 0.77)	− 0.410 (− 0.79)
Loss of income due to COVID-19 from March to October 2020 by respondent (1 if Yes, 0 if not)	0.078 (0.42)	0.040 (0.12)	0.0717 (0.21)	2.193** (2.81)	− 0.193 (− 0.27)
Age of respondent (number of years)	0.0035 (0.52)	0.02 (1.82)	0.0119 (0.80)	0.0286 (1.42)	0.0429** (2.70)
Type of crops usually grown by respondent (1 if food crops, 0 if cash crops)	− 0.007 (− 0.02)	0.368 (0.97)	− 0.0393 (− 0.09)	− 5.030*** (− 3.95)	1.541* (2.00)
Agriculture as usually main occupation of respondent (1 if Yes, 0 otherwise)	1.068*** (3.71)	1.596*** (3.89)	1.297* (2.06)	2.616** (3.16)	0.238 (0.53)
Ivory Coast	2.622[a]*** (8.00)	1.271[b]** (3.31)			
Ghana	5.446[a]*** (19.82)	3.685[b]*** (12.13)			
Senegal	1.739[a]*** (7.25)				
_cons	0.246 (0.44)	1.414 (1.60)	2.633** (2.82)	5.610*** (3.54)	− 1.462 (− 1.20)
/athrho	0.549*** (4.79)	0.749*** (4.96)			− 0.557*** (− 3.66)
/lnsigma	0.901*** (21.73)	1.098*** (21.52)			0.846*** (12.35)
LR (rho = 0): Prob > chi2	0.0000	0.0000			0.0002
Instrumental Variables	Marketing channels disrupted by COVID-19	Marketing channels disrupted by COVID-19	–	–	MANJACK
Instrumented	Type of cooperative	Type of cooperative	–	–	Type of cooperative
N	1063	600	276	178	146

Robust standard errors in parentheses. The *p*-value obtained from the Shapiro–Wilk test assumes that the distribution is normal. The presence of multicollinearity was assessed by calculating the variance inflation factor (VIF). In our case, all VIFs calculated were inferior to 10, indicating a low risk of multicollinearity [119]. The impact of the type of cooperative on FI is measured by $\frac{\partial \Delta CSI_i}{\partial C_{ji}} = \alpha_j$. A negative sign should be interpreted as follows: membership in an active cooperative is associated with less aggravation of food insecurity (smaller ΔRS)

[a] Reference country = Mali

[b] Reference country = Senegal

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

Table 9 Factors associated to the variation of the coping strategy index (CSI)

Models	(1) All countries	(2) All countries excluding Mali	(3) Ivory Coast	(4) Ghana	(5) Senegal
Estimator	ML	ML	OLS	OLS	OLS
Type of cooperative (1 if active cooperative 0 if poorly/not active cooperative)	− 10.09*** (− 3.99)	− 13.94*** (− 7.61)	− 12.24*** (− 13.80)	− 6.469* (− 2.25)	− 2.836* (− 2.12)
Gender of respondent (1 if men, 0 if women)	0.933 (1.37)	1.142 (1.10)	2.083* (2.45)	0.064 (0.02)	− 0.268 (− 0.16)
Education of respondent					
Literate level (Yes = 1, No = 0)	2.109* (2.40)	4.644* (2.75)	− 4.143 (− 1.01)	8.511* (2.50)	2.159 (1.17)
Primary level (Yes = 1, No = 0)	0.338 (0.43)	1.009 (0.83)	0.935 (1.15)	0.236 (0.07)	1.460 (0.82)
Secondary/technical level (Yes = 1, No = 0)	− 1.037 (− 1.13)	− 0.516 (− 0.40)	0.444 (0.56)	− 1.069 (− 0.21)	1.560 (0.81)
University/tertiary level (Yes = 1, No = 0)	− 5.071* (− 2.26)	− 3.657 (− 1.37)	− 2.605 (− 1.92)	5.806 (1.19)	− 1.201 (− 0.48)
Plot ownership by respondent (1 if Yes, 0 if not)	1.630* (1.99)	2.118 (1.80)	0.294 (0.30)	0.904 (0.21)	2.410 (1.52)
Loss of income due to COVID-19 from March to October 2020 by respondent (1 if Yes, 0 if No)	1.383* (2.13)	1.812* (2.14)	0.662 (0.86)	11.12*** (3.51)	− 0.375 (− 0.20)
Age of respondent (number of years)	0.005 (0.22)	0.034 (0.90)	− 0.022 (− 0.73)	0.132 (1.08)	0.067 (1.23)
Type of crops usually grown by respondent (1 if food crops, 0 if cash crops)	0.448 (0.57)	1.650 (1.61)	0.492 (0.46)	0.642 (0.10)	2.583 (1.34)
Agriculture as usually main occupation of respondent (1 if Yes, 0 otherwise)	2.610* (2.30)	3.303* (2.28)	1.063 (0.59)	7.721 (1.96)	− 0.352 (− 0.25)
Ivory Coast	8.731[a]*** (8.71)	4.796[b]** (3.79)			
Ghana	23.37[a]*** (16.31)	17.70[b]*** (12.74)			
Senegal	6.227[a]*** (8.01)				
_cons	− 1.871 (− 0.98)	1.542 (0.58)	11.27*** (4.79)	0.402 (0.05)	− 1.194 (− 0.36)
/athrho	0.37* (2.04)	0.363** (3.08)			
/lnsigma	2.238*** (43.88)	2.399*** (52.74)			
LR (rho = 0): Prob > chi^2	0.0416	0.0021			
Instrumental variables	Marketing channels disrupted by COVID-19	Marketing channels disrupted by COVID-19	–	–	
Instrumented	Type of cooperative	Type of cooperative	–	–	–
N	1062	599	276	177	146

Robust standard errors in parentheses. The impact of the type of cooperative on coping strategies is measured by $\frac{\partial \Delta CSI_i}{\partial C_{\mu}} = \alpha'_j$. A negative sign should be interpreted as follows: membership an active cooperative is associated with less aggravation of coping strategies used (smaller ΔCSI)

[a] Reference country = Mali

[b] Reference country = Senegal. The *p*-value obtained from the Shapiro–Wilk test assumes that the distribution is normal. The presence of multicollinearity was assessed by calculating the variance inflation factor (VIF). In our case, all VIFs calculated were inferior to 10, indicating a low risk of multicollinearity [119]

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

members of active or poorly/not active cooperatives. Members of poorly/not active cooperatives experienced more difficulties related to access to food than the members of active cooperatives, especially in Senegal and Ivory Coast. Although these difficulties were also observed in Ghana, there was no significant difference between members of active and poorly/not active cooperatives. These results are consistent with other studies [7, 11, 21, 76] which reported heterogeneous dynamics of household income and FI during the pandemic, with some household choosing to reduce their daily food consumption and others to maintain their food consumption in the immediate aftermath of lockdowns.

The differences in the prevalence of FI across countries could also be associated with severity of lockdown measures put in place, with some countries opting for more stringent and others for less severe measures as evidenced [75]. Different authors [10, 105] found that households exposed to a higher number of COVID-19 cases or stricter government measures experienced a significant increase in FI. Ghana, for example, where the most important rise of FI was observed, had not only the highest stringency index at the time of the survey (around 44%) but also the highest cumulative number of COVID-19 since the beginning of the pandemic. The decline in FI_{sev} prevalence during the pandemic for members of both types of cooperatives in Mali and those of active cooperatives in Senegal could be explained by the less severe lockdown measures put in place compared to other countries and the concerned members may be using coping strategies that are well adapted to the context of their cooperative members. The various interventions by the government or development partners in favor of vulnerable populations during the pandemic could also contribute to the decline in FIsev prevalence in Mali. However, these hypotheses should be verified by further research. Respondents who lost income due to COVID-19 have experienced a higher aggravation of their FI, particularly in Ghana, as evidenced by previous studies [31, 106] who found that income loss is positively correlated with food insecurity across households. Household income is the main driver of food security, and the loss of income thus translates into difficulties in accessing staple foods and explains household FI as reported by different authors [7, 10, 11, 19, 33, 76, 98, 107]. In Ivory Coast, income loss is more frequent among members of poorly/not active cooperatives than among those of active cooperatives (Table 3). A loss of income due to sanitary measures and lockdowns implemented to reduce the spread of COVID-19 is reported by many other studies [7, 8, 19, 33, 42, 76, 106–108].

Education level also had an impact on household FI status, and we found that household heads with a primary level were more food insecure than those with university/tertiary level, who were less likely to be food insecure, which is consistent with Adjimoti et al. [109]. Considered as human capital, university/tertiary education level can provide respondents with additional opportunity in terms of market opportunities and non-farm employment which may improve household food security status [110]. In addition, education level is often used as an indicator of preparedness to shocks leading to enhanced responses. Higher levels of education are considered elements of adaptive capacity [111]. Respondents who report agriculture as their main occupation experienced a higher aggravation of their FI compared to other respondents, particularly in Ghana. This result can be due to the disruption of marketing channels of agricultural products for members of both active and poorly/not active cooperatives. The sanitary measures and strict lockdowns implemented in some countries have indeed led to the disruption of supply chains [1, 8, 11–14, 16, 17, 19, 23, 27, 98, 112]. The more severe and sustained the sanitary measures, such as those implemented in Ghana and Senegal, the more disruptive the food systems were with limited circulation of staple foods or cash crops, and the higher the prevalence of FI. The pandemic had negative effects on the food supply chain in all four countries, either for staples as the case in Senegal or for cash crops as the case in Ghana, and the magnitude of these effects is related to the severity of the sanitary measures put in place [21]. Indeed, the COVID-19 disruptions to agricultural activities and income (inability to perform normal agricultural activities due to staying-at-home requirements, travel restrictions, and inability to transport/sell their outputs) significantly increased the likelihood of worrying about food insecurity as shown in Vietnam [113] and in rural Bangladesh [106].

Coping strategies used against food access constraints

Facing a more important prevalence of FI during the pandemic, members of poorly/not active cooperatives adopted in general more severe coping strategies than members of active cooperatives. Since FI has not been so affected in Mali as in the three other countries, the pandemic did not trigger major changes in the coping strategies as should be expected. In the other countries, the activities and services offered by active cooperatives probably helped their members to absorb some of the pandemic shocks to the agri-food system, confirming that cooperatives can strengthen the resilience of an economic system [34]. A link was observed between

food security and measures of coping strategies, with the severity of food insecurity reflected in the severity of coping strategies used [7, 10, 75, 114]. As shown by other authors [7, 31], our finding also shows that the propensity to engage in a coping strategy and the type of coping strategy practiced varies by country.

This study shows that literate households used more severe coping strategies against FI during the COVID-19 pandemic than formally educated respondents, probably because formally educated respondents have more opportunities to access to food than literate respondents. This finding is consistent with Battersby [115], and Rose and Charlton [116] who found that an increase in education level of the household head leads to improved household food security, through increased income, which increases the household's ability to access more food. In addition, respondents whose main occupation was agriculture, and those who lost income were obliged to use coping strategies, even the worst ones, probably due to a difficulty to access markets and to sell their products [31, 75].

Conclusion

This paper studied the resilience capacity of farming households in terms of whether their food insecurity and coping strategies increased or not during the pandemic of COVID-19 and according to the type of the cooperative (active or poorly/not active) to which they belong in four West African countries: Ivory Coast, Ghana, Mali, and Senegal. The cooperatives were indeed categorized according to their capacity to provide services to their members with endogenous responses, in the absence of social protection.

The results show that the type of cooperative played a significant role in the dynamics of household food insecurity and coping strategies. For all respondents, but more specifically in Ivory Coast, households whose individuals are members of poorly/not active cooperatives experienced a higher increase of their FI than those whose individuals are members of active cooperatives. In Mali, very few sanitary measures were implemented and/or adopted compared to other countries, and although FI levels were high prior to the pandemic, the pandemic did not apparently led to an increase in FI levels among respondents, regardless of the type of cooperative. Beyond the type of the cooperative to which respondents belong, other factors as well seem to be correlated to the dynamic of FI and coping strategies during the pandemic. Loss of income, education level, agriculture as main occupation, gender, and age of respondents, as well as the type of crops usually grown, are significantly associated with an increase in FI experienced by respondents in either active or poorly/not active cooperatives. Less educated respondents and those who experienced an income loss used more severe coping strategies.

This pandemic highlights the need to define and implement targeted policies to address the potential negative impacts of systemic shocks and protect the livelihoods of vulnerable populations. This study revealed that respondents in active cooperatives seem more resilient than those in poorly/not active cooperatives. It is therefore imperative to promote this social economy model as a key for building more resiliency among farming households. Supporting collective actions and public interventions that nurture the dynamism of cooperatives in small communities will ensure that the necessary services continue to be provided to members and, ultimately, mitigate the socioeconomic effects of potential crises such as the pandemic of COVID-19. Interventions through local organizations rooted in their communities, such as agricultural cooperatives, could be an appropriate framework for reaching the most vulnerable and poor households who face an increasingly changing and uncertain future.

Abbreviations

CSI	Coping Strategy Index
FAO	Food and Agriculture Organization
FARM	Rural Finance Project in Mali
FI	Food insecurity
FIES	Food Insecurity Experience Scale
$FI_{mod+sev}$	Moderate or severe food insecurity
FI_{sev}	Severe food insecurity
ML	Maximum likelihood
MPI	Multidimensional poverty index
OLS	Ordinary least squares
PROCED	Program for the development of inclusive and sustainable model cooperatives
rCSI	Reduced Coping Strategies Index
SI	Stringency index
WEI	Women empowerment index
WHO	World Health Organization

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Author contributions

CPK has contributed to data analysis, and paper writing. M-CB has contributed to research design, data collection, data analysis, and paper writing. CLap has contributed to research design, data collection, data analysis, and preliminary paper writing. CLam has contributed to research design, data collection, data analysis, and preliminary paper writing. IB has contributed to research design, data collection, data analysis, and paper writing.

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Availability of data and materials

All data supporting the findings of this study are available from the corresponding author on request.

Code availability
Stata and R commands and codes used for analysis are available from the corresponding author on request.

Declarations

Ethics approval and consent to participate
Agreed and signed on a consent form by each participant.

Consent for publication
Each participant agreed and signed on a consent form.

Competing interests
The authors declare that they have no competing interests.

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