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Impact of Farmer-Managed Natural Regeneration on Resilience and Welfare in Mali

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Abstract: Climate change, poverty, and low environmental education have contributed to increasing vulnerability of poor farmers in Mali. This study was done to determine the impact of low-cost adaptation strategies on resilience and welfare. We analyzed the impact of a World Vision (WV) project which promoted climate-smart agriculture (CSA) practices in Mali from 2016 to 2019. We identified the impact using a two-stage weighted regression. Results show that the WV project significantly increased the adoption of farmer-managed natural regeneration (FMNR) practice and eventually crop yield. These intermediate impacts were translated into a significant reduction in food and nutrition insecurity and an increase in household income. The impacts of the project on child health were especially greater for farmers who participated in the project for a longer time. However, the project did not have a significant impact on the adoption of a combination of CSA practices – which could have enhanced the effectiveness of the FMNR practice. The results suggest the need for future interventions to emphasize the promotion of complementary CSA practices, which significantly increases returns to farmer investments.

Keywords: farmer-managed natural regeneration (FMNR), climate-smart agriculture (CSA), climate change, vulnerability, Sahelian, Mali

1. Introduction

The Sahelian region – where Mali is located – is characterized by unreliable rainfall and frequent droughts. Having lived under a fickle climatic environment for centuries, farmers in the region have developed coping strategies that pass from one generation to another (Mortimore & Adams, 2001). However, new challenges are putting pressure on the traditional coping strategies for rural households, who heavily depend on natural resources and have limited resilience to shocks – underscoring the importance and urgency of building resilience in the Sahelian region. Barrett and Constas (2014) defines resilience as "Development resilience is the capacity over time of a person, household or other aggregate unit to avoid poverty in the face of various stressors and in the wake of myriad shocks."

The 4th assessment of the Intergovernmental Panel on Climate Change estimates that by 2050 the length of the growing period in arid and semi-arid lands of Western Africa will be reduced by 20% (Mertz et al., 2009), further increasing the vulnerability and volatility of farmers who depend on rainfed agriculture as only 5% of small-scale farmers in Mali use irrigation (Nkonya et al., 2020). Indeed, most of Mali's crop yields (e.g., maize, cowpea, millet, sorghum, and peanuts) will decrease by up to 17% (Butt et al., 2005). Climate change also negatively affects livestock, which serves a crucial role as a traditional savings and insurance instrument in the Sahel. Over 90% of rural households own livestock in the Sahelian region, and over 50% of their capital stock is in livestock form (Kamuanga et al., 2008). Butt et al. (2005) estimate that climate change in Mali will reduce forage yield by 5–36%, reducing livestock live weight by 14–16% (Butt et al., 2005).

The shocks and stressors are threatening centuries-old coping strategies of farmers, and their vulnerability is increasing. About 50% of people living in the Sahelian region are chronically food insecure (United Nations Office for the Coordination of Humanitarian Affairs, 2021), while a much greater number are affected by more severe bouts of cyclical or transitory food insecurity following periodic shocks. Foresight projection by Butt et al. (2005) shows that climate change in Mali will cause 70–142 million US dollars in losses, and the percentage of the population at risk of hunger will increase from 34% to 64%.

Strategies for addressing climate change and land degradation in Mali are emerging as overarching policy issues. Mali's climate change policy Vision is to achieve a sustainable socio-economic development framework by 2025. The Climate Change Vision integrates adaptation to climate change in all development sectors. The country is also implementing the National Action Program for Adaptation to Climate Change and has submitted the Intended Nationally Determined Contributions (INDC) to the 2016 Climate Change Paris Agreement. The INDC aims to protect forests and enhance reforestation as part of carbon mitigation. In 2014, Mali submitted its Nationally Appropriate Mitigation Actions to the United Nations Framework for Climate Change, in which sustainable land and water management (SLWM) practices are among the adaptation strategies (Food and Agriculture Organization of the United Nations, 2019). SLWM are practices that lead to the protection, conservation, restoration, and sustainable use of land and water resources and their ecosystem functions.

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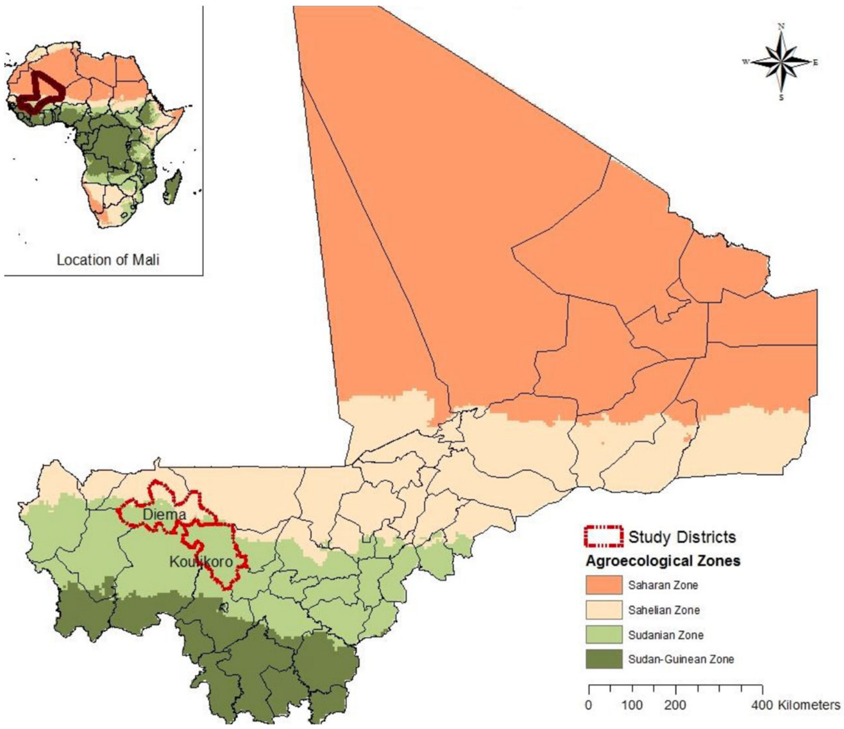
Figure 1
Mali agroecological zones



As part of the implementation of the climate adaptation and mitigation policies and strategies discussed above, Mali has significantly invested in irrigation, as 56% of its irrigation potential is equipped for it (Food and Agriculture Organization of the United Nations, 2021). Mali is also promoting other climate-smart agriculture (CSA) practices – i.e., practices that enhance climate resilience.

The government of Mali is collaborating with development partners to promote CSA practices. One such partner is World Vision Mali (WVM), an implementing agency of the Eco-Agriculture in the African Sahel (EAAS) project. The main objective of the EAAS is to develop and promote livelihood resilience building through more SLWM practices. EAAS was implemented in two phases, and the first Phase (EAAS I) started in 2013 and ended in 2015. Using Farmer Field School approach, EAAS I activities focused on the promotion of Farmer-Managed Natural Regeneration (FMNR) and other CSA practices in two case study districts – Diema and Kolokani. The EAAS promoted the widespread adoption of FMNR and other CSA practices. FMNR is a low-cost practice that protects trees and shrubs to allow them to regenerate naturally (Bayala et al., 2014; Reij et al., 2009). EAAS II was implemented in the same districts from 2016 to 2019. In addition to implementing all activities of EAAS I, EAAS II added two new key interventions – namely, value chain development and group savings. The present study evaluates the impact of the EAAS Second Phase (EAAS II).

The objectives of the study are to analyze the intermediate and ultimate impacts of EAAS II on selected outcomes. The intermediate impacts include the adoption of FMNR and other CSA practices. The intermediate impacts are expected to lead to the ultimate impacts, which include improved household income, food and nutrition security, and child well-being. Achieving these ultimate impacts is expected to lead to poverty reduction. Despite its low cost and relevancy to smallholder farmers in the Sahelian region, its economic impacts have not been rigorously analyzed. Most of the studies done on FMNR have been largely biophysical and/or descriptive in nature[1]. This is the first study known to the authors which rigorously analyzes the impacts of FMNR.

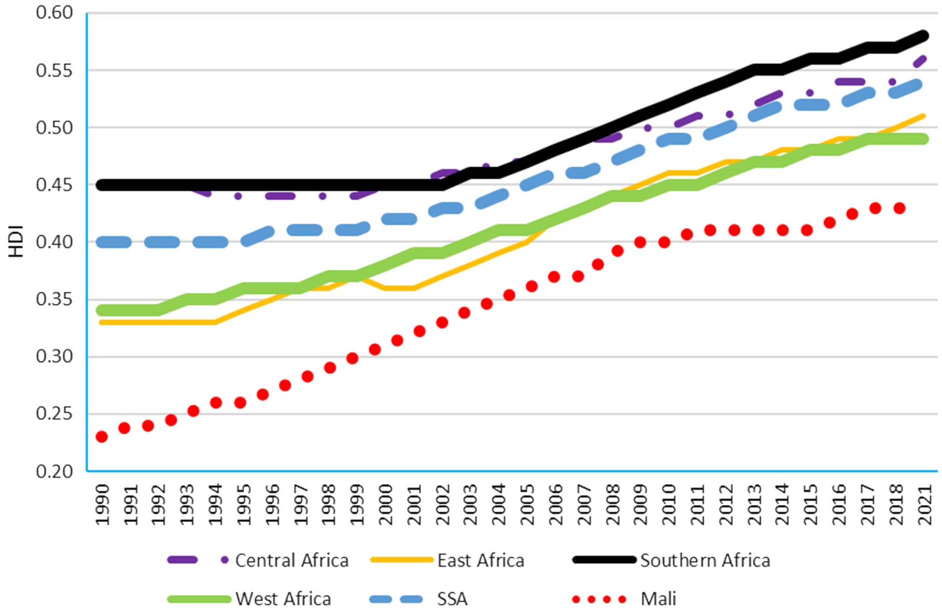
To set the stage for analyzing the impact of EAAS II, the next section discusses Mali's vulnerability. This is followed by a discussion of the EAAS theory of change and impact pathway. The analytical methods and data in the study are then discussed, after which the results are reported. Finally, the paper closes with conclusions and policy implications.

2. Mali Vulnerability

The population in the Sahelian region experiences severe vulnerability due to dependence on rainfed agriculture coupled with unreliable precipitation and limited adaptive capacity. The Sahelian region – which covers 23% of the land area – receives between 250 and 550 mm annually and is characterized by a long dry season of 9–11 months, making rainfed agriculture difficult to sustain consistently under these conditions (Figure 1). Farther south and around Gao in the eastern areas experience moderate vulnerability, while the Sudanian and Sudano-Guinean zones experience only mild vulnerability as they receive more reliable rainfall. The Sudanian zone

[1]Google scholar search using keywords showed 1050 studies, but none of them are done using rigorous economic methods of impact assessment. The keywords used in the search are "farmer managed natural regeneration," "economic," and "impacts."

Figure 2
Trend of human development index in Mali, SSA, and its sub-regions



Notes: SSA = Sub-Saharan Africa

covers 18% of the land area and receives 550–1100 mm annually (De Sherbinin et al., 2015; Food and Agriculture Organization of the United Nations, 2019). The share of population residing in the Sahelian and Sudan-Guinean zones is, respectively, 27% and 68% (Institut National de la Statistique du Mali, 2009).

The northern region in the hyper-arid agroecological zone (Sahara Desert) accounts for about 51% of Mali's land area (Figure 1), but only 5% of the population is found in this zone. Communities in the Sahara Desert largely depend on livestock for livelihood. The annual precipitation in the Sahara zone is only 0–250 mm and unreliable.

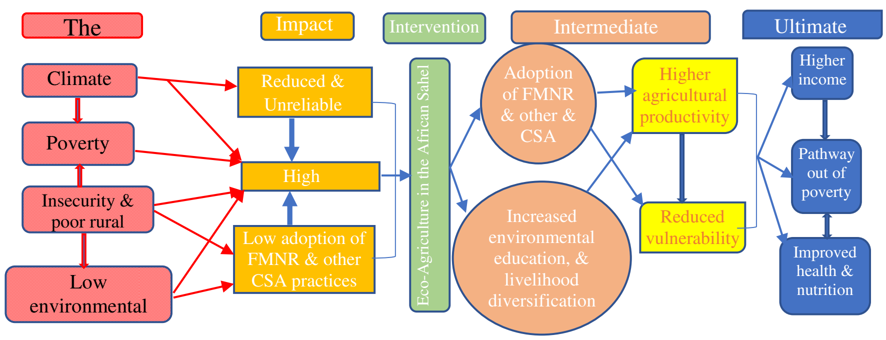
The biophysical vulnerability is compounded by poverty and weak institutions. Mali's human development index (HDI) has been lower than West Africa's regional HDI – which in turn is lower than other sub-Saharan African sub-regions as (Figure 2) (United Nations Development Programme, 2022) shows. These challenges are further compounded by increasing insecurity, which has affected the country since 2012 (United Nations International Children's Emergency Fund, 2021; World Bank, 2019). As a result of insecurity, about 201,400 were internally displaced in the first quarter of 2020 (World Food Program, 2020). Consequently, about 3.9 million – or 20% of Mali's population of 19 million (World Bank, 2019) – needed humanitarian assistance in the first quarter of 2020 (World Food Program, 2020).

These challenges increase the need for designing strategies that could help poor farmers to adapt to shocks and stressors. The next section discusses the theory of change and the impact pathway of a low-cost adaptation strategy implemented by World Vision (WV) in Mali.

3. EAAS Theory of Change and Impact Pathway

There are five levels along the impact pathway: problems, their impacts, interventions, and their intermediate and ultimate impacts (Figure 3). The major challenges which led to EAAS intervention include the high incidence of vulnerability discussed above. As discussed earlier, the high vulnerability is a result of climate change,

Figure 3
EAAS theory of change



poverty, insecurity, and poor rural services. There is also limited environmental education among policymakers and other government officials, leading to limited investment in agricultural development and environmental protection (Ardoin et al., 2020; Trewhella et al., 2005). These challenges compound poverty and vulnerability.

Our analysis will investigate the impacts of the EAAS intervention on the intermediate and ultimate impacts of EAAS interventions. Given that our analysis is based on household data, we will not analyze the impact of this intervention beyond the adoption of FMNR and CSA at the household level. For example, we will not analyze EAAS's impact of intervention on training and sensitizing communities on environmental protection principles and techniques at community and higher administrative levels.

4. Methodological Approach

EAAS placement was not random, and this presents challenges when identifying EAAS impact and making inferences on EAAS project attribution to changes in several welfare outcomes. To address non-random project placement, we used quasi-experimental statistical and econometric approaches to measure and address placement bias. The quasi-experimental approach used is matching methods (Smith & Todd, 2005), which selects the beneficiaries and non-beneficiaries who have comparable characteristics – which affect project participation and outcomes. Matching methods net out the effect of observable time-invariant drivers of project outcomes (Smith & Todd, 2005).

Matching methods are used to compute Heckman's difference-in-difference – which measures the impact of an intervention (Heckmann et al., 1997). To ensure the robustness of results, we used two types of matching methods:

(a) **Propensity score matching (PSM)** – which matches propensity scores to match program participants (EAAS beneficiaries) and non-participants (control group). Propensity scores are the estimated probability of being included in the project, which is calculated using a probit model. For small samples, PSM is the most used matching method. There are different PSM methods, but for brevity, we used the nearest neighbor (NN) matching method. The NN approach matches the pre-treatment characteristics of treatment and control groups and minimizes the distance (measured in terms of propensity scores) between treatment and control.

(b) **Covariate matching** – which matches program participants and non-participants using variables that determine participation in the program and impact on the outcome of interest (e.g., asset ownership). Examples of variables (covariates) that affect program participation include the level of education, the value of assets before EAAS project intervention, distance to market, etc.

For small samples, PSM is less efficient than covariate matching (Angrist & Hahn, 2004). Additionally, quasi-experimental design has the following disadvantages: (1) non-random placement of interventions makes control of confounding factors difficult and (2) the matching methods used to draw comparable treatment and control groups depend on observable characteristics. However, unobservable characteristics also determine participation in the program and impact on the outcomes under investigation. Econometric approaches – in which the treatment is one of the covariates – can address some of the quasi-experimental weaknesses as well as the selection bias. Given that treatment could have a non-zero correlation with other covariates, i.e., $corr(T, X_i) \neq 0$, where T = treatment and X_i is a vector of non-treatment covariates, we use two-stage weighted regression (2SWR) to address both selection bias and the bias due to $corr(T, X_i) \neq 0$. The 2SWR combines the matching method and regression to address both potential biases (Imbens & Wooldridge, 2009). In the first stage, the propensity scores are estimated and used as weights in the second-stage regression equation. The matching methods remove the selection bias while its weights purge the bias due to $corr(T, X_i) \neq 0$.

Using the 2SWR, the impact of EAAS is identified as follows:

$$\Delta y_i = \alpha + T\beta_1 + \beta_2 x_i + y_{it0} + \varepsilon_i. \quad (1)$$

where Δy_i = change in i^{th} outcome y (e.g., household income, asset endowment, dietary diversity, etc.).

T = treatment – i.e., participation in EAAS project.

y_{it0} = baseline level (time $t = 0$) of i^{th} outcome.

β_1 = coefficient associated with the treatment. The β_1 = coefficient identifies the impact of EAAS on outcome y_i.

x_i = vector of non-treatment covariates. Other variables are as defined above.

ε_i = error term, assumed to be normally distributed with zero covariance with covariates, i.e.,

$\varepsilon_i \sim N(0,1)$.

As indicated earlier, this study analyzes both the intermediate and ultimate impacts of EAAS on selected outcomes. All the intermediate and ultimate impacts are selected based on the EAAS interventions and expected impacts.

The intermediate impacts analyzed include:

(i) Adoption of CSA practices
(ii) Crop yield
(iii) Livestock production

The ultimate impacts of EAAS analyzed include:

(iv) Food and nutrition security
(v) Nutrition and health of children under 5 years
(vi) Poverty reduction
(vii) Household income
(viii) Productive asset creation (PAC)

To identify the impact of EAAS on food and nutrition security, the quantitative impact analysis focuses on the following outcomes:

(a) **Dietary diversity**: Studies have shown that dietary diversity is highly correlated with dietary quality and quantity (Hoddinott & Yohannes, 2002; Marshall et al., 2014). Additionally, dietary diversity is associated with other positive health outcomes including greater birth weight, child anthropometric status, hemoglobin concentration, reduced hypertension, cardiovascular disease, and cancer (Hoddinott & Yohannes, 2002; Ruel, 2003). Household Dietary Diversity Score (HDDS) is used to analyze dietary diversity. HDDS is the number of food groups that a household consumed in the last 7 days. HDDS is based on 12 food groups (1 = cereals; 2 = roots and tubers; 3 = vegetables; 4 = fruits; 5 = meat, poultry, offal; 6 = eggs; 7 = fish and seafood; 8 = pulses, legumes, nuts; 9 = milk and milk products; 10 = oil/fats; 11 = sugar/honey, and 12 = miscellaneous). Each food group receives a score of 1 if consumed. Thus, HDDS ranges from 0 to 12 (Swindale & Bilinsky, 2006)

(b) **Food consumption score (FCS)**: FCS combines dietary diversity and food frequency – weighted on nutritional density of consumed foods (World Food Program, 2008). Thus, FCS gives richer information than Household Dietary Diversity

Table 1
Food group weights and food consumption group thresholds

Food groups	Weight
Meat and fish	4.0
Milk	4.0
Pulses	3.0
main staples	2.0
Vegetables	1.0
Fruit	1.0
Sugar	0.5
Oil	0.5
Condiments	0.0
FCS groups	
FCS	Profiles
0–21	Poor
21.5–35	Borderline
> 35	Acceptable

Score (HDDS) since it considers the frequency of consumption and nutrition density (Table 1). FCS is divided into three groups using the thresholds shown in Table 1.

(c) **Food insecurity coping strategies**: Food coping strategies include dietary change, increase in short-term household food availability (e.g., borrowing food from neighbor/friend; consuming seed stock, etc), decrease in numbers of household members (e.g., by sending children to eat with neighbors), harvesting and eating immature crops, rationing, and other strategies. Respondents were asked to report food insecurity coping strategies in the past 30 days and the frequency each strategy was used. The more coping strategies used, the worse the food insecurity (Maxwell & Caldwell, 2008). The coping strategies were weighted by the frequency of their use: 1 = never, 2 = seldom (<1 day a week), 3 = once in a while (1–2 days a week), 4 = pretty often (3–6 days/week), and 5 = almost every day. Questions used to form the coping strategies are in Table A1 (World Food Program, 2020). The weights were summed up to make the coping strategy index (CSI).

EAAS's impact on child health is identified using World Health Organization indicators. The health indicators refer to children aged 0–59 months old. The child health indicators used are defined as follows:

Stunting – height-for-age. A child is stunted if height ≤−2 standard deviations (SD) of the WHO Child growth standards median.

Wasting (weight-for-height). A child is wasting if weight is ≤−2 SD of the WHO Child growth standards median.

Underweight (weight-for-age): A child is underweight if weight is ≤−2 SD of the WHO Child growth standards median.

Impact of EAAS on poverty reduction is identified using two major indicators:

(i) **Poverty probability index (PPI)**: PPI is used in this study to determine EAAS's contribution to reducing household poverty. Calculation of a PPI for each household used the Simple Poverty Scorecard® Poverty-Assessment Tool for Mali released in 2010 for both baseline and end-line measurements (Schreiner, 2010). PPI poverty scorecards are unique to each country and are based on analyses of 100 indicators of household endowment of human capital (education, number of children) and physical capital (type of housing and durable goods). Indicators are screened with the entropy-based "uncertainty coefficient" (Goodman & Kruskal, 1979) that measures how well an indicator predicts poverty on its own. Out of the 100 indicators, 10 indicators with a strong correlation with poverty are selected (Schreiner, 2010). Using logistic regression, the 10 indicators are given weights to generate a PPI score and the score for an individual household range from 0 to 100 (Desiere et al., 2015). For each household, the PPI score is used to find the estimated poverty likelihoods associated with that score – using "look-up" tables for different poverty lines (in the case of Mali for the 2010 scorecard, the poverty look-up tables included the National poverty line (Fcfa395 or 2005 US$1.53 per capita per day); food line (Fcfa271); and USAID "extreme" line (Fcfa228)).

(ii) **Probability of being below the poverty line**: A poverty line is a threshold that divides a population into two groups: below poverty if household or individual income is below the threshold and non-poor if income is above the threshold. The poverty threshold is commonly measured as per capita income per day. The national poverty line is a threshold that is established based on the country's specific economic and social circumstances. Specifically, the national poverty line reflects the level and composition of consumption or income needed to be non-poor. Due to this, the national poverty line cannot be used to compare poverty across nations. Instead, an international poverty line (IPL) is used. The IPL uses the purchasing power parities (PPPs) – which considers difference in prices of buying the same commodity/service across countries and converts different currencies into a common and comparable unit. In this study, we used the IPL of US$1.25PPP/day/capita, which was the extreme poverty line in 2005. We also doubled it to reflect the populations in the middle-income group.

(iii) **Impact on household income**: We measure impact of EEAS on household income using different sources of income – crops, livestock, and non-farm. We also analyze the EAAS impact on total household income.

(iv) **Impact on PAC**: The main objective of the PAC program is to enhance the resilience of beneficiaries to natural and human-induced shocks. PAC's main objective is to transform vulnerable households and communities from being dependent on emergency relief operations to self-sufficient and resilient households. EAAS program did not provide productive assets but provided training to beneficiaries acquiring productive assets when their income allows them to invest in PAC.

5. Sampling Strategy and Data

Power calculation was done to determine the optimal sample size required to statistically identify the impact or lack of impact of EAAS. Using secondary data collected by Haglund et al. (2011), the effect size – the expected impact of an intervention – of FMNR on household per capita income and value of crop production is, respectively, 37% and 57% (Table 2). This is comparable to other studies which have shown comparable impacts in the Sahelian region. For example, a study by Garrity et al. (2010) in Niger showed that FMNR increased agricultural income by $56/ha/year. This implies that with an average cropland area of 4.6 ha (RGA, 2005) and household agricultural income of US$743 per year (Save the Children, 2009), FMNR increases rural household agricultural income by 36%. Correcting for village level intra-cluster correlation of 0.2 and assuming power (the ability of a study to detect an impact) of 90% – and level of significance of 5%, the balanced sample size is 732 for the treatment group and additional 732 households for the control

Table 2
Power calculation based on income and value of crop production

	Treatment type	Gross income per capita (US$)	Value of crop production (US$)
FMNR adopters		147.95	122.57
Matched FMNR non-adopters		108.24	78.32
Effect size (%)		37%	57
Standard deviation (US$)	FMNR adopters	75	92.5
	FMNR non-adopters	60	65.4
Village intra-cluster correlation		0.2	0.2
Sample size using Haglund et al. (2011) data			
With zero attrition	FMNR adopters	732	815
	FMNR non-adopters	732	815
With 10% attrition	FMNR adopters	805	897
	FMNR non-adopters	805	897
Assuming 10% loss of unmatched sample	FMNR adopters	886	986
	FMNR non-adopters	886	986

group (Table 2). The control group households were located within the WVM area programs (APs) where the EAAS project was located and served as a comparator group for both treatments (EAAS I and II and EAAS II only).

Accounting for 10% attrition and 10% non-matching observation, the sample size increases to 886 households for each treatment and control group (Table 2). However, the actual attrition was 26% and much higher in Kolokani district (31%) (Table 3). The majority of attrition was due to the inability of district team leaders to locate households where lists did not include the full name of the head of the household. This occurred for 308 households, which could not be traced during the end-line survey. The problem was especially serious in the Kolokani district team – suggesting attrition in the sample was exogenously determined by the data team leaders and not endogenously determined by the farmers.

Table 3
Baseline and end-line sample size and attrition

		Treatment	Control	Total
Diema	Baseline	454	109	553
	End-line	362	99	471
	Attrition (%)	20.3	−10.1	14.8
Kolokani	Baseline	851	374	1225
	End-line	523	317	840
	Attrition (%)	38.5	15.2	31.4
Total	Attrition (%)	32.2	9.9	26.3

We analyzed the attrition to see if it is significant by comparing several baselines (2016) – outcome indicators of the attritors and non-attritors for the treatment households. Table 4 shows that the following statistics of attritors and non-attritors were not significantly different across several attributes: income, share of households below the poverty line, key household capital endowments, and anthropometric measurements (child weight and height for age). This suggests that despite high attrition, it did not create serious significant bias. However, our model addresses the attrition bias by including district fixed effects as a covariate in the parametric impact identification approach since the bias strongly correlated with the district.

Table 4
Comparison of baseline key statistics of attritors and non-attritors

Baseline statistic	Attritors	Non-Attritors	Test: *p*-value
Crop income (000 CFA)	207.75	289.51	0.353
Household income (000 CFA)	424.16	490.27	0.374
Poverty rates (based on US$1/day/capita poverty line) (%)	63.7	62.1	0.126
Poverty rates (based on US$2/day/capita poverty line) (%)	89.7	89.6	0.910
Farm size (ha)	8.4	8.2	0.633
% Received technical training in resilience building	56.9	54.0	0.278
Adoption rate of CSA (%)	29.9	29.6	0.931
Mean child weight (kg)	12.4	12.1	0.217
Mean child height (cm)	87.8	88.7	0.692
Mean weight for age Z-score	−1.24	−1.32	0.244
Mean height for age Z-score	−1.20	−1.24	0.664
Poverty probability index	18.8	19.6	0.226

6. Results

6.1. Participation of treatment and control groups in EAAS-related interventions

Comparison of participation in training at the end-line showed that a significantly higher share of EAAS beneficiaries participated in training on CSA, FMNR, Savings and Credit Cooperatives Society (SACCOs), dry season vegetable production, income generating activities, and having access to early warning information than the control group (Table 5). Additionally, a

Table 5
End-line household participation levels in eco-agricultural activities since 2014

Intervention	Control	Treatment	p-value
	Percent		
FMNR activities	32.8	75.4	0.000***
Training on CSA	25.0	51.1	0.000***
Participation in SACCOS groups	29.0	38.4	0.000***
Local value chain development activities	8.6	12.2	0.038**
Dry season vegetable production	18.0	31.2	0.000***
Income generating activity	12.6	23.7	0.000***
Early warning and action activities	8.2	12.3	0.018**
Participation in area development program (ADP) activities			
Household has sponsored child	24.8	24.3	0.914
Nutrition	18.4	23.0	0.043**
Water, Sanitation, and Hygiene (WASH)	23.6	29.0	0.030**
Health	21.6	25.5	0.052**
Youth vocational training	12.2	16.4	0.017**
Community-based disaster risk management	14.2	20.7	0.0026***

Notes: SACCOS = Savings and Credit Cooperatives Society

significantly higher share of EAAS beneficiaries participated in nutrition, health, and Water, Sanitation, and Hygiene training or activities than the control group households. Similarly, a higher share of EAAS beneficiaries participated in youth vocational and risk management training than the control group households. However, the differences are not as large in scale as is the case for participation in FMNR and CSA. These results show that the EAAS interventions and other WVM activities have had an impact as intended. The results form a good basis for attributing the impacts of the interventions to the outcomes, which will be analyzed in the sections below.

Both treatment and control households are located in WV APs with Child Sponsor funded programming, and about one in four sampled households had a WV-sponsored child (24.8% and 24.3%, respectively). The non-significant difference in the proportion of sponsored children was expected given that the program was not one of EAAS's interventions, i.e., EAAS beneficiaries were not targeted.

6.2. Impact of EAAS on adoption of FMNR and other CSA practices

Given the increasing frequency of drought in the Sahelian region (Spinoni et al., 2014), we asked households to report how they have responded to drought shocks. Table 6 shows the major actions taken by EAAS beneficiaries and control group households. Significantly higher share (72%) of EAAS beneficiaries than control group households (66%) took action against drought. Similarly, a significantly greater share of EAAS beneficiaries than control households diversified crop production and adopted zai (planting pits). The difference between the share of treatment and control group who took action against drought using other practices reported was either weakly significant or non-significant. The results are consistent with the higher participation of CSA advisory services or activities under the EAAS interventions (Table 5).

Table 6
Drought shock and response

Major actions taken to address drought	Treatment	control	p-value
	Percent reporting		
• Took action against Drought	71.7	65.7	0.021**
• Crop diversification	28.2	19.9	0.001***
• Crop rotation	22.6	25.6	0.227
• Increase fertilizer	19.0	15.7	0.063*
• Improved seed	12.2	12.0	0.916
• Apply compost	8.3	8.2	0.893
• Zai pits	4.5	2.4	0.053***
• SWC structures	6.1	6.0	0.942

On adoption of CSA practices, Table 7 shows EAAS significantly increased adoption of FMNR, improved seeds, and dry season irrigation. The impact of EAAS on Integrated Soil Fertility Management (ISFM) was weak as it was significant at $p = 0.100$. The results underscore the EAAS's successful promotion of the core CSA practice (FMNR), but weakness in other CSA that was not in its intervention activities. This highlights the EAAS's challenges in successfully promoting other CSA practices. This suggests the need to put more effort into promoting other CSA as a way of exploiting their synergistic attributes and enhancing returns to FMNR investments.

Table 7
Impact of EAAS on adoption of FMNR and other CSA practices

CSA	Treatment N = 852 Baseline	Treatment N = 852 End-line	Control N = 499 Baseline	Control N = 499 End-line	ATT (2SWR)
	Percent of households				
FMNR	13.4	54.8	10.2	35.4	16 ***
Agroforestry	6.1	5.1	3.2	4.2	−2
ISFM	64.9	66.8	73.5	69.3	6*
Fertilizers	62.0	60.4	69.7	58.9	9***
Improved seeds	27.3	49.4	35.4	35.4	22***
Rainy season irrigation	18.1	14.5	18.8	11.6	4
Dry season irrigation	18.5	23.4	24.6	22.8	7**
Manure	38.5	36.6	47.8	46.4	−3
SWC	1.6	1.9	1.8	4.2	−2*

Production of horticultural crops during the dry season has been shown to increase the dietary nutrition quality of the farmers and the communities in which they live (Passarelli et al., 2018; Domènech, 2015). Given that one of the EAAS II objectives was to develop and enhance farmers' on-farm water management systems, we analyzed its impact on dry-season horticultural crops. Despite EAAS's favorable impact on dry season irrigation (Table 7), Table 8 shows that EAAS's impact on dry season horticultural production is weak or negative. This suggests dry season irrigation could have been on non-horticultural crops. The results suggest the EAAS intervention needs to emphasize growing horticultural crops. This is a common problem in Sub-Saharan Africa where

Table 8
Impact of EAAS on production of horticultural crops during the dry season

	Propensity to grow horticultural crops		
Treatment	Baseline	End-line	2SWR
Control	0.204	0.192	–
Treatment	0.197	0.118	−0.045*
• Phase II	0.214	0.125	−0.043*
• Phase I and II	0.161	0.133	−0.024

the promotion of irrigation does not put emphasis on nutrition and health outcomes (Domènech, 2015).

Duration of adoption of agroforestry, FMNR, and other long-term land improvement investments increases their effectiveness and, consequently productivity. For example, nitrogen fixation of leguminous Acacia spp trees reaches maturity at the age of 5–6 years (Nitrogen Fixing Tree Association, 1989). Of the respondents who use FMNR, the average number of years since adoption for control group was 3.2 years, while for the treatment group, the average duration was only 2.3 years. This is not surprising. FMNR in the study areas is well known and linked with indigenous knowledge of agricultural and silvicultural practices common in the Sahelian region (Taylor, 2011). However, farmer perceptions or lack of knowledge often prevent the uptake of this beneficial practice. Given the significantly higher uptake of FMNR in the treatment group, the shorter duration of uptake of FMNR when compared to the control group is likely due to project targeting farmers who were not using FMNR.

Studies have shown that compared to a single practice, the combination of CSA practices has higher yields and profit (Zougmoré et al., 2005, 2016) and is more sustainable (Nkonya et al., 2020). This highlights the importance of interventions that include combinations of CSA practices that suit the local context. Based on the uptake of FMNR plus other CSA practices in the treatment group, it appears that there is much scope for improvement by EAAS (Table 9). About 8% of the control group who use FMNR apply it in combination with other CSA practices, while only about 4% of the treatment group do this. However, the combination of FMNR with fertilizer is much more promising and significantly higher in the treatment group, which reflects the project's focus on promoting fertilizer use for increased crop production. Achieving increased uptake of FMNR along with other beneficial CSA practices and fertilizer use should be fundamental to program designs moving forward.

6.3. Impact of EAAS on crop yield and livestock productivity

Adoption of improved land management practices is an intermediate impact and is expected to lead to higher crop and livestock productivity. We analyzed the impact of EAAS on the yield of major crops and livestock productivity. As expected and consistent with the favorable EAAS impact on adoption of CSA practices, EAAS significantly increased the yield of sorghum, maize, and groundnuts of beneficiary households in general (Table 10).

Table 10
Impact of EAAS on yield of major crops

Crop/Treatment	Sample	Baseline	End-line	2SWR (log yield) Impact 2SWR (Ln(yield)
		Yield (tons/ha		
Sorghum				
• Control	194	0.14	0.12	
• Treatment	442	0.13	0.16	0.797***
• EAAS II	227	0.13	0.13	0.05
• EAAS I&II	205	0.12	0.18	1.107***
Maize				
• Control	127	0.16	0.21	
• Treatment	256	0.27	0.40	1.168***
• EAAS II	170	0.11	0.42	1.190**
• EAAS I&II	87	0.53	0.39	0.905
Groundnuts				
• Control	104	0.09	0.18	
• Treatment	179	0.14	0.36	0.954**
• EAAS II	99	0.12	0.40	1.184***
• EAAS I&II	80	0.16	0.19	0.985

When the baseline was done, about half of the households in the control and treatment groups owned one or more livestock types (including cattle, sheep, and donkey). By the end-line measurement, these proportions had risen to approximately 74% in both control and treatment groups (Table 11). Livestock contributes approximately 7% to total household income according to end-line results as Figure 4 shows (Endline Survey, 2018). Average income from livestock production fell for both control and treatment households between baseline and end-line

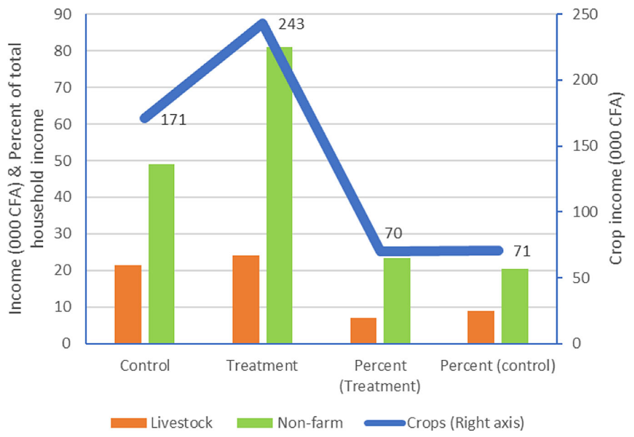
Table 9
Duration and combination of adoption of FMNR with other CSA practices

	EAAS II	EAAS I and II	Treatment	Control	*p*-value
	Duration of adoption (years)				
• FMNR only	2.25	2.33	2.3	3.2	0.053**
• FMNR + fertilizer	2.85	2.76	2.8	2.4	0.731
• FMNR + CSA	3.0	4.1	3.6	3.2	0.608
• FMNR + fertilizer + CSA	2.71	2.95	2.8	2.5	0.686
• All FMNR	2.7	3.00	2.7	2.5	0.783
Combination of FMNR with other CSA practices			Percent		
• FMNR + CSA			4.3	8.4	0.006***
• FMNR + Fertilizer			41.0	27.3	0.000***
• FMNR + CSA + Fertilizer			5.9	8.1	0.176

Table 11
Livestock ownership (baseline and end-line) and type owned (end-line)

	Baseline	End-line
	Percent owning livestock	
Control	53.1	73.9
Treatment	50.5	73.7
• EAAS II	47.9	77.8
• EAAS I&II	51.6	68.0
Type of livestock owned (end-line)		
Percent of households with:	Control	Treatment
• Improved dairy cows	1.2	1.9
• Sheep	45.6	40.2
• Donkeys	39.2	36.9

Figure 4
Contribution to household income



(Table 12). The reason behind the fall in livestock income is not clear. The magnitude of the reduction for the treatment group was slightly lower than that for the control group. This suggests that participation in the project provided some benefit in terms of reduced losses associated with livestock production over the same period (Table 12).

Table 12
Impacts of EAAS on livestock production

Treatment	Baseline	End-line	EAAS Impact ATT (2SWR)	Percent
	Livestock production (000 CFA/household)			
Control	9.77	4.40		
Treatment	19.58	9.74	5.514**	28
EAAS II	16.33	6.70	3.54	22
EAAS I and II	20.05	11.51	7.20**	36

Likewise, EAAS increased sorghum yield for beneficiaries who participated in both phases, EAAS I and II. However, for maize and groundnuts, EAAS had a significant impact on households who participated in EAAS II only and did not have an impact on those who participated in both phases. The reason behind such results is not clear. However, one possible reason could be the small number of EAAS I and II who planted maize (87) compared to 170 for EAAS II households. The same reason could explain the non-significant impact of EAAS on groundnut yield for EAAS I and II beneficiaries (Table 11).

6.4. Impacts of EAAS on household food and nutrition security and poverty reduction

Overall, EAAS beneficiary food insecurity fell by about 50% (Table 13). The reason for the big change (50%) in food security is due to control group having worsening food security, while the treatment household's food security improved. The months of food insecurity decreased from about 8 to 4 months (Table 14). However, reduction of food insecurity attributable to EAAS II and EAAS I and II was, respectively, 12% and 16%. The control households also significantly reduced months of food insecurity, suggesting other factors contributed to the reduction of food insecurity for EAAS beneficiaries. As expected, the EAAS beneficiaries who participated in both EAAS I and II experienced the largest reduction in CSI – suggesting that there was a cumulative impact.

Table 13
Impacts of EAAS on household food insecurity (food insecurity coping strategy index)

	Baseline	End-line	ATT (2SWR)	Percent change[1]
	Coping strategy index (CSI)			
Control	2.88	3.39		
Treatment	2.56	2.31	−1.295***	−50
EAAS II	2.31	2.30	−1.323***	−57
EAAS I and II	2.71	1.82	−1.702***	−64

[1]Percent change $=\frac{ATT}{y_b}*100$, where y_b = baseline value of outcome

Table 14
Months of food insecurity in the baseline and end-line periods

	Baseline	End-line	ATT (2SWR)	Impact (% change)[1]
	Months of food insecurity			
Control	7.8	4.4		
Treatment	8.5	4.3	−1.07***	13
• EAAS II	8.6	4.0	−1.36***	16
• EAAS I and II	8.6	4.5	−1.04***	12

[1]Percent change $=\frac{ATT}{y_b}*100$, where y_b = baseline value of outcome

However, care needs to be taken in interpreting the results, given that in some cases, the treatment households did not do well compared to the control households. For example, despite reporting significantly higher participation by the treatment group in nutrition and health training (Table 5), the impacts of EAAS on nutrition quality – measured as HDDS – was non-significant and significantly negative for beneficiaries who participated in EAAS II only (Table 15). The

Table 15
Impacts of EAAS on household dietary diversity score (HDDS)

	Baseline	End-line	ATT (2SWR)	Change (%)
	Household dietary diversity			
Control	5.706	6.545		
Treatment	6.065	6.444	−0.013	
• EAAS II	6.034	6.215	−0.819***	−14
• EAAS I and II	6.161	6.902	−0.216	

Note: Percent change $=\frac{ATT}{y_b}*100$, where y_b = Baseline value of outcome Only ATT significant at least at $p = 0.05$ is used to compute percent change

control group showed greater HDDS improvement, but its baseline value was lower than that of treatment households (Table 13).

HDDS in the end-line period was very similar for both control and treatment households. Similarly, control households had borderline FCS in the baseline but had significantly (at $p = 0.05$) higher FCS in 2018 (Table 16). The treatment households were in the acceptable FCS group in baseline and end-line periods. Despite relatively higher HDDS and FCS, there is a need to consider nutrition education in future interventions to enhance impacts. Studies have shown that a multi-pronged approach reduces poverty faster and is more cost-effective than interventions that address only one or fewer problems (Friedrich, 2015; United Nations Development Programme, 2019). For example, the provision of nutrition education could have been included in the EAAS by ensuring that simple messages on nutrition are given to beneficiaries – either through radio or other cheap advisory services.

Adoption of FMNR, promotion of savings groups (SGs), and development of local value chains are likely to increase household income, reducing poverty. Using PPI, Table 17 shows EAAS had a significant impact on the reduction of household poverty. The average PPI score in both groups increased significantly between baseline and end-line measurements, signaling a reduction in the likelihood that households are living in poverty. The magnitude of the improvement was strongest for EAAS households who participated in both phases of the project. These results further demonstrate that long-term engagement with beneficiaries has greater impacts than short-term engagement. This is expected since poverty reduction is a long-term process and requires long-term engagement.

The probability of beneficiary households being below the US $1.25/day/capita poverty line fell by 3.5 percentage points or 6% of its baseline share of about 61% (Table 17). However, when the poverty line is raised to US$2.50/day/capita, participation in EAAS reduces the probability of being below the poverty line by only about 3 percentage points. As expected, the level of poverty reduction for beneficiaries who participated in EAAS I and II at a

Table 17
Impacts of EAAS on household poverty reduction

	Baseline	End-line	ATT (2SWR)	Change (%)[1]
	Progress out of poverty probability index (PPI)			
Control	18.45	30.86		
Treatment	20.33	33.42	2.330***	12
• EAAS II	20.00	33.08	2.114***	11
• EAAS I&II	20.92	33.73	2.185***	21
Probability of being below the poverty line (US$1.25/day/capita)				
Control	64.13	44.7		
Treatment	60.96	40.65	−3.457***	−6.0
• EAAS II	61.13	41.38	−3.102**	−5.1
• EAAS I&II	60.21	39.72	−3.590**	−6.0
Probability of being below the poverty line (US$2.50/day/capita)				
Control	90.8	82.8		
Treatment	89.0	79.6	−2.9***	−3.3
• EAAS II	89.0	80.2	−2.6**	−2.9
• EAAS I & II	88.0	79.6	−2.4**	−2.7

[1]Percent change $=\frac{ATT}{y_b}*100$, where y_b = baseline value of outcome

US$1.25/day/capita poverty line was higher than for beneficiary households who participated in only EAAS II but comparable when the US$2.50/day/capita poverty line is considered (Table 17).

6.5. Impact of EAAS on household income

The major income sources for all households at the end-line – with percent contribution to total household income in brackets – include cropping (71%), non-farm income (22%), and livestock (7%). Non-farm income increased for all groups during the study period, but EAAS did not have a significant impact on non-farm income (Table 18). However, beneficiaries who participated in both EAAS I and II showed a weak impact on income gains, which was significant at $p = 0.10$. The EAAS II interventions with direct impact on non-farm activities include SGs and value chain and smallholder farmer agribusiness systems development. EAAS I did not have any intervention directly affecting non-farm activities. This could be the reason for the weak impact of EAAS on non-farm activities. Additionally, the share of farmers who engaged in non-farm activities was only 14%. The small percentage of farmers engaged in non-farm activities could have contributed to EAAS's weak impact on non-farm income. For example, even though non-farm income increased by 74%, it is non-significant at $p = 0.05$ due to a small sample problem, which leads to a large standard error. Livelihood diversification is an important strategy for building resilience against shocks, and

Table 16
Impact of EAAS on food consumption score (FCS)

	Baseline		End-line		Impact of EAAS	
	FCS	FCS status	FCS	Status	2SWR (ATT)	Percent
Control	32.2	Borderline	59.9	Acceptable		
Treatment	35.2	Acceptable	53.9	Acceptable	−4.81**	−14
• EAAS II	36.9	Acceptable	56.7	Acceptable	−3.76	10
• EAAS I and II	33.1	Borderline	53.0	Acceptable	−5.18**	16

Table 18
EAAS impact on major sources of household income

	Baseline	End-line	EAAS impact ATT (2SWR)	Impact (Percent)[1]
Non-farm	(000 CFA/ Household)			
Control	28.80	48.26		
Treatment	43.63	91.05	32.21	74
• EAAS II	47.44	86.78	13.22	28
• EAAS I&II	35.73	98.20	45.84*	128
Livestock				
Control	15.14	22.33		
Treatment	25.02	15.51	2.41	10
• EAAS II	23.57	18.63	8.91	38
• EAAS I&II	18.19	11.82	−3.18	−17
Crops				
Control	102.76	177.59		
Treatment	134.15	253.22	80.82***	60
• EAAS II	116.22	253.84	68.97*	59
• EAAS I&II	153.25	252.79	85.72**	56
Household income				
Control	146.69	248.19		
Treatment	202.80	359.78	103.23***	51
• EAAS II	187.23	359.24	83.94**	45
• EAAS I&II	207.17	362.81	115.82***	56

[1]Percent change $=\frac{ATT}{y_b}*100$, where y_b = baseline value of outcome

Table 19
EAAS II impact of EAAS across type of productive assets

	Control	Treatment	ATT (2SWR)
Livestock value	13.22	33.12	53.26***
Productive assets	136.49	100.38	9.93
Processing assets	10.44	13.58	18.85
Transportation asset	271.64	235.82	8.04
Total value of assets	356.86	361.86	69.47*

Table 20
Impact of EAAS II and EAAS I and II on total productive assets

	Baseline (CFA 000)	End-line (CFA 000)	ATT (2SWR)	Impact (% change)
Control	352.00	356.23		
Treatment	266.68	361.86	69.47	26*
• EAAS II	285.00	365.00	56.28	20
• EAAS I & II	268.33	372.00	56.28	35*

non-farm activities need to be prioritized in programs for enhancing resilience for communities with high vulnerability.

As expected EAAS's impact on crop income was the largest, this is consistent with the high participation in the EAAS interventions related to crop production (Table 5) and favorable impacts on adoption of CSA practices, especially FMNR, improved seeds, and fertilizer (Table 7). EAAS's impact on crop income is the greatest – as it increased it by 60% (Table 18).

The crop income of EAAS I and II beneficiaries increased by 56% compared to 59% for EAAS II beneficiaries. However, the EAAS I and II was more significant (at $p = 0.05$) than the case for EAAS II ($p = 0.10$). This suggests that even though the increase in income due to participation in EAAS II is slightly higher, it is less reliable than the impact of EAAS I and II.

EAAS had a non-significant impact on livestock productivity. This could also be due to the small sample of farmers who reported livestock income (14%). EAAS increased household income by 51% and by 56% for those who participated in both phases I and II (Table 18).

A comparison of the change in income of the Malian population and EAAS beneficiaries could shed more light on the impact of the project. Mali's agricultural GDP grew by only 5% from 2010, constant US$4607.19 to US$4828.34 million (World Bank, 2019). This means the rate of growth of EAAS beneficiaries' household income increased by about 10 times faster than the national-level agricultural GDP growth.

6.6. Impact of EAAS on productive asset creation

Analysis of the value of productive assets in 2018 (end-line measurement) shows that EAAS beneficiaries had significantly (at $p = 0.01$) higher value of livestock assets than control households (Table 19). However, EAAS did not have a significant impact (at $p = 0.10$) on the value of productive, processing, and transport assets. Similarly, EAAS had a weak impact on the total value of assets (significant at $p = 0.10$). The weak impact of EAAS on the total value of assets is not surprising, given that PAC has a lagged impact for any intervention (Morrow et al., 2018). This is illustrated by the slightly higher impact of the total value of assets (35% and significant at $p = 0.10$) for households who participated in both EAAS I and II than those who participated in only EAAS II – in which EAAS impact was only 20% and non-significant (Table 20).

6.7. Impact of EAAS project on 2018 child health

Prevalence of stunting among the control and treatment households was about 20% – which is lower than the national average of 30.5% in 2015 (Table 21). This could be due to the decrease in stunting in Mali, which fell from 30.5% in 2015 to 27% in 2018 (World Bank, 2020). Participation in EAAS is associated with a 3% reduction in child stunting, but the impact is weak ($p = 0.10$) (Table 21). However, children of beneficiary households who participated in both EAAS I and II experienced a greater reduction (5%) in child stunting, and the impact was significant at $p = 0.01$. The results illustrate further that longer-term engagement leads to significant impacts on outcomes, which change slowly. Child wasting of beneficiary households who participated in both EAAS I and II significantly (at $p = 0.05$) decreased by 4% – possibly suggesting that the increased agricultural productivity translated to better diets for children and their mothers. The rates of wasting among treatment and control groups are comparable to the national average. Similarly, EAAS significantly reduced children underweight (weight-for-age) by 6%. Beneficiaries of EAAS I and II experienced a much higher reduction of child underweight (11%) as Table 21 (World Health Organization, 2019; 2018) shows.

Table 21
EAAS impacts on child health, 2018

Child health	Percent of children	Percentage point difference	EAAS Impact ATT (2SWR)
Stunting			
National average	30.4		
Control	21		
Treatment	18	3	−0.031*
• EAAS II	19	2	−0.019
• EAAS I and II	16	5	−0.055***
Wasting (weight-for-height)			
National average	13.5		
Control	14		
Treatment	13	1	−0.006
• EAAS II	14	0	0.009
• EAAS I and II	11	3	−0.041**
Underweight (weight-for-age)			
National average	25.0		
Control	30		
Treatment	28	2	−0.061***
• EAAS II	29	2	−0.032
• EAAS I and II	24	6	−0.111***

Notes: ATT is calculated using proportions and is reported as proportions. Multiplying a proportion with 100 gives the percent used in the report Definitions (according to World Health Organization, 2018) – all referring to under 5-year-old children (U5) and WHO child growth standards:
Wasting – Moderate and severe: Percentage of U5 who are below minus two standard deviations (SD) from median weight-for-height
Stunting – Moderate and severe: Percentage of U5 who are below minus two standard deviations from median height-for-age
Underweight – Moderate and severe: Percentage of U5 who are below minus two standard deviations from median weight-for-age
Note, anthropometric indicators are averages of 2015

7. Conclusions and Policy Implications

Communities living in the Sahelian region heavily depend on natural resources, and climate change and other recent changes have increased volatility and vulnerability. The Malian government has designed a number of policies and strategies to help build resilience, reduce poverty, and enhance the well-being of its population – especially children, women, and other vulnerable groups. The major framework for achieving this is the climate change policy Vision 2025 – which aims to achieve a sustainable socio-economic development framework by enhancing adaptation to climate change.

To implement adaptation and resilience-building efforts, empirical evidence is required to provide successful and cost-effective interventions for building smallholder farmer-enhanced resilience, food and nutrition security, improving child health and nutrition, and reducing poverty. The EAAS provides a good example for designing and implementing cost-effective strategies for enhancing resilience against climate and other shocks and eventually improving livelihoods. This study shows that EAAS significantly increased the adoption of FMNR and other key CSA and eventually yield major crops. These intermediate impacts were translated into a significant reduction in food insecurity and an increase in household income. Likewise, EAAS significantly reduced under 5-year child stunting, wasting, and malnourishment. These favorable outcomes are central to achieving WV's overarching objectives of its child-centered mission. The EAAS impact on child health was especially greater for farmers who participated in both EAAS phase I and II – underscoring the importance of long-term engagement in building resilience.

This research used impact identification approaches that allow strong attribution to WV interventions' impact on key outcomes. Even though the WV intervention was short-term and its coverage limited, the results suggest that the EAAS's favorable outcomes provide key empirical evidence, which the government could use to enhance resilience and adaptation to climate change. What is most important is WV's grass-root engagement and modest operational costs – which have achieved big results in its 5-year operation (2013–18). WV and other NGOs and community-based organizations with a track record of achieving big impacts in building resilience and improving incomes and child well-being need to be used by the Malian government and its development partners to implement long-term policies and strategies. Thus, a stronger collaboration between WV and the government needs to be translated into funded long-term contracts designed to implement government programs in which WV has demonstrated a comparative advantage. Development partners could also use the same approach to ensure that they exploit WV's track record of building resilience, restoration of livelihoods, and improving child health. Consistent with the results of this study, in which impacts were more significant for households who participated in EAAS I and II, the long-term contracts with government and development partners will ensure greater impacts and more cost-effective achievement of the government objectives.

There are areas in which WV did not do well and needs to be improved to realize even greater impacts and exploit synergies of investments. WV interventions focused on FMNR with limited focus on other complementary CSA practices. Consequently, the adoption of FMNR in combination with other CSA practices was weak. A combination of CSA needs to be emphasized to enhance returns to farmer investments. The impact of WV on non-farm income was also not significant. One of the reasons for the result is that there was no direct intervention aimed at promoting non-farm activities. Non-farm activities are important strategies for diversifying rural incomes. This suggests the need to emphasize investments in promoting non-farm activities to help farmers diversify their livelihoods. Increased efforts in this area are needed without moving out of the EAAS mandate since one of the EAAS II objectives is to enhance "value chain and smallholder farmer agribusiness systems development." This means the budget for investing in the promotion of agribusiness needs to be increased in future projects.

Despite the large role which livestock plays in the Malian rural population, EAAS's impacts on livestock income were not significant. Increasing livestock productivity enhances a host of benefits – including household nutrition, soil fertility, income, and serving as a live "bank" for the rural poor. There is a need to put greater emphasis on enhancing livestock productivity in WV programs.

For CSA practices, which are outside the WV mandate or comparative advantage, EAAS could establish partnerships with other providers. For early warning and information systems, Agrhymet, whose mandate is to "inform and train on Sahelian food security, desertification control, and water control & management," could be invited to collaborate with WV. Getting information from the institute and disseminating it to farmers could help in achieving this objective.

On risk management, there is a challenge from both supply and demand of insurance services. Achieving high acceptability of Weather-Index Insurance (WII) and Index-Based Insurance (IBLI) is just the first step. The other challenge is to commercialize WII and IBLI using private businesses as providers. Smallholder farmers have not used insurance before, and their premiums are high – thus out of reach to the majority of the poor farmers who are more vulnerable and thus need them the most. Providers of IBLI and WII are also wary of doing business with poor farmers due to fear of default and the high transaction costs of dealing with sparsely distributed clients in remote rural areas. In the short term, EAAS could focus on enhancing traditional risk insurance approaches such as increasing the livestock number and, most importantly, productivity and resilience against hydrological shocks. In the long-term, EAAS can promote IBLI and WII by serving as a WII and IBLI aggregator and guarantor – an approach that made Grameen Bank very successful.

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data sharing not applicable – no new data generated.

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Appendix

Table A1
Coping strategy weights

Due to a shortage of food and income, how many days in the last 30 days did			
Coping strategy	Number of days	Severity weight	Frequency X weight
Reducing quantity of food	20	1	20
Collecting wild vegetables (spinach)	30	2	60
Eating twice a day	15	3	45
Mother skips a meal/eats less for children	15	4	60
Reducing quality of food	0	5	0
Taking money from savings	3	6	18
Taking food loan	0	7	0
Selling hens and ducks	1	8	8
Eating rice with salt and/or chilies	10	9	90
Eating once a day	5	10	50
Selling goats and sheep	1	11	11
Taking money loan with interest to buy food	0	12	0
Total CSI			362