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The Triple Challenge: Food Security and Vulnerabilities of Fishing and Farming Households in Situations Characterized by Increasing Conflict, Climate Shock, and Environmental Degradation

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Abstract: As conflict, climate shocks, and land/water degradation—the "triple challenge"—continue to exert increasing pressure upon fishing and farming livelihoods in many developing countries, a need exists to better understand how differential vulnerabilities undermine or amplify food security outcomes. In this study, we investigate how vulnerability to the "triple challenge" affect food security using an in-depth case study approach that merges social statistics and quantitative data analysis. We frame vulnerability using a combination of sensitivity, exposure, and adaptive capacity, and operationalize food security using the FAO Food Insecurity Experience Scale (FIES), which is an experience-based measure capturing the food access dimension of food security. We draw on survey data from 252 fishing and 251 farming households in the Niger Delta region of Nigeria and quantify the different components of vulnerability, deriving specific livelihood-related vulnerability scores. By merging and analyzing differential food security variables and vulnerability scores using ordered logistic models, we find that vulnerability to the "triple challenge" increases the probability of being in a severe food insecure state, particularly for households with a high dependency ratio. Parallel to this finding, we note that access to social capital and opportunities for livelihood diversification could drive gains in income, enhancing the capacity of households to attain a food-secure status in the face of recurrent instabilities. This study advances vulnerability literacy in food-insecure contexts and reveals ways to support populations on the frontline of interacting conflict, climate, and environmental crises.

Keywords: climate crisis; food insecurity; differential vulnerability; environmental degradation; rural livelihoods; ordered logistic models; SDGs; Niger Delta

Citation: Onyenekwe, C.S.; Okpara, U.T.; Opata, P.I.; Egyir, I.S.; Sarpong, D.B. The Triple Challenge: Food Security and Vulnerabilities of Fishing and Farming Households in Situations Characterized by Increasing Conflict, Climate Shock, and Environmental Degradation. *Land* **2022**, *11*, 1982. https://doi.org/10.3390/land11111982

Academic Editor: Adrianos Retalis

Received: 17 September 2022
Accepted: 31 October 2022
Published: 5 November 2022

1. Introduction

1.1. The "Triple Challenge" in Food Security Contexts

Fishing and farming households support food production in many ways [1], but they are often susceptible to stressors, shocks, and recurrent instability [2]. In deeply divided societies, such as the Niger Delta region of Nigeria, where climate risks evolve and persist along with exposure to conflict and environmental degradation, disruptions to fishing and farming livelihoods often undermine the food and agricultural value chains [3]. Populations in settings such as this face multiple vulnerabilities as their adaptive capacities are tremendously weakened [4]. Interacting climate and conflict risks and land and water degradation render vulnerable fishing and farming households despondent [5]. At the same time, climate and conflict deplete their economic and natural assets [6] and, in extreme cases, force them to resort to maladaptive behaviors such as food theft, land grabbing and illegal fishing [7].

In order to reduce vulnerability and sustain food production and access in situations characterized by interacting climate, conflict, and environmental degradation (the "triple challenge"), it is vital to understand how citizens' vulnerabilities constrain or enable food security outcomes. Local actors, community leaders, and organizations that aim to design and implement adaptation and resilience programs for local resource users often lack an understanding of climate-conflict vulnerability and food insecurity relations [8], including ways to decouple food security actions from risks emerging from the "triple challenge" [9].

Previous research, e.g., [10,11], echoes the limited attention given to food security issues in places where climate, conflict, and land/water degradation amplify livelihood vulnerability and depletion of assets. Relatedly, although vulnerability assessment in contexts of protracted crisis has gained relevance in the broader literature on resilience and adaptive capacity, e.g., [12,13], detailed empirical case study analyses accounting for food insecurity concerns in times of increased vulnerability to the triple challenge are sorely lacking. In particular, little is known about how local people's inability to cope with multiple interacting stressors undermines their capacity to improve their food security status, including the barriers and opportunities associated with fishing and farming livelihoods where food security programs are required to account for differential vulnerability to compounding risks.

In this study, we investigate the effect of vulnerability to the "triple challenge" on food security amongst fishing and farming households. In our context, unraveling how vulnerability influences food security outcomes requires an in-depth case study approach, merging social statistics and quantitative analysis of survey data from populations on the frontline of interacting conflict, climate, and environmental crises [14,15].

The study is consistent with the call by researchers, e.g., [16,17], to improve understanding of compounding vulnerabilities in food systems under protracted crisis. It also aligns with suggestions by [1,18] to redefine current thinking on climate-sensitive agricultural livelihoods by reconsidering what is unique about vulnerability reduction strategies in fragile places. The study proposes a different approach to research on the "triple challenge" in natural-resource-dependent settings, one that begins with a scholarly assessment of the link between food (in)security and livelihood vulnerability to socioecological threats. By directing attention towards this link in places where fishing and farming livelihoods are predominant, the study stretches beyond asking which of fishing and farming livelihoods is more vulnerable to the "triple challenge". Similarly, by not appearing vulnerability-centric or focusing solely on the broad notion of food (in)security, the study adopts "food access" as a core element of food security. In using food access data collated through the FAO Food Insecurity Experience Scale (FIES)—which is an experience-based measure capturing the food access dimension of food security—the study advances an innovative statistical approach that combines food security and vulnerability scores within a set of interlinked analytical models.

1.2. Literature Review: Framing the Link between Food (In)Security and Vulnerability in Contexts Characterized by Increasing Conflict, Climate Shock and Environmental Degradation

The link between food (in)security and vulnerability in the context of increasing resource conflict, climate shock and environmental degradation crosscuts several intermediate steps (Figure 1). Prominent ones include reduced access to inputs for agriculture and food production, low food quality, reduced crop/fisheries harvest leading to food shortages and/or high food prices, and eventually a reduction in food access and consumption [19].

In addition to land and water degradation, climate change and conflict amplify a number of socio-economic and ecological factors that drive this chain of problems [20]. For example, increased conflict vulnerability fuels household stress in many ways, e.g., by spurring distress sale of assets [21], including decisions to abandon farmlands and migrate, leading to increased food scarcity, hunger, and malnutrition [22,23]. Damaged infrastructure and a breakdown in social cohesion can reduce access to markets and farmlands [24], which in turn could undermine food security gains [15].

Climate vulnerability, on the other hand, compounds existing socioeconomic stressors that conflict-afflicted households face [25], impacting changes in food storage and transportation networks and shaping local and regional patterns of grievances and struggles for food [26]. These reinforce violence of all types [27], amplifying damage to the natural capital and triggering livelihood underperformance [28]. In the Sahel and Lake Chad region, for example, increased vulnerability to the "triple challenge" constitutes a major contributor to low food access and consumption across agricultural communities [5]. This inhibits resilience and societal stability. Here, crop and fish outputs and prices co-vary with climatic conditions [29], and local capacity for transregional trade, including actual food access, are often stifled in times of droughts, leading to hikes in food prices, as well as high costs of fuel and transportation. More broadly, given the complexity of food security in the context of the "triple challenge", links between vulnerability drivers and food security are expectedly indirect and multidimensional (Figure 1).

Several analytical approaches can be adopted to make sense of this link, e.g., based on a combination of approaches in the social sciences and statistics [18]. To quantify the effect of vulnerability (in contexts where climate, conflict, and land/water degradation are closely linked) on food security outcomes (focusing on food access, for example), the first entry point is usually to pin down what vulnerability entails. Other steps include identifying the vulnerability assessment tools that work well for a particular setting, including unpacking contextual definitions of household food security.

Since vulnerability varies across people and livelihoods, we conceptualize vulnerability in this study as a condition or state of weakness and stress (experienced by fishing and farming households in our case) determined by a combination of stressors linked to climate, conflict, and land/water degradation [1]. We assess vulnerability using composite indicators that capture exposure, sensitivity, and adaptative capacity [30]. Household food security refers to a state where households have economic and physical access to safe, plentiful, and nutritious food that satisfies their dietary needs and food preferences at all times to live an active and healthy life [31]. Four dimensions of food security arising from this definition are food availability (e.g., the quantity of food available in a household), food accessibility (capturing household social, physical, and economic access to sufficient, safe, and nutritious food), food stability (relating to steady food supplies in a household), and food utilization (encompassing how food is utilized/prepared to meet family dietary needs). Food insecurity, in contrast, implies limited ability to secure and consume sufficient and quality food, often leading to adverse effects on household well-being. Relatedly, we define conflict as disagreements, competitions, or disputes over access, use, management, and allocation of natural resources.

We focus on food access as a measure of food security, and we link the impact of vulnerability to the "triple challenge" on food security outcomes using ordered logistic models (see Section 2). In doing this, we identify different fishing and farming households that are vulnerable to the "triple challenge". Thereafter we quantify how vulnerability (to the triple challenge) affects a specific type of food security outcome (i.e., food access) that could be expected for agricultural households. Lastly, we identify the extent to which other (observable) socioeconomic factors amplify the effect of vulnerability on food security outcomes.

This article is structured around five sections. Immediately after this introduction, Section 2 describes the study area, research approaches, and methodologies. Results addressing the aim of the study and a discussion of the results are presented in Sections 3 and 4, respectively. Section 5 concludes by outlining the key research findings and the main contributions and recommendations of the study.

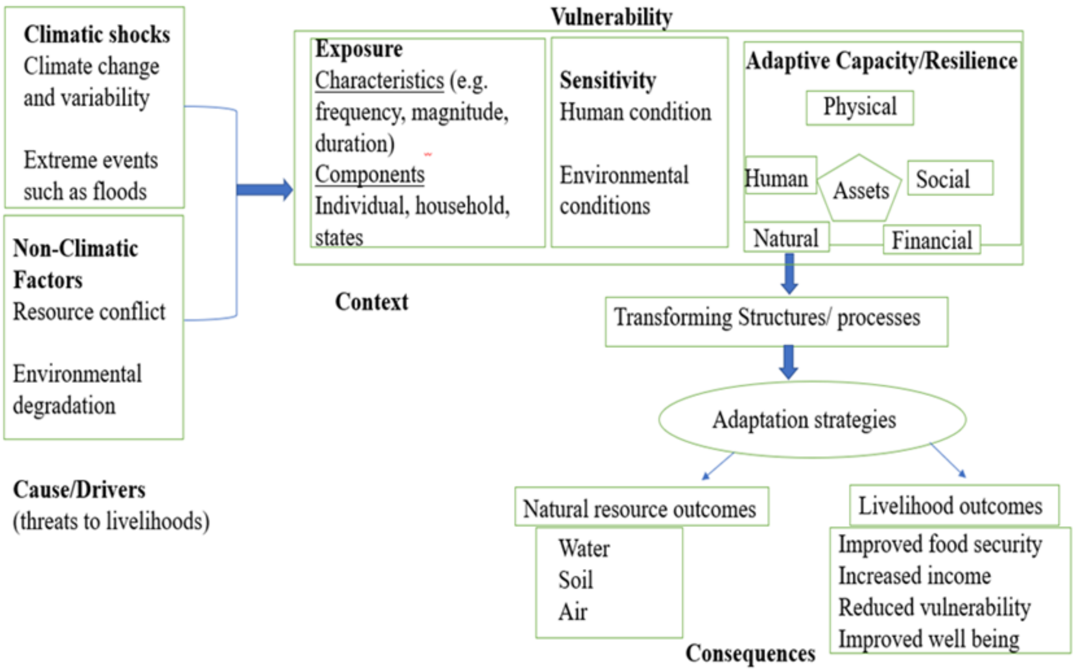

Figure 1. Conceptual framework linking climate shocks, environmental degradation, and resource conflict in contexts of vulnerability and food security. Adapted from [32,33].

2. Materials and Methods

2.1. Description of the Study Area

The study area is the Niger Delta region (Figure 2), situated on the Atlantic Coast of southern Nigeria [34]. As the second largest delta in the world with a coastline covering around 450 km [35–37], the region is home to all the oil and gas produced and exported from Nigeria, accounting for 80% of the country's revenue [38]. Yet, it is among Nigeria's least developed regions, with poverty and unemployment level higher than the national average and lacking basic infrastructures such as electricity, healthcare facilities, roads and tap water [39].

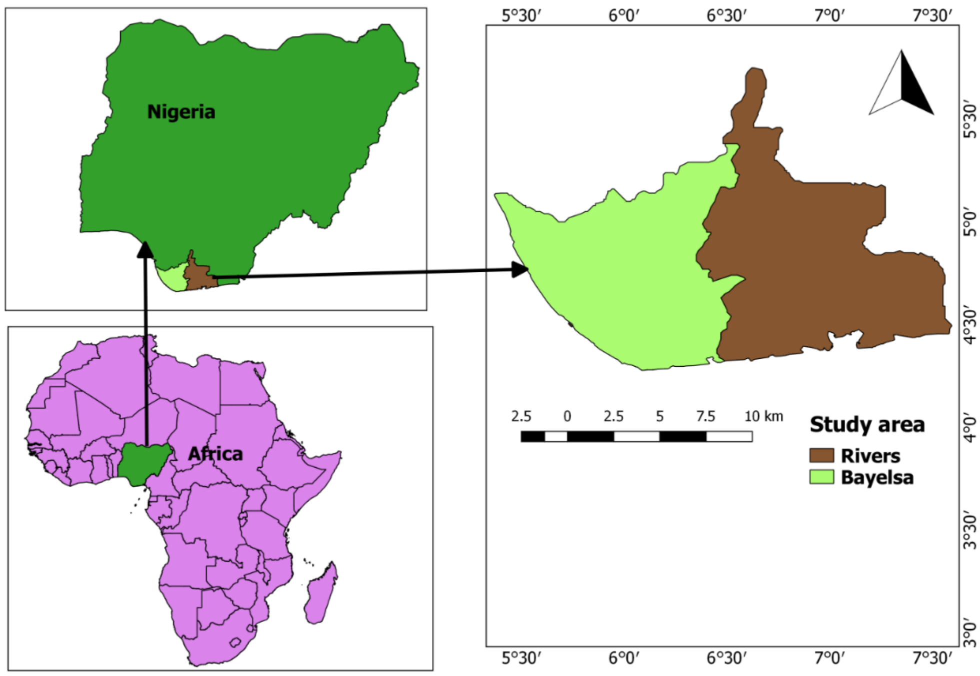

Figure 2. Location of the study in Niger Delta showing Rivers and Bayelsa states.

The region has over 40 ethnic groups in an estimated 3000 communities [40] with an estimated population of about 36 million [41]. Prominent ethnic groups are Ijaw, Urhrobo, Itsekiri, Isoko, and Ilaje [42]. The region is characterized by ethnic conflicts amongst these major ethnic groups [42,43]. Ethnic conflicts are often the result of unequal distribution of oil wealth, elites' greed, struggles over limited land and water resources, and the divide-and-rule strategy employed by the state and multinational oil companies.

The majority of the population depends on fishing and farming as sources of livelihood. Artisanal fishing is mostly carried out on a small-scale basis by self-employed fishermen and women using wooden or motorized canoes rather than as a commercial enterprise, but commercial trawlers regularly operate offshores. In recent times, aquaculture has gained popularity because of depleting fisheries [44]. Food crops grown in the region include plantain, maize, yam, cassava, and vegetables.

Reported evidence of climate change in the region includes: temperature increases, changes in rainfall patterns, rise in soil temperature, rising sea levels causing flooding of farmlands and roads, and increase in tropical diseases (see [45–47]). Oil extraction, oil pollution, gas flaring, and deforestation are the main sources of GHG emissions contributing to changes in the climates around the region [30,34,36,48–50]. There are no strict regulations to curb practices that generate GHGs across the region [48]. There is also a lack of social responsibility on the part of major oil firms to drive oil and gas conservation and environmental sustainability; at the same time government has been unable to provide the expected development benefits that the region needs despite huge returns from crude oil sales – this has contributed in fueling violence in the region [51].

Conflicts involving fishers and farmers in the Niger Delta region are often around agricultural land and water resources. Conflicts over land with oil deposits usually occur amongst communities, between communities and the government, or between communities and multinational oil companies. One of the root causes of conflict is attributed to oil extraction, which isolates the locals from their land and in turn undermines their livelihood activities [38,52,53]. Oil extraction by multinational oil companies often lead to oil spillage and gas flaring. Spilled oil on farmlands and water bodies destroys fisheries ecosystems, forest vegetations, and natural wildlife habitats. This, in turn, undermines rural livelihoods and spurs local grievances and violence. For instance, between 1976 and 1996, about 4600–7000 oil spills were recorded, with a total volume of 2.4–3.6 million barrels of oil wasted [37,54]. There are reports of inter-communal violence and unrest leading to the bombing of oil installations and the destruction of lives and properties [55,56]. In some cases, oil workers and expatriates are abducted for ransom or killed. Notable examples of conflicts in the region include the Ijaw-Arogbo/Ilaje crises, the Warri crisis, Obobutu vs. Elf, and Ogoni vs. Shell [55–58].

A study carried out by [59] to explore local perceptions of oil exploration on food security reported that oil-induced degradation of land and water bodies reduced crop yields and fish catch and led to food scarcity and hunger. Relatedly, oil pollution has continued to undermine the quantity and quality of food consumed by households in the region. These challenges are amplified by flooding, rising sea levels, and coastal erosion.

2.2. Sampling Procedure

Data for this study were collected from fishing and farming households in Rivers, and Bayelsa states in the Niger Delta region. Our sampling procedure was organized into multiple stages. First, we selected Rivers and Bayelsa out of the nine states that make up the region due to their (i) high dependence on cropping and fishing activities, (ii) notable pollution activities of oil companies that degrade the soil and water bodies, (iii) the prevalence of conflict and climate shocks, and (iv) the coastal nature of the states, which predisposes residents to frequent flooding and coastal erosion. Second, we selected 13 local government areas (LGAs) that are predominantly agrarian (and highly affected by the triple challenges) out of 23 from Rivers, and 4 LGAs out of 8 from Bayelsa (LGAs are similar to counties, administered by a council chairman elected democratically or appointed by the state). Third, we used proportional random sampling to select 18 and 8 communities from the selected LGAs in Rivers and Bayelsa States, respectively. Lastly, across 26 communities, we used proportional random sampling to select 251 farming and 252 fishing households, resulting in a sample size of 503 agricultural households. We adopted the United Nations (2005 p. 44–45) sample size formula (see Equation (1)). Using a confidence interval (Z) of 95%, 50% default value of prevalence of indicators (r), a sample size of 430 households was required. However, to account for possible missing (data) values and outliers, the sample size was increased to 503.

$$N = \frac{[(Z^2)(r)(1-r)(f)(k)]}{[(p)(n)(e^2)]} \quad (1)$$

where: N = sample size;

Z = confidence interval (95% level is 1.96);

r = estimate of key indicators being measured (default value is 0.5);

f = sample design effect (has a default value of 2);

k = multiplier accounting for non-response (1.1);

p = proportion of the total population accounted for by the target population (0.4);

n = mean of household size (5);

e = precision level (10% precision level equals 0.01 r).

2.3. Data Collection

We collected data from fishing and farming households using survey questionnaires designed to capture data on vulnerabilities to the triple challenge and food insecurity experiences. Questionnaires were pre-tested through scoping visits and modified where necessary before actual data collection (e.g., we modified the framing of some questions that appeared ambiguous to better target the goal of the study). Questionnaires had sections on socio-demographic and institutional characteristics, livelihood income strategies, social and political networks, household income sources and expenditure, livelihood assets, food security (see Section 2.4.3), perceptions on climate shocks and impact, conflict events, and environmental degradation concerns. All respondents gave verbal consent to participate in the study before they were allowed to complete the questionnaires.

2.4. Data Analysis Approaches

2.4.1. Deriving a Framework for Vulnerability Assessment

We used a composite indicator approach to calculate the vulnerabilities of farming and fishing households [60]. In doing this, we combined two frameworks: the sustainable livelihood framework and the IPCC vulnerability framework [61–63]. The sustainable livelihood framework provides a holistic approach to understanding how people make a living [64,65]. At its core is the assessment of the assets (natural, human, social, physical, and financial) at the disposal of people from which they make a living and an evaluation of the vulnerability context (shocks, stresses, trends, and seasonality) in which assets are utilized. We adopted the IPCC's definition of vulnerability as a function of exposure, sensitivity, and adaptive capacity as a starting point in operationalizing vulnerability to the triple challenge [50]. This approach has been applied in previous vulnerability studies, e.g., [1,62,63,66,67], to focus on three vulnerability components: exposure, sensitivity, and adaptive capacity. For the exposure component, we captured three sub-components: exposure to climate shocks, resource conflict, and environmental degradation. Sensitivity was measured by considering two sub-components: the current state of food, water, health status, and physical/natural assets. Adaptive capacity was measured by considering three sub-components: the socio-demographic profile, livelihood income strategies, and socio-political networks. Eight indicator sub-components were derived overall- they were selected deductively from a review of relevant literature, e.g., [1,66–68].

Figure 3 presents our vulnerability framework in the context of climate shocks, conflict, and environmental degradation. A detailed description of all indicators associated with each of the sub-components, their units of measurement, and the basis for selecting the indicators are presented in Table S4 (supplementary material).

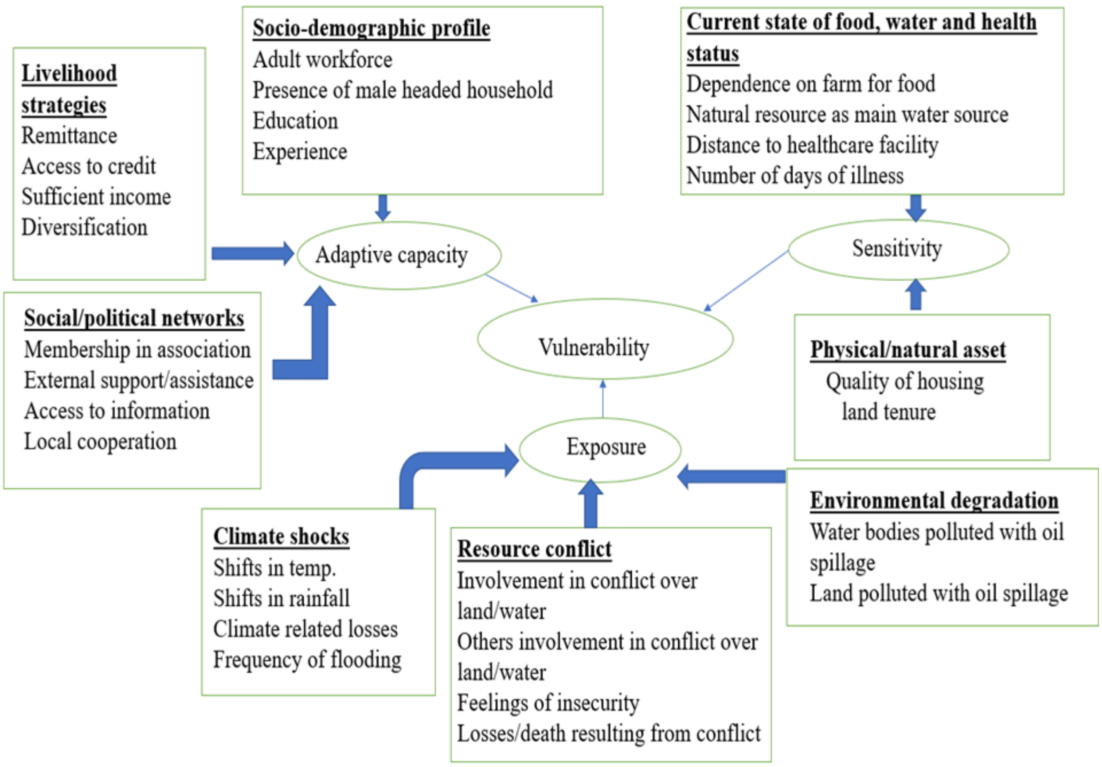

Figure 3. Analytical framework for vulnerability assessment. Adapted from [1].

2.4.2. Estimating Vulnerability to the "Triple Challenge"

We adopted a variety of steps in estimating vulnerability to the triple challenge. To determine the household vulnerability index, we first transformed each of the different units of measurement associated with our indicators into a uniform scale to allow for comparison and aggregation into a single index [69]. We adopted the maximum–minimum standardization technique used by [70], defined as:

$$\text{Index}_S = \frac{S - S_{min}}{S - S_{max}} \quad (2)$$

where:

Index_S = standardized indicators for each livelihood group;
S = raw data for the indicator associated with each livelihood group;
S_{min} = minimum value of each indicator;
S_{max} = maximum value of each indicator.

Next, we assigned weights to each indicator. We used the equal weighting method employed in previous studies [1,71,72], which assumes that all indicators contribute equally to vulnerability. The standardized indicators were averaged to derive a specific value for each sub-component using the formula in Equation (3):

$$M_i = \frac{\sum_{i=1}^{n} \text{index}_{s_i}}{n} \quad (3)$$

where:

M_i = one of the eight sub-components for each livelihood group;
index_{s_i} = the standardized indicators that make up each sub-component;
n = number of indicators in each sub-component.

The next step involved aggregating the sub-components to derive the major components–exposure, sensitivity, and adaptive capacity. We derived the major components using the formula in Equation (4):

$$M_j = \frac{\sum_{j=1}^{n} \text{index}_{s_j}}{n} \quad (4)$$

where:

M_j = one of the three major components for each livelihood group;

index_{s_j} = the standardized sub-components that make up each major component;

n = number of sub-components in each major component.

Finally, the major components were averaged using the formula in Equation (5) to derive a composite vulnerability index.

$$CVI_l = \frac{EP + SN + (1 - AC)}{3} \quad (5)$$

where:

CVI_l = composite vulnerability index;

EP = exposure;

SN = sensitivity;

AC = Adaptive capacity.

The CVI was scaled from 0 (least vulnerable) to 1 (most vulnerable). Classification into different vulnerability groups was conducted following [73] as follows: Low vulnerability ($CVI < 0.33$), Moderate vulnerability ($0.33 \leq CVI < 0.66$), and High vulnerability ($0.66 \leq CVI \leq 1.0$)

2.4.3. Estimating Food Security Using the Food Insecurity Experience Scale

For this study, we used the Food Insecurity Experience Scale (FIES) to measure food insecurity [74]. The FIES is a self-reported food insecurity measure based on a methodology developed by the Food and Agriculture Organization's (FAO) Voices of the Hungry (VoH) project [75,76], and it has been adopted and validated by FAO not only as a good tool for measuring food insecurity but also for monitoring food insecurity globally [75].

FIES comprises of 8 questions (see Table 1) and captures the food access dimension, including the behavioral and psychological responses to food insecurity. Specifically, it focuses on three domains of household food access: anxiety over food access, insufficient food quality, and insufficient food quantity [77]. FIES is beneficial because it offers a direct measure of food insecurity, unlike other measures such as FAO's prevalence of undernourishment (food balance sheet), food insecurity determinants such as food availability or income (household income and expenditure surveys), and food outcomes such as nutritional status (anthropometry). In addition, it is both time and cost-efficient, and easy to use [75].

Table 1. Questions that make up the food insecurity experience scale.

Response Questions: A1–A8
In the past 4 weeks, was there a time you or any member of your household
A1. Became worried your household would run out of food because of lack of money or other resources?
A2. Found it difficult to eat healthy and nutritious food because of lack of money or other resources?
A3. Ate only few types of food because of lack of money or other resources?
A4. Ate less than is required (quantity) because of lack of money or other resources?
A5. Ran out of food because of lack of money or other resources?
A6. Skipped a meal because of lack of money or other resources?
A7. Went to bed at night hungry because of lack of money or other resources?
A8. Went a whole day and night without eating anything because of lack of money or other resources?

Source [74].

The questions in Table 1 are unidimensional, continuous, and unobservable. As such, to estimate the FIES, we applied the Rasch model, which is a type of non-linear factor analytic approach (see [62,63]). Previous studies focusing on experience-based food security measures, e.g., [74,78,79], have used this type of model. In this study, the FIES score represents a continuous measure of the level of food insecurity experienced by individuals or households in the past four weeks. Following [74], each of the questions in Table 1 is scored 1 when the household answered in the affirmative. The scores of the items are summed up, and they range from zero to eight (0–8). The higher the score, the higher the food insecurity experienced by the household. Households that did not answer in the affirmative to any of the questions score zero (0) and are considered highly food secure; households that score between one and three (1–3) are categorized as mildly food insecure; those that score between four and six (4–6) are considered moderately food insecure; while those that score between seven and eight (7–8) are categorized as severely food insecure.

2.4.4. Estimating the Effect of Vulnerability to the "Triple Challenge" on Food Security

We used an ordered logit model [77] to estimate the effect of vulnerability (to conflict, climate shock, and environmental degradation) on the food security status of farming and fishing households. The ordered logit model is an econometric approach and is considered appropriate for this study because it accounts for the ordered nature of the dependent variable (food security): severe food insecure, moderate food insecure, mild food insecure, and highly food secure. For example, a household in the moderate food insecure category is "worse off" than a household in the mild food insecure and highly food secure category but is "better off" than a household in the severe food insecure category.

In the ordered logit, there is an observed ordinal variable Y. Y, in turn, is a function of another continuous variable, Y*, that is not measured. Y* has different cut-off points (thresholds). Let FIS_i denote the observed food insecurity level in household i, which is a proxy for the theoretical (unobserved) food insecurity $FIS_i{}^*$. The ordered logit model with the latent food insecurity measure FIS* is stated below:

$$FIS_i{}^* = \beta X_I + \varepsilon_i \tag{6}$$

where i is the individual households, i =1, 2 ... 503; X is the vector of independent variables representing vulnerability indices, i.e., socio-economic characteristics; β is the vector of unknown parameters to be estimated; ε_i is the error term which is identically and independently distributed.

Let j represent the number of food insecurity categories which in our study is equal to four (j = 1, 2, 3, and 4) and μ_k is the cutoff point (threshold). Since there are four categories, three cut-off points will be estimated (k = 1, 2, and 3). Therefore, the relationship between the observed food insecurIty FIS_i and latent food insecurity measure $FIS_i{}^*$ can be represented as:

$$FIS_i = \begin{cases} 1 \text{ if } FIS_i{}^* \leq \mu_1 \text{ (highfoodsecurity)} \\ 2 \text{ if } \mu_1 < FIS_i{}^* \leq \mu_2 \text{ (mildfoodinsecurity)} \\ 3 \text{ if } \mu_2 < FIS_i{}^* \leq \mu_3 \text{ (moderatefoodinsecurity)} \\ 4 \text{ if } FIS_i{}^* > \mu_3 \text{ (severefoodinsecurity)} \end{cases} \tag{7}$$

It should be noted that there is no constant. The unknown parameters (β, μ_1, μ_{12} and μ_3) are estimated by the maximum likelihood estimation technique in STATA 14 software. STATA sets the constant to zero and estimates the cut-off points for separating the various levels of food security. The cut-offs can be viewed as constants. The probability of food insecurity category j for a given household i is thus:

$$P(FIS_i > j) = P_{ij} = \frac{e^{(\alpha_j + \beta X_j)}}{1 + \sum e^{(\alpha_j + \beta X_j)}} \tag{8}$$

where α is the constant (other variables in the equation have been specified above). The marginal effects of changes in the independent variables are computed as specified in the equation below:

$$\frac{\delta prop\left(y = \frac{1}{X}\right)}{\delta_X} = -f(\mu_1 - X_\beta)\cdot\beta \quad (8a)$$

$$\frac{\delta prop\left(y = \frac{2}{X}\right)}{\delta_X} = -[f(\mu_2 - X_\beta) - f(\mu_1 - X_\beta)]\cdot\beta \quad (8b)$$

$$\frac{\delta prop\left(y = \frac{3}{X}\right)}{\delta_X} = -[f(\mu_3 - X_\beta) - f(\mu_2 - X_\beta)]\cdot\beta \quad (8c)$$

$$\frac{\delta prop\left(y = \frac{4}{X}\right)}{\delta_X} = f(\mu_3 - X_\beta)\cdot\beta \quad (8d)$$

where 1, 2, 3, and 4 are the different categories of food insecurity, and f is the cumulative probability function.

One key assumption of the ordered logit model is that the data must satisfy the proportional odds or parallel lines assumption, which states that the relationship between two categories in the dependent variable is the same; hence, the coefficient (β) is the same across different categories of food insecurity (j = 1, 2, 3, and 4), differing only at the cut off points, (μ_1, μ_2, and μ_3) [80,81]. There are several tests for this assumption, namely Brant, gologit LR, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) [82,83]. In this study, this assumption was tested using the Brant test in STATA 14. Testing of the overall significance of the model was conducted using the chi-squared (χ^2) value and the log-likelihood ratio criteria, which is usually displaced with the regression output.

The estimated model is stated in Equation (9)

$$\begin{aligned} FIS_i = \alpha_0 + \alpha_1 VIn + \alpha_2 Ylog + \alpha_3 Mstat + \alpha_4 Save + \alpha_5 Non\_farm + \alpha_6 DepR \\ + \alpha_7 Store + \alpha_8 help + \alpha_9 Fsize + \alpha_{10} Age + \alpha_{11} HHsize + \beta_{12} State + \beta_{13} LVG \end{aligned} \quad (9)$$

The definition and apriori expectation of the explanatory variables used in the ordered logit model are presented in Table 2.

Table 2. Description of explanatory variables and hypothesized signs.

Variable	Description	Measure	Apriori Expectation
Dependent variable FIS_i	Food security level	Dummy (0 = food secure 1 = mildly food insecure 2 = moderately food insecure 3 = severely food insecure)	
Explanatory variables			
Vin	Vulnerability indices	Continuous	+
Ylog	Logarithm of household annual income	Continuous	−
Mstat	Marital status	Dummy 0 = single, 1 = married, 2 = others	+/−
Savings	Households saves with formal institutions	Dummy 1 = yes, 0 = no	−
Nonfarm	Engagement in non-farm or non-fishing job	Dummy 1 = yes, 0 = no	−
DepR	Dependency ratio	Continuous	+

Table 2. *Cont.*

Variable	Description	Measure	Apriori Expectation
Store	Households store food	Dummy 1 = yes, 0 = no	−
Help	household receive help during difficult times	Dummy 1 = yes, 0 = no	−
Fsize	Total farm size cultivated (hectares)	Continuous	−
Age	Age of household head	Continuous	−
HHsize	Household size	Continuous	+/−
State	Location of household	Dummy 1 = Bayelsa; 0 = Rivers	+/−
LVG	Livelihood group	Dummy 1 = Farming households, 0 = Fishing households	+/−

Note: Single, Rivers and farmers are the omitted base category.

The sign of the coefficient "beta" is the same as the sign of the marginal effect for the highest food insecurity category, but it is opposite the sign of the marginal effect for the lowest category. For the middle category, the sign could go either way. For the coefficient only, the sign is interpreted and not the magnitude; the marginal effects are rather used to measure the magnitude of the effect. The marginal effect can be interpreted to mean that for a unit increase in the independent variable, the dependent variable is expected to change by the corresponding magnitude while keeping the other variables in the model constant.

In this study, a significant negative coefficient means that a unit increase in the independent variable increases the probability that a household will be food secured, while a significant positive coefficient means that a unit increase in the independent variable decreases the probability that a household will be food secured.

3. Results

We present our results in three sections below. First, we report on the food security status of farming and fishing households and provide a cross-tabulation of households by vulnerability levels and food security status (3.1). Next, we show the effect of vulnerability to the "triple challenge" on food security, including a highlight on the correlation between the food security estimates and vulnerability index (3.2 and 3.3).

3.1. Food Security Status of Farming and Fishing Households

Table 3 outlines the main food sources of households in the study area. Approximately 69.3% of farming households produce their own food, while 76.2% of fishing households access local markets to buy their food. Fishers trade in fish and use part of their income to purchase food items. Only about 16.7% of fishing households are engaged in farming.

Table 3. Main food sources of households.

Main Food Source	Farming Households	Fishing Households
Own production	174 (69.3)	60 (23.8)
Purchases	77 (30.7)	192 (76.2)
Total	251	252

Source: Field survey (2018). Note: Figures in parentheses represent column percentages.

The food security status of households is presented in Table 4. For the farming households, 30.3% and 24.7% fell into the category of food secured and mildly food insecure, respectively, while 19.9% and 25% fell into the category of moderately food insecure and severely food insecure, respectively.

Table 4. Food security levels of farming and fishing households in the study area.

	Pooled Sample	Farming Households	Fishing Households
Food secure	140 (27.83)	76 (30.28)	64 (25.40)
Mildly food insecure	142 (28.23)	62 (24.70)	80 (31.75)
Moderately food insecure	103 (20.48)	50 (19.92)	53 (21.03)
Severely food insecure	118 (23.46)	63 (25.10)	55 (21.83)
Total	503 (100)	251 (100)	252 (100)

Source: Field survey (2018). Note: Figures in parentheses represent column percentages.

On the other hand, for the fishing households, 25.4% and 31.8% belong to the category of food secured and mildly food insecure, respectively, while 21.0% and 21.8% belong to the category of moderately food insecure and severely food insecure, respectively. Taken together, approximately 56% of the sampled households were food secure, while the remaining 44% were food insecure.

Table 5 presents a cross-tabulation of households by vulnerability levels and food security status. As expected, households with low vulnerability fell into the food secure and mildly food insecure categories, respectively. On the other hand, the majority (70%) of the households with high vulnerability levels fell into the category of severely food insecure. For households with moderate vulnerability levels, the distributions between the various food security categories were similar.

Table 5. Cross tabulation of Farming and Fishing households by vulnerability level and food security status.

	Low Vulnerability	Moderate Vulnerability	High Vulnerability	Total
Food secure	41 (50.6)	97 (23.5)	2 (20)	140
Mildly food insecure	27 (33.3)	115 (27.9)	0	142
Moderately food insecure	9 (11.1)	93 (22.6)	1 (10)	103
Severely food insecure	4 (4.9)	107 (26)	7 (70)	118
Total	81	412	10	503

Source: Field survey (2018). Figures in parenthesis represent column percentages

3.2. The Effect of Vulnerability to the "Triple Challenge" on the Food Security

Here, we examine the parameter estimates of the ordered logit model to understand the effect of vulnerability to the triple challenge on food security. Table 6 shows this effect (also see Table S2 (in the supplementary material) for the summary statistics of the variables used in the ordered logit model).

The dependent variable in our model is a set of four ordered variables which depict the differential categories of household food insecurity (see Sections 2.4.3 and 2.4.4). The signs, significance level, and magnitude of the coefficients are given for each category of food insecurity. A coefficient with a positive sign in a category (e.g., mildly food insecure) means that an increase in that variable will increase the likelihood of belonging to that category, while a negative sign decreases the likelihood of belonging to that category. In other words, a significant positive coefficient means that a unit increase in the explanatory variable increases the probability of the household falling in the category of the food insecure, while a significant negative coefficient means that a unit increase in the explanatory variable decreases the probability that the household will fall into the category of the food insecure.

As shown in Table 6, the predictors or explanatory variables, such as the vulnerability index and dependency ratio, increase the probability of being in the higher categories of food insecurity, whereas household annual income, household size, remittances, farm size, and participation in non-farm income increase the probability of being food secure. The marginal effects associated with the estimated model are presented in Table 7. The coefficient of the vulnerability indices is significant at 1% in the entire category.

Table 6. Estimated Coefficient of Ordered Logit Model.

Variable	Coefficient	Std. Error	*p*-Value
Vulnerability indices	5.400	0.993	0.000 ***
Household annual income	−0.284	0.111	0.011 **
Marital status			
Married	0.464	0.323	0.151
Others	0.399	0.407	0.327
Age	0.003	0.008	0.745
Household size	−0.144	0.053	0.007 ***
Dependency ratio	0.188	0.082	0.022 **
Store food	0.022	0.181	0.905
Remittances	−0.402	0.184	0.029 **
Farm size	−0.914	0.275	0.001 ***
Savings	0.004	0.175	0.980
Non-farm work	−0.061	0.203	0.000 ***
State			
Bayelsa	−0.032	0.192	0.867
Livelihood group			
Fishing households	−0.671	0.247	0.007 ***
Cut 1	−3.0828	1.6157	
Cut 2	−1.5823	1.6154	
Cut 3	−0.3904	1.6133	
No of observations	503		
LR chi2 (12)	163.51		
Prob > chi2	0.0000		
Pseudo R^2	0.1180		
Log likelihood	−611.32485		

Source: Field survey (2018). Note: *** and ** indicate significance at 1% and 5% respectively.

Table 7. Marginal Effects associated with the Ordered Logit Model.

	Food Secure	Mildly Food Insecure	Moderately Food Insecure	Severely Food Insecure
Vulnerability scores	−0.849 ***	−0.196 ***	0.236 ***	0.809 ***
Household annual income	0.045 **	0.010 **	−0.012 **	−0.043 ***
Marital status				
Married	−0.077	−0.011 **	0.023	0.065
Others	−0.067	−0.009	0.021	0.055
Age	−0.000	−0.000	0.000	0.000
Household size	0.023 ***	0.005 **	−0.006 ***	−0.022 ***
Dependency ratio	−0.030 **	−0.007 **	0.008 **	0.028 **
Store food	−0.003	−0.001	0.001	0.003
Receive help	0.063 **	0.015 **	−0.018 **	−0.060 **
Farm size	0.144 ***	0.033 ***	−0.040 ***	−0.137 ***
Saving	−0.001	−0.000	0.000	0.001
Non-farm work	0.184 ***	0.032 ***	−0.065 ***	−0.151 ***
State				
Bayelsa	0.005	0.001	−0.001	0.005
Livelihood group				
Fishing household	0.105 ***	0.022 ***	−0.028 ***	−0.100 ***

Source: Field survey (2018). Note: *** and ** indicate significance at 1% and 5% respectively.

Table 7 indicates that as the vulnerability of households increases, the probability of households belonging to the food secure and mildly food insecure categories decreases, while the probability of belonging to the moderately food insecure and severely food insecure categories increases. It should be noted that vulnerability indices range from 0 to 1; a value of 1 means that the household is highly vulnerable, while 0 implies less vulnerability. Food security is a dummy variable with four categories (0–3), where 3 is the highly food insecure category. The vulnerability score and food security score move in the same direction. The coefficient of household annual income is significant at 1%. An increase in household size increases the probability of households belonging to the food secure and mildly food insecure category and decreases the probability of being moderately food insecure and severely food insecure.

Further, an increase in the dependency ratio decreases the chances of belonging to the food secure and mildly food insecure categories and increases the chances of belonging to the moderately food insecure and severely food insecure categories. The dependency ratio is significant at 5%. In other words, an increase in the proportion of households not employed (i.e., the elderly and children) decreases food security. Households who receive help from family and friends are more likely to fall into the food secure and mildly food insecure categories and less likely to belong to the category of moderately food insecure.

Tables 6 and 7 further show that an increase in farm size increases the probability of households being food secure and mildly food insecure and decreases the chances of being moderately food insecure and severely food insecure. The coefficient of the non-farm work is significant at 1%. Participation in non-farm work increases the chances of households being food secure or mildly food insecure and decreases the chances of being moderately food insecure and severely food insecure. The coefficient of the livelihood group was found to be significant at 1%.

3.3. Correlation between Food Insecurity and Vulnerability Index

The correlation matrix between the food insecurity index and the major components of the livelihood vulnerability index is presented in Table 8. The result shows that 'exposure' and 'adaptive capacity' are apparently two major components of the vulnerability index that significantly affect food insecurity. A positive relationship exists between exposure and food insecurity (0.2079), whereas adaptive capacity is negatively correlated with food insecurity.

Table 8. Correlation Matrix between Food Insecurity index and vulnerability index.

	Food Insecurity Index	Exposure	Sensitivity	Adaptive Capacity
Exposure	0.2079 **	1.0000		
Sensitivity	0.0762	−0.1194 **	1.0000	
Adaptive capacity	−0.3473 **	0.2018 **	−0.1995 **	1.0000

Field survey (2018); Note: ** indicates significance at 5%.

Table S2 in the supplementary material shows the results of the correlation matrix between the food insecurity index and the sub-components and indicators that make up exposure and adaptive capacity. The indicators of exposure, such as involvement in conflict related to land, feelings of insecurity, and losses resulting from conflict, were found to significantly ($p < 0.05$) affect food insecurity. For adaptive capacity, factors such as remittances, income, diversification, membership of association, access to external support, and local cooperation were found to be significant ($p < 0.05$) in reducing food insecurity.

4. Discussion

Does vulnerability to the "triple challenge" affect the food security status of fishers and farmers? Our ordered logit modeling approach shows that the coefficient of our vulnerability indices is significant at 1% across all food security categories. This means that most farmers and fishermen households in our sampled location were in a situation of food insecurity. Previous studies [1,6] suggest that vulnerability to climate shocks and environmental degradation can undermine livelihood productivity, which in turn can fuel household food insecurity. In demonstrating a strong relationship between vulnerability to the "triple challenge" and food insecurity, our result aligns with previous research while also providing contextual insight relating to fishermen and farmers in Niger Delta, Nigeria.

Our analysis shows that several indicators of vulnerability relate closely to food security. Household income comes across as an important indicator/factor in determining food security outcomes—this is not a surprise. The estimated annual income for the sampled farmers and fishermen is approximately USD 2000 and USD 1800, respectively. An income level above these for each group could amplify food security and reduce vulnerability to the "triple challenge". The marginal effect of the Ordered Logit highlighted in Table 7 shows that an increase in household annual income increases the probability of households attaining a food secure or a mildly food insecure status but decreases the chances of being moderately food insecure or severely food insecure. This is expected as an increase in income increases food consumption expenditure and access to quality food, as well as offering opportunities for a more diversified food consumption pattern. Additionally, income gains enable resource users to invest in relevant assets (e.g., land, improved seedlings, and motorized fishing tools), which could help boost production and, in turn, spur food security. Past research [84] found that gain in income is among the most important determinants of food security amongst indigenous households in natural resource-dependent societies.

Our study also found that households that are large in size (e.g., 6–8 family members) are relatively more food secure or mildly food insecure. This suggests that a large household where members are gainfully employed can lead to higher income gains for the household. Higher income could be used to increase access to desired quantity and quality of food. Moreover, larger households with an increase in income gains or asset holding are likely to be resilient in vulnerable societies facing multiple interacting stressors. These findings agrees with [85], who studied food insecurity among indigenous households in India. Similarly [86], found that larger households were more food secure in Nigeria.

Similar to other authors who suggested that poor families with young adults (who are generally unemployed) may be food insecure [87,88], we found that household dependency ratio and food security status are related: an increase in the number of unemployed household members (i.e., if there are several elderly people and children) could exert pressure on household resources, which in turn increases food insecurity.

Further, we find that external support (help received) from family and friends enables food security. Past studies show that access to social capital enables resilience building and constitutes an important asset that households draw upon during difficult times [89,90]. Joining and participating in activities of fishermen groups increase the chances of fishermen becoming food secure or mildly food insecure, decreasing the probability of being moderately food insecure and severely food insecure.

Relatedly, access to natural capital could support food security. For example, we found that farmers with large farm areas were relatively food secure or mildly food insecure compared to those with small farms. We note that large-scale farmers tend to be more efficient in the use of resources and are food secured. These results agree with the findings of [91]. Our result shows a positive relationship between "participation in non-farm work" and "being food secured and mildly food insecure". Engagement in non-farm enables households to earn extra income, which could, in turn, facilitate investment in food production and access to quality food. This result agrees with previous studies such as [92–95].

Focusing on exposure to the "triple challenge" (a sub-component of our vulnerability index) and its link with food security, we note that our indicators of exposure, such as involvement in conflict related to land, feelings of insecurity, and losses resulting from conflict, negatively affect food insecurity. Relatedly, the more exposed households are, the more likely they are to be food insecure.

Similarly, "adaptive capacity" has a negative relationship (−0.3473) with food insecurity, and this implies that households with greater adaptive capacity have the probability of being less food insecure in the context where this study was carried out. This is expected as previous studies have shown that adaptive capacity plays an important role in achieving food security and that improving adaptive capacity (e.g., through access to financial capital, social capital, and livelihood diversification) fosters local people's productivity [66]. The correlation between our food security index and the indicators that make up exposure and adaptive capacity shows that: involvement in conflicts was positively associated with food insecurity, while access to remittances, external income, livelihood diversification opportunities, and membership of association were associated with reducing food insecurity. This corroborates the findings of [96] who found that adaptive capacity plays an important role in fostering progress towards food security. Receiving external support from family and friends—a form of social capital—facilitates food security; such support constitutes an important asset that households draw upon during difficult times [89,90].

Other vulnerability indicators/factors related to food security include: (i) farm size–the positive association between farm size and the probability of being food secure or mildly food insecure conforms to a prior expectation that large farm size increases food security [91]; and (ii) participation in non–farm work—this enables households to earn extra income and could spur increase in access to food [92–95].

5. Conclusions

This study examines the effect of vulnerability to the "triple challenge" on food security outcomes using data collected from 503 households (252 fishermen and 251 farmers) in the Niger Delta region of Nigeria. The food security levels of farmers and fishermen were determined using the FAO food insecurity experience scale (FIES), focusing in particular on household food access. A composite index approach was used to estimate the vulnerabilities of farming and fishing households, and an ordered logit model was employed to determine whether and how vulnerability undermines food security.

Our results show that vulnerability to "the triple challenge" undermines food access. In particular, the majority of households (>70%) with high vulnerability levels were found to be severely food insecure. The results of the ordered logit model indicate that vulnerability factors such as high dependency ratio (i.e., families with many children and elderly people who have no sources of income) and types of livelihood activities (whether fishing or farming) increase the probability of being food insecure. Similarly, factors such as higher household annual income, greater household size, inflow of external/social support (i.e., gains in family income), large farm size, and participation in non-farm activities decrease the probability of being food insecure. Fishing households were found to be more food secure than farming households because they gained more family income per annum.

At this point, we ask: how would farmers and fishers achieve food security based on the social, institutional, and territorial configurations in the Niger Delta region, and what kind of resources exist in the region that could help local people to build resilience to the 'triple challenge'? To improve food security in contexts of increasing instability, it is important that policy makers pursue programs aimed at reducing vulnerability to compounding risks (such as climate, conflict, and environmental degradation), accounting for the ways in which these risks interact and alter livelihoods. The provision of social safety packages (such as credits and index-based insurance) can help families with high dependency ratio to cope with food insecurity and build resilience.

Climate-resilient production technologies (e.g., developing climate-sensitive and pollution-tolerant seeds, plants, and trees) and community peace clubs, including vulnerability literacy, are examples programs that have proven useful in protecting food security gains in fragile settings [1]. Vulnerability literacy, just like climate literacy, is an awareness and understanding of people's vulnerability to certain challenges. Vulnerability literacy is lacking in the study region and addressing this would require new insights such as those offered in this study, including mass education and community campaigns that spur farmers and fishers to share their knowledge in systematic ways among each other and with relevant care-giving stakeholders.

In addition, monitoring the activities of multinational oil companies can curtail the menace of oil spillage and gas flaring on the environment and agriculture. Monitoring can happen, e.g., through agencies that ensure that sanctions are enforced when companies violate standard exploratory practices. It can also happen by leveraging the power inherent in ethnic diversity, which recognizes and respects the abilities of communities to self-organize around natural resource management. Ethnic and cultural diversity in the Niger

Delta region can be harnessed to build bridges of trust, respect, and understanding across farmer and fishermen groups in ways that foster resilience and regional stability.

Relatedly, to reduce food insecurity, actions to improve fishing households' access to land for farming to diversify their income sources would be necessary. Similarly, community leaders could map out some areas for households that do not currently have access to land. Providing livelihood diversification opportunities, e.g., by enabling conditions for small and medium scale enterprises to thrive, could provide extra employment opportunities, improving household income and food security situation. This is important as livelihood diversification was identified as an important adaptation strategy employed by the two livelihood groups.

The use of multi-method approaches to uncover new ways of thinking about and understanding food security in multiple stressors contexts characterized by high livelihood vulnerability underlies the significance of this study. Our study offers new methods for unraveling vulnerabilities and unpacking new knowledge about the many-sided dimensions of vulnerability that are often hidden and less recognized in the academic and policy circles and by local resource users themselves. Our findings provide an empirical case to buttress the need to support vulnerability literacy and promote resilience and food security of farming and fishing populations on the frontline of conflict and climate crises.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land11111982/s1, Table S1: Summary statistics of variables in the ordered logit model. Table S2: Correlation Matrix Between Food Security and Vulnerability Index. Table S3: Food Insecurity Questionaire. Table S4: Major components and sub-components used in calculating the composite vulnerability index, definition, rationale for their selection and units of measurement.

Author Contributions: Conceptualization, C.S.O. and U.T.O.; Methodology, C.S.O. and U.T.O.; Software, C.S.O.; Validation, C.S.O., P.I.O. and U.T.O.; Formal Analysis, C.S.O.; Investigation, C.S.O.; Resources, C.S.O. and U.T.O.; Data Curation, C.S.O.; Writing—Original Draft Preparation, C.S.O.; Writing—Review and Editing, U.T.O., C.S.O., P.I.O., I.S.E. and D.B.S.; Funding Acquisition, C.S.O. and U.T.O. All authors have read and agreed to the published version of the manuscript.

Funding: This work benefited from funding from TRECCAfrica (Transdisciplinary Training for Efficiency and Climate Change Adaptation) offered to Chinasa Onyenekwe and a UK Research and Innovation grant funding offered to Uche Okpara (Grant No: MR/V022318/1).

Informed Consent Statement: Informed consent was obtained from participants involved in this study.

Acknowledgments: We sincerely thank the fishing and farming communities in the Niger Delta region who provided information for this study.

Conflicts of Interest: The authors declare no conflict of interest. The funders have no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript; and in the decision to publish the results.

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