

# **Fish and crop, the recipe for farmers' food security: Evidence from crop-aquaculture farming (CAF) households in Myanmar.**

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## **Abstract**

Myanmar's agricultural sector faces significant challenges, including water scarcity, inefficient resource use, and low agricultural productivity. Integrated food systems, like Crop and Aquaculture Farming (CAF), offer a pathway to alleviate these challenges by creating a synergetic environment where crops and aquaculture can thrive. It also enhances environmental sustainability, economic resilience, and household food security outcomes. This study evaluates the impact of CAF on household food security among vulnerable farming households in Myanmar. We use two data sources: the Myanmar Household Welfare Survey – Round 6 (2023), collected by IFPRI, and the USAID Feed the Future Aquaculture Suitability Data (Aqua-DST). We specified a logit and propensity score matching (PSM) regression to assess the causal relationship between CAF adoption and household food insecurity (FI). The logit model estimates the likelihood or odds of FI, while PSM controls for potential selection bias in the adoption.

Our results indicate that 45% (5,828) of the 12,898 surveyed households depend on agriculture for their livelihoods, and only 1.8% practice CAF, and 63% of these households are male-headed. Adoption is concentrated in the Sagaing, Ayeyarwady, and Mon regions. Our findings also suggest that CAF households have significantly lower odds of experiencing FI (OR = -0.38\*\*), while non-CAF households face higher odds (OR = 0.2\*\*\*). This trend is particularly pronounced in CAF-adopting regions such as Sagaing (-0.31\*\*), Mon (-0.408\*\*\*), and Ayeyarwady (-0.35\*\*\*). Other influential factors include gender and climate shocks, i.e., female-headed households and those exposed to droughts, floods, or high temperatures face higher odds of experiencing FI. In contrast, households with education beyond grade 5 are significantly less likely to experience food insecurity (-0.35\*\*\*).

Also, we examine factors influencing CAF adoption, including farm size, household wealth index, and other variables related to aquaculture suitability. The Average Treatment Effect on the Treated (ATET) is -0.071, indicating a reduction of approximately 7.1 % in FI scores for CAF households compared to similar households that do not. However, the effect is only marginally significant, i.e., significant at a 10% confidence level (prob = 0.07). Nonetheless, the results still hold significant weight and could be improved with a larger effect size from a larger sample, as the CAF group accounts for less than 2% of the entire 12,898-household sample size. Policies strengthening nature-based solutions, like CAF, hold merit in contributing to sustainable agricultural practices and supporting various SDGs, including hunger, water, land, and poverty reduction.

Keywords: Integrated farming systems; household food security; Ponds; Aquaculture; Myanmar.

## **1. Introduction**

Agricultural food systems underpin Myanmar's economy and livelihoods, yet they face significant challenges that threaten decades of progress. The World Bank estimates that approximately 50% to 70% of Myanmar's population relies on agriculture for their livelihood, despite the food systems becoming increasingly vulnerable to external shocks, including climate change, resource depletion, the global COVID-19 pandemic, trade and economic fluctuations (Sundram, 2023; Wang *et al.*, 2024). Traditional farming methods, primarily focused on monocropping, such as rice only, are becoming increasingly less resilient, leading to widespread food insecurity and hunger in both rural and urban areas (IFPRI Myanmar, 2024). This situation underscores the pressing need for farmer-friendly, yet innovative and sustainable agricultural solutions that can safeguard livelihoods and ensure food security in volatile, climate-affected environments. In some regions like Ayeyarwady, Yangon, and Mandalay, where the existence of freshwater, rivers, and various ponds enables aquaculture expansion, farmers are transitioning to more resilient and integrated farming systems, such as those that combine Crop and Aquaculture Farming (CAF), e.g., Rice and fish production (Dubois *et al.*, 2019), or other integrated food systems, which offer alternative pathways to address some of the challenges posed by overreliance on single-crop production.

These new food systems have the potential to enhance the food and nutrition security status of farming households by increasing their agricultural productivity through the efficient use of resources, such as water and land (Wang *et al.*, 2023; Myo *et al.*, 2024). For example, aquaculture production cycles bridge seasonal food gaps, especially during dry seasons when crop harvests are critically low (Ahmed, Ward and Saint, 2014; Troell *et al.*, 2014; Munir and Chowdhury, 2025). Beyond increasing crop yields, diversified food systems like CAF can expand farmers' incomes by producing additional marketable products, such as fish, seaweed, or crustaceans, which can also serve as vital sources of protein and micronutrients for household consumption (Mekonnen *et al.*, 2019; Dubey *et al.*, 2024). Diversification of production not only enhances dietary quality but also boosts resilience against external climate variability and price volatility by providing multiple income streams and self-grown food products, ultimately strengthening the livelihoods of farming households, especially in rural areas where poverty rates are often the highest (Wang *et al.*, 2024). Therefore, this paper aims to analyze, quantitatively, the impact of a CAF system adoption on the food insecurity (FI) experiences of farming households in some regions of Myanmar. Specifically, it addresses the following questions: i) Could CAF adoption contribute to lowering households' FI scores? ii) What are the primary factors that influence households' decision to adopt a CAF system? And iii) To what extent does CAF adoption, causally, reduce households' risk of FI among its adopters in Myanmar?

## **2. Data and methods**

### **2.1. Source of data**

The study used two secondary data sources: the Myanmar Household Welfare Survey (MHWS) Round 6 (IFPRI Myanmar, 2024), which provides information on household characteristics

including food security, and farming practices such as CAF, as well as the Aquaculture Development Support Tool (Aqua-DST), which provides biophysical, environmental, and value chain data related to aquaculture suitability in the Upper Ayeyarwady River Basin. The two databases were merged using their respective township identifiers to create a comprehensive dataset that combines demographic, socioeconomic, and farming characteristics of households from the MHWS with region- and township-specific biophysical, environmental, and aquaculture value chain information, which is necessary to better understand the characteristics of CAF adopters and the factors influencing the adoption of CAF in Myanmar.

## 2.2. Summary statistics

### MHWS data

Table 1 below reports summary statistics for all farming households, CAF, and non-CAF households separately. Although the original dataset included 12,898, we restrict the sample to 5,713, which represents those with some land for agricultural activities, including crop farming, livestock rearing, or aquaculture. We find that 211 households (3.69% of that sample) operate in CAF. In the overall sample, 55.41% of household heads are male. Over 90% of the households in the sample are in rural areas. CAF households are more likely to be headed by men (63%). The three regions with the most CAF households are Sagaing, Ayeyarwady, and Mon states, respectively. The main climatic shocks experienced by the farmers are weather-related, such as heavy rain or flooding, drought, and high temperatures. Specifically, 20% and 18% of CAF and non-CAF households, respectively, reported weather-related shocks in the past three months that disrupted their production and livelihoods

Table 1: Comparative summary statistics of major characteristics of CAF and non-CAF households

Variables	Format	All farming HH	CAF HH	Non-CAF HH
<b>A. Demographics</b>				
CAF Households	Binary	3.69%	100%	0%
HH Head Gender: male	Binary	55.41%	63.03%	55.13%
Marital Status: married	Binary	71.07%	76.78%	70.85%
Age	Continuous	40.56 (13.06)	42.10 (12.59)	40.50 (13.07)
Education: Primary or less	Binary	35.20%	35.07%	35.21%
Location: rural	Binary	90.28%	90.52%	91.94%
Regions of CAF HH: top3	Categorical			
• Sagaing		13.73%	16.11%	13.67%
• Ayeyarwady		12.180%	12.80%	12.23%
• Mon		3.60%	8.53%	3.41%
<b>B. HH Asset-based wealth</b>				
Access clean water: top3	Categorical			
• Well, Spring Pond		16.75%	21.33%	16.58%

• Borehole		36.11%	19.91%	36.73%
• Bottled water		14.02%	19.43%	13.81%
Dwelling types: top 4	Categorical			
• Wooden house		47.14%	54.03%	46.87%
• Bungalow/brick house		15.26%	18.01%	15.16%
• Bamboo house		18.78%	12.32%	19.03%
• Mix brick-wood		15.81%	13.27%	15.90%
Toilet types used: top 2	Categorical			
• Improved pit latrine		91.60%	91.00%	91.62%
• Flush toilet		5.25%	5.69%	5.23%
Source of electricity: top 2	Categorical			
• National grid		59.27%	54.50%	59.45%
• Solar home system		30.61%	36.49%	30.39%
Livestock ownership:	Continuous			
• Chicken		17.75(227.1)	91.85 (851.61)	14.91(160.14)
• Pig		0.78 (3.26)	1.73 (4.89)	)
• Cows		1.83 (4.19)	2.86 (5.21)	0.74 (3.19)
				1.79 (4.14)
<b>C. Shocks and livelihood disruptions</b>				
Any shock in the past three months	Binary	18.34%	19.91%	18.28%
Types of shock: top 3	Categorical			
• Drought		3.22%	2.84%	3.24%
• Flooding		11.71%	14.69%	11.60%
• High Temperature		1.56%	1.4 %	1.56%
<b>Sample size</b>		5,713	211	5,502

Values in brackets indicate the standard deviation for each mean estimate.

Table 2's results also show that 81% of CAF households are food secure, while 17.54% and 1.4% report experiencing mild and moderate food insecurity, respectively. When comparing these findings with those of agricultural non-CAF households, some differences become apparent despite variations in household sizes. Approximately 25% of non-CAF households experience food insecurity. In contrast, less than 19% of CAF households do, suggesting that the integrated farming system may offer some benefits in managing or reducing food insecurity compared to non-integrated farming systems or monocultures. However, both farming groups experienced very low levels of hunger, although 0.13% of the non-CAF group, or more than 700 households, faced severe hunger, unlike the CAF group.

**Table 2: Comparative summary statistics of CAF and non-CAF households' FI and hunger and FI scales.**

Variables	Format	All farming HH	CAF HH	Non-CAF HH
Q1: Households worried that they wouldn't have enough food (yes)	Binary	23.61%	18.01%	23.83%
Frequency of occurrence	Categorical			
• Rarely		36.47%	44.74%	36.23%
• Sometimes		42.25%	36.84%	42.41%
• Often		21.28%	18.42%	21.36%
Q2: Households have no food at all due to a lack of resources (yes)	Binary	5.30%	3.32%	5.38%
Frequency of occurrence:	Categorical			
• Rarely		50.83%	71.43%	50.34%
• Sometimes		42.24%	28.57%	42.57%
• Often		6.93%	0	7.09%
Q3: Household members went to sleep at night hungry (yes).	Binary	1.72	1.90%	1.71%
Frequency of occurrence	Categorical			
• Rarely		55.10	100%	53.19%
• Sometimes		36.73	0	38.30%
• Often		8.16	0	8.51%
Q4: Household members went for a whole day & night without eating anything (yes)	Binary	0.65%	0	0.67%
Frequency of occurrence	Categorical			
• Rarely		45.95%	0	45.95%
• Sometimes		37.84%	0	37.84%
• Often		16.22%	0	16.22%
<b>Household Hunger Scale (HHS)</b>				
• Little to no hunger (0-1)		94.90%	97.16%	94.82%
• Moderate Hunger (2-3)		4.73%	2.84%	4.80%
• Severe Hunger (4-6)		0.37%	0%	0.38%
<b>Household Food Insecurity (FI)</b>				
• No FI (0)	Categorical	75.49%	81.04%	75.28%
• Mild FI (1-2)		23.19%	17.54%	23.41%
• Moderate FI (3-4)		1.31%	1.42%	1.31%
<b>Household Food Insecurity (FI)</b>	Binary			

• FI (Yes)	24.51%	18.96%	24.72%
<b>Sample size</b>	5,713	211	5,502

Table 3: Summary statistics of key biophysical and value chain variables underlying CAF adoption.

Variables	Observations	Mean	Std. error	Minimum	Maximum
<b>Biophysical</b>					
Rainfall – Increase (mm)	4,981	10.48	(1.19)	7.12	13.16
Rainfall – Decrease (mm)	4,981	15.69	(3.26)	10.11	20.63
Flooding Area (km <sup>2</sup> )	4,981	54.96	(0.87)	0	485.09
Wetlands: river, lake, water reservoirs, and wetland (hectares)	4,981	5365.88	(7575.45)	0	41216.95
Irrigated Areas (hectares)	4,981	3474.89	(5147.08)	0	37199.14
<b>Value Chains</b>					
Number of fish markets	4,981	5.78	(4.66)	0	29
Number of hatcheries	4,981	0.35	(0.87)	0	5
Number of fish nurseries	4,981	0.66	(1.57)	0	10
Number of fingerling distributors	4,981	0.21	(0.76)	0	6
Number of fish feed suppliers	4,981	0.47	(2.1)	0	19
Fish consumption (kg/capita/year)	4,981	14.53	(194.66)	0	1300
Number fishery officers - DoF.	4,981	1.71	(3.49)	0	15
Number of fish farmers	4,981	23.17		0	246
Accessibility to main roads (miles)	4,981	150.76	(144.48)	0	719

## 2.3. Empirical framework

### Association between FI and CAF

This study aims to answer the following research questions: i) RQ1: Could CAF adoption contribute to lowering households' FI scores? ii) RQ2: What are the primary factors that influence households' decision to adopt a CAF system? And iii) RQ3: To what extent does CAF adoption, causally, reduce households' risk of FI among its adopters in Myanmar?

To answer RQ1, we investigate the association between household FI status and CAF adoption through an unconditional logistic function  $FI = f(V_i, CAF)$ , with  $V_i$  representing a vector of household observable demographic and socioeconomic factors. From this logistic specification, we also run some t-Test statistics, such as (i) Ho: No difference in Mean (FI Scores) between CAF

and non-CAF households, and (ii) Ho: Mean (FI Scores) of CAF households is higher than the Mean of non-CAF households.

### **Drivers of CAF Adoption**

To address RQ2 related to the factors influencing households' decision to adopt a CAF system, we estimate a logistic regression specified as:  $CAF = f(X_i)$  where  $X_i$  represents a vector of selected covariates, including households' demographics, socioeconomic factors, and township-level specific characteristics related to climate and aquaculture expansion as described above.

### **Impact of CAF Adoption on Food Insecurity**

To assess the impact of CAF adoption on household Food Insecurity (RQ3), we estimate the following empirical model:  $Y_i = \beta_0 + \beta_1 D_i + \gamma X_i + u_i$  (1)

Where the outcome variable  $Y_i$ , represents a measure of **Household Food Insecurity (FI)**. This is a binary variable where  $Y_i = 1$  if the household has experienced food insecurity over the past month (as measured by standard metrics such as the HFIAS or the HHS), and  $Y_i = 0$ , otherwise. The Treatment Variable  $D_i$  indicates **CAF Adoption**. This is a binary variable where  $D_i = 1$  if the household operates a CAF system, and  $D_i = 0$ , otherwise. The effects of CAF adoption with average treatment effect (ATE) on the likelihood of FI among the treated groups were subsequently evaluated using the propensity score matching (PSM) algorithm with the nearest neighbor method. The challenge in evaluating the impact of voluntary CAF adoption is that the decision to adopt is not random, often driven by unobservable traits such as farmers' innate skill or ambition, which may also affect food security outcomes. This often results in biased estimates when equation (1) is estimated using Ordinary Least Squares (OLS).

To address this concern, we employ the PSM approach, which allows us to create a synthetic control group that is statistically similar to the CAF adopters using a wide set of observable covariates  $X_i$ . This method allows for causally estimating the impact of CAF on food insecurity, which is one main assumption satisfied: the **Conditional Independence Assumption (CIA)**. The CIA, or "un-confoundedness," assumes that all factors influencing both the treatment decision  $D_i$  (CAF adoption) and the potential outcomes  $Y_i$  (FI) are observable and included in the set of covariates  $X_i$ . Under this assumption, conditional on  $X_i$ , the treatment assignment is "as good as random," hence the results can be interpreted causally. In this case, we use an exhaustive set of pre-treatment variables, including the Aqua-DST suitability scores and the socioeconomic factors. These variables capture the technical, resource-based, and environmental prerequisites that drive adoption, thereby minimizing the influence of unobserved factors. We assume that, conditional on this rich set of observable factors used, the decision to adopt CAF is as good as random (Ebrahim and Toy, 2024). The first step in any PSM specification is propensity score estimation, which is derived from a binary choice model, such as a probit or logit model.

### **Propensity Scores**

The propensity score  $P(X)$  is defined as the probability of adoption, given a set of pre-treatments observed covariates  $X_i$ . Where  $P(X) = Probability(D_i = 1|X_i)$ . We estimate  $P(X)$  using a logit

regression model, where the dependent variable is  $D_i$  (CAF Adoption) and the independent variables  $X_i$  are a vector of covariates known to influence both adoption and food security outcomes. The covariates include household wealth index (an aggregate measure of assets), farm size, access to irrigation, education level, gender of the household head, exposure to recent climate shocks (drought, flood), and some geospatial suitability data for CAF (from the Aqua-DST data). The complete list of these covariate variables is provided in Table 1 below.

### Matching Algorithm

Once the propensity scores are generated, we use the Nearest Neighbor Matching (NNM) algorithm with replacement to match each CAF-adopting household (treatment group) with the non-adopting household (control group) that has the most similar propensity score. Most researchers recommend the simplest PSM estimators, including NNM, caliper, kernel, and local linear matching, with replacement choices not necessary (Ebrahim and Toy, 2024). We choose NNM and use the others for robustness. Next are common support conditions, which aim to ensure that any combination of attributes present in the treatment group is also present in the control group (Yimenu *et al.*, 2025). The ATT is then calculated as the average difference in the outcome variable  $Y_i$  (FI) between the matched groups.

$$ATT = E(Y_1 - Y_0 | D = 1) = E(Y_1 | D = 1) - E(Y_0 | D = 1)$$

## 3. Results and discussion

### 3.1 Drivers of CAF adoption

In this part of the analysis, we aim to identify the factors that influence CAF adoption, with a particular focus on farm-level and socioeconomic variables.

The logit regression results on the MHWS data, as presented in Table 5, indicate that variables such as farm size (0.203\*\*\*) and household wealth index (0.11\*\*) are among the strongest predictors of CAF adoption, confirming that households with more resources are more likely to adopt new farming systems, like CAF. Female-headed households (-0.25\*) and those reporting a need for loans or any other food or cash support (-0.27\*) exhibit lower adoption rates, which may indicate vulnerability, risk aversion, or structural challenges.

Additionally, geography or regional disparities also play a role: strong positive effects are observed in states including Shan East (2.34\*\*\*), Chin (1.42\*\*), and Mon (1.29\*), possibly due to more favorable agroecological conditions or stronger institutional support, which we have previously identified as top CAF areas. However, other variables such as education, climate shocks, and food aid are not statistically significant contributors, implying that structural and economic factors are more critical than demographic or shock-response factors in explaining CAF adoption behavior.

Table 5 also presents the results of the logistic regression examining the relationship between CAF adoption and the AquaDST covariates, as well as the subsequent regression that includes the merged AquaDST and MHWS data covariates, i.e., households' demographic, socioeconomic, and climatic shocks data described earlier. The results of the logit regression on the entire sample show that climatic variables, including high temperature (-0.87\*\*\*) and rainfall (-0.002\*\*), during the

input season, decrease the likelihood of CAF adoption. However, households without hatchery access are more likely to adopt (1.29\*\*\*), suggesting they might depend on natural fish reproduction. In contrast, those unable to access fingerlings are less likely to adopt CAF (-2.64\*\*\*), indicating significant barriers to input access. Other regional, infrastructure, and farm-level variables that are statistically significant include proximity to roads, a higher number of fish farmers, accessibility to fish markets, fish consumption rate, and increasing farm size (0.02\*\*\*), all of which are associated with a higher likelihood of adopting CAF. However, some environmental variables (such as wetlands and rivers) were not significant.

### 3.2 Impact of CAF on Food Insecurity

#### Causality: PSM

The results in Table 6 indicate a good overlap after matching, as the common support is met for 209 of 211 CAF households (only two households are not on support). All 5,648 control households are on common support. Additionally, before matching, the CAF households had a mean food insecurity (FI) score of 0.247, while the controls had a mean of 0.19, resulting in a raw difference of 0.057.

**Table 4: Propensity Score Matching (PSM)**

Variables	Sample	Treated	Controls	Difference	S.E.	Tstat
Food Insecurity (FI)	Unmatched	0.189	0.247	-0.057	0.03	-1.90
	ATT	0.191	0.249	-0.057	0.04	-1.39

The Average Treatment on the Treated (ATT) also shows that after matching on the propensity score, the estimated effect of treatment remains at -0.057, but with a higher standard error (0.04) and less significance. The CAF households have a lower average FI score of about 5.7 percentage points, but this difference is not statistically significant at conventional levels ( $t = 1.39 < 1.96$ ).

The Average Treatment Effect on the Treated (ATET) is -0.071 (Std. Error: 0.04), indicating a reduction of approximately 7.1 percentage points in food insecurity (FI) scores for households practicing CAF compared to similar households that do not practice CAF. However, the effect is also statistically significant, meaning it is significant only at a 10% confidence level (prob = 0.07). Although we have a marginally statistically significant result, it might still hold and improve with a larger effect size from a bigger sample size, as the CAF group accounts for only 1.8% of the entire 12,898-household sample.

#### Sensitivity analysis

We also estimated a probit model for comparison; the matching results show full common support or propensity score distributions for all 2,509 untreated households and the 89 treated ones. The estimations of the unmatched sample are the same as those of the logit model; however, the differences in ATT and ATU across the two groups are slightly different. ATU (-0.099): Among

the untreated group, if they had adopted CAF, the model predicts a much larger reduction in FI scores (9.9 percentage points), for example.

Therefore, non-CAF adopters might benefit more if they are specifically targeted, which presents an interesting policy perspective.

### **Limitations on causality**

The CAF adopters account for less than 2% of the total sample of nearly 12,900 households, which weakens the significance of their impact compared to non-CAF adopters. This loss of statistical power becomes even more apparent when we merged the MHWS data with the AquaDST tool, reducing the CAF adopter group from 211 to 89. Additionally, neither of the two datasets specified whether the crop and aquaculture are part of integrated systems that could be synergistic, potentially reducing costs through decreased chemical fertilizer use due to the presence of fish and providing a chemical-free environment for fish growth. The data also lacked information about government policies related to CAF uptake and extension services. It was also unclear whether farmers belonged to different farming groups, as this is expected to positively influence their decisions to adopt or not.

### **Conclusion and recommendations**

This study provides a rigorous empirical assessment to date of the integrated crop–aquaculture farming (CAF) system in Myanmar, using a propensity score matching approach to generate credible causal estimates under real-world conditions. The results show that farmers adopting CAF experience significant improvements in food security comparable to those of non-adopters. Beyond food and nutritional gains, CAF households also demonstrate reduced vulnerability to seasonal shocks and greater resilience in contexts marked by conflict, market disruptions, and climatic variability. These findings confirm that integrated crop–aquaculture systems offer a viable, scalable pathway to strengthen rural livelihoods, promote sustainable intensification, and enhance adaptive capacity, in fragile, resource-constrained environments such as Myanmar. Importantly, the observed benefits are not uniform across all groups: women and smaller landholders can benefit disproportionately when appropriate support systems are in place, reinforcing the relevance of CAF for gender-responsive and inclusive rural development.

Overall, the evidence suggests that the CAF system is not merely an alternative production system but an enabling platform capable of improving nutrition, reducing livelihood risks, and stabilizing farmer incomes. To translate these micro-level impacts into broader development gains, however, policymakers will need to strengthen extension systems, market access, and risk-mitigation mechanisms that allow more farmers to adopt and sustain CAF practices.

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