The Effectiveness of Agricultural Commercialization in Improving Food Security of Rural Population in Development Countries

Qinye Jiang
Department of Agricultural Economics
Texas A&M University
qyjiang@tamu.edu

Ariun Ishdorj
Borlaug Institute for International Agriculture
Department of Agricultural Economics
Texas A&M University
aIshdorj@tamu.edu

Elizabeth Tabares
Borlaug Institute for International Agriculture
Texas A&M University
elizabeth.tabaresvil@ag.tamu.edu

Siwan Song
Department of Agricultural and Applied Economics
University of Wisconsin
siwan.song@wisc.edu

Roger Norton
Borlaug Institute for International Agriculture
Department of Agricultural Economics
Texas A&M University
roger.norton@ag.tamu.edu

Selected Paper prepared for presentation at the 2023 Agricultural & Applied Economics Association Annual Meeting, Washington DC; July 23-25, 2023

The Effectiveness of Agricultural Commercialization in Improving Food Security of Rural Population in Development Countries

Qinye Jiang, Ariun Ishdorj, Elizabeth Tabares, Siwan Song, and Roger Norton

ABSTRACT

Food insecurity continues to be a significant challenge for rural populations in low- and middle-income countries. Cash crop commercialization can play an important role in improving the food security status of these populations. This paper employs systematic review and meta-analysis techniques to investigate the impact of cash crop commercialization on food security and nutrition outcomes. A total of 46 studies were identified from two evidence gap maps, out of which 29 studies were included in the meta-analysis. These studies were categorized into four main groups: production, market, risk, and rural development and governance. The majority of the included studies focused on interventions related to the production stage, while only a few explored the effects of interventions targeting risk management. To assess the quality of each study, a risk of bias domains approach was used. Standard Mean Difference (SMD), also known as Cohen's d, was used as the effect size measurement in the univariate random effects meta-analysis. The selected outcomes for the meta-analysis included household dietary diversity score, food insecurity access scale, food consumption score and food expenditure. Preliminary meta-analysis results, where interventions are not separated, indicated that the estimated effects were not significant for household dietary diversity score and household food insecurity access scale, however while significant effects were observed for food expenditure and food consumption score.

Keywords: Food security; nutrition; cash crop; commercialization; Systematic review; Meta-analysis.

The Effectiveness of Agricultural Commercialization in Improving Food Security of Rural Populations in Development Countries

Low food security and inadequate nutrition status persist as substantial challenges for rural populations in low- and middle-income countries. The 1996 World Food Summit (WFS) defined food security as "Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (Capone et al. 2014). Agricultural interventions are pivotal in ensuring food security for rural populations in developing countries (Sasson 2012; Salazar et al. 2016). Households acquire food for both self-consumption and income generation by engaging in agricultural production and selling their products in the markets. Commercialization is the process moving from subsistence-oriented pattern to market-oriented pattern (Babu, Gajanan, and Sanyal 2014). The crops grown for sale can be defined as cash crops (Von Braun and Kennedy 1994). Commercialization of cash crops, such as cotton, coffee, and soybeans, can bring economic benefits to farmers and rural communities and has been regarded as one of the effective ways in improving food and nutrition security for smallholder farmers. Previous studies examined the effect of agricultural commercialization on enhancing farm income which in turn increases household's potential spending and indirectly influences food consumption and nutritional adequacy (Pingali and Rosegrant 1995; Von Braun and Kennedy 1994; van Asselt and Useche 2022).

A previous evidence gap map (EGM) examined various aspects of food system interventions and their impact on food and nutrition outcomes (Moore et al. 2021). In their EGM, a total of 1,838 impact evaluations and 178 systematic reviews were identified. Among the systematic reviews, 54% were rated as low confidence, 26% as medium confidence, and 19% as

high confidence. Qaim et al. (2018) conducted a meta-analysis examining the relationship between production diversity, diet, and nutrition outcomes. Their study identified 45 studies from 26 countries, with less than 20% of selected studies demonstrating consistently positive and significant associations. However, a systematic synthesis of the causal effects between agricultural commercialization and food security and nutrition outcomes is currently lacking.

This paper adopts the systematic review and meta-analysis methods to answer the research question: What are the impacts of interventions related to cash crop commercialization on improving food and nutrition security of households and altering producers' tendency to grow subsistence crops? This review explores various pathways that connect commercialization to food security with a particular emphasis on the income pathway and its impact on food security and nutrition outcomes.

Theory of Change

The impact of agricultural commercialization on food security and nutrition outcomes among rural populations is influenced by various factors. Von Braun and Kennedy (1994) identified four key exogeneous factors of commercialization: 1) population, demographic change; 2) new technologies, new crops; 3) infrastructure and market creation; 4) macroeconomy and trade policy. Additionally, there are endogenous factors related to household decision-making that are important in understanding food security and nutrition outcomes. To explore the mechanisms linking agricultural commercialization interventions to food security, we have developed a logic model, which is presented in Figure 1. The primary focus of our investigation lies in the endogenous pathway connecting cash crop commercialization to food security and nutrition outcomes of households.

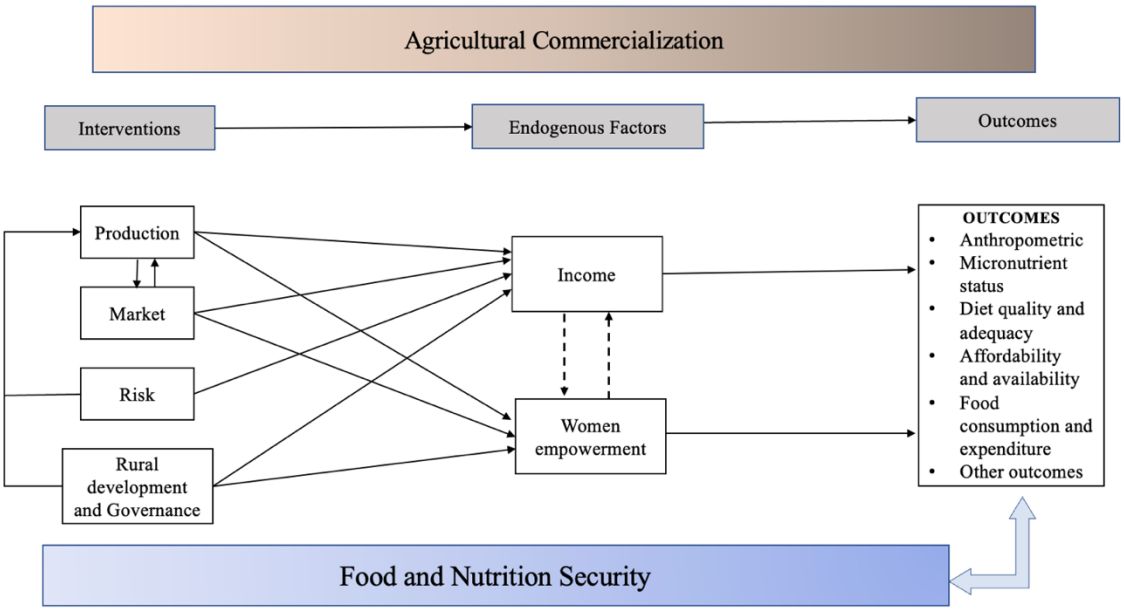

Figure 1. Logic model

Many programs aimed at improving the productivity and output quality and reducing the production costs are designed to increase the food security among rural populations. The production of subsistence food doesn't necessary lead to food security of vulnerable households in developing countries. Cash cropping can also lead to improvement in households' welfare if the agronomic and market conditions are appropriate (Norton 2004). Von Braun and Kennedy (1994) confirmed the link between technology adoption, commercialization, and nutrition status of household members. A meta-analysis conducted by Qaim et al. (2018) found positive, albeit modest, marginal effect of production diversity on dietary diversity and nutrition outcomes. As households increase their production of food crops, they gain the flexibility to decide how much to allocation for self-consumption and how much to sell in the market. Improved production levels result in a surplus crops available for sale, provided other conditions remain constant. The factors such as market access, market structure, infrastructure, and other market related conditions all influence households' selling decisions. Farmers in rural areas are usually self-sufficient in staple crops due to lack of access to markets and presence of high transaction costs in output and input

markets (Fafchamps 1992; Poulton, Dorward, and Kydd 2010). Interventions that promote market support might have a significant effect on food security and nutrition through the market pathway. When households facing same production choices but have different levels of market support, those who have improved market access, and better market information are more likely to choose to sell a larger portion of their crops, resulting in higher revenues. The increase in income generated from selling in the market can be used to buy more quantities or/and higher quality food for the family members. Interventions aimed at enhancing farm income can, therefore, have substantial impacts on household food security.

The gender dimension plays a significant role in how agricultural commercialization impacts the food security of rural populations. Cash crops often fall under the purview of men, while subsistence crops are predominantly associated with women (von Braun and Kennedy 1994*;* Fischer and Qaim 2012). Although the income earned from the commercialization may improve the households' food security, the loss of women's control over resources may have adverse effects on the food security and nutrition outcomes (Fisher and Qaim 2012). In general, men tend to have greater control over crop production, while female-headed households exhibit better dietary diversity (Sørensen 1996; Argaw, Phimister, and Roberts 2021). The primary factors that lead to this situation are gender differences in production, price, and income. Cash crop interventions may have an additional impact on food security when they also prioritize on women empowerment. Women's empowerment is therefore included as one of the endogenous factors in our logic model, aimed at better understanding the underlying mechanisms. As shown in figure 1, our logic model includes four intervention groups that help with production and market decisions. Our main outcomes of interest focus on food security and nutrition factors. Several pathways are examined

in this study and income pathway is our main interest. Other pathways like women empowerment are also discussed in this review.

Methodology

This review is done by the following steps: (1) developing the protocol, logic model, and eligibility criteria; (2) screening of the titles and abstracts of the studies extracted from two evidence gap map: Food Systems and Nutrition Evidence Gap Map (Moore et al. 2021) and Agricultural innovation: an evidence gap map (Lopez-Avila et al. 2017); (3) full-text reading of studies selected from step (3); (4) risk of bias assessment for the included studied studies; (5) data extraction for both study level and effect size level; (6) meta-analysis and narrative synthesis. Two independent reviewers completed steps (2) through (5) and the disagreements at each step are resolved by the third reviewer or discussion.

PICOS and Eligibility Criteria

A detailed protocol was developed that include specific inclusion and exclusion criteria based on the research question. This review includes peer-reviewed articles, policy papers, working papers, and other studies that met the following eligibility criteria:

(1) Participants/Population (P): Cash crop growing farmers, farmers practicing subsistence agriculture transitioning to crop commercialization, smallholder farmers in developing countries (low, middle, and upper-middle income countries according to World Bank classification 2018).

(2) Interventions/Exposures (I): Interventions to promote agricultural commercialization that include, but not limited to, interventions connecting the farmers to markets (contract farming, certification, etc.); interventions promoting (voluntary) market participation (strengthening farmers' organizations, uses of information and communication technology, extension services that provide market information to farmers, etc.); interventions to provide supporting services

(extension, infrastructure, etc.); interventions to address climate change or catastrophic events, and involve commercialization; Multicomponent agricultural interventions that involve crop commercialization.

(3) Comparator(s)/Control (C): Cash crop growers in intervention and control groups; farmers moving from subsistence agriculture to cash crop agriculture (before and after, intervention vs control); cash crop intervention vs another agricultural intervention; cash crop intervention vs doing nothing or wait-list control; early-vs-late comparison in the implementation of an intervention/program.

(4) Outcomes (O): Income path or cash crop (for sale) must be explicit in the studies; Studies report any measurement of market participation or income; A preliminary list of possible groups of food/nutrition security outcomes includes (but not limited to): Anthropometric: Linear growth, weight, relative weight, mid-upper arm circumference (MUAC), anthropometric other; Micronutrient status: Iron, Iodine, Vitamin A, Zinc, other micronutrients; Diet quality and adequacy: dietary diversity, dietary adequacy, insufficient diet, micronutrient intake, other quality/adequacy; Affordability and availability: food access, household food insecurity access scale, food availability and supply, affordability, food insecurity measures, food stressed household, other food security outcome; Food consumption and expenditure: food consumption recall, household food consumption by weight of food, per capita calorific intake, household food expenditure, individual/household dietary intake; Other outcomes: hunger index (length of the hungry season), hunger scale, seasonal hunger, household perceptions of food security, diet composition, undernourishment, coping strategy index, etc.

(5) Study design (S): Quantitative impact evaluation studies: randomized designs, quasi-randomized controlled trials, natural experiments, or papers that identify causation among self-

elected groups (pre-and-post test data with comparison, multiple pre- and post- test data without comparison, cross-sectional with comparison, post-test studies using instrumental variables).

The protocol was registered in PROSPERO under identification number CRD42023400142.

Study Search and Selection

The data search uses two existing evidence gap maps published in 3ie, Food Systems and Nutrition Evidence Gap Map (Moore et al. 2021) and Agricultural Innovation: An Evidence Gap Map (Lopez-Avila et al. 2017). The study selection process consists of three stages: (1) the reviewers conduct a title/abstract screening based on the PICOS framework; (2) the full text of the records from the first stage are evaluated; and (3) important data are extracted from the papers that have been included. All studies are uploaded to Covidence, a web-tool used to screen and conduct systematic review more efficient. Each step is done by two reviewers independently. The disagreements are resolved by the third reviewer or discussion.

Risk of Bias (RoB) Assessment

The internal validity of the studies included in this review are evaluated to make sure the selected studies are free from bias. We use the tool developed by 3ie experts in impact evaluation in developing countries and reported in Waddington et al. (2014). The four domains assessed by this tool are: selection bias and confounding, spillover effect bias, selective reporting bias, and other sources of bias. Analysis reporting bias and outcome reporting bias are named together as selective reporting bias domain in the Waddington et al. (2014).

(1) Selection bias and confounding domain stresses on the quality of attribution methods. A goal for the systematic review is to find out the causal effect of the intervention on specific outcomes. It includes strict criteria to assess both quasi-experimental research designs using

observational data and randomized controlled trials for their suitability in causal inference. Most of the quasi-experimental research in this type of interventions are: Ordinary regression and panel methods, Matching and reweighting estimators, Instrumental variables (IV) and related methods, and Regression discontinuity (RD) designs. The tool offers criteria to assess the rigorousness in building the counterfactual or comparison group and to consider important variables that explain food security and nutrition outcomes.

(2) Spillover effect bias assessment concentrates on the possibility of spillovers to farmers in control groups. The intervention provided to farmers may create 'contamination' that can cause biased estimations. This tool is adopted to identify the proximity and blurred boundaries between treated groups and control groups. The ideal situation is that spillover effects do not exist or are not significant (e.g., participants and non-participants are geographically and/or socially separated)

(3) Any biased exploratory research methods or evidence that outcomes were selectively reported were checked by the selective reporting biases tool. A well-executed study requires the valid methods to deal with the attrition and that all relevant outcomes are reported in the methods/results sections.

(4) Other sources of bias include the blind of outcome assessors or data analysis; courtesy bias from outcomes collected through self-reporting; coherence of results, for example between descriptive statistics and outcome questions; baseline data collected retrospectively; inappropriate instrument used for information collection.

Low, medium, or high risk of bias are identified in this study using the criteria specified in Piza et al. (2016). Low risk of bias studies are those measurements are clear and control for confounding, don't have any unobserved confounding, have small risk of spillover due to well-defined intervention and comparison group. The medium risk of bias studies have moderate biases

from the validity of the attribution methods, spillover risks, inappropriate standards of intervention or comparison groups, or reporting biases. Studies identified as high risk of bias have serious threats to the validity of the statistical procedure, spillovers, or contamination and reporting bias. The RoB assessment is conducted by a pre-tested online Google form. Each selected study is assessed by two independent reviewers and the discrepancies are resolved by the third reviewer.

Data Extraction

We extract data in two levels, one for the study level and another for the effect size level. First, the general study level data for each selected study is extracted using the pre-tested Google form. The following information are extracted: identification (study ID number, authors, publication year), context (country, population, program activities, program dates, intervention category, cash crops), study design (statistical methods, data collection or survey conducted time), pathways, and outcomes (food security outcomes except for standard measurements in the effect size level, nutrition outcomes).

The effect size level data are extracted using another pre-tested Google form. Studies reporting the following outcomes need to extract the effect size calculation information: Food Consumption Score (FCS); Household Dietary Diversity Score (HDDS); Individual Dietary Diversity Score (IDDS); Women Dietary Diversity Score (WDDS); Coping Strategy Index (CSI); Reduced Coping Strategy Index (rCSI); Household Food Insecurity and Access Scale (HFIAS); Household Hunger Scale (HHS); Self-Assessed measure of Food Security (SAFS); Latin American and Caribbean Food Security Scale (Spanish acronym) (ELCSA); Spending on Food. We use this form to extract the following effect size information for those outcome: statistical method used for the effect, net effect reported (average treatment effect on the treated (ATT), coefficient of regression, local average treatment effect (LATE), etc.), standard error, t-value,

sample size for both treatment group and control group, mean of outcome for both groups, standard deviation for both groups and total sample, and other useful information for effect size calculation. Both forms are done by two reviewers and the third reviewer checks the results.

Effect Size Calculation and Synthesis Strategy

The effect size is a number that reflects the magnitude of the relationship between two variables. The most important consideration is the comparability of the effect size from different studies. We adopt the formulas presented in the appendix to calculate the Standard Mean Difference, also known as Cohen's *d*, and Composite Cohen's *d*. Cohen's *d* is used to compare the difference between the means through the standardized measure of effect size (Cooper, Hedges, and Valentine 2019). Composite Cohen's d combines the effect sizes within outcomes through the composite standardized mean difference (Borenstein et al. 2009).

Univariate meta-analysis is used in this study to estimate the magnitudes of the effect for different studies and to investigate the diverse patterns of outcomes. We use random effect model to synthesize the effect. Random effect models assumes that the effect size of the selected studies is from a distribution of effect size (Borenstein et al. 2010). Two sources of variance are considered when using the random effect model: one is within study error in estimating the effect in each study and another is across study variation (Borenstein et al. 2009). We generate the forest plot for each outcome in this analysis. All the meta-analysis and plots are conducted using STATA software version 17.

Preliminary Results

Searching and Study Selection

Figure 2 shows the PRISMA chart related to the study's search and selection criteria. There are 787 studies identified from the two Evidence Gap Map and 1 study from the manual search. After removing the duplicates, the titles and abstracts of 775 studies were screened. Abstracts that didn't meet the inclusion criteria of the protocol were excluded. A total of 252 studies were selected for full-text screening of which forty-six studies selected to be included in the systematic review. The risk of bias assessment and extracted data of 46 studies were done from which 29 studies were included in the quantitative synthesis and meta-analysis. The results provided in this paper are preliminary results as more studies will be screened and added to this systematic review.

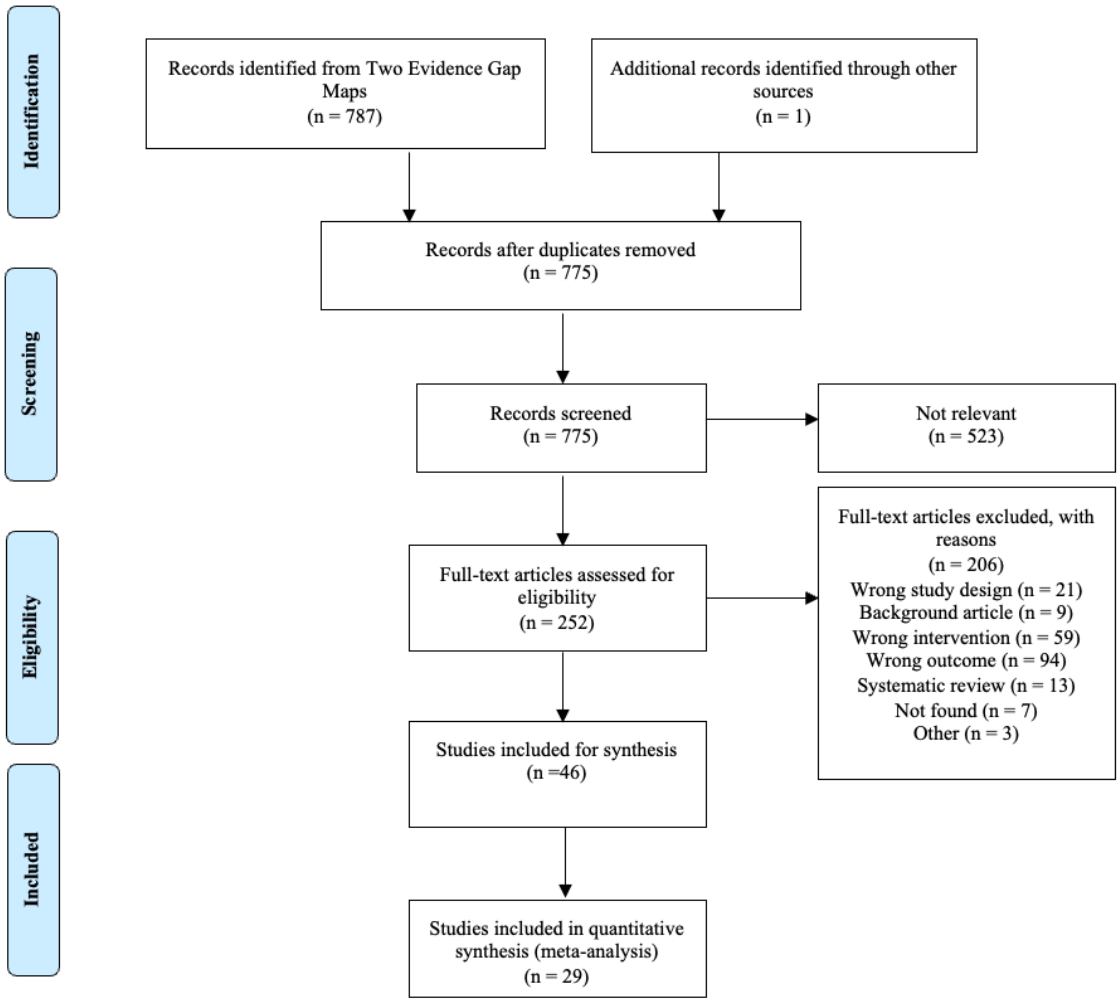

Figure 2. PRISMA

Risk of Bias (RoB) Assessment

The included studies use diverse methods to correct the self-selection ands and endogeneity problems such as Propensity Score Matching (PSM), Instrument Variables (IV), Inverse Probability Weighting (IPW), Endogenous Switching Regression (ESR), Difference-in-Difference method (DiD), Fixed Effect Model, Heckman Selection Model, and Randomized Control Trial (RCT). Figure 3 shows the summary results of risk of bias assessment and the detail results are in appendix. We adopt the criteria used in Piza et al. (2016) and assign the risk of bias scores to the included studies. Studies are low risk of bias if they are graded low at least four domains. Medium risk of bias studies are those graded low in three domains and high risk of bias are those graded low up to two domains.

From the overall assessment results in the appendix, we have graded 12 low risk of bias studies, 19 medium risk of bias studies, and 15 high risk of bias studies. All the included studies addressed the selection and confounding biases to some extent. The most frequent used methods are PSM and DiD. The spillover bias is the domain that has the greatest number of high and medium risk of bias studies. Most studies assume that the control group and treatment group are independent with each other while not all of them address the spillover effect quantitatively appropriate. Most of our included studies report the outcome and analysis with low risk of bias. Only one study is graded as high risk of bias in analysis reporting domain because the IV results are not shown in the study.

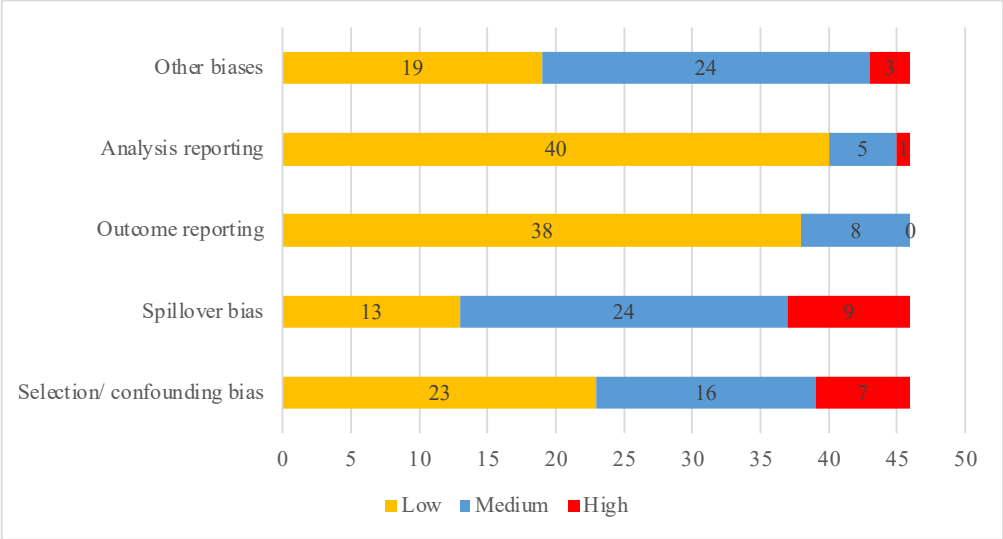

Figure 3. Risk of Bias Assessment Results

Included Studies

Forty-six studies were included in the review. They were classified according to the main objective of the intervention studied. We found four main categories of intervention's goal on agricultural settings: (i) production stage, (ii) market access and marketing of cash crops, (iii) risk management, (iv) governance and rural development. Detailed information for programs, methods, and findings of these 46 studies by category and subcategory of intervention presented in Tables 1 to 4 (specific findings and pathways are summarized in the appendix). Some studies examine complex programs with different activities, and they appear in more than once in the tables.

Table 1 presents the description for 34 studies included in the production categories. In the production category, we have several sub-categories, and they are irrigation, technology adoption, new varieties, Farmer Field School (FFS)/Farmer-to-farmer (F2F), extension, post-harvest and storage, and credit, financing options. (1) Five studies report the irrigation intervention and four of them report the significant improvement on household food security. Mekonnen et al. (2022), Tesfaye et al. (2008), and Garbero and Songsermsawas (2018) all examine the impacts of small-scale irrigation, but not all of them have significant results on food security outcomes. (2) The

second sub-group is technology adoption, which we focus on the programs promoting the agricultural technology adoption during the production process. There are seven studies included in this group. Positive effects on food security and nutrition outcomes are reported in most studies in this group although some of them are insignificant. (3) Five papers are included in the new varieties sub-group. In this sub-group, most programs are designed to promote the adoption of maize new variety. Among these studies, most of them indicated positive improvement of food security while some are insignificant. Only one study in this sub-group reports negative effect on HDDS. (4) The next sub-group includes five studies associated with Farmer Field School (FFS) and Farmer-to-Farmer (F2F) programs. Four out of five programs are implemented in Africa, and only one program is in Asia. All five studies indicate the positive enhanced effect on food security status. (5) We include seven studies related to traditional or e-extension interventions in the extension sub-group. Not all the studies have significant results on food security and nutrition outcomes, but they all report positive improvement on food security or reduced food insecurity status. (6) Four papers are grouped into post-harvest and storage category. These studies report improvement food security status and mixed effects on the food consumption. (7) The last sub-group in production category is credit, financing options. We include seven studies related to the subsidy, credit, voucher, and other financing interventions during production process in this group. Those studies have positive effects on food security indicators and negative results for food insecurity variables.

Table 1. Interventions focused on improving production

Authors	Program	Country	Crops	Methods	Outcome measurements
Irrigation					
Kassie and Alemu (2021)	Koga irrigation development project (KIDP)	Ethiopia	Wheat, potato, shallot, pepper, garlic, onion, tomato, and maize	PSM	***Food security***: 1. Multidimensional household food security (MFI). It has been developed from seven common food security indicators through a comparative empirical analysis
Mekonnen et al. (2022)	Innovation Laboratory for Small Scale Irrigation (ILSSI) project	Ethiopia, Tanzania	NA	Panel fixed effect model, Linear probability model,	***Food security***: 1. HDDS; 2. WDDS; ***Nutrition***: Children's anthropometric assessment: 1. weight-for-height z-scores (WHZ); 2. height for age z-scores (HAZ); 3. wasting; 4. stunting
Tesfaye et al. (2008)	Small Irrigation (Filtino and Godino irrigation schemes)	Ethiopia	Onion, tomato, potato, chickpea	Heckman's Two-step Estimation; Heckit model	***Food security***: 1. Food expenditure
Burney and Naylor (2012)	Solar Market Garden (SMG) project	Benin	High-valued vegetables	DID	***Food security***: 1. Food expenditure; 2. Food insecurity score: A measure of ability to meet daily household food needs
Garbero and Songsermsawas (2018)	Participatory Small-scale Irrigation Development Programme (PASIDP)	Ethiopia	Teff, wheat, maize, barley, sorghum, root crops, vegetables, and fruits	Inverse probability weighting (IPW), IV	***Food security***: 1. Food expenditure
Technology adoption					
Aramburu et al. (2014)	"Programa de Apoyos Directos para la Creación de Iniciativas Agroalimentarias Rurales" (CRIAR)	Bolivia	Rice, barley, corn, quinoa, wheat, coca, potato, and cassava	PSM	***Food security***: 1. ELCSA
Kumar and Quisumbing (2011)	Vegetable and polyculture fish management technologies	Bangladesh	Vegetables	DID, PSM	***Food security***: 1. Food expenditure; ***Nutrition***: 1. Per-adult equivalent calorie availability: Percent change in total calorie; 2. Total calorie consumption by children, men, women; 3. Total protein consumption by children, men, women; 4. Total iron consumption by children, men , women;

Authors	Program	Country	Crops	Methods	Outcome measurements
					5. Total vitamin A consumption by children, men, women; 6. Height-for-age z-score (HAZ) for children; 7. body mass index z-score (ZBMI) for children; 8. Change in body mass index (BMI) for adult men and women
Del Prete et al. (2019)	Crop Intensification Program (CIP)	Rwanda	Maize, beans, cassava, rice, wheat, and Irish potato	DID, PSM	***Food security***: 1. HDDS; 2. Food Consumption Quantities: sum of the quantities of home-produced food and purchased foods (grams) per capita per day in each food group, using an adult equivalent household size measure; ***Nutrition***: 1. Nutrient availability: macro- and micronutrients derived from food consumption quantities
Deschamps-Laporte (2013)	National Agriculture and Livestock Extension Programme (NALEP)	Kenya	Maize, sweet potatoes, millet, grain amaranth, beans, sorghum, kales, sunflower	PSM	***Food security***: 1. Household experienced hunger in 2011: Dummy=1 if household faced hunger in 2011; 2. Length of hungry spell in 2011: Duration of hungry if the household experienced hunger in 2011
Nagwekar et al. (2020)	Solar Conduction Dryer (SCD)	India	Fruits, vegetables, spices	DID	***Food security***: 1. WDDS; ***Nutrition***: 1. Body Mass Index (BMI)
Nyyssölä et al. (2014)	Lutheran World Federation (LWF) village development programme	Mozambique	Maize, cow peas, peanut, pumpkin, watermelon	IV, Fixed effect model, DID	***Food security***: 1. FCS; 2. CSI; 3. Ability to have regular meals: the binary indicator on whether the households were able to have regular meals
Nkala et al. (2011)	Conservation Agriculture (CA)	Mozambique	Maize, cow peas, pigeon peas.	PSM	***Food security***: 1. Food security: dummy variable =1 if improvement in food security is reported
New Varieties					
Takeshima and Nagarajan (2012)	Intervention on varietal diversity and production of minor millets	India	Minor millet	PSM	***Food security***: 1. HDDS; 2. HFIAS
Dibba et al. (2017)	New Rice for Africa (NERICA)	Gambia	Rice	IV	***Food security***: 1. FCS; 2. Food security: 4 statuses created based on the food consumption score: <21=severely food insecure, 20 to 35= borderline food insecurity, 34-77= moderately food insecure, >77=food secure
Otieno et al. (2022)	The Seeds for Needs (S4N) project	Kenya, Uganda	Beans, maize, millet and sorghum	PSM	***Food security***: 1. Food security: whether household has ever gone without food, dummy=1

Authors	Program	Country	Crops	Methods	Outcome measurements
					if never slept hungry, 0 for has slept hungry more than once
Khonje et al. (2015)	Sustainable Intensification of Maize–Legume Systems for the Eastern Province of Zambia (SIMLEZA)	Zambia	Maize	PSM, ESR (endogenous switching regression)	***Food security***: 1. SAFS
Kassie et al. (2014)	Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA)	Tanzania	Maize	Ordered probit regression, Generalized Propensity Score matching, Linear Regression Model	***Food security***; 1. Food expenditure; 2. Food security: dummy=1 if food secure; 3. Chronic food insecurity: dummy=1 if Household suffers from it; 4. Transitory food insecurity: dummy=1 if Household suffers from it; 5. Break-even food security: dummy=1 if Household has breakeven food security; 6. Food surplus in food security: dummy=1 if Household has food surplus food security
FFS/F2F					
Garbero and Chichaibelu (2018)	Agricultural Sector Support Programme (ASSP) and Agricultural Sector Development Programme-Livestock (ASDP-L)	Tanzania	Vegetable, bananas, cassava, paddy rice	PSM, Inverse probability weighting with regression adjustment (IPWRA)	***Food security***: 1. HDDS; 2. CSI
Kangmennaang et al. (2017)	Malawi Farmer to Farmer Agroecology project (MAFFA)	Malawi	NA	DID	***Food security***: 1. HFIAS
Larsen and Lilleør (2014)	RIPAT (Rural Initiatives for Participatory Agricultural Transformation	Tanzania	Banana	Quasi DID, ITT, PSM, simple cross-sectional assessment	***Food security***: 1. HHS; 2. No hunger; 3. At least three meals, worst month (children); 4. At least three meals, best month (children); 5. At least three meals, previous four weeks (children). (2-5: dummy=1 if 'yes'); ***Nutrition***: 1. Had meat previous week; 2. Had eggs previous week; 3. Had dairy previous week. Dummy=1 if 'yes'

Authors	Program	Country	Crops	Methods	Outcome measurements
Santos-Rocha (2017)	JENGA II project	Democratic Republic of the Congo (DRC)	Cassava, Mosaic Resistant Sawa Sawa and Liyayi; maize, peanuts, beans, and rice	DID, IPW, PSM, IV	***Food security***: 1. HDDS; 2. HFIAS
DANIDA (2011)	Agriculture Sector Programme Support Phase II (ASPS II)	Bangladesh	Rice, vegetables, tree crops	DID, PSM	***Food security***: 1. Probability of experiencing food shortage (%)
Extension					
Diagne and Cabral (2017)	The National Agency for the Integration and Agricultural Development (ANIDA) Program	Senegal	Horticulture, cereals, arboriculture	Inverse Propensity Score Matching	***Food security***: 1. Food insecurity: dummy = 1 if the household has struggled to meet its food needs over the last 12 months
Olney et al. (2016)	Enhanced-homestead food production (E-HFP)	Burkina Faso	Fruit, vegetable	DID, RCT	***Food security***: 1. HDDS; ***Nutrition***: 1. Body Mass Index (BMI): kg/m^2; 2. Prevalence of underweight (BMI <18.5kg/m2)
Del Prete et al. (2019)	Crop Intensification Program (CIP)	Rwanda	Maize, beans, cassava, rice, wheat, and Irish potato	DID, PSM	***Food security***: 1. HDDS; 2. Food Consumption Quantities: sum of the quantities of home-produced food and purchased foods (grams) per capita per day in each food group, using an adult equivalent household size measure; ***Nutrition***: Nutrient availability: macro- and micronutrients derived from food consumption quantities
Salazar et al. (2016)	Programa de Apoyos Directos para la Creación de Iniciativas Agroalimentarias Rurales (CRIAR)	Bolivia	NA	IV	***Food security***: 1. ELCSA; 2. Concern about lack of food at home; 3. Unable to eat healthy and nutritious food; 4. Skipped a meal; 5. Unable to eat healthy and nutritious food for children; 6. Children skip a meal. (2-6: dummy=1 if 'yes'
Deschamps-Laporte (2013)	National Agriculture and Livestock Extension Programme (NALEP)	Kenya	Maize, sweet potatoes, millet, grain amaranth, beans, sorghum, kales, sunflower	PSM	***Food security***: 1. Household experienced hunger in 2011: dummy=1 if household faced hunger in 2011; 2. Length of hungry spell in 2011: duration of hungry if the household experienced hunger in 2011
Pan et al. (2018)	BRAC's agricultural extension program	Uganda	Mainly maize, other crops	RD	***Food security***: 1. Food expenditure; 2. Overall food sufficiency: measured as whether households

Authors	Program	Country	Crops	Methods	Outcome measurements
			choice: millet, rice, groundnut, bean, coffee		had sufficient food to meet family needs over the previous year; 3. Other measures of food security per capita food consumption; 4. Worry about insufficient food; 5. Limited variety; 6. Limited portion; 7. Skip meals
Ntakyo and van den Berg (2019)	Area-Based Agricultural Modernization Program (AAMP)	Uganda	Rice	PSM, IV	***Food security***: 1. HDDS; 2. HFIAS; ***Nutrition***: 1. Calorie consumption (per adult equivalent/day): the calorie consumption per day per adult male equivalent where adult male equivalent equals (AME) to number of adults + (number of children <18 years) *0.5
Post-harvest and storage					
Del Prete et al. (2019)	Crop Intensification Program (CIP)	Rwanda	Maize, beans, cassava, rice, wheat, and Irish potato	DID, PSM	***Food security***: 1. HDDS; 2. Food Consumption Quantities: sum of the quantities of home-produced food and purchased foods (grams) per capita per day in each food group, using an adult equivalent household size measure; ***Nutrition***: Nutrient availability: macro- and micronutrients derived from food consumption quantities.
Brander et al. (2021)	On-farm storage	Tanzania	Maize	ITT, ANCOVA	***Food security***: 1. prevalence of severe food insecurity: measured through rCSI, (a) Food secure or mildly food insecure (rCSI values 0–4), (b) Moderately food insecure (5–10), and (c) Severely food insecure (>=11).
Nagwekar et al. (2020)	Solar Conduction Dryer (SCD)	India	Fruits, vegetables, spices	DID	***Food security***: 1. WDDS; ***Nutrition***: 1. Body Mass Index (BMI)
Basu and Wong (2015)	Storage program and credit program	Indonesia	Maize, rice	RCT, OLS	***Food security***: 1. lack food last month: dummy variable =1 if the household reported lacking food in the previous month; ***Nutrition***: 1. Staple consumed in kCal: calculated as rice consumed plus maize consumed (both in calories)
Credit, financing options					
Diagne and Cabral (2017)	The National Agency for the Integration and Agricultural	Senegal	Horticulture, cereals, arboriculture	Inverse Propensity Score Matching	***Food security***: 1. Food insecurity: dummy = 1 if the household has struggled to meet its food needs over the last 12 months

Authors	Program	Country	Crops	Methods	Outcome measurements
	Development (ANIDA) Program				
Gignoux et al. (2021)	Project of Technology Transfer to Small Farmers (PTTA)	Haiti	Rice	RCT, OLS, ITT	***Food security***: 1. HHS; 2. Severe hunger: if household gets 4-5 for HHS
Adu-Baffour et al. (2019)	John Deer Initiative (JD Initiative)	Zambia	Maize	PSM	***Food security***: 1. HDDS; 2. Food expenditure; 3. Skipping meals: frequency of food consumed by respondent household
Fink et al (2020)	Subsidized loans	Zambia	Maize	Intension-to-treat regression	***Food security***: 1. Months with enough food; 2. Food security: households' perceived food security; 3. Meals per day hungry season (adult): measured during the short recall data collection rounds; 4. Meals per day harvest season: measured during the long-recall surveys
Le Cotty et al. (2023)	An inventory credit (or warrantage) program	Burkina Faso	Maize, cotton, Sorghum, millet	OSM, IV, OLS, Inverse probability weighted regression adjustment estimator	***Food security***: 1. Cereals still in stock; 2. Cereals in sufficient quantities; 3. Self-sufficiency: the number of days of self-sufficiency; 4. Quantity of maize in stock (kg); 5. Quantity of sorghum in stock (kg); 6. Quantity of millet in stock (kg). (1 and 2: dummy=1 if 'yes')
Tamini et al. (2019)	Crop production intensification credit [Crédit d'Intensification de la Production Agricole] (CIPA)	Burkina Faso	Maize, cowpea	PSM	***Food security***: 1. Food: food available in the household measured in kg per adult equivalent of all production
Basu and Wong (2015)	Storage program and credit program	Indonesia	Maize, rice	RCT, OLS	***Food security***: 1. lack food last month: dummy variable =1 if the household reported lacking food in the previous month; ***Nutrition***: 1. Staple consumed in kCal: calculated as rice consumed plus maize consumed (both in calories)

Most of our included studies are in the production category and there are fewer studies in the Market category. We found only three studies that analyzed the effect of value chain related programs on food security. Three programs provide market information and other market support to farmers and are included in the second sub-group. Only one study runs the analysis on the certification intervention in Ghana. In addition, we find one study for the contract farming sub-group and it only reports the food security outcome. Most studies find positive effects on food security outcome, and only one study shows significant negative effect on HDDS.

Only two studies are grouped into 'Risk Management' category. Both programs are designed to help farmers with climate event and against extreme weather risk like drought. They all include food security as their outcome, but no nutrition outcome analysis. One study finds negative insignificant result on food insecurity (Diagne and Cabral 2017) but positive effects on welfare and other outcomes, while the other study reported positive impact on food security status (Isaboke et al 2016).

Coordination, governance, land access, and land consolidation related programs are included in the Govrnance and Rural Development category. We find three papers for the land access and land consolidation, and one paper related to governance. Diagne and Cabral (2017), Del Prete et al. (2019), and Santos et al. (2014) run the analyses of the intervention of land access and land consolidation on food security. Most of the studies in this category find insignificant effect on food security factors.

Thirty-one studies report the standard food security outcomes, while fifteen studies use their own measurements which can't be used to compare with each other. Nutrition outcomes are not common in our included studies. Only ten studies report the nutrition outcome. The common

nutrition outcome used in these studies are Body Mass Index (BMI), calorie consumption, weight-for-height z-scores (WHZ), height for age z-scores (HAZ), and some micro-nutrients consumption.

Several production group studies report the income pathway in their studies: 5 studies in irrigation subcategory, 6 studies in technology adoption, 4 studies in new varieties group, 2 studies in FFS/F2F, 4 studies in extension, 3 studies in post-harvest and storage, and 4 in credit and financing options. Only 8 studies examine the women empowerment pathway in the production category. In the market category, five papers reported the income pathway. We haven't found any study reported the women empowerment pathway in market category. One study in risk category reports the income pathway. Two studies in rural development and governance category report income and one study reports the women empowerment pathway.

Table 2. Interventions focused on improving market access and marketing of cash crops

Authors	Program	Country	Crops	Methods	Outcome measurements
Value chain					
Rutherford et al. (2016)	Agriculture for Children's Empowerment (ACE) Project.	Libera	Rice, bitter ball, hot pepper, cassava	DID	***Food security***: 1. IDDS; 2. HFIAS; 3. Percent who missed one or more meals in the last 7 days: Percent of children who missed one or more meals in the last 7 days
Kafle et al. (2021)	The High-Value Agriculture Project in Hill and Mountain Areas (HVAP)	Nepal	Apple, ginger, turmeric, timur, beans, potato, tomato, cabbage, vegetables	OLS, PSM, IPWRA	***Food security***: 1. FCS; 2. HDDS; 3. Household is food insecure: It was measured with FAO's food insecurity experience scale (FIES), dummy =1 if yes
Biggeri et al. (2018)	Agricultural Value Chains Project in Oromia (AVCPO)	Ethiopia	Durum wheat	PSM, IV	***Food security***: 1. HDDS; 2. HFIAS; 3. Frequency of 'eating smaller meals'; 4. Frequency of 'eating fewer meals' (3 and 4: variables take value 0, 1 or 2 depending on whether farmers used coping strategy 'eating fewer meals' never, sometimes, or often, respectively)
Market information, participation, and other support					
Takeshima and Nagarajan (2012)	Intervention on varietal diversity and production of minor millets	India	Minor millet	PSM	Food security: 1. HDDS; 2. HFIAS
Osei et al. (2018)	AMEDD programme	Mali	Grains (maize, millet, sorghum and rice)	DID	***Food security***: 1. Food shortage experience: The households are asked 6 questions about the food insecurity experiences in the last 12 months. Dummy=1 if household responded 'yes' to at least one of the questions
Ntakyo and van den Berg (2019)	Area-Based Agricultural Modernization Program (AAMP)	Uganda	Rice	PSM, IV	***Food security***: 1. HDDS; 2. HFIAS; ***Nutrition***: 1. Calorie consumption (per adult equivalent/day): the calorie consumption per day per adult male equivalent where adult male equivalent equals (AME) to number of adults + (number of children <18 years) *0.5
Certification					
Iddrisu et al. (2020)	UTZ-RA cocoa certification program	Ghana	Cocoa	PSM	***Food security***: 1. HFIAS

Contract farming					
Arouna et al. (2021)	Experiment on contract farming	Benin	Rice	RCT, OLS, ANCOVA	***Food security***: 1. FCS; 2. HFIAS

Table 3. Interventions focused on risk management

Authors	Program	Country	Crops	Methods	Outcome measurements
Insurance					
Diagne and Cabral (2017)	The National Agency for the Integration and Agricultural Development (ANIDA) Program	Senegal	Horticulture, cereals, arboriculture	Inverse Propensity Score Matching	***Food security***: 1. Food insecurity: Dummy = 1 if the household has struggled to meet its food needs over the last 12 months
Isaboke et al. (2016)	Kilimo salama (Safe Agriculture in Kiswahili) insurance	Kenya	Maize	PSM	***Food security***: 1. HDDS; 2. Food security score: a range of 0–15. Respondents are asked 15 questions which determine the food security status of a household

Table 4. Interventions focused on governance and rural development

Authors	Program	Country	Crops	Methods	Outcome measurements
Diagne and Cabral (2017)	The National Agency for the Integration and Agricultural Development (ANIDA) Program	Senegal	Horticulture, cereals, arboriculture	Inverse Propensity Score Matching	***Food security***: 1. Food insecurity: Dummy = 1 if the household has struggled to meet its food needs over the last 12 months
Del Prete et al. (2019)	Crop Intensification Program (CIP)	Rwanda	Maize, beans, cassava, rice, wheat, and Irish potato	DID, PSM	***Food security***: 1. HDDS; 2. Food Consumption Quantities: sum of the quantities of home-produced food and purchased foods (grams) per capita per day in each food group, using an adult equivalent household size measure; ***Nutrition***: Nutrient availability: macro- and micronutrients derived from food consumption quantities
Pamuk et al. (2015)	Integrated Agricultural Research for Development (IAR4D)	Uganda, Rwanda, the Democratic	NA	DID	***Food security***: 1. FCS

		Republic of Congo (DRC)			
Santos et al. (2014)	West Belgal's land policy	India	NA	PSM	***Food security***: 1. HDDS; 2. Food security: binary indicator that captures whether households reported experiencing times when they did not have food or money to buy food in the last three months; 3. Average adult female food share; 4. Average adult male food share; 5. Average young female food share; 6. Average young male food share. (3 to 6: Gap between the average number of full meals consumed by each demographic group (adult females, adult males, young females, and young males) and the most food-secure person in the household) ***Nutrition***: 1. Protein consumption: dummy =1 if any household member consumed protein in the last 24 hours

Meta-analysis results

Data from 29 studies were used in meta-analysis. Not all of studies and outcomes are used for meta-analysis since insufficient number of studies report the outcome. We adopt the random-effect model on four outcomes: HDDS, HFIAS, FCS, and food expenditure. We did not separate the interventions in the preliminary meta-analysis since insufficient studies for each intervention category and more papers will be included later when the selection process on 6,405 records retrieved from database search ends. We have finished screening 5,954 titles/abstracts (446 studies are duplicated) and excluded 5,760 irrelevant studies. 253 studies are now under full-text review process.

Household Dietary Diversity Score (HDDS)

Twelve studies reported the HDDS outcome. Four studies show negative insignificant results, and six studies show positive insignificant results. Among all the 12 studies, Isaboke et al. (2016) and Ntakyo and van den Berg (2019) have positive significant results. Figure 4 shows that the overall effect of interventions related to cash crops on dietary diversity is positive but not significant since the 95% CI include zero and p-value equals to 0.1. We preliminary include all the interventions in the analysis, and surprisingly found a moderate level of heterogeneity given by the low numbers of I^2, T^2, and H^2 are not large, which is in part due to the standardized metrics of the indicator that retrieves clear and specific information from households.

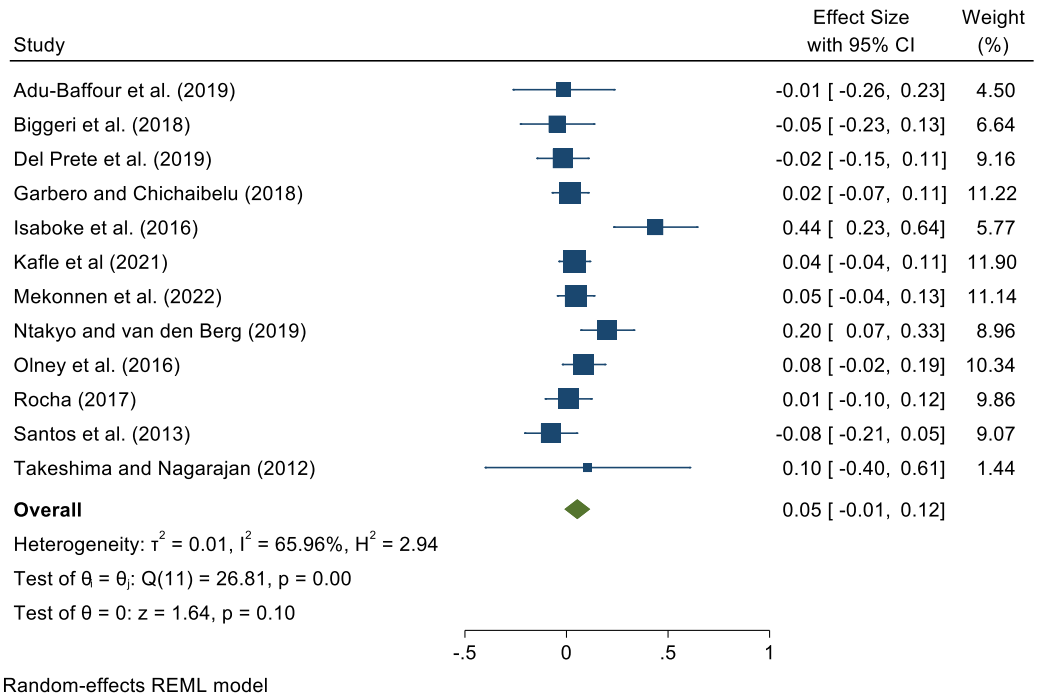

Figure 4. Meta-analysis Results for HDDS

Household Food Insecurity Access Scale (HFIAS)

A total of eight studies have examined the effects of interventions related to cash crops on HFIAS. Five studies report negative results, and three results report the positive results. Iddrisu et al. (2018) and Takeshima and Nagarajan (2012) show positive substantial effect on HFIAS. Iddrisu et al (2018) examines the relationship between double certification program and household food security status. They find that the program negatively impacts the food security status for participants. The extra income they earned from certification might not be enough for the cost and lead to extra required food for the household. Takeshima and Nagarajan (2012) analyzes the market participation on two different groups in hills and plains, while they only report the HFIAS results for plains. Figure 5 presents the results for HFIAS outcome. The overall effect is negative but insignificant which indicates the trivial and diminishing effect of interventions on household food

insecurity status. The numbers of I^2, T^2, and H^2 indicate the considerable heterogeneity between the studies. This is consistent with our expectation due to the mix of interventions.

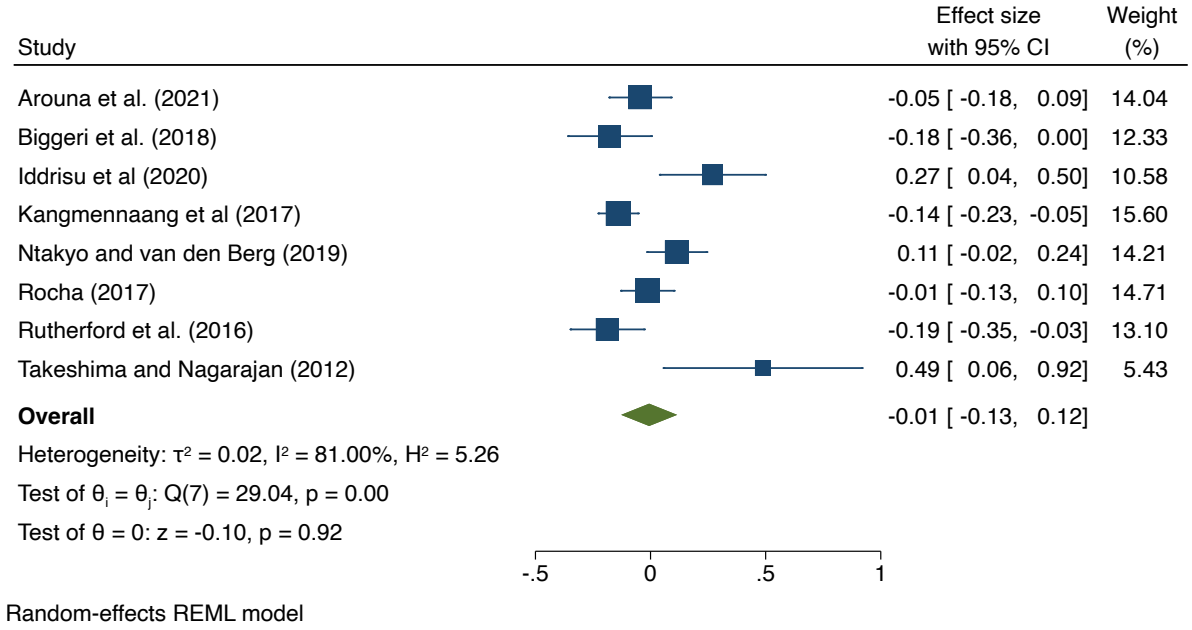

Figure 5. Meta-analysis Results for HFIAS

Food Consumption Score (FCS)

The third outcome for the meta-analysis is FCS and the results are shown in figure 6. Five studies report this outcome and the heterogeneity between studies is as our expected. The overall effect is positive significant for FCS. The intervention effect on household food consumption score for treatment group is 0.15 higher than the control group. All the studies show positive effect size for FCS, but not all are significant. Three studies show positive significant results in the analysis, and they drive the overall result to positive significant.

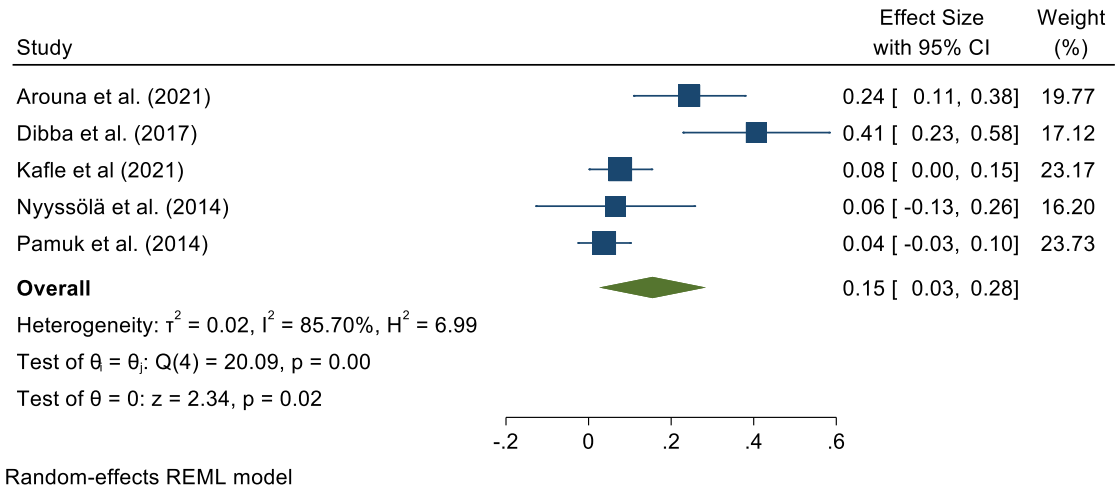

Figure 6. Meta-analysis Results for FCS

Food expenditure

Seven studies report the impact of cash crop interventions on this outcome, all the interventions were focused on improving production process and outcomes. Results in figure 7 show that the overall effect is positive significant which indicate the better food security status for treatment group than control group. The production interventions have substantial positive impact on the household food expenditure for the treatment group. All studies show positive effect size, and four of them have significant results in the analysis.

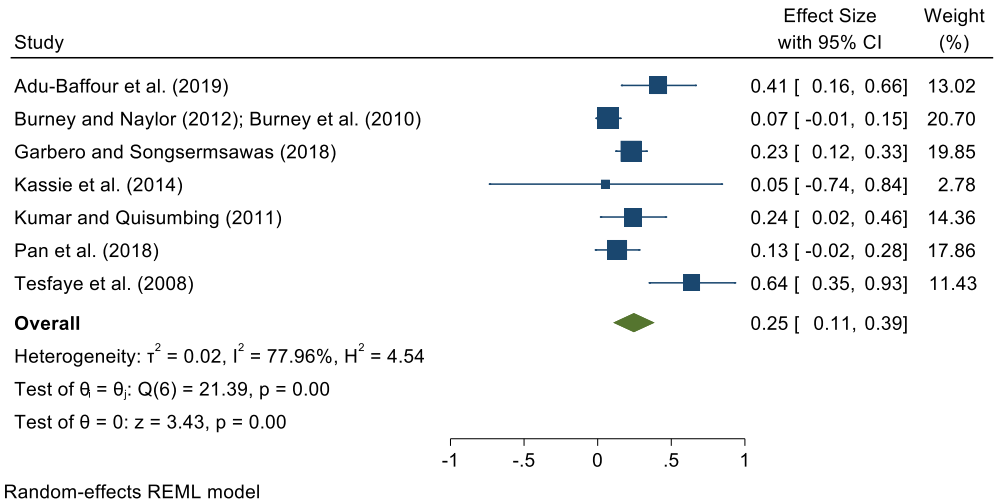

Figure 7. Meta-analysis Results for Food Expenditure

Conclusion

This study adopts the systematic review and meta-analysis methods to explore the impact of cash crop commercialization interventions on food security and nutrition outcomes in low and middle countries. This paper, so far, presents findings of included studies retrieved from two evidence gap maps. In total, we include 46 studies for the synthesis and 29 studies in the meta-analysis. We categorize these 46 studies into 4 main groups, and they are production, market, risk, and rural development and governance. Under each group, several sub-groups are formed (e.g., irrigation under production group). 34 studies are included in the production group, 8 studies in the market intervention, 2 studies in the risk group, and 4 in the rural development and governance category. All the included studies measure the food security outcomes while only 10 studies are found to have nutrition outcomes. The studies use BMI, calorie consumption, and micro-nutrients as their nutrition outcome measurements quite often. For the food security measurements, 29 studies used the standard measurements including FCS, HDDS, IDDS, WDDS, HFIAS, HHS, CSI, rCSI, SAFS, ELCSA, and Food Expenditure.

We assess the risk of bias for each included study and assign the scores for different risk domains. In general, 12 studies are graded as low risk of bias, 19 studies graded as medium risk of bias, and 15 studies are graded as high risk of bias. The meta-analysis is done for four outcomes using the random-effect model. The overall estimated effect for 12 studies reported HDDS outcomes is positive but not significant. The overall estimated effect size for HFIAS is -0.43 and not significant, but there is an outlier leading the effect size to negative sign. The results for food consumption score and food expenditure are substantially positive. The heterogeneity for the analysis is not small since we didn’t separate the intervention while doing the analysis.

The analysis presented here will be complemented and updated with the new wave of included studies when the selection process on the set of 6,405 records retrieved from database search is completed. The preliminary results reported in this paper will give us a potential pattern for the studies related to the research question, but will not provide finals results related to policy interventions and implications.

Acknowledgement

This research was funded by the USDA Food for Progress Project FX18TA-10960R029. Authors would like to thank Prof. Margaret Foster, Mengqiao Liu, and Yaqing Zheng at Texas A&M University for their valuable help in this project.

Reference

Argaw, T.L., E. Phimister, and D. Roberts. 2021. "From farm to kitchen: how gender affects production diversity and the dietary intake of farm households in Ethiopia." *Journal of Agricultural Economics* 72:268–292.

Babu, S., S. Gajanan, and P. Sanyal. 2014. *Food security, poverty and nutrition policy analysis: statistical methods and applications*. Academic Press.

Borenstein, M., L.V. Hedges, J.P. Higgins, and H.R. Rothstein. 2010. "A basic introduction to fixed-effect and random-effects models for meta-analysis." *Research synthesis methods* 1:97–111.

—. 2009. Introduction to meta-analysis. John Wiley & Sons.

Capone, R., H.E. Bilali, P. Debs, G. Cardone, and N. Driouech. 2014. "Food system sustainability and food security: connecting the dots." *Journal of Food Security* 2:13–22.

Cooper, H., L.V. Hedges, and J.C. Valentine. 2019. *The handbook of research synthesis and meta-analysis*. Russell Sage Foundation.

Fafchamps, M. 1992. “Cash crop production, food price volatility, and rural market integration in the third world.” *American journal of agricultural economics* 74:90–99.

Fischer, E., and M. Qaim. 2012. “Gender, agricultural commercialization, and collective action in Kenya.” *Food security* 4:441–453.

Lopez-Avila, D., S. Husain, R. Bhatia, M. Nath, and R.M. Vinaygyam. 2017. “Agricultural innovation–An evidence gap map.” *EGM Report* 12.

Moore, N., C. Lane, I. Storhaug, A. Franich, H. Rolker, J. Furgeson, T. Sparling, and B. Snilstveit. 2021. “The effects of food systems interventions on food security and nutrition outcomes in low-and middle-income countries.”, *EGM Report.*

Norton, R.D. 2004. *Agricultural development policy: Concepts and experiences*. John Wiley & Sons.

Pingali, P.L., and M.W. Rosegrant. 1995. “Agricultural commercialization and diversification: processes and policies.” *Food policy* 20:171–185.

Piza, C., T.A. Cravo, L. Taylor, L. Gonzalez, I. Musse, I. Furtado, A.C. Sierra, and S. Abdelnour. 2016. “The impact of business support services for small and medium enterprises on firm performance in low-and middle-income countries: A systematic review.” *Campbell Systematic Reviews* 12:1–167.

Poulton, C., A. Dorward, and J. Kydd. 2010. “The future of small farms: New directions for services, institutions, and intermediation.” *World development* 38:1413–1428.

Salazar, L., J. Aramburu, M. Gonz´alez-Flores, and P. Winters. 2016. “Sowing for food security: A case study of smallholder farmers in Bolivia.” *Food Policy* 65:32–52.

Sasson, A. 2012. “Food security for Africa: an urgent global challenge.” *Agriculture & Food Security* 1:1–16.

Sørensen, P. 1996. “Commercialization of food crops in Busoga, Uganda, and the renegotiation of gender.” *Gender & Society* 10:608–628.

van Asselt, J., and P. Useche. 2022. “Agricultural commercialization and nutrition; evidence from smallholder coffee farmers.” *World Development* 159:106021.

Von Braun, J., and E. Kennedy. 1994. “Agricultural commercialisation, economic development and nutrition.” *Baltimore, The Johns Hopkins University press for IFPRI*.

Waddington, H., B. Snilstveit, J. Hombrados, M. Vojtkova, D. Phillips, P. Davies, and H. White. 2014. “Farmer field schools for improving farming practices and farmer outcomes: A systematic review.” *Campbell systematic reviews* 10:i–335.

Appendix

Table A1. Findings and Pathway for Interventions in Production Stages

Authors	Findings	Pathway
Irrigation		
Kassie and Alemu (2021)	1. Most of the sample group in this study were found to be mild food insecure, 12.4% were food secure and 14.4% were severe food insecure; 2. The results suggested that better food security status didn't result from the increasing income; 3. Study showed positive significant results of the impact on food security.	Income
Burney et al. (2010)	1. the Solar-powered drip irrigation significantly decreased the food insecurity score of the participants; 2. augments household food purchase, particularly during the dry season, and is cost effective compared to alternative; technologies; 3. solar-powered drip irrigation can provide substantial economic, nutritional, and environmental benefits to populations in the Sudano–Sahel.	Income
Mekonnen et al. (2022)	1. In Ethiopia and Tanzania, women participants have higher WDDS than women non-participants when facing drought; 2. In Tanzania, irrigating households have higher HDDS than non-irrigating households; 3. Children in irrigating households have higher WHZ score than children in non-irrigating households; 4. Children under-five in irrigating households have higher WHZ scores than those in non-irrigating households when the households reported having experienced a drought in the 5 years preceding the survey.	NA
Tesfaye et al. (2008)	1. The small-scale irrigation significantly increased the households' food security in the study area; 2. the adoption of small-scale irrigation also helped farmers with increased productivity, and higher income.	Income
Burney and Naylor (2012)	1. The study found out the significant reduction on household food insecurity score and increase on food expenditure for treated households; 2. results also indicated the high returns in the short term	Income; Women empowerment
Garbero and Songsermsawas (2018)	1. Significant improvement in household food expenditure was found; 2. PASIDP beneficiaries had more crop yield, income and they consumed lower values of crops from own production; 3. The results also suggested higher crop yields and more diverse of crops, although the results were not significant.	NA
Technology adoption		
Aramburu et al. (2014)	1. The results showed significant positive impact of the program on food security, while insignificant effect on productivity; 2. The program had a positive impact on sales at the farm gate, market sales, agricultural income from sales, and a decrease in the proportion of production allocated for home consumption.	Income
Kumar and Quisumbing (2011)	1. The results showed insignificant long-term effect on household consumption expenditures and asset accumulation in vegetables sites, but significantly positive in fishponds sites; 2. the impacts on individual nutrient intake, nutrient adequacy, and nutritional status were different with the household level impact.	Income
Del Prete et al. (2019)	1. The program had a positive impact on consumption of roots and tubers; 2. negative effect was found on meat, fish and fruits consumption and the potential availability of vitamin B12.	Income
Deschamps-Laporte (2013)	1. The effect on the Household experienced hunger in 2011 was not significant, while the household's' hungry spell length was significantly reduced for the treatment households; 2. The participants changed their crop rotation practices and increased their fertilizer usage, but they were less likely to store their surplus maize; 3. Productivity was not significantly affected for program beneficiaries, while the off-farm income was higher.	Income

Authors	Findings	Pathway
Nagwekar et al. (2020)	1. The results suggested an impact on the dietary diversity, economic and social status of the women; 2. Impacts on BMI and clinical profile of the treated group were not significant.	Women empowerment; Income
Nyyssölä et al. (2014)	1. The results showed the increased adoption of new technologies among farmers' groups; 2. Significance of the effect on the ability to have regular meals varies greatly depending on the model specification.	NA
Nkala et al. (2011)	1. The project had positive impacts on the beneficiaries on enhancement of productivity, yield, income, and food security.	Income
New Varieties		
Takeshima and Nagarajan (2012)	1. The impact of the market participation showed slightly negative effect on HDDS in the Reduced NNM model. Other model results were all statistically insignificant on both HDDS and HFIAS in the Plains; 2. The results also suggested that market participation help improve the on-farm minor millet diversity; 3. The results indicated that market participation in the Plains has a significantly positive effect on minor millet income.	Income
Dibba et al. (2017)	1. The results indicated a significantly increase in household food security; 2. The adoption of NERICA rice didn't show significant impact on health status.	Income
Otieno et al. (2022)	1. Significant increase on the income was observed from the results for the treatment households; 2. Participation in this program can help farmers cope with climate change; 3. Treatment households benefited with increasing productivity, food availability, and food security.	Income
Khonje et al. (2015)	1. The results suggested a positive but insignificant effect on food security; 2. It also indicated that the adoption of improved maize varieties was associated with education, group membership, access to extension advice and market information, household size, and ownership of oxen and non-oxen assets; 3. The adoption of improved maize varieties also help increase income and reduce poverty.	Income
Kassie et al. (2014)	1. The treated households resulted in modest and significant improvement on food security but varied with the level of adoption.	NA
FFS/F2F		
Garbero and Chichaibelu (2018)	1. FFS helped both livestock and crop producers increase their revenue; 2. Participants can diversify their source of income and then enhance their household food security and market access; 3. The program also empowered women participants on land ownership, production decision, control over the use of income, access, and decision on credit; 4. Results indated the significant poverty reduction among the participants.	Women empowerment; Income
Kangmennaang et al. (2017)	1.The results suggested that the project significantly increase the household income and reduce the food insecurity, resulting in improved welfare.	Income
Larsen and Lilleør (2014)	1. The study found strong positive effects on food security, but no effect on poverty.	NA
Santos-Rocha (2017)	1. The results indicated significant improvements on HDDS, while not significant on HFIAS; 2. The adoption of improved agricultural technologies was not a successful mediator for improving food security; 3. In general, FFS and F2F positively helped with household access to food and dietary diversity.	NA
DANIDA (2011)	1. The project contributed to the increased food production significantly which resulting the improvement of food security; 2. The beneficiaries had lower probability of experiencing food shortage after FFS, especially for low-income households.	Women empowerment; Income

Authors	Findings	Pathway
Extension		
Diagne and Cabral (2017)	1. The impact of ANIDA on food insecurity was negative but insignificant; 2. The results significantly showed improvement on depth and severity poor; 3. The program participants had lower intention to migrate, and they were better equipped with irrigation technologies; 4. They spent more on inputs and yielded more production than non-participants which is also helpful for the resilience to climatic events.	Income
Olney et al. (2016)	1. Results showed that the program significantly increased mother's intake of fruit, marginally increased meat/poultry, and dietary diversity; 2. The prevalence of underweight was significantly reduced among mothers in treatment compared with control villages; 3. While the changes in BMI were not significant different between mothers in different groups; 4. A greater increase of BMI was observed among the underweight mothers; 5. The study program had significant improvement on women empowerment.	Women empowerment
Del Prete et al. (2019)	1. The program had a positive impact on consumption of roots and tubers; 2. Negative effects were found on meat, fish and fruits consumption and the potential availability of vitamin B12.	Income
Salazar et al. (2016)	1. Results showed significantly improve of the food security; 2. Additionally, it also indicated the positive effect on the agricultural productivity, agricultural sales, and eventually on household income.	Income
Deschamps-Laporte (2013)	1. The effect on the Household experienced hunger in 2011 was not significant, while the household's hungry spell length was significant reduced for the treatment households; 2. The participants changed their crop rotation practices and increased their fertilizer usage, but they were less likely to store their surplus maize; 3. Productivity was not significantly affected for program beneficiaries, while the off-farm income was higher.	Income
Pan et al. (2018)	1. The eligible farmers were more likely to grow coffee and adopt improved cultivation methods; 2. The results suggested significantly improved household food security and better shock-coping strategies except for food anxiety. It might be caused by the increased yield or agricultural income.	NA
Ntakyo and van den Berg (2019)	1. Commercial rice production had positive significant impacts on HDDS and had no significant effect on HFIAS; 2. Households engaged in market-oriented rice production are more likely to experience low caloric consumption	NA
Post-harvest and storage		
Del Prete et al. (2019)	1. The program had a positive impact on consumption of roots and tubers; 2. negative effect was found on meat, fish and fruits consumption and the potential availability of vitamin B12.	Income
Brander et al. (2021)	1. Enhanced on-farm storage significantly decreased the probability of seasonally food insecure; 2. The intervention also substantially improved the food security for smallholder farmers.	NA
Nagwekar et al. (2020)	1. The results suggested an impact on the dietary diversity, economic and social status of the women; 2. Impacts on BMI and clinical profile of the treated group were not significant.	Women empowerment; Income
Basu and Wong (2015)	1.Both storage and credit led to increases in non-food consumption or reported income but no significant effects on staple consumption; 2. The storage program increased returns to savings and non-food consumption in the harvest and lean seasons. While the effects on health or outcomes related to seasonal fluctuations were not found; 3. The credit program showed enhanced income and more resilient against risk. However, credit led to some deterioration in health in the harvest season.	Income
Credit, financing options		

Authors	Findings	Pathway
Diagne and Cabral (2017)	1. The impact of ANIDA on food insecurity was negative but insignificant; 2. The results showed significant improvement on depth and severity poor; 3. The program participants had lower intention to migrate, and they were better equipped with irrigation technologies; 4. They spent more on inputs and yielded more production than non-participants which is also helpful for the resilience to climatic events.	Income
Gignoux et al. (2021)	1. The study revealed that participation in the program helps decline in household hunger score; 2. It also indicated lower input use and yields when subsidies were received.	Income
Adu-Baffour et al. (2019)	1. Adopting the private-sector mechanization showed a great increase in the farmers' income. 2. The increasing income was observed to be used in children's education and getting more food, while the significant improvement of food diversity was not observed. The demand for hired labor increases due to land expansion and due to a shift from family labor, including that of children, to hired labor.	Women empowerment; Income
Fink et al (2020)	1. The loans provided to poor farmers helped improve food security, increase wages, and enhance agricultural output; 2. The results addressed the importance of seasonal income, credit access, and liquidity for labor markets and agricultural production.	NA
Le Cotty et al. (2023)	1. The results indicated strong and long-term effects on production, savings, and food security.	NA
Tamini et al. (2019)	1. The results suggested positive effects on the area planted, yield, production, and sales. 2. the results also varied in terms of gender, province, and perceived quality of services to producers; 3. The impact on food available in the household was not significant.	Women empowerment
Basu and Wong (2015)	1.Both storage and credit led to increases in non-food consumption or reported income but no significant effects on staple consumption; 2. The storage program increased returns to savings and non-food consumption in the harvest and lean seasons. While the effects on health or outcomes related to seasonal fluctuations were not found; 3. The credit program showed enhanced income and more resilient against risk. However, credit led to some deterioration in health in the harvest season.	Income

Table A2. Findings and Pathway for Interventions focused on Market Access and Marketing

Authors	Findings	Pathway
Value chain		
Rutherford et al. (2016)	1. The results indicated a significant decrease in the food insecurity among the treatment households; 2. For both treatment group and control group, children's diet were less diverse and the proportion of children who missed one or more meals in the last 7 days decreased overtime; 3. the program contributed to positive farm outcomes like agricultural productivity, but it was not sufficient to improve household welfare, child health and nutrition.	NA
Kafle et al. (2021)	1. The study indicated enhanced household food security, dietary diversity, and household resilience; 2. The increased income was resulted from the higher sale volumes, lower output price, and more agricultural revenue.	Income
Biggeri et al. (2018)	1. Significant evidence of positive impact on cereal production value was found; 2. The results also showed great improvement of education and reduction of household food security outcomes, while the effects on household diet was not significant.	NA
Market information, participation, and other support		
Takeshima and Nagarajan (2012)	1. The impact of the market participation showed slightly negative effect on HDDS n the Reduced NNM model. Other model results were all statistically insignificant on both HDDS and HFIAS in the Plains; 2. The results also suggested that market participation help improve the on-farm minor millet diversity; 3. The results indicated that market participation in the Plains has a significantly positive effect on minor millet income.	Income
Osei et al. (2018)	1. The study found a significant negative effect on the food shortage experience for the program participants; 2. The program significantly influenced the timing of the grain harvest, the adoption of improved grain storage methods, and lowered the incidence of pre-harvest grain losses; 3. the results didn't show significant sign on the income and the likelihood of selling grains through aggregation centers.	Income
Ntakyo and van den Berg (2019)	1. Commercial rice production had positive significant impacts on HDDS and had no significant effect on HFIAS; 2. Households engaged in market-oriented rice production are more likely to experience low caloric consumption	NA
Certification		
Iddrisu et al. (2020)	1. The program led to an increase in yield and household income; 2. Negative effect on the food security was found; 3. Results suggested that increased productivity ad income might not cause improvement in food security.	Income
Contract farming		
Arouna et al. (2021)	1. Contract farming contributed to welfare and productivity measures. Specifically, it led to enhanced FCS, increase rice income, and marginally reduction HFAIS.	Income

Table A3. Findings and Pathway for Interventions focused on Risk Management

Authors	Findings	Pathway
Insurance		
Diagne and Cabral (2017)	1. The impact of ANIDA on food insecurity was negative but insignificant; 2. The results significantly showed improvement on depth and severity poor; 3. The program participants had lower intention to migrate, and they were better equipped with irrigation technologies; 4. They spent more on inputs and yielded more production than non-participants which is also helpful for the resilience to climatic events.	Income
Isaboke et al. (2016)	1. The insurance had a positive impact on food security status.	NA

Table A4. Findings and Pathway for Interventions focused on Governance and Rural development and

Authors	Findings	Pathway
Diagne and Cabral (2017)	1. The impact of ANIDA on food insecurity was negative but insignificant; 2. The results significantly showed improvement on depth and severity poor; 3. The program participants had lower intention to migrate, and they were better equipped with irrigation technologies; 4. They spent more on inputs and yielded more production than non-participants which is also helpful for the resilience to climatic events.	Income
Del Prete et al. (2019)	1. The program had a positive impact on consumption of roots and tubers; 2. Negative effects were found on meat, fish and fruits consumption and the potential availability of vitamin B12.	Income
Pamuk et al. (2015)	1. Significant reduction in poverty was found, but insignificant effects on food insecurity; 2. The project was more effective in poverty alleviation than traditional extension; 3. Different platforms placed different importance level for innovations.	NA
Santos et al. (2014)	1. The program contributed to significant positive effect on variables that were expected to be fundamental for food security in the future; 2. Women participants were more tenure secure than non-participants; 3. Program beneficiaries were more likely to invest in agriculture and use improved inputs.	Women empowerment

Table B. Effect Size Calculation Formula

Effect size measure	Information needed	Formula
Standard Mean Difference (SMD)	The pooled standard deviation S_p: Standard deviation of the dependent variable for treatment group SD_t and for control group SD_c sample size for the treatment group n_t and control group n_c; ATT: Average Treatment Effect on the Treated.	$S_p = \sqrt{\frac{SD_t^2(n_t-1)+SD_c^2(n_c-1)}{n_t+n_c-2}}$ $SMD = \frac{ATT}{S_p}$ $SE(SDM) = \sqrt{\frac{n_t+n_c}{n_t*n_c}+\frac{(SMD)^2}{2(n_t+n_c)}}$
Approximated Standard Mean Difference (SMD')	t statistics of the regression coefficient. Sample size for the treatment group n_t and control group n_c	$SMD' = t\sqrt{\frac{1}{n_t}+\frac{1}{n_c}}$ $SE(SMD') = \sqrt{\frac{n_t+n_c}{n_t*n_c}+\frac{(SMD')^2}{2(n_t+n_c)}}$
Approximated Standard Mean Difference (SMD')	t statistics of the regression coefficient. Total sample size N	$SMD' = \frac{2t}{\sqrt{N}}$ $SE(SMD') = \sqrt{\frac{4}{N}+\frac{SMD'^2}{2N}}$

Table C. Details for Risk of Bias Assessment Results

Authors	Selection/confounding bias	Performance/Spillover bias	Outcome reporting bias	Analysis reporting bias	Other biases	Overall assessment
Adu-Baffour et al.	Medium	Medium	Low	Low	Low	Medium
Aramburu et al.	Low	Low	Low	Low	Low	Low
Arouna et al.	Low	Low	Low	Low	Medium	Low
Basu and Wong	Low	Medium	Low	Low	Medium	Medium
Biggeri et al.	High	Low	Low	Medium	Low	Medium
Brander et al.	High	Medium	Low	Low	Low	Medium
Burney and Naylor; Burney et al.	Low	High	Medium	Low	Low	Medium
Le Cotty et al.	Medium	Low	Medium	Low	Low	Medium
Datar et al.	Medium	Low	Low	Low	Medium	Medium
Del Prete et al.	Medium	Medium	Low	Low	Medium	High
Deschamps-Laporte	Medium	High	Low	Low	Medium	High
Diagne and Cabral	Medium	Medium	Medium	High	Medium	High
Dibba et al.	Low	Medium	Low	Medium	Medium	High
Fink et al.	Low	Medium	Low	Low	Low	Low
Garbero and Chichaibelu	Medium	High	Low	Low	Medium	High
Garbero and Songsermsawas	Medium	Medium	Low	Low	Medium	High
Gignoux et al.	Low	Low	Low	Low	Low	Low
Iddrisu et al.	Medium	Medium	Low	Low	Low	Medium
Isaboke et al.	High	Low	Low	Medium	Low	Medium
Kafle et al.	Medium	Medium	Low	Low	Medium	High
Kangmennaang et al.	Medium	High	Medium	Low	Low	High
Kassie and Alemu	Medium	Low	Low	Low	Medium	Medium
Kassie et al.	Low	Medium	Low	Low	Medium	Medium
Khonje et al.	Low	High	Low	Low	Low	Low

Authors	Selection/confounding bias	Performance/Spillover bias	Outcome reporting bias	Analysis reporting bias	Other biases	Overall assessment
Kumar and Quisumbing	Low	Medium	Low	Low	Medium	Medium
Larsen and Lilleør	Low	Medium	Low	Medium	Medium	High
Mekonnen et al.	High	Medium	Low	Low	Low	Medium
Ministry of Foreign Affairs of Denmark	High	High	Medium	Medium	Medium	High
Nagwekar et al.	Medium	Medium	Medium	Low	Low	High
Nkala et al.	Low	Medium	Low	Low	High	Medium
Ntakyo and van der Berg	Low	Medium	Low	Low	Medium	Medium
Nyyssölä et al.	Low	Medium	Low	Low	Medium	Medium
Olney et al.	Medium	Medium	Low	Low	Low	Medium
Osei et al.	Low	Low	Low	Low	Medium	Low
Otieno et al.	High	High	Low	Low	Medium	High
Pamuk et al.	Low	Low	Low	Low	Medium	Low
Pan et al.	Low	Medium	Low	Low	Low	Low
Rocha	Low	High	Low	Low	Low	Low
Rusike et al.	Medium	Medium	Low	Low	Low	Medium
Rutherford et al.	Low	Medium	Low	Low	Medium	High
Salazar et al.	Low	High	Low	Low	Low	Low
Santos et al.	Low	Low	Low	Low	Medium	Low
Takeshima and Nagarajan	Low	Medium	Low	Low	High	Medium
Tamini et al.	Medium	Medium	Medium	Low	Medium	High
Tesfaye et al.	High	Low	Medium	Low	Medium	High
van Asselt and Useche	Low	Low	Low	Low	High	Low

Included Studies

Adu-Baffour, F., T. Daum, and R. Birner. 2018. "Can big companies' initiatives to promote mechanization benefit small farms in Africa? A case study from Zambia." A Case Study from Zambia (June 12, 2018). *ZEF-Discussion Papers on Development Policy*.

Aramburu, J., M. González Flores, L. Salazar, and P. Winters. 2014. "When a Short-term Analysis is not a Short-term Approach: Impacts of Agricultural Technology Adoption in Bolivia." Working paper, IDB Working Paper Series.

Arouna, A., J.D. Michler, and J.C. Lokossou. 2021. "Contract farming and rural transformation: Evidence from a field experiment in Benin." *Journal of Development Economics* 151:102626.

Asante, F., L.S. Hodey, P.N. Adu, K. Adu-Ababio, and M. Coulibaly. 2018. "Impact of voice reminders to reinforce harvest aggregation services training for farmers in Mali.".

Basu, K., and M. Wong. 2015. "Evaluating seasonal food storage and credit programs in east Indonesia." *Journal of Development Economics* 115:200–216.

Biggeri, M., F. Burchi, F. Ciani, and R. Herrmann. 2018. "Linking small-scale farmers to the durum wheat value chain in Ethiopia: Assessing the effects on production and wellbeing." *Food Policy* 79:77–91.

Brander, M., T. Bernauer, and M. Huss. 2021. "Improved on-farm storage reduces seasonal food insecurity of smallholder farmer households–Evidence from a randomized control trial in Tanzania." *Food Policy* 98:101891.

Burney, J.A., and R.L. Naylor. 2012. "Smallholder irrigation as a poverty alleviation tool in sub-Saharan Africa." *World Development* 40:110–123.

Datar, G., X.V. Del Carpio, and V. Hoffmann. 2009. “Can a market-assisted land redistribution program improve the lives of the poor? Evidence from Malawi.” *Evidence from Malawi (October 1, 2009). World Bank Policy Research Working Paper*.

Del Prete, D., L. Ghins, E. Magrini, and K. Pauw. 2019. “Land consolidation, specialization and household diets: evidence from Rwanda.” *Food Policy* 83:139–149.

Deschamps-Laporte, J.P. 2013. “The impact of extension services on farming households in Western Kenya: A propensity score approach.” Working paper, Working Paper.

Diagne, A., and F.J. Cabral. 2017. “Agricultural Transformation in Senegal: Impacts of an Integrated Program.” *Partnership for Economic Policy Working Paper*.

Dibba, L., M. Zeller, and A. Diagne. 2017. “The impact of new Rice for Africa (NERICA) adoption on household food security and health in the Gambia.” *Food Security* 9:929–944.

Fink, G., B.K. Jack, and F. Masiye. 2020. “Seasonal liquidity, rural labor markets, and agricultural production.” *American Economic Review* 110:3351–3392.

Garbero, A. 2018. “Agricultural sector development programme–livestock (ASDP-L) and the agriculture service support programme (ASSP).” *IFAD*.

Garbero, A., and T. Songsermsawas. 2018. “Impact of modern irrigation on household production and welfare outcomes: Evidence from the Participatory Small-Scale Irrigation Development Programme (PASIDP) project in Ethiopia.” *IFAD Research Series*, pp. 1–47.

Gignoux, J., K. Macours, D. Stein, and K. Wright. 2021. “Agricultural input subsidies, credit constraints and expectations of future transfers: evidence from Haiti.”.

Iddrisu, M., R. Aidoo, and C.A. Wongnaa. 2020. “Participation in UTZ-RA voluntary cocoa certification scheme and its impact on smallholder welfare: Evidence from Ghana.” *World Development Perspectives* 20:100244.

Isaboke, H.N., Q. Zhang, and W.N. Nyarindo. 2016. “The effect of weather index based micro-insurance on food security status of smallholders.” *Agricultural and Resource Economics: International Scientific E-Journal* 2:5–21.

Kafle, K., T. Songsermsawas, and P. Winters. 2021. “IFAD Research series 65–impacts of agricultural value chain development in a mountainous region: evidence from Nepal.” *IFAD Research series* 65.

Kangmennaang, J., R.B. Kerr, E. Lupafya, L. Dakishoni, M. Katundu, and I. Luginaah. 2017. “Impact of a participatory agroecological development project on household wealth and food security in Malawi.” *Food security* 9:561–576.

Kassie, K.E., and B.A. Alemu. 2021. “Does irrigation improve household’s food security? The case of Koga irrigation development project in northern Ethiopia.” *Food Security* 13:291–307.

Kassie, M., M. Jaleta, and A. Mattei. 2014. “Evaluating the impact of improved maize varieties on food security in Rural Tanzania: Evidence from a continuous treatment approach.” *Food Security* 6:217–230.

Khonje, M., J. Manda, A.D. Alene, and M. Kassie. 2015. “Analysis of adoption and impacts of improved maize varieties in eastern Zambia.” *World development* 66:695–706.

Kumar, N., and A.R. Quisumbing. 2011. “Access, adoption, and diffusion: understanding the long-term impacts of improved vegetable and fish technologies in Bangladesh.” *Journal of Development Effectiveness* 3:193–219.

Larsen, A.F., and H.B. Lilleør. 2014. “Beyond the field: The impact of farmer field schools on food security and poverty alleviation.” *World Development* 64:843–859.

Le Cotty, T., E.M. D'hˆotel, and J. Subervie. 2023. "Inventory credit to enhance food security in Burkina Faso." *World Development* 161:106092

Mekonnen, D.K., J. Choufani, E. Bryan, B. Haile, and C. Ringler. 2022. "Irrigation improves weight-for-height z-scores of children under five, and Women's and Household Dietary Diversity Scores in Ethiopia and Tanzania." *Maternal & Child Nutrition* 18:e13395.

Nagwekar, N.N., V.B. Tidke, and B.N. Thorat. 2020. "Seasonal nutritional food security to Indian women through community-level implementation of domestic solar conduction dryer." *Ecology of Food and Nutrition* 59:525–551.

Nkala, P., N. Mango, and P. Zikhali. 2011. "Conservation agriculture and livelihoods of smallholder farmers in Central Mozambique." *Journal of Sustainable Agriculture* 35:757–779.

Ntakyo, P.R., and M. van den Berg. 2019. "Effect of market production on rural household food consumption: Evidence from Uganda." *Food Security* 11:1051–1070.

Nyyss¨ol¨a, M., J. Pirttil¨a, and S. Sandstr¨om. 2012. "Helping poor farmers to help themselves: Evidence from a group-based aid project in Mozambique." Working paper, WIDER Working Paper.

Olney, D.K., L. Bliznashka, A. Pedehombga, A. Dillon, M.T. Ruel, and J. Heckert. 2016. "A 2-year integrated agriculture and nutrition program targeted to mothers of young children in Burkina Faso reduces underweight among mothers and increases their empowerment: a cluster-randomized controlled trial." *The Journal of Nutrition* 146:1109–1117.

Otieno, G., R.J.O. Ogola, T. Recha, J.N. Mohammed, and C. Fadda. 2022. "Climate change and seed system interventions impact on food security and incomes in East Africa." *Sustainability* 14:6519.

Pamuk, H., E. Bulte, A. Adekunle, and A. Diagne. 2015. “Decentralised innovation systems and poverty reduction: experimental evidence from Central Africa.” *European Review of Agricultural Economics* 42:99–127.

Pan, Y., S.C. Smith, and M. Sulaiman. 2018. “Agricultural extension and technology adoption for food security: Evidence from Uganda.” *American Journal of Agricultural Economics* 100:1012–1031.

Rocha, J.S. 2017. “Agricultural extension, technology adoption and household food security: evidence from DRC.” PhD dissertation, Wageningen University and Research.

Rusike, J., N. Mahungu, S. Lukombo, T. Kendenga, S. Bidiaka, A. Alene, A. Lema, and V.M. Manyong. 2014. “Does a cassava research-for-development program have impact at the farm level? Evidence from the Democratic Republic of Congo.” *Food Policy* 46:193–204.

Rutherford, D.D., H.M. Burke, K.K. Cheung, and S.H. Field. 2016. “Impact of an agricultural value chain project on smallholder farmers, households, and children in Liberia.” *World Development* 83:70–83.

Salazar, L., J. Aramburu, M. Gonz´alez-Flores, and P. Winters. 2016. “Sowing for food security: A case study of smallholder farmers in Bolivia.” *Food Policy* 65:32–52.

Santos, F., D. Fletschner, V. Savath, and A. Peterman. 2014. “Can government-allocated land contribute to food security? Intrahousehold analysis of West Bengal’s microplot allocation program.” *World Development* 64:860–872.

Takeshima, H., and L. Nagarajan. 2012. “Minor millets in Tamil Nadu, India: local market participation, on-farm diversity and farmer welfare.” *Environment and Development Economics* 17:603–632.

Tamini, L.D., I. Bocoum, G. Auger, K.G. Lawin, A. Traor´e, et al. 2019. “Enhanced microfinance services and agricultural best management practices: what benefits for smallholders farmers? An evidence from Burkina Faso.” *CIRANO Working Papers-Center for Interuniversity Research and Analysis on Organizations*, pp. .

Tesfaye, A., A. Bogale, R.E. Namara, and D. Bacha. 2008. “The impact of small-scale irrigation on household food security: The case of Filtino and Godino irrigation schemes in Ethiopia.” *Irrigation and Drainage Systems* 22:145–158.

Udenrigsministeriet, D. 2011. Evaluation of the Farmer Field School Approach in the Agriculture Sector Programme Support Phase II, Bangladesh. Ministry of Foreign Affairs of Denmark.

van Asselt, J., and P. Useche. 2022. “Agricultural commercialization and nutrition; evidence from smallholder coffee farmers.” *World Development* 159:106021.