A climate-smart agriculture practice in Cambodia: Smallholder’s uptake of intercropping and food security

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Abstract

The increasing adoption of intensified and simplified cropping systems, known for their heightened susceptibility to pests and diseases, has escalated the climate vulnerability of smallholder farmers, adversely affecting food security in Cambodia. This study investigates the determinants of smallholder farmers adopting mono-cropping and intercropping as climate-smart agriculture (CSA) practices and estimates their impact on household food security. The study collected data from 391 smallholder farmers located in four provinces, representing different geographical clusters in Cambodia. First, the findings suggest that climate impact perceptions, such as perceptions of climate severity, inform, and support, are associated with intercropping adoption. Secondly, by employing control function methods to address self-selection bias in smallholder farmers' unobservable in intercropping adoptions, the results indicate that intercropping practices among smallholder farmers contribute to a 9.8 percentage point increase in food security and a 13.9 percentage point reduction in food insecurity. However, intercropping adoption has a limited impact on reducing food insecurity among moderately and severely food-insecure households. This study provides valuable insights to inform the design of agricultural resilience practices and policies aiming to promote the adoption of climate-smart practices for enhancing productivity and improving food security in Cambodia.

Keywords: Climate-smart agriculture, Food security, intercropping, climate change, smallholders, Cambodia

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1. Introduction

The majority of farmers in rural areas across Southeast Asia are smallholders managing farms of less than 10 hectares, primarily dependent on natural resources. Since 1950, Southeast Asia has experienced warming temperatures, changes in the seasonal rainfall pattern, and an increase in frequency of extreme climatic events (IPCC, 2014). Smallholder farmers in Southeast Asia, similar to smallholder farmers in other developing countries, are highly dependent on the natural resources for their livelihoods, making them vulnerable to climate change (Brown et al., 2019). Residing in one of the most climate-vulnerable regions in the world (IPCC, 2014) and with limited adaptive capacity (Landicho, Wulandari, Visco, & Huy, 2019), smallholder farmers, particularly the poor in Southeast Asia are hit hard by changing climate. Indeed, simulation studies show that yield variability explained by climate variability is between 20 to 25% for Vietnam, Laos, and Cambodia (Ray, Gerber, MacDonald, & West, 2015). Surveys from Southeast Asia show a large proportion of households reporting yield reduction due to climate change (Waibel, Pahlisch, & Völker, 2018).

The rise of, and dependence on, intensified and simplified cropping systems that are proven to be highly susceptible to pests and diseases (Liu, Kuchma, & Krutovsky, 2018) has further exacerbated farmers' climate vulnerability in Southeast Asia. In many developing countries including those in Southeast Asia, prolonged intensive cropping systems have resulted in groundwater depletion, biodiversity erosion, and environmental pollution (Palombi & Sessa, 2013). Particularly on mono-cropped sloping land, farmers' application of soil and water conservation technologies is limited due to the high cost. This results in the loss of a large amount of fertile topsoil. This process undermines future land productivity, causing declined farm yields and increased input costs (van Noordwijk et al., 2020). Intensive, mono-cropping systems are also problematic from an economic perspective. Research in Vietnam reported that relying on single crops such as coffee which are associated with large price volatility, implies that farmers, especially the poor, are faced with considerable market risks (Pham, Reardon-Smith, Mushtaq, & Deo, 2020) and thus income variation. Adoption of agricultural practices that can both reduce agriculture's negative impacts on the environment and ensure yield stability is urgently needed.

In this respect, Climate-Smart Agriculture (CSA) can be a potential solution to address interconnected pressures from climate change, food insecurity, and environmental degradation induced by intensified and simplified farming systems in Southeast Asia. CSA is based on three pillars including sustainably increasing agricultural productivity and incomes, adapting and building climate resilience, and reducing and removing greenhouse gas emissions (Palombi & Sessa, 2013). Given this definition, sustainable intensification and CSA are closely interconnected (Campbell, Thornton, Zougmoré, Van Asten, & Lipper, 2014). Among the various CSA practices classified by FAO, intercropping is particularly common among small farmers in developing countries (Maitra, Shankar, & Banerjee, 2020). Intercropping is the practice of growing two or more species on the same plot at the same time (Glaze-Corcoran et al., 2020). The practice has shown potential for improving farmers' income and food security via yield improvement and stabilization (Raseduzzaman & Jensen, 2017) while contributing to environmental sustainability via the reduced chemical input used (Bedoussac et al., 2018). Given its ability to improve soil conservation, pest management, and the efficient use of resources, intercropping can safeguard field cropping from anticipated climate change and the associated weather variability (Himanen, Mäkinen, Rimhanen, & Savikko, 2016). The practical adoption of any CSA practice is the choice of the individual smallholder. Therefore, to better understand and support the adoption of CSA in general and intercropping in particular we need to understand what factors are decisive in smallholders' adoption processes. Accordingly, this study aims to assess and compare the reasons for heterogeneity in adoption of CSA in Vietnam, Laos, and Cambodia, through the lens of climate change adaptation. In particular, we focus on intercropping as a promising CSA in the each geographical cluster of Cambodia and assess the socio-economic and psychological factors related to climate change as the determinants of intercropping, then gauge the effects on smallholder farmer's food security.

In the scientific literature, there is a growing research interest in farmers' adoption of climate-smart practices in relation to food security in Southeast Asia. In this respect, Bairagi, Mohanty, Baruah, and Thi (2020) investigated the impact of adopting climate-resilient strategies through intercropping on food security in Cambodia while Saptutyningsih et al. (2020) examined the willingness to participate in the climate change adaptation process among Indonesian farmers. However, studies explicitly focusing on the factors that determine the adoption of CSA are limited. Little is thus known about enabling, and disabling factors associated with smallholders' adoption of intercropping in Southeast Asia. Noticeably, cross-country analyses that compare the adoption of climate-smart practices across space are even scarcer in this region, although such analysis would contribute useful insights into how conditions for adoption vary across different regions with different economic, cultural, and political conditions. This results in a fragmented and incomplete understanding of farmers' uptake of climate-smart practices across Southeast Asia. Cross-country comparisons are relevant in this region. Southeast Asia countries are heterogeneous in culture and economic development. Considering Vietnam, Laos, and Cambodia, most Vietnamese and Laotians follow Mahayana Buddhism which is collectively oriented while the main religion in Cambodia is Theravada Buddhism which is individually oriented (Kim, 2002). GDP per capita in Vietnam, Laos, and Cambodia are 3694, 2551, and 1591 USD, respectively (worldbank.org). Such understudies and differences are await to explain in farmers' adoption of climate-smart practices across Southeast Asia countries, particularly in Cambodia agriculture-climate change context that are currently not well understood.

This study examines the determinants of intercropping practices through the lens of climate smart agricultures and estimates its effects on smallholder farmer food security. Using primary data collection from 391 smallholder farmers located in four provinces, representing different geographical clusters in Cambodia, the study first used a logistic regression model to estimate the determinant of intercropping adoption among smallholder farmers. The empirical findings suggest that climate impact perceptions, such as perceptions of climate severity, inform, and support, are associated with intercropping adoption. Taking into account the self-selection bias in the adoption of intercropping, the study employed the control function method to correct the observable factor affecting such decisions. The results indicate that intercropping practices among smallholder farmers contribute to a 9.8 percentage point increase in food security and a 13.9 percentage point reduction in food insecurity. However, intercropping adoption has a limited impact on reducing food insecurity among moderately and severely food-insecure households.

This study contributes to current agricultural policy development and strategic actions in a number of fronts. First, we consider a range of potential psychological drivers of intercropping as a climate-smart practice. These include perceived social support, perception of the severity of climate change and its impact, information acquisition about adaptation, perceived ease, and perceived usefulness of adoption. Second, we examined the influence of households' social and economic conditions on the adoption tendency toward intercropping. Third, this study sheds light into the understanding in factors affecting the uptake of a typical climate-smart practice in Cambodia and estimating its impact on household food security. Therefore, the study provides useful insights to support the design of agricultural resilience policies that aim to foster the adoption of climate-smart practices in Cambodia.

The remainder of the article is structured as follow. The first section provides an overview of trend and development of the climate change and the importance of the intercropping and climate smart-agriculture, followed by the literature review. Section 3 illustrates the theoretical framework on the decision of intercropping uptake and channel that effects on household food security. Section 4 demonstrates empirical approaches used in the study including the data and identification strategies to ensure the robustness of the findings. Last section concludes and provides the implications of the study.

2. Literature review

Previous studies have identified a range of factors that shape farmers' decision-making process in relation to the adoption of CSA practices and agricultural technologies in developing countries (Khoza, de Beer, van Niekerk, & Nemakonde, 2021). Amadu, McNamara, and Miller (2020) and Lalani, Dorward, Holloway, and Wauters (2016) pointed out that understanding the driving forces that influence farmers' decisions to accept and adopt CSA practices requires integrating perceptions, knowledge and experiences of farmers who observe and experience climate changes from different perspectives. Abu Hatab et al. (2022) illustrated that people's knowledge and perception determine their subsequent behavioural responses to environmental risks and opportunities, and thus shape their adaptation options and outcomes. In this regard, Mashi, Inkani, and Obaro (2022) found that farmers' perception of CSA practices is closely related to their awareness and knowledge of such practices, which they obtain from their prior experiences, access to information about climate change and CSA practices, and from the climate-induced challenges that encounter their farming businesses. Information acquisition on climate change and adaptation strategies might directly influence the adoption of intercropping in particular, which is technically complex. This information helps farmers to plan efficiently and effectively their farming activities (e.g. land preparation, planting date, crop variety selection, scheduling of fertilizer application, and harvest time (Djido et al., 2021).

In connection with this, Meshesha, Birhanu, and Ayele (2022) found that perceived economic and non-economic benefits are key determinants of farmers' adoption of a CSA practice. Teklewold, Mekonnen, and Kohlin (2019) found that farmers evaluate new agricultural innovations and practices based on the benefits that such innovations are anticipated to provide.

That is, some CSA practices may generate multiple and importantly perceived benefits whereas others can have limited perceived benefits. For instance, a farmer may adopt a CSA option to mitigate the effect of climate-induced risks (i.e. droughts or floods), whereas another farmer may adopt CSA technologies that reduce the cost of production or increase productivity.

Furthermore, previous studies have shown that farmers’ perceived behavioural control and its related term “perceived ease” feed into and explain their behavioural intentions and actual behaviors (Islam, Sabiha, & Salim, 2022). Specifically, farmers’ adoption of CSA practices is associated with their perception of their own capacity and confidence to use these practices, which encapsulates whether the farmer believes to have the means and resources necessary (e.g. skills, institutional support, and financial resources) to perform a behaviour relating to adopting CSA practices (Lalani et al., 2016). In particular, a farmer’s perceived behavioral control (Ajzen, 1991) or perceived ease can have significant implications for behavior materialization; Theory of Planned Behaviour (Ajzen, 1991) postulates that humans may fail to perform a specific behavior, despite having a positive summary evaluation of the behaviour, if they do not believe that they have sufficient means and confidence to do so.

Furthermore, farmers’ perception of their access to resources in terms of informal social support (or safety net/ social protection) might influence intercropping adoption in developing countries. Informal social support, in this study, refers to support from families, friends, neighbours, and other social actors within individuals’ kinship and/or community networks. This type of support can be considered as a bonding social capital that is an important asset for farmers to cope with extreme climate events (Adger, 2010). In rural areas of Southeast Asia, where strong bonding relationship among farmers, their relatives, neighbours, and friends is common (Tran & Rodela, 2019), informal social support might be particularly relevant. It has been shown that in this region, social support can take many forms such as informal loans, group sharing losses, supporting the worst off (Resurreccion, Sajor, & Fajber, 2008), and sharing of knowledge and information (Tran & Rodela, 2019). Since intercropping is cost and labour intensive, smallholders who have access to financial, information, and labour support from their informal social networks will be able to remove production constraints, and thus are able to intercrop.

Previous literature has also highlighted the role of socio-economic and demographic characteristics in influencing the perception that a farmer holds about a particular CSA practice, and subsequently determine adoption behaviors (Ali, 2021; Li, Yuan, Yue, Zhang, & Huang, 2021). Socioeconomic and demographic characteristics are assumed to vary across different socio-economic status groups and to influence both farmers’ perception of climate-induced risks to agricultural production, and their capacity to implement risk management strategies including the adoption of CSA practices. Accounting for farmers’ socioeconomic characteristics is therefore crucial to understand intergroup differences regarding decisions to adopt CSA practices. Most frequently, previous studies regarding farmers’ technology adoption accounted for the role of socioeconomic variables such as gender, age, education, farming experience, farm income, off-farm income, farm size, and tenure (Ashrit & Thakur, 2021; Zhang et al., 2020). In developing countries, home gardens are common and they have proven to enhance food security and malnutrition, provide livelihood opportunities for resource-poor families, and deliver ecosystem services (Galhena, Freed, & Maredia, 2013). Households with home gardens might be motivated to intercrop on their gardens to obtain a range of food for family consumption. As such, there might be a link between home garden and intercropping adoption.

While a rich literature has previously investigated farmers' uptake of CSA and how adoption is determined, several gaps remain. Previous studies have not integrated factors reflecting adoption of the intercropping such as social support, perception of climate change severity, and the usefulness of intercropping. Other factors that might affect the adoption of intercropping are smallholders' characteristics (age, education, farming experience) and households' social and economic conditions (poverty status, land area, the presence of off-farm jobs, home gardens). In addition, there are few studies that have taken into account the potential issues of selection bias and omitted variable bias in estimating the impact on household food security. Therefore, in this study, we examines the abovementioned issues, improving estimation through exploring the identification strategies and estimate the impact of intercropping adoption on household food security.

3. Method and data

This section detail selected areas of the study, household survey and its instrument, a description of data and measurement, household food security index, and empirical strategies used in the study.

3.1 Study area

Our study area covers four provinces in Cambodia including Prey Veng, Kampong Speu, Siem Reap, and Kampot. In these provinces, droughts and floods have occurred frequently and caused drastic impacts on agricultural production.

Prey Veng's economy is dominated by agriculture, with 141,052 hectares under cultivation. The rice crop was a significant proportion of agricultural products in this province (NIS, 2019). Prey Veng generates over 10% of Cambodia's rice production yearly, with much of it exported to neighboring provinces. Prey Veng produced around 250,000 tons of rice during the 2007 wet season. Mung bean, sugarcane, and sesame agriculture are all significant in the region (USAID, 2008). This province was highly vulnerable to climate hazards and floods, and drought significantly impacted agricultural production (Monin, 2021; NCSD, 2016; Zhang, 2021).

Kampong Speu represents one of the highest number of households holding land less than 1 hectare among other provinces in Plateau and Mountainous zone (Agriculture Census, 2013). This province is one of Cambodia's most disaster-prone provinces. It is especially vulnerable to flash floods during the rainy season and drought during the dry season. The province's tragedies have contributed to it becoming one of the poorest in the country (MOE & UNDP, 2011). An EEPSEA vulnerability mapping identified Kampong Speu province as the third most susceptible province among Cambodia's 17 provinces (Yusuf & Francisco, 2009).

Siem Reap: Most people are employed in the agricultural section, with about 67% engaged in agriculture(MIS, 2011; WFP, 2022). Drought and Flood have affected Siem Reap Province for several years, mainly damaging agriculture production. UNDP (2022) reported 322 flood events and 114 drought events from 2000 to 2019. Rain and drought variations were the main shocks to households that threat to their income and food consumption (WFP, 2022).

Kampot has the most agricultural households among the coastal provinces, with over 100,000 agricultural families (NIS, 2019). Drought and flooding have caused crop devastation in this province during the previous two decades (UNDP, 2022). The biggest shock to agricultural families in the coastal zone from weather events is more likely in livestock production than crop output (NIS, 2019).

3.2 Household survey

We used random sampling method to select participants but have taken into account the proportion of gender among households and the presence of varying economic status of the surveyed households. In total, 391 household representatives (141 from Prey Veng, Kampong Spue 88 households, Siem Reap 86 households, and Kampot 76 households) including both men and women headed household participated in the survey.

Table 1: Sample distribution

Province	Mono-cropping	Intercropping	Total
Kampong Speu	80	8	88
Kampot	63	13	76
Prey Veng	73	68	141
Siem Reap	66	20	86
Total	282	109	391

Source: Author's fieldwork, data collection was implemented from 15 to 30 August 2023

The survey executes about 20 minutes on average. Kobo Toolbox (https://www.kobotoolbox.org/) is used to collect and monitor the data. It is a free and open digital data collection platform was used to gather and manage the data. This tool is time- and cost-efficient while assuring quality control (Lakshminarasimhappa, 2022). Using Kobo Toolbox, the survey questionnaire was scripted into a digital form, then deployed on mobile devices for data collection. The interviewers were provided full training to ensure they understood the survey question and how to administer a digital questionnaire form for the survey.

3.2. Data analysis

We first performed the Polychoric Principle Component Analysis (PPCA) then a control function approach with logistic model. PPCA is used for survey items on CSA perception (perceived social support, perceived climate severity, perceived climate impact, and information). The factor scores obtained from PPCA, perceived ease and perceived usefulness of intercropping, socio-economic, and demographic variables were further regressed to identify the determinants of adoption tendency toward intercropping.

It is imperative to note that the nature of our household data involves both binary and categorical variables. The polychoric PCA appears to be a more effective method as it can efficiently account for both discrete choice and continuous types of data (Kolenikov & Angeles, 2004). Kolenikov and Angeles (2004) posit that polychoric PCA is an alternative version of PCA designed to address issues that PCA cannot handle, particularly when dealing with collected household asset data expressed in discrete values ranging from 1 to 5, as exemplified by Tong (2012). Consequently, the polychoric PCA approach will be employed in constructing a household wealth index for this study.

3.3.1. Polychoric Principle component analysis (PPCA)

PPCA is one of the data reduction approaches that transforms a large and correlated dataset into a smaller number of uncorrelated principle components with minimum loss of original information (Hair et al., 2019). The original 18 items/ questions that were included in the survey to capture various perceptions held by the surveyed farmers' towards CSA practices were subjected to PCA to identify different dimensions of CSA perception (Table 2). The Kaiser-Meyer-Olkin (KMO) value of 0.78, and the scale of reliability coefficient is at 0.67 which is an acceptable level. Also, the significant result of Bartlett's Test of Sphericity indicate that the data are suitable for Polychoric PCA which is statistically significance at 1 percent level. Four components that had Eigenvalues greater than 1.0 were retained and they were denoted Social Support, Perceived Climate Severity, Perceived Climate Impact, and Inform.

Table 2: Polychoric Principle Component Analysis Result

Variable	Factor1	Factor2	Factor3	Factor4	Uniqueness
Perceive climate change					
Hotter	0.717				0.419
Drought	0.527				0.642
Raining	-0.658				0.446
Cold	-0.522				0.720
Flood	-0.732				0.402
Strom					0.977
Perceive Support					
Friend				0.668	0.470
Individual				0.7596	0.413
Government					0.677
Other				0.524	0.634
Perceive climate severity					
Impact on crop			0.512		0.615
Impact on livestock					0.818
Impact on food			0.7420		0.401
Impact on income			0.723		0.421
Inform					
Receive training information		0.765			0.408
Knowledge of climate change		0.827			0.281
Share with household		0.820			0.291
HH member received training		0.708			0.436

Source: Author's calculation

3.3.2. Constructing household food security index

We construct household food security index using in the indicator developed by Coates et al. (2007) on household food insecurity access scale (HFIAS) for measurement of food access. The indicators have been employed by Food and Agriculture Organisation of the United Nation (FAO), and USAID.

An index accounted for HFIAS consist of nine questions with other nine sub questions, equivalent a total of 18 questions (See Coastes et al., 2007). A set of question was developed to access the experience of food insecurity and examine the response that lead to the understanding of the anxiety over food, perception on insufficient food, whether or not if there is any reduction of food intake, consequences of reduced food intake, and whether or not household would feel shame for resorting to have food resources (Coates et al., 2007). In this study, we assess two main components of the HFIAS such as household food insecurity access scale score and the average HFIAS score, and household food insecurity access prevalence which categorises household into four level of food security: 1) Household with food secured, 2) food insecure, 3) moderately food insecure, 4) severely food insecure.

Figure 1: Household food security category by province

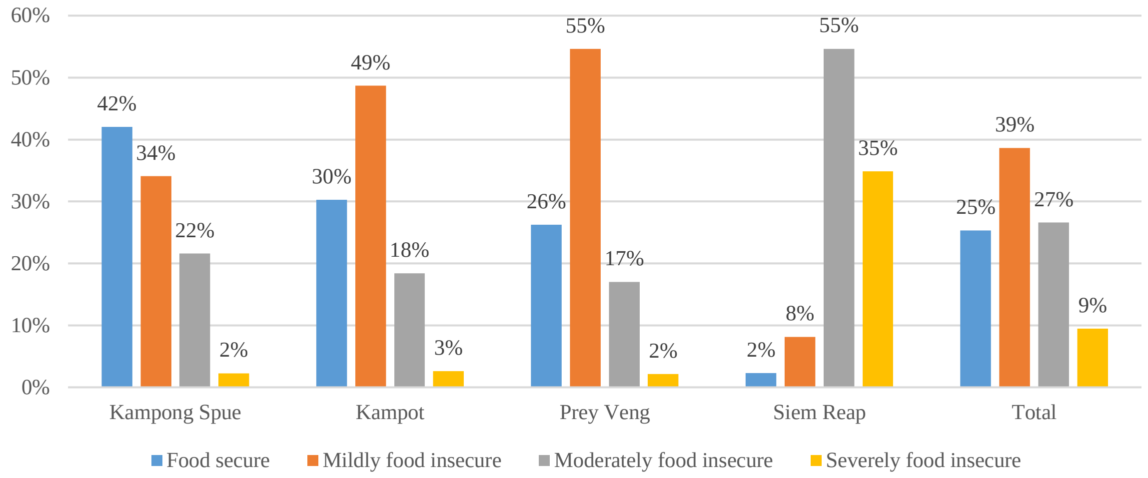

Figure 1 depicts degrees of food insecurity across the surveyed regions, emphasizing the disparities in the prevalence of food security challenges among households. In Kampong Spue, 42% of households fall under the food-secure category, 34% are mildly food insecure, 22% are moderately food insecure, and only 2% are severely food insecure. Moving to Kampot, 30% of households are food secure, 49% are mildly food insecure, 18% are moderately food insecure, and 3% are severely food insecure. In Prey Veng, 26% of households are food secure, 55% are mildly food insecure, 17% are moderately food insecure, and 2% are severely food insecure. Siem Reap has the lowest percentage of food-secure households at 2%, with 8% mildly food insecure, 55% moderately food insecure, and a significant 35% severely food insecure. The cumulative percentages for all regions indicate that 25% of households are food secure, 39% are mildly food insecure, 27% are moderately food insecure, and 9% are severely food insecure.

3.3.3. Descriptive statistics

Table 1 shows a simple statistical test by comparing household characteristic to the intercropping and mono-cropping adoption. The results show that Firstly, the mean Household Food Insecurity Access (HFIA) score is slightly higher for intercropping adopting households. This suggests that, on average, these households may face slightly greater challenges in accessing food security. Conversely, mono-cropping adopting households exhibit a marginal advantage in terms of food security. The data indicates a slightly higher incidence of food security within this group, implying a more stable food situation compared to their intercropping counterparts. However, the advantage in food security for mono-cropping households is counterbalanced by a higher incidence of food insecurity, particularly severe food insecurity, among intercropping adopting households. This sheds light on a potential trade-off between the two agricultural practices and their implications for household food security.

Table 3: Household characteristic by intercropping adoption

Variables of interest	Intercropping adopting household		Mono-cropping adopting household		Diff. Mean
	Observation	Mean	Observation	Mean	
HFIA score	282	4.780	109	4.7615	0.0187
HH food secure	282	0.248	109	0.2661	-0.0178
HH food insecure	282	0.394	109	0.3670	0.0266
HH moderate food insecure	282	0.259	109	0.2844	-0.0255
HH severely food insecure	282	0.099	109	0.0826	0.0167
HH head gender	282	0.823	109	0.7431	0.0796*
HH head age	282	48.571	109	51.724	-3.1538**
HH marital status	282	0.918	109	0.8991	0.0194
HH head no schooling	282	0.152	109	0.1284	0.0240
HH head primary education	282	0.507	109	0.4954	0.0117
HH head secondary education	282	0.230	109	0.2294	0.0011
Number of plots of land	282	3.170	109	3.8349	-0.664***
Land per capita	282	0.216	109	0.2750	-0.0593*
HH working members	282	3.369	109	3.3028	0.0660
HH elder with no income	282	0.230	109	0.1651	0.0654
HH number of children	282	1.599	109	1.4954	0.1039
HH access to pipe water	282	0.330	109	0.2110	0.1188**
Member of association	282	0.096	109	0.1376	-0.0419
Using mobile for payments	282	0.011	109	0.0550	-0.044***
Perceive climate severity	282	2.312	109	2.5800	-0.268***
Perceive inform	282	0.905	109	0.9558	-0.0505
Perceive climate impact	282	2.864	109	2.8013	0.0626
Perceive support	282	2.599	109	2.7602	-0.1608*
Irrigation system	282	0.507	109	0.1927	0.314***
HH distance to market	282	6.803	109	6.2247	0.5779

*Source: Author's calculation, The Wald test is performed to test the null hypothesis of equal means. * p<0.1, ** p<0.05, ***p<0.01*

A significant sociodemographic difference emerges between the two groups. Intercropping households have a noteworthy higher proportion of female heads, highlighting gender disparities in agricultural practices and decision-making within these households. Intercropping strategy is more likely to be adopted by female headed household. Furthermore, intercropping households, on average, have a younger demographic profile. This age difference may have implications for household dynamics, resource management, and decision-making processes.

In terms of land use, intercropping households tend to have fewer plots of land, but the land per capita is higher. This suggests a more intensive land-use pattern among intercropping households, potentially influencing agricultural productivity and efficiency. Access to resources also varies, with intercropping households having more access to pipe water. Additionally, these households are more likely to utilize irrigation, indicating a potentially greater investment in modern agricultural practices and technology. A pronounced difference in the perception of climate change and its impacts is evident, with intercropping households expressing a higher level of awareness. This finding suggests that the choice of agricultural practices may be influenced by the perceived impacts of climate change.

Lastly, geographical proximity to the market differs between the two groups, with intercropping households being closer. This proximity can have implications for market access, transportation costs, and overall economic dynamics within these agricultural/household communities.

3.3. Empirical models

3.3.1. The determinants of intercropping adoption

To begin our exercise, we estimate the determinant of intercropping adoption using the logistic regression model then using a control function approach (Cameron & Trivedi, 2005; Woodridge, 2015) to estimate the impact of inter-cropping on household food security using the index constructed. We first estimate the decision to adopt intercropping in the reduce form in equation 1 and 2 by using the logistic regression model; then estimate the predicted residual and substitute into the structural equation gauging the effect on different level of household food security in equation 4. Following Greence (2018) the estimated equations can be expressed as following:

Considering the probability of P_i that a household *i* chose to adopt intercropping:

$$P_i = Prob\ (Z_i = 1) = \frac{e^{X_i \beta_i}}{1 + e^{X_i \beta_i}} \tag{1}$$

Considering the probability of a household *i* chose to adopt Mono-cropping can be expressed 1- P_i :

$$1 - P_i = Prob\ (Z_i = 0) = 1 - \frac{e^{X_i \beta_i}}{1 + e^{X_i \beta_i}} \tag{2}$$

Where β_i is the parameter to be estimated. Z_i is the dependent variable taking the value of 1 for every *i* household that had adopted the intercropping; otherwise 0 for those adoption of mono-cropping practices. X_i is the vector of the determinants of intercropping adoption including household head characteristics (gender, age, level of education, and marital status), household characteristics (household working member, number of elder with no income, number of children, number of plots of land, farmland per capita, household access to pipe water system, whether or not household member is a member of any association in the community, and whether or not household use mobile or other digital platform to make a payment on agriculture inputs), perception on climate change, village characteristic, and our instrumental variable, measuring the distance from household to the nearest market.

3.3.2. The effect of intercropping on household food security

3.3.2.1. Identification strategies

The potential issue of endogeneity in self-selection threat our estimation and could yield inconsistent result. This derives from the fact that in the context of farmers select themselves into adaptation strategies positing a significant challenge associated with selection bias. This occurs when farmers make choices based on their individual unobservable characteristics that cannot capture from the survey such as those who prior received extension services, training, or other forms of training related to climate change adaptation and awareness. These unobservable factors play a crucial role in shaping the decisions of farmers regarding the adoption of specific agricultural strategies.

Moreover, aspects like farming skills, motivation, and the availability of resources to implement intercropping practices further contribute to the complexity of self-selection. Farmers with greater skills, motivation, or resources may be more inclined to choose intercropping, potentially introducing bias into any estimated effects of intercropping adoption. This self-selection bias, if unaddressed, can lead to inconsistent and unreliable estimations of the true impact of intercropping on agricultural practices and outcomes.

To navigate these challenges and obtain more accurate and unbiased estimates, it becomes imperative to implement strategies that address and control for self-selection bias. We employ the control function method, with careful consideration given to their relevance and exogeneity. In this context, the distance from the household to the nearest market can serve as a suitable instrumental variable. This variable is likely to influence the decision to adopt intercropping due to factors such as improved access to information and resources, without directly affecting the outcomes under investigation.

To validate the admissibility of the instrument, we used a simple falsification test to verify and provide evidence to ensure that distance to market do not affect household food security directly but only through household intercropping practices (Di Falco et., 2011; Seng, 2018).

Therefore, based on Woodridge (2015) and Cameron and Trivedi (2005) for control function method, the estimation equations start from the reduce form equation derived from equation (1) and (2) and structural equation which can be expressed as follow:

Structural equation

$$HFS_i = \beta_0 + \beta_1 Z_i + \beta_2 X_i + \mu_i + u_1 \tag{3}$$

Where HFS_idenotes level of food security for household i. Z_i is the intercropping adoption which is an endogenous variable. X_i is a vector of exogenous explanatory variables including household head characteristics, household characteristics, perception on climate severity, impact, inform, and support. μ_i denotes village characteristic whether or not household located in the village having irrigation system. $\beta_0, \beta_1, and\ \beta_2$ are the parameters to be estimated. Since Z_i is an endogenous variable, we introduce our instrumental variable Z'_i measures as the distance between household to the nearest market.

To account for the endogeneity in self-selection bias, we estimate the determinants of intercropping practice with the instrumental variable (IV) in the reduce form:

$$Z_i = \gamma_0 + \gamma_1 Z'_i + \gamma_2 X_i + \mu_i + v_1 \qquad (4)$$

Where γ_0, γ_1, and $\gamma_2$are the parameters in the reduce form and $v_1$denote the error component. However, it is important to note that our instrumental variable Z'_i and intercropping the error term v_1 are not correlated where $E(\widehat{Z'_\iota}v_1)$=0. However, while v_1 and u_1 are correlated for equation (3) and (4) $Cov(v_1 u_1) \neq 0$, it can be written as:

$$u_1 = \rho_1 v_1 + e_1 \qquad (4.1)$$

Where $\rho_1 = E(v_1 u_1)/E(v_1^2)$ and v_1 and Z'_i and other household head, household, and village characteristics are not correlated with the error term e_1 in equation (4.1). In addition, error term e_1 is uncorrelated withHFS_i Therefore, substitute equation (4.1) into (3):

$$HFS_i = \beta_0 + \beta_1 Z_i + \beta_2 X_i + \mu_i + \rho_1 \hat{v}_1 + e_1 \qquad (5)$$

Therefore, to gauge the impact of intercropping adoption on household food security can be estimated through equation (5).

4. Results and discussion

This section demonstrates findings and discussions on the determinants of intercropping practices and its effects on household food security.

4.1. The determinants of intercropping adoption

Table 4 illustrates the determinants influencing the adoption of intercropping among smallholder farmer households, utilizing a logistic regression model across five distinct sets of models. These models incorporate varying combinations of household head and household characteristics. The findings reveal that household head age, no schooling and primary education among household heads, the number of household plots of land, household access to piped water, and the presence of an irrigation system in the village are significant determinants of intercropping adoption.

Notably, in Model 3 when estimating the impact of key variable on perceive climate change, the perception of climate severity by the household emerges as a crucial determinant of intercropping adoption. This suggests that households perceiving the severity of climate impacts may be inclined to adopt intercropping as a strategic response to mitigate climate risks and diversify farming options. Such findings underscore the importance of considering not only demographic and resource-related factors but also the perceptual dimensions of climate impacts in understanding the drivers behind intercropping practices among smallholder farmer households. In addition, it is discovered that intercropping is positively and statistically significantly correlated with the perception of support. This finding highlights the criticality of establishing a comprehensive support system to assist households that are inclined to implement intercropping techniques. To aid and encourage the successful integration of intercropping into agricultural practices, endeavors should be focused on establishing networks of support that include family, friends, local communities, governmental bodies, and non-governmental organizations (NGOs).

Table 4: Determinants of Adoption of Inter-Cropping

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model Full
Household head characteristics					
HH head gender (1=Male)	-0.563*			-0.711**	-0.527
	(0.316)			(0.326)	(0.343)
HH head age	0.0320***			0.0396***	0.0346***
	(0.0109)			(0.0124)	(0.0131)
HH marital status	0.162			0.309	0.235
	(0.468)			(0.474)	(0.529)
HH head no schooling	-0.986**			-0.994**	-1.393***
	(0.467)			(0.484)	(0.525)
HH head primary education	-0.572			-0.625*	-1.107***
	(0.362)			(0.379)	(0.404)
HH head secondary education	-0.359			-0.224	-0.445
	(0.398)			(0.414)	(0.451)
Household characteristics					
Number of plots of land		0.173***		0.133**	0.166**
		(0.0653)		(0.0657)	(0.0775)
Land per capita		-0.227		-0.223	-1.225**
		(0.567)		(0.531)	(0.590)
HH working members		-0.0432		-0.131	-0.0723
		(0.0855)		(0.0947)	(0.111)

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model Full
HH elder with no income		-0.338		-0.339	-0.473
		(0.266)		(0.278)	(0.307)
Number of children		-0.0678		-0.0822	-0.0991
		(0.100)		(0.102)	(0.113)
HH access to pipe water		-0.708**		-0.908***	-0.0824
		(0.314)		(0.323)	(0.384)
Member of association				0.327	-0.0577
				(0.395)	(0.410)
Using mobile for payment				2.091***	2.133**
				(0.726)	(0.921)
Perception on climate change					
Perceive climate severity			0.447***		0.221
			(0.151)		(0.175)
Perceive inform			0.432*		0.287
			(0.242)		(0.256)
Perceive climate change impact			-0.157		-0.137
			(0.125)		(0.129)
Perceive support			0.330*		0.523***
			(0.174)		(0.196)
Irrigation system			-2.095***		-2.474***
			(0.404)		(0.450)
HH distance to market (instrumental variable)		-0.0657	-0.509***	-0.0716	-0.560***
		(0.0993)	(0.147)	(0.113)	(0.161)
Constant	-1.752**	-0.577	0.971	-1.332	1.026
	(0.767)	(0.725)	(1.026)	(1.088)	(1.397)
Observations	391	391	391	391	391

*Note: Robust standard errors in parentheses; * p<0.1, ** p<0.05, ***p<0.01*

Source: Author's calculation

Importantly, our instrumental variable, the distance to the market, exhibits statistical significance in models 3 and 5. This implies that as the distance between households and the market increases, the likelihood of households adopting intercropping practices decreases. The reasoning behind this trend lies in the reduced accessibility of agricultural inputs, such as seeds, fertilizers, and other essential materials necessary for intercropping adoption when household located further away from the market.

In line with this finding, the results also indicate that households with access to mobile payment services and engagement with financial services are statistically significant at 5 percent level. This suggests that household are more inclined to adopt intercropping when they can use mobile payment service. This noteworthy observation implies that stakeholders involved in intercropping adoption programs should explore the integration of a mobile phone platform. Such a platform could facilitate farmers in learning, practicing intercropping techniques, and gaining insights into the implications of climate change on intercropping and its effects on their livelihoods. In addition, the underlying concept in these findings suggests that households with access to mobile payment services are also likely to have access to credit. This aligns with previous studies, particularly in the context of credit's role in climate change adaptation in Pakistan (Di Falco et al., 2011). These studies emphasize that the importance of credit for farming communities in Pakistan is underscored by the fact that the lack of access to finances poses a significant constraint for farmers seeking to adapt to climate change. Therefore, our findings implies that credit plays a crucial role as a prominent resource for adopting strategies related to input intensification and incorporating new crop varieties.

4.1. Impacts of intercropping on household food security

As mentioned earlier, to assess the impacts of intercropping on household food security, we utilise the control function method to account for household self-selection bias in inter-cropping adoption. This therefore allows us to isolate the inter-cropping adoption impact of household food security from the observables which potentially deter our estimation. The predicted residual derived from equation (4) is substituted into equation (3) which is shown all models (1-4) in Table 5, particularly for household levels of food security.

The results depicted in Table 5 show that the statistically significant influence of inter-cropping adoptions on maintaining food security and reducing the incidence of food insecurity at 10 and 5 percent significance levels in Model (1) and (2). However, our findings indicate a lack of substantial positive effects on households facing high levels of food insecurity for Model (3) and (4). This suggests that inter-cropping practices may serve as a complementary livelihood strategy for smallholder farmers and household with food insecure seem to have already adopted inter-cropping practices.

This emphasises the nuanced nature of inter-cropping practices at the smallholder farmer level, where it appears to provide a significant livelihood strategy but may not fully address the challenges faced by those in severe food insecurity. This reflects that inter-cropping practices benefits are not uniformly distributed across all levels of food insecurity. Additionally, our findings suggest that inter-cropping practices yield positive outcomes by helping prevent households from falling into moderate and severe food insecurity. This understanding is critical for policymakers and practitioners seeking to design targeted interventions that consider the specific needs and challenges faced by different segments of the population.

Assessing the impact of climate perception on household food security, the findings suggest that perceptions of support, climate impacts, climate severity, and information are statistically significantly associated with the level of household food security across various estimated models at 1 percent, 5 percent, 10 percent level. Firstly, the perception of support are less likely association with both food-secure and food-insecure households. This implies that within these household categories, there may not be a substantial demand for support in the context of climate change. However, perceptions of support are more likely to be positively and statistically significantly associated with households experiencing moderate and severe food insecurity. This indicates that, while intercropping practices may not have any effect on reducing such level of food insecurity, smallholder households are in need of support to enhance their consumption. Secondly, it is found that perceive climate impact is negatively associated with household experience severely food insecurity. This suggest that such households do not realized the impact of climate change due to limited knowledge and understand about climate change. In addition, they are commonly from poor households having little or no household assets and agricultural outputs, therefore, the realisation of climate impact is too minimal. Third, perceive inform is found to be positive and statistically significant associated with severely food insecure household at 10 percent level suggesting the demand to keep such household informed. Forth, findings highlight the interconnectedness of climate severity perception and food security. Perception on climate severity is found to be statistically associated with household with food secure, insecure and moderately food insecure at 1 and 10 percent level. For example, food secure household may perceive less climate severity compared to a strong and positive tendency of climate severity among household with food insecure suggesting that such households may experience climate change, and are more vulnerable to climate change than their counterparts.

Table 5: Impacts of intercropping on household food security

VARIABLES	(1) Food Secure	(2) Food insecure	(3) Moderately food insecure	(4) Severely food insecure
Inter-cropping	0.569*	-0.660**	0.314	-0.332
	(0.319)	(0.295)	(0.298)	(0.475)
Predicted Residual	-1.213	2.780*	-1.395	-6.815
	(1.533)	(1.458)	(1.580)	(5.519)
HH head gender (1=male)	-0.934**	1.386***	-0.673*	-0.998
	(0.421)	(0.429)	(0.379)	(0.813)
HH head age	0.0106	-0.000696	0.00411	0.0125
	(0.0163)	(0.0146)	(0.0157)	(0.0431)
HH marital status	0.851	0.341	-0.123	0.221
	(0.673)	(0.684)	(0.524)	(0.640)
HH head no schooling	-1.148	0.474	-0.0953	-0.862
	(0.716)	(0.644)	(0.670)	(1.651)
HH head primary education	-0.355	-0.000745	0.495	-1.502
	(0.456)	(0.438)	(0.523)	(1.419)
HH head secondary education	0.365	-0.330	0.448	-1.439
	(0.430)	(0.437)	(0.512)	(1.060)
Number of plots of land	0.133	-0.0490	-0.178*	0.281
	(0.0915)	(0.0906)	(0.0991)	(0.349)
Land per capita	0.186	0.113	0.123	-2.088
	(0.628)	(0.612)	(0.639)	(1.856)
HH working members	0.299	0.0516	-0.535	-0.400
	(0.324)	(0.307)	(0.369)	(0.815)
HH elder with no income	-0.168	0.137	-0.0202	-0.102
	(0.108)	(0.101)	(0.107)	(0.185)
Number of children	-0.118	0.536*	-0.0277	-1.363**
	(0.293)	(0.293)	(0.277)	(0.609)
HH access to pipe water	-0.198	0.122	0.0231	-0.0868
	(0.126)	(0.105)	(0.118)	(0.233)
Member of association	1.170***	-0.793*	-0.187	-1.052
	(0.405)	(0.451)	(0.406)	(1.018)
Using mobile for payment	0.723	-1.000	0.773	
	(1.022)	(0.876)	(0.962)	
Perceive climate severity	-0.343*	1.323***	-0.596***	-0.275
	(0.207)	(0.209)	(0.195)	(0.454)
Perceive inform	0.172	-0.421	0.167	0.881*
	(0.256)	(0.263)	(0.291)	(0.469)
Perceive climate impact	0.0954	-0.135	0.197	-0.548**
	(0.130)	(0.124)	(0.150)	(0.279)
Perceive support	-0.432**	-0.524***	0.486**	1.991***
	(0.172)	(0.166)	(0.197)	(0.744)
Irrigation system	0.939*	0.402	-0.488	-4.024*

VARIABLES	(1) Food Secure	(2) Food insecure	(3) Moderately food insecure	(4) Severely food insecure
	(0.559)	(0.512)	(0.552)	(2.428)
Constant	-0.162	-4.345***	-0.406	-2.265
	(1.194)	(1.206)	(1.269)	(2.331)
Observations	391	391	391	382

*Note: Robust standard errors in parentheses; * p<0.1, ** p<0.05, ***p<0.01*
Source: Author's calculation

Interestingly, the study found that households that are food secure tend to be a member of association while household with food insecure are less likely to be in any member. This reflects that membership in the community such as agricultural cooperative or farmer association would leverage the livelihood of the smallholder farmer and keep informed about livelihood strategies that could coup with the climate change. In addition, we found that irrigation system available in the village plays an important role in addressing food insecurity as it contributes to agricultural activities and outputs. Its availability is strongly associated with level of severity food insecurity at 1 percent level and increase food security at 10 percent level. The study also posit a significant result concerning gender aspects in the estimation. The estimation results suggest that female headed households are more susceptible to food insecurity, as their status is associated with being moderately food insecure and less likely to fall into the category of food-secure households. This indicates that female headed households are not only vulnerable to the adverse impacts of climate change but are also more predisposed to encountering levels of moderate to severe food insecurity.

4.1.1. Average Marginal Effects

Table 6 presents the marginal effects of intercropping adoption on household food security, offering a nuanced understanding of its impact across different categories. The findings reveal noteworthy insights into the relationship between intercropping practices and food security. The results demonstrate that households engaging in intercropping experience a notable increase in food security, with a substantial 9.8 percentage points maintaining in the food secure category. This significant finding unravels the positive contribution of intercropping practices to the maintenance of food security. Equally intriguing is the observed decrease of 13.9 percentage points in the food insecure category, indicating a potential role of intercropping in alleviating food insecurity among households.

However, while there is a tangible positive effect on the food secure and insecure categories intercropping adoption do not have any impact or reduce food insecure among household with moderately and severely food insecure, suggesting a limited impact of intercropping practices. This implies that intercropping practices may not be as effective in reducing food insecurity among households facing more severe challenges in this regard. There is a need for enhancement of current approach of intercropping enhancing productivity and yields that can positively and potentially reduce the household with moderately and severely food insecure.

Table 6: Average marginal effect of logit model of intercropping on household food security

Variable	Marginal Effects
Food secure	0.098*
	(0.058)
Food insecure	-0.139**
	(0.058)
Moderately food insecure	0.057
	(0.0564)
Severely food insecure	-0.007
	(0.01007)

Note: Robust standard errors in parentheses; * $p<0.1$, ** $p<0.05$, *** $p<0.01$
Source: Author's calculation, (See appendix for all variables estimated)

An alternative interpretation of these findings suggests that moderately and severely vulnerable households may encounter with challenges such as limited access to resources and information, credit constraints, and susceptibility to the effects of climate change. Consequently, these factors place them in a precarious position of vulnerability, and even when they adopt intercropping practices, the impact on improving household food security appears to be minimal or non-existent. This underscores the critical need for targeted interventions addressing not only agricultural practices but also broader issues like access to resources, information dissemination, and resilience-building measures to enhance overall household well-being.

5. Conclusions

This study examines the determinants of intercropping practices through the lens of climate smart agricultures and estimates its effects on smallholder farmer food security. The rational of this study built upon the conventional understanding of intensified and simplified cropping systems which have been shown to be highly vulnerable to pests and diseases. It has also worsened the climate vulnerability and food security especially among smallholder farmers in Cambodia. Such prolonged and intensive cropping systems have also led to the depletion of groundwater, erosion of biodiversity, and pollution of the environment. Farmers have limited use of soil and water conservation technologies, especially on sloping land where only one crop is grown, because of the expensive cost involved. This leads to the depletion of a significant quantity of fertile topsoil. This process undermines the future productivity of the land, resulting in decreased yields from farms and higher costs for inputs, contributing food insecurity among smallholder farmers.

Using primary data collection from 391 smallholder farmers located in four provinces, representing different geographical clusters in Cambodia, the study first used a logistic regression model to estimate the determinant of intercropping adoption among smallholder farmers. The empirical findings suggest that climate impact perceptions, such as perceptions of climate severity, inform, and support, are associated with intercropping adoption. Taking into account the self-selection bias in the adoption of intercropping, the study employed the control function method to correct the observable factor affecting such decisions. The results indicate that intercropping practices among smallholder farmers contribute to a 9.8 percentage point increase in food security and a 13.9 percentage point reduction in food insecurity. However, intercropping adoption has a limited impact on reducing food insecurity among moderately and severely food-insecure households.

This study sheds light on the determinants of intercropping adoption and provides valuable insights for policymakers and practitioners. These findings underscore the potential of intercropping as a climate-smart agricultural practice to enhance productivity and elevate food security levels in Cambodia. The nuanced understanding of the differential impact on food security across various levels of insecurity informs the design of targeted agricultural resilience practices and policies and the broader discourse on sustainable agriculture and resilient food systems, offering practical guidance for promoting climate-smart practices to benefit smallholder farmers and enhance food security in Cambodia.

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Appendix

System	***Definition***	***Remarks***
Monocropping	The continuous growing of the same species on a piece of land over a sequence of growing seasons	Risk of residual transfer of pests, diseases, and weeds from one season to the next
Ratooning	The residual stumps of a crop are allowed to regrow to produce a second crop	Cheap, low-input second crop with shorter growing period than sequential cropping. Yields of second crop are often poor and unreliable, often because of pest and disease transfer. Restricted to crops such as sorghum, millet, rice, and pigeonpea
Sole crop	Crop composed of individual plants of the same variety of one species	Interactions occur between plants that are all at the same stage of growth. Management of inputs, control measures, and irrigation can be synchronized to meet the temporal and spatial demands of the crop. Mechanization is possible

System	***Definition***	***Remarks***
Sequential cropping	Crops are grown one after the other with no overlapping phase	Usually involves an additional crop after the harvest of the main single rainy season crop. Potential residual effects in the reservoir of nutrients, weeds, or pests and diseases with implications for the succeeding crop or crops. Requires a relatively long potential growing period (over 180–200 days). The growth of the second crop is often risky because of the limited amount of residual moisture. Typically includes legumes or oilseeds after paddy rice or rainfed cereals
Multicropping	Two or more species growing on the same piece of land, where at least part of the growth cycles of different species overlap	Plants of different species are close enough to allow interactions between them, usually at different stages of their growth
Intercropping	A multicrop composed of two or more annual crops grown simultaneously on a piece of land within a single growing season	Intercrops may retain the same population as the sole crops that they are composed of in which each plant of one species is replaced by a single plant of one or more other species (“replacement intercrop”) or additional plants of one or more species may be fitted into an existing population of sole crops (“additive intercrop”)
Mixed intercrop	Multicrops of randomly arranged plants of different species	Such crops may be planted as replacement or additive intercrops where the grower requires an additional output from a second species without affecting the yield of the main crop
Row intercrop	Intercrops grown in structured arrangements of different species arranged in alternating blocks of narrow rows	Interspecies interactions occur between rows and intrarow competition occurs within rows. Individual species may be sown, fertilized, and harvested separately

System	***Definition***	***Remarks***
Strip intercrop	Intercrops where blocked rows of each species are grown separately	Strips are wide enough for some plants within each block to behave as if in a sole crop
Relay cropping	The interplanting of one species with a second species before the first crop reaches maturity	The very short overlap means competition between species is minimal. The second crop may have better soil moisture conditions because of earlier sowing and protection from the first crop. Sowing of second crop before harvest of first crop reduces labor peaks at harvest. There may be damage to seedlings of second crop at harvest of first. Examples include paddy rice and legumes, cereals and legumes, cereals and other cereals
Agroforestry	Land use systems in which woody perennials (trees, shrubs) are grown in association with herbaceous plants (annual or perennial crops, or pastures) and/or livestock	Capture and use of resources is distributed in space and time. Plants within the system make demands on resources at different times (“temporal complementarity”) or use resources more efficiently at any one time (“spatial complementarity”). In agroforestry systems the woody component/s may provide more than one product (e.g., timber, fuelwood, fodder, fruit) and/or “services” (shelter, shade, soil or water conservation)
Alley cropping	A specific form of agroforestry in which trees and shrubs are established in hedgerows within arable cropped land	The woody component is always planted in rows but the spacing between rows depends on the species mix and topography. Sometimes known as “hedgerow intercropping”

Source: *https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/multiple-cropping#:~:text=PRODUCTION%20SYSTEMS%20AND%20AGRONOMY%20%7C%20Multicropping&text=Such%20multicrops%20may%20take%20the,a%20series%20of%20growing%20seasons.*

Average Marginal Effect Estimation

1.Food secure

```
Marginal effects after logit
      y  = Pr(foodsecureHH) (predict)
         =  .20306004
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
cropping*|   .0988455      .05892    1.68   0.093  -.016628  .214319   .278772
      cr |  -.1962337      .24677   -0.80   0.426  -.679892  .287424   .278772
Q5_Gen~r*|  -.1752664      .08765   -2.00   0.046  -.347065 -.003467   .800512
  Q6_Age |   .0017113      .00261    0.65   0.513  -.003412  .006835   49.4501
HH_mai~e*|   .1104107      .06694    1.65   0.099  -.020788  .241609   .913043
no_Sch~g*|   -.144278      .06691   -2.16   0.031  -.275428 -.013128    .14578
HHprim~u*|  -.0574409       .0737   -0.78   0.436  -.201884  .087003   .503836
HHseco~u*|   .0624377      .07737    0.81   0.420  -.089206  .214081   .230179
 landppc |    .030138      .10149    0.30   0.766   -.16877  .229046   .232276
Q15_Does*|   .0500526      .05633    0.89   0.374   -.06035  .160455   .296675
workin~r |  -.0271391       .0174   -1.56   0.119   -.06124  .006962   3.35038
elder_~e |   -.019049      .04749   -0.40   0.688   -.11212  .074022   .212276
Q10_Ch~n |  -.0320967      .02051   -1.57   0.118  -.072287  .008093   1.57033
 Q43_Are*|   .2364728       .0927    2.55   0.011   .054792  .418154   .107417
  Q44_Do*|   .1400415      .22712    0.62   0.537  -.305102  .585185   .023018
 Q20_How |   .0215698      .01498    1.44   0.150  -.007793  .050932    3.3555
P_clim~y |  -.0555197      .03275   -1.70   0.090  -.119703  .008663    2.3867
P_inform |   .0278381      .04108    0.68   0.498  -.052686  .108363    .91932
P_clim~t |   .0154381      .02095    0.74   0.461  -.025624  .056501   2.84648
P_supp~t |  -.0699807      .02775   -2.52   0.012   -.12436 -.015601   2.64424
irriga~n*|   .1587488      .09794    1.62   0.105  -.033203  .350701   .419437
------------------------------------------------------------------------------
(*) dy/dx is for discrete change of dummy variable from 0 to 1
```

2. Food Insecure

```
.
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
cropping*|  -.1395853      .05832   -2.39   0.017  -.253899 -.025272   .278772
      cr |    .622159      .32507    1.91   0.056  -.014973  1.25929   .278772
Q5_Gen~r*|   .2583935      .06216    4.16   0.000   .136572  .380215   .800512
  Q6_Age |  -.0001558      .00328   -0.05   0.962  -.006582   .00627   49.4501
HH_mai~e*|    .072586      .13673    0.53   0.596   -.19541  .340582   .913043
no_Sch~g*|   .1107615      .15571    0.71   0.477  -.194421  .415944    .14578
HHprim~u*|  -.0001667        .098   -0.00   0.999  -.192247  .191913   .503836
HHseco~u*|  -.0715149      .09155   -0.78   0.435  -.250946  .107916   .230179
 landppc |    .025297      .13681    0.18   0.853   -.24285  .293444   .232276
Q15_Does*|   .0115951      .06916    0.17   0.867  -.123952  .147142   .296675
workin~r |   .0306398      .02269    1.35   0.177  -.013829  .075109   3.35038
elder_~e |   .1200265      .06528    1.84   0.066  -.007919  .247972   .212276
Q10_Ch~n |   .0273537      .02332    1.17   0.241  -.018353  .073061   1.57033
 Q43_Are*|  -.1563148      .07552   -2.07   0.038   -.30433   -.0083   .107417
  Q44_Do*|  -.1820666      .12057   -1.51   0.131  -.418385  .054252   .023018
 Q20_How |   -.010962      .02023   -0.54   0.588   -.05061  .028686    3.3555
P_clim~y |   .2960973      .04676    6.33   0.000   .204443  .387752    2.3867
P_inform |  -.0942852      .05906   -1.60   0.110  -.210033  .021463    .91932
P_clim~t |  -.0301545       .0276   -1.09   0.275  -.084244  .023935   2.84648
P_supp~t |  -.1172794      .03703   -3.17   0.002  -.189864 -.044694   2.64424
irriga~n*|   .0906247      .11602    0.78   0.435  -.136761   .31801   .419437
------------------------------------------------------------------------------
(*) dy/dx is for discrete change of dummy variable from 0 to 1
```

3. Moderately food insecure

```
Marginal effects after logit
      y  = Pr(moderatefoodins) (predict)
         =  .22972483
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
cropping*|    .057551      .05649    1.02   0.308  -.053168   .16827   .278772
      cr |  -.2467781      .28054   -0.88   0.379  -.796635  .303079   .278772
Q5_Gen~r*|  -.1314939      .08069   -1.63   0.103  -.289646  .026659   .800512
  Q6_Age |   .0007269      .00278    0.26   0.794  -.004727   .00618   49.4501
HH_mai~e*|  -.0224438      .09778   -0.23   0.818   -.21408  .169192   .913043
no_Sch~g*|  -.0165551      .11428   -0.14   0.885  -.240549  .207438    .14578
HHprim~u*|    .087489      .09197    0.95   0.341  -.092763  .267741   .503836
HHseco~u*|   .0844023      .10181    0.83   0.407   -.11514  .283945   .230179
 landppc |   .0216994      .11298    0.19   0.848  -.199744  .243143   .232276
Q15_Does*|  -.0890814      .05806   -1.53   0.125  -.202885  .024722   .296675
workin~r |  -.0035825      .01902   -0.19   0.851  -.040864  .033699   3.35038
elder_~e |  -.0049039      .04908   -0.10   0.920  -.101104  .091296   .212276
Q10_Ch~n |   .0040883      .02085    0.20   0.845   -.03678  .044957   1.57033
 Q43_Are*|  -.0318039      .06634   -0.48   0.632  -.161819  .098211   .107417
  Q44_Do*|   .1615805      .22669    0.71   0.476  -.282721  .605882   .023018
 Q20_How |  -.0314636      .01742   -1.81   0.071  -.065607  .002679    3.3555
P_clim~y |  -.1054371      .03396   -3.11   0.002  -.171991 -.038883    2.3867
P_inform |    .029577      .05168    0.57   0.567  -.071709  .130863    .91932
P_clim~t |   .0349101      .02629    1.33   0.184  -.016622  .086442   2.84648
P_supp~t |   .0860189      .03514    2.45   0.014   .017147  .154891   2.64424
irriga~n*|  -.0845414      .09357   -0.90   0.366  -.267932  .098849   .419437
------------------------------------------------------------------------------
(*) dy/dx is for discrete change of dummy variable from 0 to 1
```

4. Severely food insecure

```
Marginal effects after logit
      y  = Pr(foodsevereins) (predict)
         =  .02316497
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
cropping*|  -.0070086      .01007   -0.70   0.487  -.026749  .012731   .269634
      cr |  -.1542196      .09751   -1.58   0.114  -.345339    .0369   .269634
Q5_Gen~r*|  -.0309434      .02959   -1.05   0.296  -.088942  .027056   .798429
  Q6_Age |   .0002837      .00089    0.32   0.750  -.001458  .002026   49.6283
HH_mai~e*|   .0045963      .01176    0.39   0.696   -.01846  .027653   .910995
no_Sch~g*|  -.0149989      .01772   -0.85   0.397  -.049731  .019733   .149215
HHprim~u*|   -.036905      .03036   -1.22   0.224  -.096416  .022607   .502618
HHseco~u*|  -.0242899      .01244   -1.95   0.051  -.048667  .000087   .232984
 landppc |  -.0472534      .03674   -1.29   0.198  -.119257   .02475   .232207
Q15_Does*|   -.008412      .01613   -0.52   0.602  -.040034  .023211   .295812
workin~r |  -.0023102      .00396   -0.58   0.559  -.010067  .005446   3.34817
elder_~e |  -.0308316       .0146   -2.11   0.035  -.059443  -.00222   .209424
Q10_Ch~n |  -.0019647      .00513   -0.38   0.702  -.012027  .008097   1.55759
 Q43_Are*|  -.0167155      .01226   -1.36   0.173  -.040736  .007305   .109948
 Q20_How |    .006358      .00688    0.92   0.355  -.007124   .01984   3.32984
P_clim~y |  -.0062166      .01219   -0.51   0.610  -.030116  .017683   2.38719
P_inform |   .0199392      .01076    1.85   0.064  -.001153  .041032   .915097
P_clim~t |  -.0124003       .0064   -1.94   0.053  -.024947  .000147   2.85785
P_supp~t |   .0450478      .01594    2.83   0.005   .013797  .076299   2.65617
irriga~n*|   -.111142      .07522   -1.48   0.140   -.25858  .036296   .418848
------------------------------------------------------------------------------
(*) dy/dx is for discrete change of dummy variable from 0 to 1
```