FARA Research Report

FRR Vol 7(32):408-422

Disseminating and Scaling up Climate-Smart Agriculture Adoption Through Participatory Action Research: Lessons from the Agriculture Centre of Excellence Methodology

Angeline Mujeyi [1*], Farai Dube[1] , Martin Philani Moyo[1], Melesse Mequanint[1] , Ronald Veremu[2], Daniel Chawatama[2] & Kumbirai Nhongo [2] , Tawanda Hove[2]

[1]*International Crop Research Institute for Semi-arid Tropics, A.Mujeyi@cgiar.org; F. Dube@ Cgiar.org; M.Moyo@cgiar.org; M.Melesse@cgiar.org*

[2] *Welthungerhilfe, Block 8 Arundel Office Park, Harare, Zimbabwe Ronald.Veremu@welthungerhilfe.de; Daniel.Chawatama@welthungerhilfe.de; Kumbirai.Nhongo@welthungerhilfe.de*

**Correspondence: A.Mujeyi@cgiar.org; +263773199804*

Citation: Mujeyi A, Dube F, Philani M.M, Mequanint M,Veremu R, Chawatama D, Nhongo K, and Hove T. (2023) Disseminating and Scaling up Climate-Smart Agriculture adoption through participatory action research: Lessons from the Agriculture Centre of Excellence Methodology. FARA Research Report *Vol 7(32):408-422*. https://doi.org/10.59101/frr072332

Abstract

Climate Change and variability have negatively affected agriculture productivity and effects differ from one location to the other. The Zimbabwe Agriculture Knowledge and Innovation Project (ZAKIS) deployed participatory action research through the Agricultural Centres of Excellence (ACEs) to facilitate the adoption of climate-smart agriculture (CSA) technologies by diverse farmers in the contrasting dryland and sub-humid agro-ecological regions of the country. A basket of eight CSA technologies was disseminated through CSA demonstrations in the initial season and farmers then chose and adopted their preferences in the subsequent seasons. This study examines the effectiveness of the ACE model in the diffusion and adoption of CSA technologies. A cross-sectional survey of 402 households, 16 community focus group discussions, and over 30 key informant interviews in four districts of Zimbabwe was done to gather evidence. Data were analysed using SWOT analysis and the negative binomial regression model. Findings show that over 60% of the farmers are aware of the ACES and over 40% have visited the ACEs for services such as training or exchange visits and field days. More than 70% highlighted that the ACE showcased CSA technologies and indicated that they had high satisfaction levels with the training provided and had the opportunity for hands-on practice and feedback from researchers and extensionists. Farmers however highlighted the limited availability of regular trainings, longer distances to ACEs, and limited market linkages. The analysis on adoption showed that adoption of climate CSA technologies for livestock value chains are still very low at less than 30% of the households showing use of fodder production (15%), breed smart technologies (Artificial Insemination 6%) and improved livestock management practices (28%). Adoption of CSA is highest for conservation agriculture and increasing for in-field water harvesting (32%) and diversification (49%) where farmers are embracing the adoption of various drought-tolerant crops and varieties in view of climate change and variability. Adoption intensity was significantly affected by participation in CSA demonstrations, experience in livestock marketing, distance to all-weather roads, livestock ownership and ownership of smartphones. Results show that access to demonstration plots under the ACE model increase the probability of CSA adoption. To strengthen market-oriented and demand-driven action-oriented research, ACEs need to involve farmers to have clear regular training plans, link farmers to markets, and continuously identify needs.

Keywords: Technology adoption; Climate-smart agriculture technologies; Adoption intensity; impact; Agriculture Centre of Excellence

1. Introduction

Southern Africa is facing numerous challenges and chief among them is climate change and variability, particularly in farming communities who that rely on rain-fed agriculture for both their food security and livelihoods. This has seen the region experiencing declining agriculture productivity due to erratic rainfall patterns, rising temperatures and increased frequency and severity of extreme weather conditions (Radeny et al. 2022; Steiner 2019; Serdeczny et al. 2016). Empirical models predict further losses of major crops due to climate change at 17% (wheat), 5% (maize), 15% (sorghum) and 10% (millet) (Vlek, Terry, and Sikora 2019; Serdeczny et al. 2016). Governments and development organisations have therefore disseminated and promoted Climate-smart agriculture (CSA)to help overcome these challenges using various approaches (Mujeyi, Mudhara, and Mutenje 2021; Ngomi et al. 2020). CSA refers to an approach that sustainably increases productivity, enhances resilience (adaptation), reduces GHGs (mitigation) where possible, and enhances achievement of food security and development goals (Palombi and Sessa 2013). Despite the proven potential benefits of CSA by researchers on station and on-farm, adoption is generally low in SSA with very low rates as 10% reported for technologies like cereal-legume rotation, minimum tillage and soil water conservation while some technologies such as improved maize varieties have been adopted at scale in some countries even going over 60% (Kurgat 2020). The low adoption of CSA technologies has been linked to socioeconomic factors, farm and farmer characteristics, institutional characteristics , access to resources, access to agricultural and climate information services (Andati et al. 2022; Negera et al. 2022). The empirical literature on the adoption and impact of CSA technologies point to scaling models as playing a key role in reaching out to farmers (Kirina et al. 2022; Ogunyiola, Gardezi, and Vij 2022). Some researchers have advocated for location specific community based and needs driven approaches in promoting CSA (John et al. 2021). Zimbabwe Agriculture Knowledge and Innovation Services (ZAKIS) Project adopted the Agricultural Centres of Excellence (ACEs) model approach to coordinate market-oriented, demand-driven research, education, and extension as replicable proof-of-concept models. Researchers, educationists, and extensionists working with key value chain stakeholders such as farmers and private sector collaborated to test various crop and livestock CSA technologies and stimulate adoption. Evidence on the effectiveness and impact of the ACE model is not available in Zimbabwe. This study examines the role of the ACE approach in promoting the adoption of CSA technologies through answering the following questions:

i. What is the role and effectiveness of the ACE model in CSA technology dissemination?

ii. What are the current CSA adoption levels for technologies promoted through the ACE model and which factors affect the intensity of adoption?

This paper shares experiences, results and insights from the ACE model. The findings of this study can inform policymakers and rural development practitioners in strategically planning to scale up successful CSA practices. Building on collaborating, Learning, and Adapting during the implementation of the project, this paper provides practical elements to guide thinking and planning around scaling up and mapping pathways for taking CSA to scale.

The ACE Model

The agricultural knowledge and information systems promotes an interactive model of networking systems, which integrate knowledge production, adaptation, advice and education (Sutherland 2021). It recognises that farmers empowered with knowledge on technologies through engagement with research, extension, agriculture education services and value chain actors .The project set up two Agricultural Centres of Excellence (ACEs) located at Chibero College of Agriculture in the sub-humid and Matopos Research Institute in the drylands to enable farmer to access CSA technologies through interactions with food system actors in order to improve their livelihoods. These flagship centres are each mirrored by smaller District Agricultural Centres of Excellence (DACEs) located in Insiza, Matobo, Chegutu, and Mhondoro Ngezi districts to bring activities closer to the farmers (figure 1).

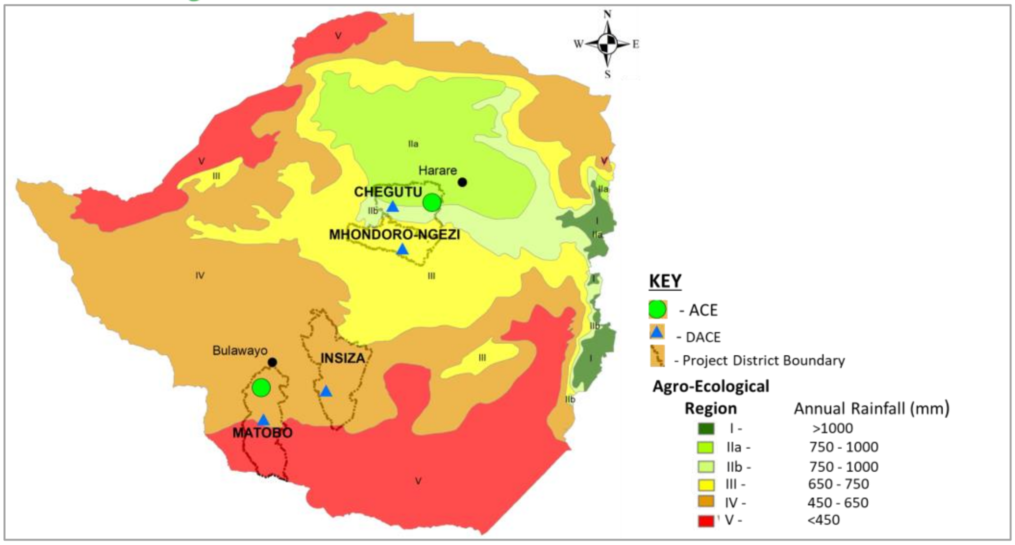

Figure 1: Map of Zimbabwe showing Natural agroecological regions, project districts, ACEs and DACEs

The activities at DACECs are further cascaded down to farmers through CSA demonstrations at Lead model farmers. Ward information centres (WICs) are also set up within wards with laptops and free wifi from which farmers can watch podcasts on CSA technologies and download fact sheets, brochures and manuals from the established online library ZimAgrihub. Private sector ranging from seed houses, agro chemical and fertiliser manufactures, livestock feed companies to crop and livestock buyers participate through demonstrations and product development trials at the ACEs (figure 2).

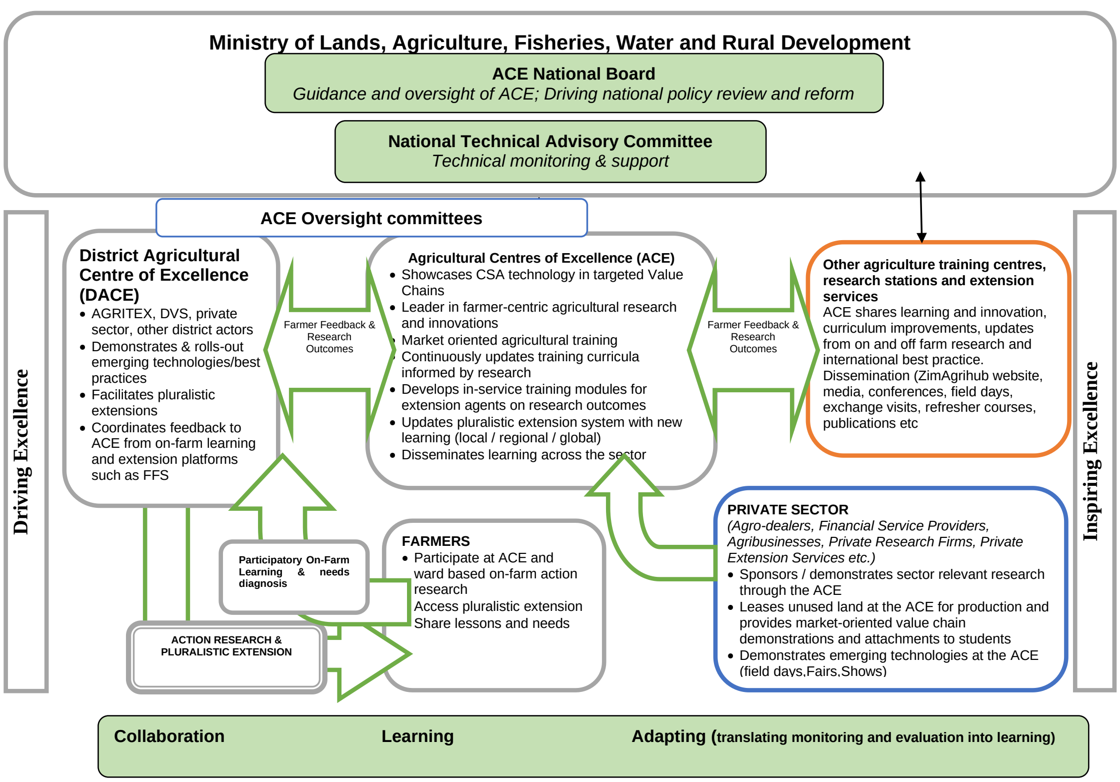

Figure 2: The ACE model

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Participatory action research (Figure 3) is done at all these sites to demonstrate climate sensitive and market-focused best practices in crop and livestock production. The centres are used for farmer training and the private sector partners are able to demonstrate their best practice for optimum results as they market their products and immediately establish relationships with the participating farmers and beyond. The private sector players anticipate that the farmers will be better informed and are therefore likely to procure inputs from suppliers they have a relationship with. The ACE benefits from the free private sector inputs and at harvest, all grain/ produce from trials and demonstrations are freely donated to ACEs for use in supplementing income used to fund any trainings or localised research with farmers. Agriculture students also participate at ACEs through hands-on on practical, internship and research.

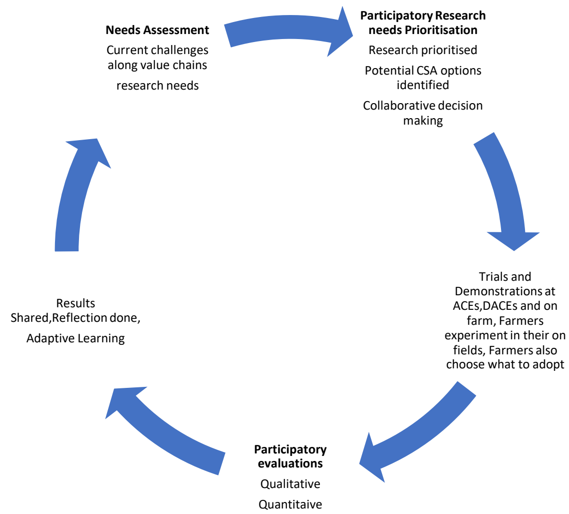

Figure 3: Participatory Action research under the ACE model

2. Methodology

2.1. Research Design, Study site, Sampling

Zimbabwe has endured various natural hazards including decrease in annual precipitation leading to droughts in some years, late onset and early season cessation of the rainy season and an increase in mean annual temperature of about 0.03°C/year from 1970 to 2016, floods and storms which have put stress on the agriculture sector (World Bank 2021). From 1900 to 2017, the country encountered 7 drought events, 22 epidemic episodes, 12 floods, and 5 storms, which resulted in total deaths of roughly 7000 people, with more than 20 million people affected, and total damage of $950 million USD and farmers have seriously been affected by these climate change induced stressors (World Bank 2021). The analysis of this paper is based on a comprehensive cross sectional household survey carried out in 2021/22 in the integrated crop (cereal–legume) livestock farming systems of Zimbabwe. The empirical data comes from the farming households residing the project districts where the technologies have been disseminated through the ACE model.

A total of 402 households from 4 districts (2 in the sub-humid and 2 in the drylands) were interviewed. Three intervention wards and one non-beneficiary ward in each district were randomly selected. These data were collected by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) in collaboration with project partners (WHH, CTDO, SAT) and the Ministry of Lands, Agriculture, Fisheries, Water and Rural Development. Three villages and households were randomly selected from the ward lists supplied by the extension and village heads. The project target was to have farmers adopt at least three CSA technologies in the short run.

2.2 Data Analysis

Descriptive statistics such as mean, standard deviation, percentages, and graphs were used. Furthermore, test statistics such as t-test for continuous variables and chi-square ($\chi 2$) test for dummy/discrete variables were employed to compare means of socioeconomic characteristics among those who adopted at least three technologies and those who adopted less. The SWOT analysis was used to discuss effectiveness of the ACE model. To analyse adoption and its determinants, the negative binomial regression model was used.

2.2.1. SWOT Analysis

A strength, weakness, opportunities and threat analysis were carried out for the ACE approach. A strength is "any activity the ACE does well or any unique resource the ACE has. A weakness refers to activities that the ACE does not do well or the lack of some resources to do well. An opportunity is any Positive trend in the external environment that can make the ACE to perform better. Finally, threats are external factors that are out of ACE ACE's control and will have a negative effect. The SWOT analytical technique helped to provide answers to the questions related to each of these four words i.e., Strengths (area of excellence, comparative advantage, relevant resources and available partnerships), Weaknesses (areas of poor performance, areas to improve), Opportunities (favourable trends and comparative advantages, available enabling factors) and Threats (areas to avoid, obstacles that interfere with and hinder success. The results of the analysis helped in rea commendation that may improve effectiveness and efficiencies of the ACEs even after the project.

2.2.2. Negative Binomial Model

Count data analysis estimation models have been used in the literature when the dependent variable is an integer i.e. non-negative count for an event (Favero, L. P. and Belfiore 2019). The Poisson regression model which assumes that the mean is equal to variance has been widely used to analyse count based datasets. (Favero, L. P. and Belfiore 2019). This assumption does n, however, hold for the collected dataset which is showing over-dispersion and as such the negative binomial regression is recommended. The intensity of adoption was measured as the number of CSA technologies being used by the farmer. The basic general linear model (GLM) can be expressed as follows:

$Yi=\beta Xi+\varepsilon i$………………………………………………..(i))

Where Yi is the adoption intensity of farmer I, Xi is a set of farm I, farmer, and socio-economic characteristics which are the explanatory variables while β are the parameters to be estimated. The predictors (socio-economic factors, see Appendix A) used in the models were informed by a literature review where farmer attributes (gender, age, education), farm characteristics, access to services such as extension and markets as well as economic factors (livestock ownership, household income) were found to influence the intensity of CSA adoption ((Negera et al. 2022; Andati et al. 2022). The dependent variable takes on a non-negative integer value whose average is small and is assumed to follow a negative binomial distribution where the mean is not equal to the variance.

3 Results and Discussion

3.1The ACE model and SWOT Analysis

Information market imperfections in agriculture value chains has been identified as one of the causes of low adoption of productivity enhancing technologies by farmers (Wossen et al, 2017). Access to information through ACEs, ward information centres, smartphones and other means enhances the timeliness and quality of such agriculture information. This section discusses how farmers, agricultural researchers, agriculture diploma students and extension workers are utilising these platforms promoted by the ZAKIS project. This is very pertinent because researchers generate information which is then disseminated by extensionists to farmers on various new or productivity enhancing technologies. Private sector and markets also provide agriculture information on their products and markets which is useful to farmers and even extension on the ground who are the main source of technical knowhow for farmers. The agriculture diploma students also make use of information from researchers and even extension as they formulate research projects. Some of the main challenges of extension is ability to reach out to all households that he or she serves in a timely manner and as such the new platforms compliment the work of research, education and extension pillars. The findings show that awareness of the DACE which is closer to the farmers has reached reasonability higher levels at more than 60% in both the MACE and CHACE region and indications were that farmers are receiving an average of 5 trainings in the MACE region and 3 in the CHACE region annually. This was reiterated by key stakeholders e.g. "I am aware of the practical demos that include; stover treatment, Push and Pull technology to control FAW and preservation, fodder production for livestock, especially drip irrigation must be adopted due to frequent droughts in our area so that farmers utilize every drop", indicated the DAEO for Matobo. Awareness of WIC is still very low in the CHACE region and thus more work need to be done. Farmers indicated that they visited the DACE 8 and 6 times in the MACE and CHACE region consecutively. Satisfaction levels for trainings provided and services provided at the DACEs were cited as being moderate to very high quality by more than 90% of the farmers in both regions, a figure which surpasses the targeted 60%. The farmers however cited some weaknesses of the DACEs which included lack of regular sessions (cited by 41 and 61 % in MACE and CHACE respectively). The key stakeholders also highlighted that the DACE was not accessible to all farmers due to longer distances. It was therefore necessary to have WIC for every ward such that all wards get to know of DACE activities via other ICT means like videos etc. The stakeholders also felt that extension as the "foot soldiers" needed to do on promotion of these sustainable productivity enhancing technologies. For the past 2 agricultural seasons, the ACEs have been showcasing CSA technologies such as Conservation agriculture, in field water harvesting technologies, Integrated Pest Management technologies, fodder production and processing, artificial insemination, diversification including small grains among others.

The tables 1 and 2 shows that the mean farmers' perception regarding ACEs. In table 3 farmers were asked if they agreed with the statements while in table 2 satisfaction of ACE services was gauged on a 5-point Likert scale against the two main statements on rating the quality of trainings obtained from ACEs and satisfaction rates. Perceived effectiveness of ACEs was evaluated in terms of relevance (being farmer centric), service provision (market linkages, trainings, information provision), show casing of technologies needed by farmers and the quality of the services (rating and satisfaction level).

Table 1: Farmer perceptions about ACEs

		% Frequency		
Statements	**Response**	**ZAKIS Dryland**	**ZAKIS Sub-humid**	**Non-ZAKIS**
ACEs are farmer-centric	yes	39.90	44.00	2.10
ACEs provides market linkages	yes	24.10	24.20	0.00
ACEs provides adequate Training	yes	19.00	21.20	0.00
ACEs provides regular training sessions	yes	41.40	60.60	66.70
ACEs improves knowledge	yes	88.30	91.50	66.70
ACEs show cases modern technologies	yes	68.30	83.10	0.00
ACEs changes attitudes of farmers	yes	71.70	84.50	66.70

The majority (more than 80%) farmers in the project sites felt that ACES could improve their knowledge through showcasing modern technologies, running capacity building training. There was however need for more effort to link farmers to markets for their produce. Extension programs at ACEs also need to design regular sessions throughout a crop cycle in order to help equip farmers with knowledge and skills on CSA.

Table 2:Farmer rating on quality of ACE services and satisfaction levels

		Region		
Variable	**Response**	**ZAKIS Dryland**	**ZAKIS sub-humid**	**Non-ZAKIS**
ACE Training Quality rating	very low	0.00%	0.00%	0.00%
	low	6.60%	1.40%	33.30%
	moderate	19.70%	8.50%	0.00%
	high	36.10%	25.40%	0.00%
	very high	37.70%	64.80%	66.70%
ACE Services Satisfaction rate	very low	0.00%	0.00%	0.00%
	low	6.60%	0.00%	33.30%
	moderate	21.30%	9.90%	0.00%
	high	34.40%	23.90%	0.00%
	very high	37.70%	66.20%	66.70%

Findings show that in the subhumid and non-ZAKIS sites the majority of farmers (more than 64 %) felt that the quality of trainings at ACEs were very high while 38% in the dryland rated the training as of very high quality. Very few (less than 7%) in the project sites felt that trainings were of low quality. These results implies that the ACEs still have to consider room for improvement to meet the farmer needs. Stakeholders like the Rural district councils highlighted that DACE sustainability could be achieved through a multi-sectoral approach. The Councils are potential avenues for linking farmers to markets as they have a history of hosting auctions for livestock value chains e.g., cattle and goats as well as provision of open markets for crops (field and horticulture crops). More stakeholders including all NGOs in the district could work together in improving the quality of services at the DACEs. Accountability, transparency can be achieved by regular sharing of updates through reports. The other stakeholders also felt that the DACE could be made 100% functional by having a permanent resident extension worker who over sees that day to day operations. For sustainability, they felt that the appointment of a full-time officer by AGRITEX would go a long way in improving operations.

Table 3 summarises the strengths, weakness, opportunities, and threats (SWOT) analysis of the ACE model collated from FGDs and KI interviews. The salient opportunities include demand for technical know-how by the farmers, demand for demonstration space by the private sector, and researchers to showcase their products (seed houses, pesticides, and fertilizer companies) and do trials as well as government and donor support to showcase of resilience building technologies. The established ACEs have the resource (land , water and capital) curently and they should take advantage to make sure CSA are showcased all year round for the benefit of the farmers. Capacity building is however needed to strengthen extension skills in business model management so that reasonable revenue to support contnued research are always available.

Table 3: ACE SWOT analysis results

Strengths	**Weaknesses**
• **Land and water Availability for hands on practical demonstrations** • **Infrastructure to support research, education and advisory activities** • **Human capital – Experienced research officers extension staff** • **Vehicles for Mobility and training facilities for theory**	• Underutilization of the existing infrastructure • Inadequate motivation for research and support staff • Poor financial business models to support activities
Opportunities	**Threats**
• **Demand for technical knowhow from farmers** • **Demand for product testing and demonstration space by private sector** • **Existing development projects within the sites** • **Budgetary allocation (funding) support from the government** • **Government and donor willingness to support resilience Climate smart agriculture technologies**	• Potential loss of experienced staff due to poor remuneration and working conditions • Lack of business acumen:weak pricing policy for business models • The volatile prevailing macro economic environment

Adoption of CSA technologies

Adoption Rates

Adoption patterns varied by practice and region during the 2021/22 agriculture season (table 3). The results from the study shows that adoption of climate CSA technologies for livestock value chains are still very low at less than 30% of the households showing use of fodder production (15%), breed smart

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technologies (Artificial Insemination 6%) and improved livestock management practices (28%). These are key technologies in livestock given inadequate grazing during the dry season, longer calving intervals and high mortality rates due to tick borne diseases like January disease. Farmers during FGDs cited that they were willing to adopt fodder production but the challenge was seed access. The fodder seeds were not readily available in shops and even locally as farmers who had seed got it through projects by researchers or NGOs. The same reasons were cited for the push pull technologies for fall army worm (FAW) control where the legume (push crop) and the pull crop seeds were also not available. There is therefore need for continued efforts to encourage private seed companies to also invest in seed multiplication for fodder crops. The ACEs and DACEs are also a potential conduit through which seed multiplication can be done in addition to community seed multiplication initiatives. FAW is a problem pest in cereals particularly if farmers plant late and yet they are not aware of such low cost and environmentally friend options for its control like the push pull methodology. Awareness of Integrated soil fertility Management is still low and there is need for capacity building in this area as soil fertility is key to productivity levels. Adoption of CSA is highest for CA and increasing for in field water harvesting (32%) and diversification (49%) where farmers are embracing adoption of various drought tolerant crops and varieties in view of climate change and variability. There was significance difference in adoption of all technologies across the ZAKIS and non-ZAKIS sites except for in field water harvesting and fodder production.

Table 4: CSA technologies and practices

Household Uses CSA technology	non-ZAKIS site	ZAKIS site	Whole Sample	Chi square
Push pull technology	0.0%	6.5%	5.0%	6.51**
Infield water harvesting	28.4%	33.6%	32.3%	0.87
Artificial Insemination	2.1%	7.5%	6.2%	3.61*
Improved Animal husbandry	10.5%	33.2%	27.9%	18.60***
Conservation agriculture	62.1%	81.8%	77.1%	15.88***
Diversification	38.9%	52.1%	49.0%	5.04**
Fodder Production and processing	10.5%	16.9%	15.4%	2.29
ISFM	14.7%	35.2%	30.3%	14.34***
Smart Irrigation	1.1%	4.9%	4.0%	2.79*

*, **, *** a significance level of 10%, 5% and 1%, respectively.

Determinants of intensity of adoption of CSA technologies

Farmers adopt technologies individually, in a stepwise manner and in some cases in bundles depending on their constraints or production objective (see table 5). Few interviewed farmers (0% in the drylands and 2.5% in the subhumid) have not adopted any CSA technology while the rest had adopted from one to nine CSA technologies. About 65% of the farmers adopted between 1 and three technologies. The mean number of CSA technologies was highest in the drylands at 2.93 followed by farmers in the sub humid region at 2.52 and lowest for the non-ZAKIS wards at 1.33.

Table 5: Adoption intensity

Number CSA adopted by HH	ZAKIS Drylands	ZAKIS Sub-humid	non-ZAKIS	ALL
0	0	2.50%	14.70%	4.50%
1	22.30%	30.80%	38.90%	29.60%
2	31.10%	25.20%	26.30%	27.60%
3	11.50%	12.60%	12.60%	12.20%
4	16.90%	15.10%	2.10%	12.70%
5	10.10%	11.30%	2.10%	8.70%
6	4.10%	1.90%	2.10%	2.70%
7	2.00%	0	1.10%	1.00%
8	1.40%	0.60%	0	0.70%
9	0.70%	0	0	0.20%
	100.00%	100.00%	100.00%	100.00%
Mean Adoption (Number of technologies/HH)	2.93(1.75)	2.52(1.56)	1.33(1.11)	2.47(1.75)
Mean Area under CSA/HH (Acres)	1.84 (5.16)	1.60(1.42)	1.33(1.11)	1.63(3.30)

The area under CSA is also highest in the drylands at 1.84 acres and overally area under CSA is higher at 1.63. The negative binomial regression was run to analyse determinants of intensity of adoption of CSA (table6). The analysis shows that experience in marketing livestock, frequency of visit to ACE, goat ownership, cattle ownership and participation in CSA demonstrations are statistically significant and positively influence the number of CSA technologies adopted farmers in ZAKIS sites. Distance to all weather road and experience in crop marketing were however negative and significant. All weather roads are key to accessing markets and where they exist, transport cost is reasonably cheaper compared to sites with gravel roads. Increased distance to tarred roads thus increases the transaction costs involved in accessing and transporting inputs and produce to markets. The more the experience in livestock marketing, the higher the likelihood of adopting more CSA technologies. Other researchers have also found this positive and significant relationship and the reason for such was that marketing enhanced social capital with value chain actors and generated income which helped in the accumulation of physical assets(Abegunde, Sibanda, and Obi 2019). This can increase the capacity to adopt recommended CSA technologies.

Ownership of goat and cattle increase the intensity of adoption. This might be because of complementarity nature of some CSA technologies. Manure from livestock is used in integrated soil fertility management to improve soil fertility. On another hand livestock can be sold to generate income for any bought inputs. Cattle are also key for technologies such as ripping, tied ridges that were being promoted and could be done with the assistance of draft power. In addition, farmers with more resources have been found to be less risk averse and are more eager to test technologies that have the potential to increase agricultural productivity and income. Those farmers with increased frequent visits to ACEs had a higher chance to adopt more CSA technologies. This is because they would be exposed to the variety options of CSA. Participation in CSA demonstration increased the chances of the farmer adopting more technologies. Adoption of more CSA require good technical knowledge and the CSA demonstrations offered that. Farmers learnt throughout the season from the model lead farmer whose fields were the school to learn the technologies. The demonstrations also afforded the farmers and opportunity to earn through farmer-to-farmer knowledge sharing. This goes in agreement with researchers who found that knowledge increase adopted of integrated pest management in Ghana and Benin (Sekabira et al. 2022). It is however surprising that increased interaction with extension is associated with decreased intensity of CSA adoption. This might be because the interactions were not focused of CSA knowledge sharing. This finding contradicts other researchers who found positive significant relationship between adoption of CSA and extension interaction(Tanti et al. 2022).

Table 6: Factors that influence the adoption intensity of CSA technologies

Model Negative Binomial	**ZAKIS site**		**Non-ZAKIS**		**Whole Sample**	
Variable	**Coef.**	**Std.Err**	**Coef.**	**Std. Err**	**Coef.**	**Std.Err**
ageHH	0.001	0.004	0.012	0.01	0.002	0.003
EduSecandabove	-0.01	0.081	0.101	0.202	-0.011	0.074
years_marketing_livestock_1	0.009**	0.004	0.01	0.01	0.01**	0.004
years_marketing_crops_1	-0.008*	0.004	0	0.008	-0.007*	0.004
HHlabour_1	0.009	0.02	0.025	0.06	0.014	0.018
arableland_1	-0.001	0.008	0.023	0.027	0.003	0.007
kminputmkt_1	-0.001	0.002	-0.001	0.003	0.000	0.001
kmoutputsource_1	-0.001	0.002	0.005	0.006	0.000	0.002
kmtar_1	-0.01**	0.004	-0.008	0.008	-0.011***	0.003
logincomeHH	0.099	0.079	0.809***	0.204	0.194*	0.072
soilLessfertile	0.085	0.073	0.052	0.212	0.034	0.067
aceVisitFreq	0.007**	0.003	0.03	0.281	0.008***	0.003
goatownership	0.265***	0.095	0.277	0.2	0.272***	0.083
cattleownership	0.157*	0.088	0.19	0.3	0.178*	0.082
smart_cellphone	0.104	0.08	0.259	0.188	0.12*	0.072
seasonalforecastget	0.184*	0.096	0.064	0.226	0.145*	0.087
demoparticipationcsa	0.247**	0.12	0.339	0.219	0.335***	0.103
_cons	-0.338	0.408	-3.878***	1.145	-0.884**	0.372
/lnalpha	-17.833	568.586	-16.725	606.403	-16.278	355.606
Alpha	1.800	0.000	5.450	0.000	8.520	0.000
LR Chi2 (17)	55.090		50.050		104.020	
Prob > Chi2	0.000		0.000		0.000	
Pseudo R2	0.049		0.169		0.071	
Log likelihood	-540.460		-123.270		-680.460	

*, **, *** a significance level of 10%, 5% and 1%, respectively.

4. Conclusions

Climate change and variability has negatively affected agriculture productivity thereby impacting negatively food security. Climate smart agriculture is now being promoted as a panacea to these challenges. One of the challenges to the adoption of such climate change adaptation strategies is limited access to technical information. An important approach is the use of pluralistic extension and the ZAKIS project has introduced the ACE model where equipped extension learn from the ACE and take to information to communities through participatory action research demonstrations on the technologies. The findings from this study show that ACE model has potential to spearhead adoption. Farmers perceived the ACE model to be moderately effective. They recommended that for ACE services to be considered effective, they should be of good quality; farmer-centric, improve agricultural productivity and link farmers to markets. The model can be improved by having regular structured trainings per each prioritised value chain in the regions where they are located and the ACE acting as a convergence point for all actors within the value chains to work together in addressing any bottlenecks. Findings further show that the demonstrations set up within communities are accessible and beneficial as farmers learn throughout the season through hands on practical. More demonstrations should therefore be set up in order to reach more farmers with technical knowhow on CSA.

Author Contributions: All authors contributed to the conception, design, review and editing of the manuscript.
Funding: This research was funded by the European Union through the ZAKIS project.
Institutional Review Board Statement: Not applicable
Informed Consent Statement: "Informed consent was obtained from all subjects involved in the study
Data Availability Statement: Data supporting results can be found and is available
Acknowledgments This research is based upon work supported by the European Union through the Zimbabwe Agriculture Knowledge and Innovation Service (ZAKIS) project. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the European Union.
Conflicts of Interest: "The authors declare no conflict of interest."

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Appendix A: Variable names used in the regression model

Variable	Explanation	Variable type	
sexhh	Sex of Household Head	Dummy	1=male 0=female
eduhhdummysec	Education Level of Household head	Dummy	1=At least secondary level 0=otherwise
agehh_1	Age of Household head	Continuous	years
years_marketing_livestock_1	Experience of livestock marketing in years	Continuous	years
years_marketing_crops_1	Experience of crops marketing in years	Continuous	years
hhlabour_1	Household labour size	Continuous	Number
arableland_1	Size of arable land in acres	Continuous	acres
CattleOwn	Household owns cattle	Dummy	1=yes 0=No
goats2022	Household owns Goats	Dummy	1=yes 0 0=No
kminputmkt_1	Distance to input source in KM	Continuous	KM
kmoutputsource_1	Distance to produce market in KM	Continuous	KM
kmtar_1	Distance to all weather tarred road in KM	Continuous	KM
smart_cellphone	Household owns smart phone	Dummy	1=yes 0=No
seasonalforecast	Household has access to seasonal forecasts	Dummy	1=yes 0=No
demopartiCSA	Household participates in Climate Smart Agriculture technologies demonstrations	Dummy	1=yes 0=No
soildummy	Soil type/fertility	Dummy	1=less fertlile 0=otherwise
logincomehh	Log Household Income	Continuous	