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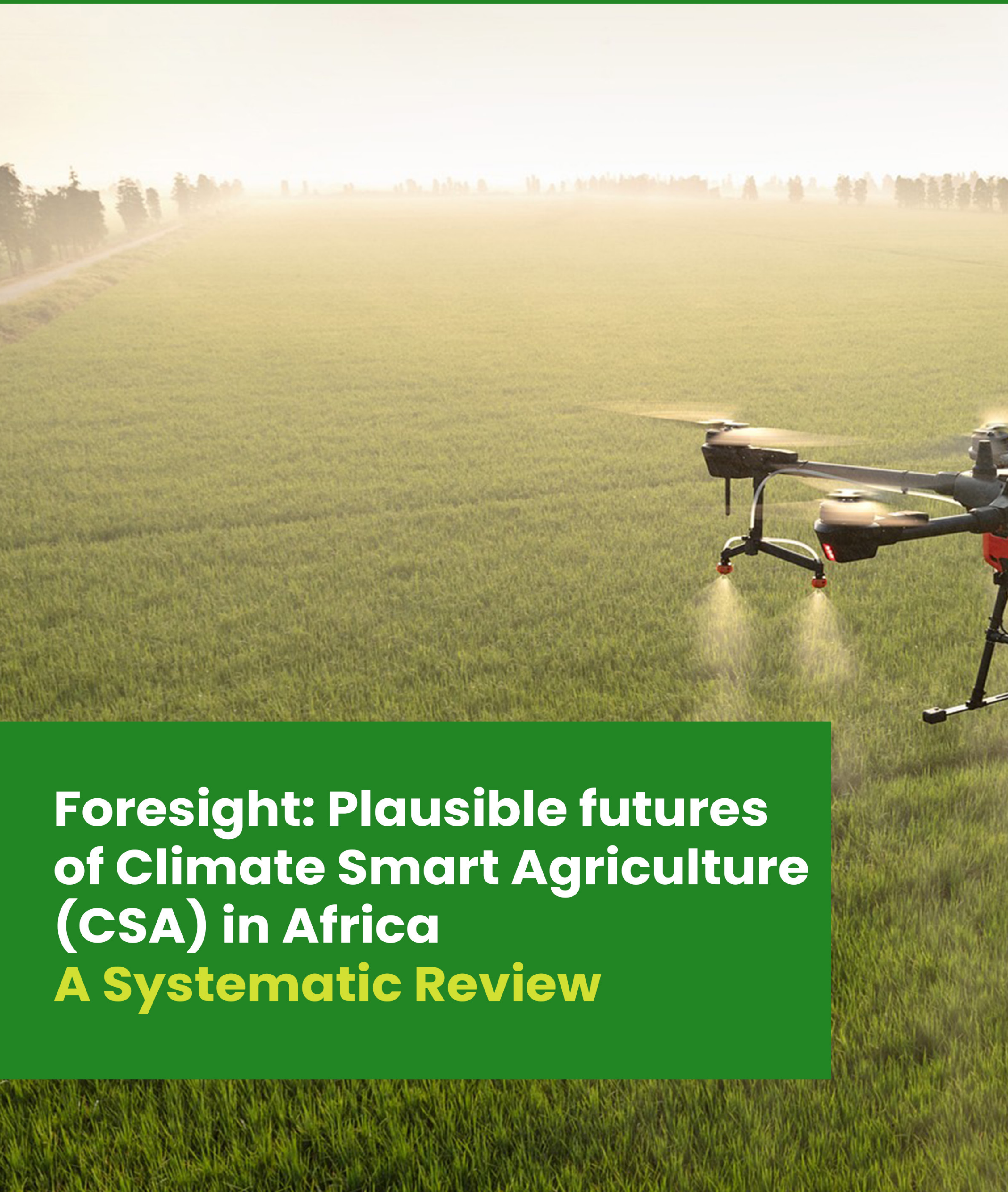

Foresight: Plausible futures of Climate Smart Agriculture (CSA) in Africa

A Systematic Review

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A Commissioned Study conducted by Dr Nasiru Taura (presented at the Biennial Africa Climate Smart Agriculture conference – hosted by FARA on the 14th-September-22 @ Alisa Hotel Accra Ghana)

ABSTRACT

With growing interest on Climate Smart Agriculture (CSA) in Africa, numerous studies have examined its implication for African agriculture. However, we still lack a holistic understanding of plausible futures of CSA in Africa. Given the significance and relevance to the future we want for Africa, this study utilises a desk-based exploratory systematic review and analysis to identify research gaps from published literature, to develop a summary of the current state of research on CSA plausible futures in Africa. Using a comprehensive systematic secondary search of 'the Science Direct' to identify, map, and analyse the most relevant articles, the study conducted an analysis of prior publications of CSA in Africa. The studies identified adopted various foresight frames but mainly focused on planning and scenaric frames, while the critical, and transformative frames – appeared to be under-utilised in our continuous search for a plausible futures explanation of CSA in Africa. The study also identified some selected CSA best practices across the African continent suggesting the limitation for developments in silos and call for more collective intelligence through learning from our best practices. The study also notes the limited application of industry 4.0 for CSA in Africa perhaps due to low absorptive capacity. Finally, the study identified some emerging CSA critical success factors necessary for developing a plausible future in Africa namely the need for more training (awareness & capacity building), gender and youth mainstreaming, accommodating the voice of the smallholder farmers, and going beyond socio-economic barriers to encompass the analyses of relevant CSA policy instruments in Africa. The study concludes with a set of five (5) propositions with clear implications to technical and public policy options for plausible futures of CSA in Africa.

Key words: Foresight, Plausible Futures, & Climate Smart Agriculture, Africa

Introduction: Background & Research Questions

Climate change posed risks for African Agricultural and food systems linked to food insecurity, nutrition, yield, livelihood as well as overall productivity levels (Amadu et al., 2022; Ng'ang'a et al., 2021). Climate smart agriculture (CSA) has been heralded as strategic option to enable Africa to mitigate the risks posed by the climate changes to specifically to vulnerable climate extreme environments in Africa (Mutenje et al., 2019; Derbile et al., 2022). CSA adoption in Africa have been adopted to multiple contexts and many types of CSA practices are being utilised across the continent. CSA in Africa have not only been applied to improve yield, productivity (Amadu et al., 2022; Ng'ang'a et al., 2021), but also the application encompasses multiple contexts including conservation, forestry and ecology, climate information services (Michler et al., 2019; Sarr et al., 2020; Mwongera et al., 2017). Despite all the benefits of the CSA, still Africa's adoption rate remains low. Thus, the Africa's low adoption to CSA requires multiple approaches to handle (Amadu et al., 2020; Musafiri et al., 2021; Branca and Perelli., 2022).

Conducting a systematic review of CSA plausible futures is a critical step to understanding the patterns/directions for CSA in Africa. Thus, the questions addressed in this study includes what types of CSA have been adopted and in what contexts have they been addressed? what have we learnt from previous adoptions of African CSA in hindsight? And is there a trend/pattern to Africa's CSA adoption? what were the foresight Analytical frames applied in previous African CSA futures? what are the critical factors to be considered in mapping of plausible futures for CSA in Africa? To our knowledge, there are no studies that have addressed the questions tin respect to CSA plausible futures in Africa through systematic review, with view to providing insights on critical success factors for CSA in Africa going forward. Given the complexity of operationalising CSA plausible futures range of definitions are evaluated prior to coming up with operational definition for this study as discussed below.

Operational Definition: Defining CSA Plausible Futures

Defining CSA plausible futures is complex since the definition overlaps between the CSA dimensions on one hand as well as foresight on the other. According to Mutenje et al. (2019) (CSA) "comprise a suite of interventions that aim to sustainably increase productivity whilst helping farmers adapt their farming systems to climate change and to manage risk more effectively". Since CSA comprises suite of interventions with certain characteristics leading improved productivity, adaptation, mitigation, risk management etc, it is therefore bound to be multi-dimensional. Regarding plausible futures, it has been previously defined as a 'capacity' to see the future prior to its actualisation (Schumpeter, 1934: 85). It can also be regarded as a future based 'orientation' to the future in which a repository of 'strategic awareness' is developed for purposes anticipatory emergence to solve problems (Gibb and Scott, 1985). Lastly, some foresight scholars argue that, although plausible futures are forward looking, they must be grounded in the past (Brooks & Place, 2019). For them plausible futures must be informed by learning in hindsight, as a springboard upon which plausible futures is contemplated, assumed, and considered (Brooks & Place, 2019). This study identifies and adopts aspects of the definitions, that is CSA as a suite of interventions that yield positive results with climate benefits on one hand and plausible futures as a capacity, orientation, to the future grounded in learning from the past as a springboard. Thus, in this study, CSA plausible future is defined as a systematic process of anticipatory emergence of reliable, authentic, inclusive future informed by learning in hindsight. This definition is vital for this study as it broadly captures the transformational changes foreseeable or at least desired in coming decades. It also enables us to systematically look back and trace the analytical frameworks utilised as lenses for future assumptions, contemplations, visioning, and what if scenarios. The definition also enables us to understand foresight in hindsight such that we are able to trace back some developments in CSA adoption in the past and our current knowledge with likelihood to generate changes in African food systems (Brooks & Place, 2019).

Literature Review:

CSA Adoption in Africa: How could the barriers to slow CSA adoption be overcome in Africa?

The international community have invested billions of dollars towards advancing and supporting various CSA initiatives globally (Festus et al., 2020). The outcome of the investment is not universally the same across the world. Despite, the promise for CSA adoption to lead the processes of transition from traditional to a more sustainable, cleaner, circular productive food systems studies have found the adoption rate to be slower in Africa when compared other parts of the world (Amadu et al., 2020; Musafiri et al., 2021; Branca and Perelli., 2022). Scholars have repeatedly raised alarm regarding the low adoption rate arguing that, Africa's socio-economic, institutional, & bio-physical factors could be a contributing factor- thus limiting the continent to achieve her full potentials (Musafiri et al., 2022; Branca and Perelli., 2022).

For the purposes of understanding how to overcome the slow adoption rate of CSA in Africa, this study critically reviewed literature from behavioural psychology and behavioural economics (Terlau and Hirsch., 2015). These theoretical frameworks have been applied here to evaluate the critical success factors which inhibits the CSA adoption particularly bridging the gaps of attitude-behaviour gaps at multi-levels of individual, local community, and society (Terlau and Hirsch, 2015). Some scholars argue that creating awareness could shorten the attitude behaviour gaps (Carrington, et al., 2014; Eckhardt, et al., 2010; Han et al., 2017) enabling more African farmers adopt CSA in Africa. There arguments for the explanation of the attitude-behaviour gaps is associated with information deficit (Burgess et al.,1998).

Contrary, to the previous studies could not prove the relationships between awareness level and behavioural changes or in some instances even opposite results have been recorded (Antimova et al, 2012; Hares et al., 2010) leading to CSA adoption. Some reasons for non-translation of attitude to positive behaviour in favour of CSA adoption could be due to some beliefs and opinions (Antimova et al., 2012). Here emphasis for understanding the attitude-behaviour gaps lies in examining the values and belief system (moral, personal and group norms) as either facilitators or inhibitors (Thøgersen, 1999). Studies have demonstrated that as social animals, social learning is crucial to understanding attitude-behaviour gap of farmers and CSA adoption in Africa. Some farmers will only adopt CSA if they observe that other farmers are adopting as they don't want to be left out from the group norms (Antimova et al., 2012). Perhaps, here is an opportunity for African governments to initiate early adopters' scheme which could trigger a domino effect of chains of CSA adoption by behavioural imitations (Bramwell and Sharman, 1999).

In addition to above, other scholars argue that to encourage the translation of attitude to positive behaviours for CSA adoption training and capacity building have been found to be effective (Zakaria et al., 2020). Farmers who participated in training or capacity building have been reported as having a higher likelihood to positive CSA adoption in Africa (Zakaria et al., 2020). These are training particularly conducted through the extension agents – thus, farmers with access to the extension workers are more likely to behave favourably towards CSA adoption in Africa. Unfortunately, the extension workers themselves are reported to be under-trained and lacking in many skills required to train the farmers including technical, communication, & demonstration skills (Philip et al., 2021).

Methodology

The study adopts systematic literature review to ensure standard procedures for quality assessment and assurances of empirical evidence (Pittaway et al., 2004 Transfield et al., 2003). The evidence-based approach enables the researcher to apply systematic procedures to identify and organise relevant data about plausible futures of CSA in Africa (Transfield et al., 2003; Thorpe et al., 2006). This research followed systematic process to: a) conduct systematic search; b) categorise the contents; c) select studies with rigour d) identification and categorisation of themes; d) and finally a thematic analysis of emergent themes (Lucarelli and Berg, 2011). To ensure rigour we adopted a well-established system referred to as the PRISMA – Preferred Reporting Items for Systematic Reviews guidelines for retrieval of articles. This study also focuses on identifying peer reviewed articles from 'Science Direct' only, to reduce possibilities of system integration errors. Below, we discuss the details of the search process, inclusion/exclusion criteria, data preparation, extracting, and sorting. See the image of PRISMA protocol applied below:

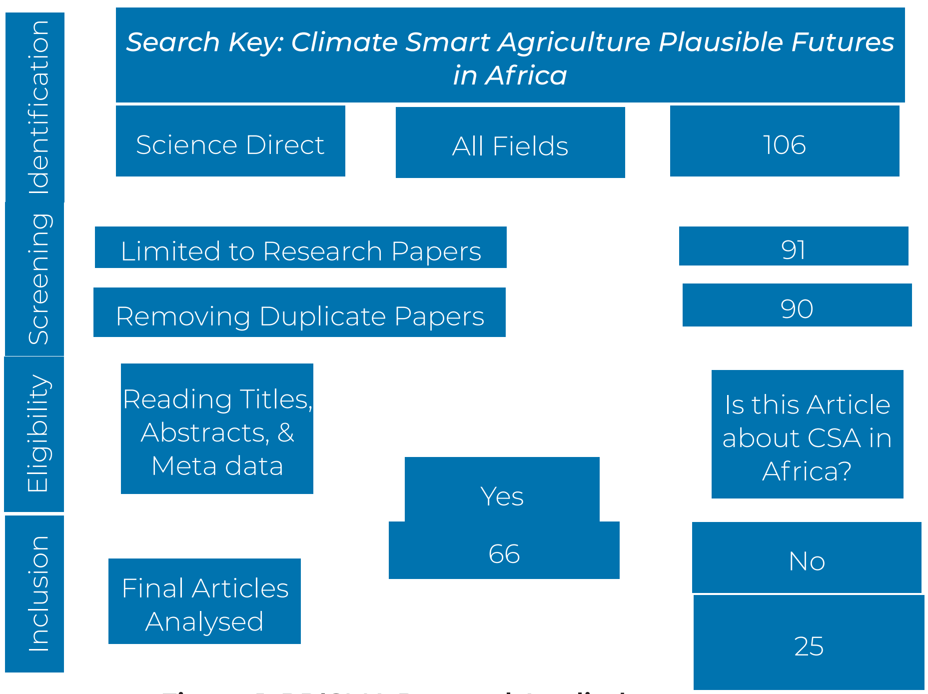


Figure 1: PRISMA Protocol Applied

Search Process

This study adopts a two stage/phased search processes namely automatic and manual (Kitchenham, 2007; Webster & Watson, 2002). Both processes are based on a desk-based exploratory systematic process to identify relevant sources for review and analysis. The exploratory systematic review's goal is to identify research gaps from published peer reviewed literature and develop a summary of the current state of research on CSA futures in Africa (Ahmed et al., 2019). By utilising peer reviewed materials from verifiable sources, the quality of the data sources is guaranteed – with no additional criteria (Chan et al., 2017). Thus, the first step in the search process includes the use of relevant keywords with higher likelihood to discover relevant publications from 'Science Direct'. The Science Direct was selected after reviewing other popular data bases such as SCOPUS and Web of Science as it appears more promising given the access to the specialist nature of the systematic research conducted on CSA in Africa. The search process in Science Direct encompasses

- Years: includes 10 years.
- Type of documents: Research Articles (Journals)
- Subject Area: All

Given the multiple dimensions of CSA plausible futures, We use the following combination of words to improve our searchability likelihood: "Futures AND CSA*) OR (Scenario planning AND CSA*) OR (Vision AND CSA*) OR

(“Foresight” AND CSA*) OR (“Anticipatory*” AND CSA*) OR (“Systems thinking*” AND CSA*) OR (Predictions AND CSA*) OR (“Forecast” AND CSA*) OR (“Plausible Futures” AND CSA*) OR (“Planning*” AND CSA*) OR (“Strategic Foresight” AND CSA*) OR (“Narrative Foresight” AND CSA*) OR (“Critical” AND CSA*) OR (“Transformative” AND CSA*). A complementary search was conducted, and it involves reviewing references/bibliography of the articles utilised in the first search phase leading to identification of additional relevant body of work on plausible futures for CSA in Africa (Webster & Watson, 2002). The review is limited to studies that are Africa facing. About 106 papers have been downloaded to our library of contents for review and analysis. Our search reveals that in recent times CSA futures publications have spontaneously grow out of Agricultural Sciences, to embody other scientific enquires in Biomedical Sciences, Genetic Sciences, as well as Social Sciences (see Table 1).

Inclusion and exclusion criteria:

To ensure that only relevant materials were included in the review and analysis, we screened the articles using inclusion and exclusion criteria. Abstract reviews were conducted for quick identification of articles that might not be fully relevant. Afterwards, we apply the following screening steps:

- For exclusion purposes and given the specificity and nature of plausible futures CSA in Africa, we exclude all materials that are not Africa facing enough in their content. This leads to exclusion of …articles.
- For inclusion criterion we include only research papers which addressed CSA adoption in a way that lend itself to learning in hindsight for Africa’s plausible futures.
- We also limit our library of contents to articles with only climate smart Agriculture contents instead of generic climatic discussions or Agriculture without climate smart. Afterwards, number of articles remain.

Data preparation, extracting, & sorting

To prepare the data for analysis, we extract all the eligible data (106 articles) and recorded them in Microsoft Word table format. We then classify the articles according to data of interest on each article such as title of the study, author, year of publication, type of CSA adopted; foresight analytical frames, context applied; and learning in hindsight (factors for mapping plausible futures) (See Appendices: Table 6).

Analyses and Syntheses of data.

Prior to analysis, we organise the data set to provide better contextual understanding. In so doing, we extract and present the articles that are published in the top 11 journals (by way of publications of the subject matter – please see Table 1). Together these articles represent over 76% of the articles in this study. Of the 11 journals, the top 2 publishers are Agricultural systems (2017-22) & Heliyon (2021-22) with 18 publications (9 respectively). This is interesting since both journals have substantial natural science content including but not limited to farm, landscape, biology, ecology, all sometimes combined with social sciences. The inclination to science-based publications demonstrates the willingness of African scholars to examine the CSA adoptions through the scientific lenses.

The next journal with 5 publications is *World Development*. World Development is a multi- disciplinary journal enabling broader level discourses about CSA adoption in Africa. Afterwards, the next 8 Journals considered are *Journal of Cleaner Production; Technology in Society; Environmental Challenges; Environmental Development; Climate Risk Management; Climate Services; Land Use Policy; Ecological Economics.* Each of these 7 journals published at least 3 articles each over the years (2018-2022). Again, some these journals are multi-disciplinary (*Environmental Challenges; & Ecological Economics*), while others are specific with emphasis on future (*Environmental Development*); climate change (*Climate Risk Management*); climate information related services (*Climate Services*); & geography, agriculture, forestry, irrigation, environmental conservation, housing, urban development, and transport (*Land Use Policy*).

While the journals are considered as they published more articles for consideration in this systematic review, we also note some vital publications in other top notched journals who published 1 or 2 articles. These journals include the following: *Agricultural Water Management: Scientific African; International Journal of Disaster Risk Reduction; Ecosystem Services; Geoforum; Food Policy; Technological Forecasting; Journal of Environ-*

mental Economics and Management; Journal of Environmental Management; Regional Sustainability; Soil and Tillage Research; Agricultural and Forest Meteorology; Smart Agricultural Technology; Procedia Computer Science; Environmental Science and Policy; Agriculture, Ecosystems & Environment. Of these journals our biggest surprise, was lesser publications in journals with higher likelihood of publishing CSA contents given its technological and computer driven nature – particularly the journals of *Technological Forecasting; Smart Agricultural Technology; and Procedia Computer Science.*

TABLE 1: ***Number of Articles considered in TOP journals***

Journal	*Subject Area*	*Initial Articles*	*Eligible Articles for the Study*
Agricultural Systems	*substantive natural science content (especially farm- or landscape-level biology or ecology, sometimes combined with social sciences),*	*17*	*9*
Heliyon	*all-science, open access journal*	*18*	*9*
Word Development	*multi-disciplinary monthly journal of development studies*	*12*	*5*
Journal of Cleaner Production	*transdisciplinary journal focusing on Cleaner Production, Environmental, and Sustainability research and practice*	*10*	*3*
Technology in Society	*Global discourse at the intersection of technological change and the social, economic, business and philosophical transformation of the world around around us.*	*9*	*3*
			3
Environmental Challenges	*multidisciplinary journal, related to all applied and management aspects of environmental engineering, management, policies, and stakeholder involvement at a larger scale, case studies, and regional issues.*	*5*	*3*
Environmental Development	*future-oriented journal that contributes both theoretical and practice-based knowledge for sustainable and low carbon futures*	*6*	*3*
Climate Risk Management	*climate variability and climate change in decision and policy making on climate change responses*	*7*	*3*
Climate Services	*Science-based and user-specific climate information underpinning climate services (open access journal)*	*8*	*3*
Land Use Policy	*geography, agriculture, forestry, irrigation, environmental conservation, housing, urban development and transport*	*8*	*4*

Ecological Economics	*trans/Inter-disciplinary integrating the understanding of the interfaces and interplay between "nature's household" (ecosystems) and "humanity's household" (the economy)*	*6*	*3*
		106	

4.1.1. Type of Studies (Analytical Frames & Orientation)

(Table 2) shows a table of classification by types of studies and year of publications4. We find that more than 45% of the articles utilises quantitative approaches; 25% mixed approaches; and 20% qualitative approaches.

TABLE 2: ***Types of Studies (Analytic Frames & Orientation)***

Type of Study	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*Total Papers*	*%*
Quantitative *Research by estimates, regressions, Algorithms, & Modelling*					*1*		*1*	*5*	*8*	*7*	*8*	*30*	*45%*
Quantitative Survey						*1*			*2*			*3*	*4.5%*
Trial/Pilot/ *Experiment*						*1*		*2*		*1*		*4*	*6%*
Qual							*1*		*1*		*1*	*3*	*4.5%*
Cost & Benefit Analysis								*2*			*2*	*4*	*6%*
Other Mixed *(Survey, content, Interviews, & Focus Groups etc*								*2*	*1*	*5*	*1*	*9*	*14 %*
Foresight (Qualitative & Quantitative)						*1*	*4*		*1*	*5*	*2*	*13*	*20%*
TOTAL					*1*	*3*	*6*	*11*	*13*	*18*	*14*	*66*	

4.1.1. Studies: Foresight Specific Analytical Frames

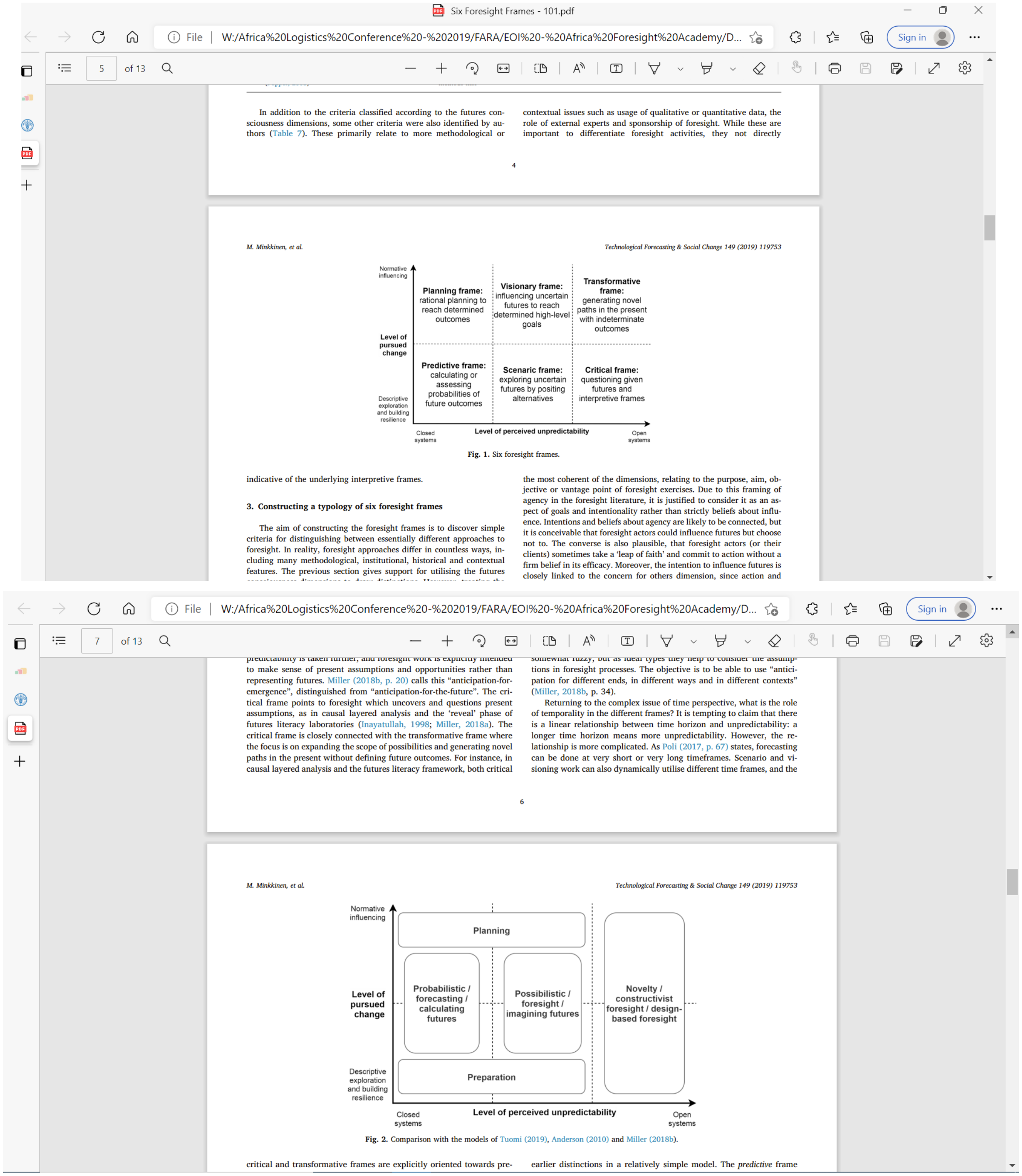
(Table 3) shows a table of classification by nature/type of study and year of publication. We find that more than 55% of the articles utilises quantitative approaches; Quantitative Survey 4.5%; Trial/Pilot/Experiment 6%; Qualitative 4.5%; Cost and Benefit Analysis 6%; mixed approaches 14%; foresight analysis 20%.

TABLE 3: ***Foresight Frames: Towards Plausible futures in Africa CSA***

Journals	**Authors & Topics**	**Nature of Research**	**Foresight Analytical Frames**
Agricultural Systems	*2017* *An Notenbaert, Catherine Pfeifer, Silvia Silvestri, Mario Herrero,* *"Targeting, out-scaling and prioritising climate-smart interventions in agricultural systems: Lessons from applying a generic framework to the livestock sector in sub-Saharan Africa"*	*Framework Development*	*Future planning & priority setting*
	2018 *B.K. Paul, R. Frelat, C. Birnholz, C. Ebong, A. Gahigi, J.C.J. Groot, M. Herrero, D.M. Kagabo, A. Notenbaert, B. Vanlauwe, M.T. van Wijk,* *"Agricultural intensification scenarios, household food availability and greenhouse gas emissions in Rwanda: Ex-ante impacts and trade-offs"*	*Policy Analysis (Multiple Policy Case Based)*	*Scenario Policy Assessments*
	2021 *Renata Jagustović, George Papachristos, Robert B. Zougmoré, Julius H. Kotir, Aad Kessler, Mathieu Ouédraogo, Coen J. Ritsema, Kyle M. Dittmer (2021)* *"Better before worse trajectories in food systems? An investigation of synergies and trade-offs through climate-smart agriculture and system dynamics"*	*System dynamics, simulation, & modelling*	*Systems thinking*
	2022 *Alex Zizinga, Jackson-Gilbert Majaliwa Mwanjalolo, Britta Tietjen, Bobe Bedadi, Himanshu Pathak, Geofrey Gabiri, Dennis Beesigamukama,* *"Climate change and maize productivity in Uganda: Simulating the impacts and alleviation with climate smart agriculture practices"*	*Quantitative (Field experiments & Modelling)*	*Scenario planning projections & prioritisation)*
	2022 *Komlavi Akpoti, Thomas Groen, Elliott Dossou-Yovo, Amos T. Kabo-bah, Sander J. Zwart,* *"Climate change-induced reduction in agricultural land suitability of West-Africa's inland valley landscapes"*	*Quantitative Machine Learning Modelling*	*Scenario Planning*
Climate Risk Management, *2018,*	*Amarnatha,* , G.W.H. Simonsb,c , N. Alahacoona , V. Smakhtind , B. Sharmae , Y. Gismallaf , Y. Mohammedf , M.C.M. Andriessenb (2018)* *"Using smart ICT to provide weather and water information to smallholders in Africa: The case of the Gash River Basin, Sudan G."*	*Case Study analysis*	*Planning /transformational*

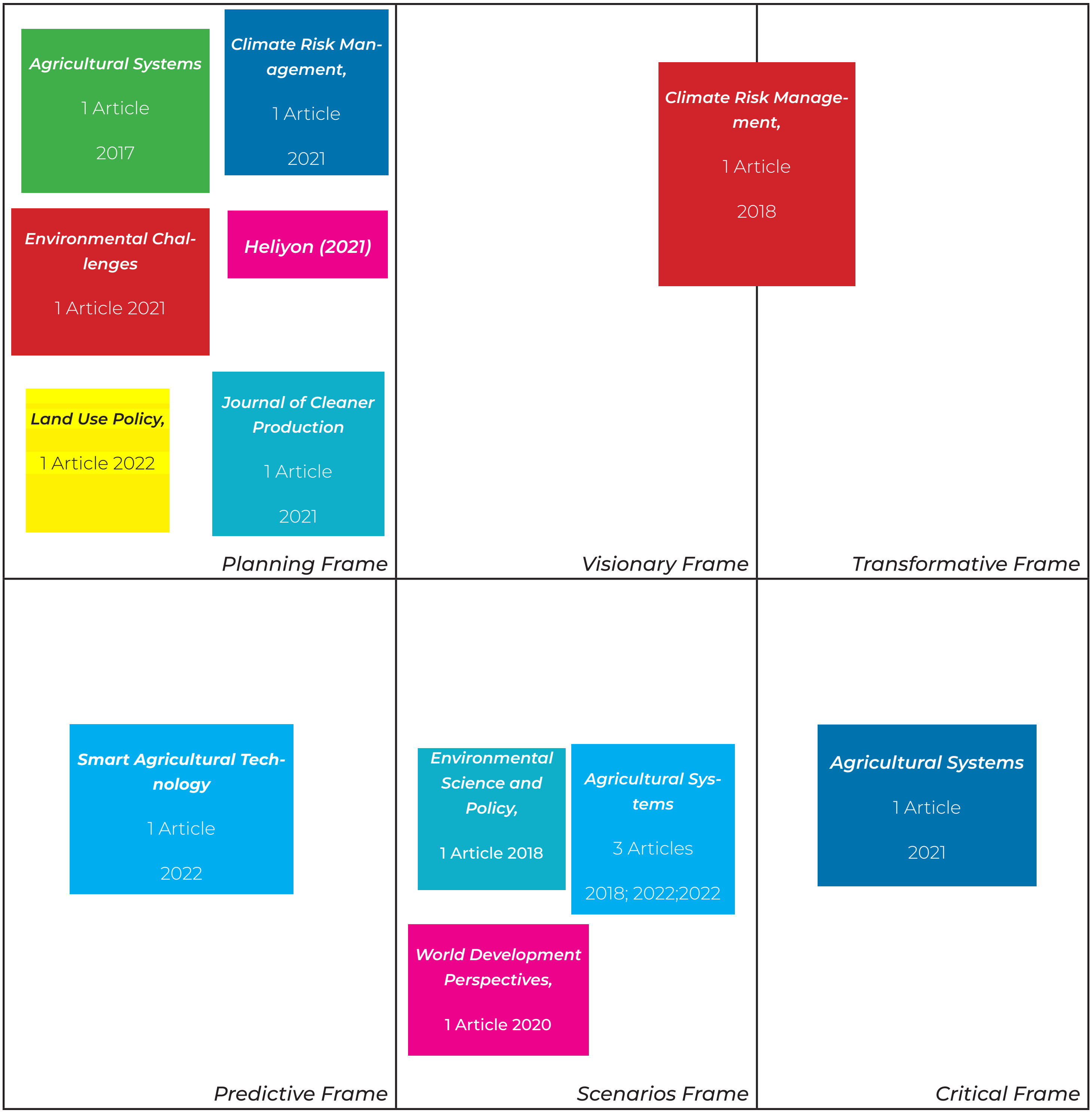
Environmental Science and Policy, 2018,	*Marije Schaafsmaa,b,* , Henri Utilac , Mark A. Hirons (2018) "Understanding trade-offs in upscaling and integrating climate-smart agriculture and sustainable river basin management in Malawi"*	*Assessment*	*Scenario Planning*
World Development Perspectives, 2020	*Maurice Juma Ogada, Elizaphan J.O. Rao, Maren Radeny, John W. Recha, Dawit Solomon, "Climate-smart agriculture, household income and asset accumulation among smallholder farmers in the Nyando basin of Kenya"*	*Quantitative analysis*	*Adaptive pathways/scenarios*
Heliyon (2021)	*Stanley Karanja Ng'ang'a, Vail Miller, Evan Girvetz, "Is investment in Climate-Smart-agricultural practices the option for the future? Cost and benefit analysis evidence from Ghana,"*	*Quantitative (Cost Benefit Analysis)*	*Planning: Future Options /Discounted Cashflows*
Climate Risk Management, 2021,	*Abdoulaye Djido, Robert B. Zougmoré, Prosper Houessionon, Mathieu Ouédraogo, Issa Ouédraogo, Ndeye Seynabou Diouf, (2021) "To what extent do weather and climate information services drive the adoption of climate-smart agriculture practices in Ghana?,"*	*Quantative probit model analysis*	*Planning: Future adaptive pathways*
Environmental Challenges 2021	*Anja du Plessis, (2021) "Necessity of making water smart for proactive informed decisive actions: A case study of the upper vaal catchment, South Africa"*	*Case Study*	*Planning by (evading future predicament*
Journal of Cleaner Production 2021	*Giacomo Branca, Ademola Braimoh, Yuxuan Zhao, Motselisi Ratii, Puseletso Likoetla, Are there opportunities for climate-smart agriculture? Assessing costs and benefits of sustainability investments and planning policies in Southern Africa,*	*Cost Benefit Analysis*	*Policy planning*
Land Use Policy, 2022	*Marieke Sassen, Arnout van Soesbergen, Andrew P. Arnell, Emma Scott, (2018) "Patterns of (future) environmental risks from cocoa expansion and intensification in West Africa call for context specific responses"*	*Risk Analysis based on trend (project past deforestation rates forward),*	*Future planning & prioritisation based on mapping*
Smart Agricultural Technology 2022	*Rubby Aworkaa , Lontsi Saadio Cedric a , Wilfried Yves Hamilton Adoni b, , Jérémie Thouakesseh Zoueuc,d , Franck Kalala Mutomboa,e , Charles Lebon Mberi Kimpoloa , Tarik Nahhal f , Moez Kricheng,h "Agricultural decision system based on advanced machine learning models for yield prediction: Case of East African countries"*	*Case Study*	*Predictions*

Mapping Using the Six Foresight Frames



Figures 2: The Six Foresight Frames

We adopted Minkkinen (1999) six foresight frames typology to map the foresight studies. From above (figures 2), predictive and planning frames – have united assumptions towards futures as dimension of time which can be reduced to probabilistic forecasting hence subject to rational planning. These tend to be accompanied by preparatory tendencies. For scenaric and visionary frames the uncertainty of the future is considered too complex to be subjected to rational planning or assessment of probabilities. These tend to be accompanied by exploratory tendencies such that they enable the practitioners to design scenarios for questioning their model of reality and adjust flexibly to changes when necessary. The critical and transformative frames share the drive for 'anticipatory emergence' that is present actions with future implications. They pursue a change mechanism for control over futures instead of predictions. These to focus on real live experiences (critical), as well as experimentation and search for evolutionary pathways (transformative). The transformative frame resembles latent opportunities, constructivism, design-based foresight, and expansive learning. We utilise the above six foresight frames to enable us to map the CSA papers that address the Africa's plausible futures (which constitute 20% of papers in our data base). Please see below (Figure 2 for the CSA foresight frames mapping in Africa).



Looking at above (figure 2), first we can see that interest in foresight/futures studies within the context of CSA is gaining traction (at least since 2017 in out data set). Although, this is a welcoming news, but the traction/ interest appears incoherent, unfragmented as a legitimate stream of interest. This is evident in the data set as most of the journals published only one article relating to CSA futures in Africa, an then unable to sustain the interest overtime. In our data set, as seen in the diagram (figure 3) above, we can see that there is only one journal '**Agricultural Systems**' that has a sustained publication track from 2017-2022 publishing range of CSA futures related articles of interest.

We hope given the importance of CSA especially in Africa more journals would sustain publications of CSA relevant contents accordingly.

In addition to above, we can also see from the (figure 3 above), that majority of the studies that addressed the CSA in Africa tended use ‘planning frame’ and ‘scenaric frame’ as the main lenses of enquiry for probing the future. While it is interesting to see African practitioners utilising both rational planning tools as well as exploratory scenario-based tools as a strategic future way finding, we would like to see more attempts at critical/transformative related studies. In our data set, there are only 2 articles which attempt to some extent to mention/embed such foresight tools/terminologies. An example of study which seeks to demonstrate the embedding of critical/transformative frames we find interesting is a study by Amarnatha et al., (2018). In view of the above, taking into consideration the potential for transformative and critical frames in generating learning from doing as well as in hindsight (Minkkinen, 1999)), we suspect that applying transformative and critical frames is more likely to lead to the plausible futures Africa seeks to achieve. Thus, we state the following proposition below.

Proposition 1: The higher the application of CSA transformative action and critical frames, the higher the likelihood for achieving plausible futures in Africa.

5.0: Discussion & Analysis of Emerging Themes: Learnings in Hindsight for Foresight

5.1 CSA Adoption in Africa: Slow but Steady across regional blocks

Although adoption rate has reported as being slow, where CSA have been trialled or fully implemented the results reported have been remarkable across the continent of Africa. CSA in Africa is helping farmers manage/mitigate risks, improve yield, livelihood, food security, climate stress management, & achieve sustainable and cleaner production systems (please see Table 4) for full details of spectrum of adoption across the African continent. Also, although the adoption of CSA across the continent does not reveal a peculiar strategy/approach dependent on the unique regional bloc’s characteristics, we note through a closer inspection, that country specific approaches tended to be more unique to them. Please see the next section for more details about country specific approaches and the potential for African countries to learn from one another. Thus, we state the proposition below.

Proposition 2: The higher the variety of CSA technological/practices, the higher the likelihood for achieving plausible futures in Africa.

TABLE 4: ***CSA Adoption: Learning from (Regional Specific Focus)***

Regional Block	*Contextual Background*	*Type of CSA Applied (Practice & Technology)*	*Number of Articles*
Sub- Saharan Africa	*Sub Saharan Africa (SSA), the content, effectiveness, and mode of delivery of training programs remain a debate.* *Livelihood & Food security* *Climate Stress Management, & Soil* *South-South Cooperation* *Climate Change*	*Technologies* *Technological innovations (framework)* *Conservation Agriculture* *conservation agriculture (CA) and sustainable intensification (SI).* *improved seed, and conservation agriculture in the soybean, faba beans, and peanut value chains respectively*	*4*

West Africa	*large-scale implementation of climate-smart agricultural practices* *environmental risks from cocoa expansion and intensification*	*Technology intervention* *decision-support tools for policymakers to support large-scale implementation of climate-smart agriculture* *Conservation Biodiversity*	*2*
East Africa	*the links between farming and livelihood practices, other possible adaptation options, and the effects on farm performance,*		*1*
Eastern-Southern Africa	*the adoption and diffusion of climate-smart technologies have been slow.*	*Technologies*	*1*
Southern Africa	*enhancing livelihood of farmers* *Balancing Gender & Technology* *informed management of water resources* *sustainable and cleaner production systems*	*Conservation Agriculture* *Rainwater Harvesting, Early maturing seed Varieties & Drought Tolerance* *soil and water* *conservation management practices based on the principles of conservation agriculture (CA), improved varieties, and associations of cereal-legume crop species* *application of determining hydrological responses to predict possible water quality changes towards land cover change in the Vaal river catchment*	*3*

5.2 There is plenty of opportunity for African counties to learn from each other's best practices

A closer inspection of the country specific focus by the type of CSA implements and the context in which it was applied reveals some interesting insights (Table 5). The first thing we note is that, while some countries approach to CSA is broad across variety of technologies and practices, others follow identified a narrower path to adopting CSA. For example, a close inspection to Table 5 below reveals that Malawi's approach to CSA adoption is broad and pragmatic. From our data set, we identified Malawi as a country in Africa which appears to apply CSA more broadly to a wider context including: managing risk of climate change for soil and water management, climate stress for maize resistance, resilience of smallholder farmers, food security production under extreme weather events & gender participation, yield impacts with CSA aid interventions among smallholder farmers, resource intensiveness, maize productivity, inequality, and farmer livelihoods (refer to study codes 4, 13, 20, 46, 57 in Appendices: Table A for details of these studies) . Given the wider contexts for CSA implementation Malawi has adopted range of CSA technology and practices such as Conservation Agriculture, Agro-forestry, Agro-ecology etc (Table 5). We believe, this pragmatic approach is enabling Malawi to approach the climate change from multiple fronts is an approach other African countries could apply given the available resources. Also, Malawi's application of Conservation Agriculture with diversification(rotation) (intercropping) and or to drought tolerant maize, and improved legume varieties are examples of climate change management strategies of good practice for smallholder farmers in Africa to learn from. There are their examples of good practice reported such as the Malawi Social Action Fund (MASAF), and the integrated catchment management (ICM) at landscape level.

On the other hand, we find the Ghanaian approach to CSA adoption to be organised from broad to specifics. For example, broadly CSA adoption in Ghana tended to be applied in the context of crop vulnerability to climate change induced extremes, negative effect of climate change variability risks, smallholder farmers livelihoods etc and more specifically to for example climate-smart cocoa governance risks entrenching old hegemonies. We also find, in our data set Ghanaian tendency to focus on activities requiring CSA services-oriented approach. For example, many studies in our data base (refer to study codes 44, 35, 31 and 18 in Appendices: Table A) for details of these studies) that shows Ghana's focus on climate risk & information, climate information services, and Agricultural extension services information etc (See Table 5). We suppose the development of service-based economy, might have contributed to this development – hence placing Ghana to be one of the best practices in targeting farm household participation in training, agricultural extension services in training/supporting farmers to adapt to climate change as reported in some papers. All these suggests the developmental traction of a knowledge intensive service-based economy making CSA adoption insightful for other African countries to learn from.

TABLE 5: ***CSA Adoption: Learning from (Country Specific Focus)***

Specific Countries	***Contextual Background***	***Type of CSA Applied (Practice & Technology)***	***Number of Articles***
		CSA Technologies & Examples of good practice	*5*
Nigeria	*Rain fed Agriculture & irrigation*	*Integrated Technology Platform: integrating remote sensing, Geographical Information Systems (GIS), flood forecasting models and communication platforms*	
Tanzania	*rainfed system of rice intensification (land degradation, climate change, and limited access to improved technology)*		
Zimbabwe and Malawi	*agricultural credit and extension on adoption*		
Sudan	*spate irrigation (flood-recession farming)*		
Uganda & Tanzania	*CSA priorities among different social groups (gender) and agro-ecological zone*		
Ghana	*farmers' risk attitudes and household livelihood diversification*		
		Conservation Agriculture (CA) & Examples of good practice	*4*
Malawi, Mozambique, and Zambia,	*Managing risk of climate change for soil and water management*	*Conservation Agriculture with diversification over time (rotation) (intercropping).*	
Ethiopia	*Gender: Women farmers,*		
Malawi	I) *Climate Stress for maize resistance* II) *constraints experienced by farming households*	*Conservation agriculture, drought tolerant maize, and improved legume varieties are key climate change management strategies for smallholder farmers in southern Africa*	
Zimbabwe	*production or climate resilience*		
Malawi and Zimbabwe.	*resilience of smallholder farmers*		

		Agroforestry & Agro-ecology: examples of good practice	*4*
Southern Malawi	*Food security*		
Ethiopia	i) *Farmers' willingness to accept payments for ecosystem services on agricultural land*	*Payment for Ecosystem Services (PES) schemes that promote large-scale adoption of climate-smart agroforestry,*	
Kenya	i) *Socio-economic determinants of adoption: Feed scarcity, especially in drier agro-ecological zones.*	*Improved planted forages such as Brachiaria grass have been recommended as one of the strategies of alleviating feed scarcity, especially in drier agro-ecological zones*	
Ghana	i) *Motivations, enablers and barriers to the adoption*	*produce and storage, emergency seed banking, appropriate and timely weed and pest control, and early planting as practices to build climate resilience*	

Zambia	*cropland expansion and deforestation in*	*CSA Practices/Initiatives & examples of good practice*	*20*
Ghana	i) *crop specific vulnerability to climate change induced extremes and the implications for climate change adaptation planning* ii) *Farm household participation in training* iii) *agricultural extension services in training/ supporting farmers to adapt to climate change* iv) *negative effect of climate change and variability risks on smallholder farmers livelihoods.* v) *Climate Risk & information* vi) *Climate Information Services* vii) *Food Systems*	*diversification of crops, change of planting time and crop rotation/mixed cropping.* *mobile phone delivery channels of weather forecasts through the ESOKO platform Climate Smart Village (CSV) Lawra-Jirapa in northern Ghana* *Climate Smart Social (CSS) practices (agroforestry, intercropping, liming, organic manure use, inorganic fertilizer, and improved hybrid seeds)* *The impact of a major CSA aid effort (the United States Agency for International Development-funded Wellness and Agriculture for Life's Advancement (WALA) project*	
Côte d'Ivoire and Ghana	*Climate-smart cocoa governance risks entrenching old hegemonies*	*cover crops planting and minimum tillage practices. Soil amendments, conversion of waste to compost, agro-forestry, resource conservation and use of agro-weather related initiatives.*	
Kenya	ii) *Low adoption rate – determinants* iii) *Determinants of CSA Adoption* iv) *livelihood of farmers (income)* v) *Rehabilitation & Protection of Soil* vi) *Foundations for climate services* vii) *Lack of awareness of farmers & gender issues* viii) *Communicating Climate Change Information (dissemination)*	*The three information dissemination pathways included media, neighbours and friends, and extension officers*	
Malawi	i) *production under extreme weather events & gender participation* ii) *Adoption and yield impacts with CSA aid interventions among smallholder farmers* iii) *Resource intensiveness & low adoption* iv) *Impacts of CSA practice on Maize productivity* v) *Inequality*	*Malawi Social Action Fund (MASAF), and three widely promoted climate smart agriculture (CSA) practices.*	
Malawi & Zimbabwe	*Institutional credit & extension services*	*integrated catchment management (ICM) at landscape level* *Including improved agronomy, soil and water conservation, drought tolerant high yielding crop variety, small-scale irrigation, integrated disease, pest, and weed management, and integrated soil fertility management,*	
Mali	*Complex and integrated goals of increasing yields, improving resilience, and promoting a low emissions agricultural sector.*	*The parklands deliver multiple benefits, including fuelwood, soil nutrient replenishment, moisture conservation, and improved crop yield underneath the canopy. Its microclimate modification may provide an affordable climate adaptation strategy which needs to be explored*	
Ethiopia	i) *improving crop and livestock production and farmer income while reducing greenhouse gas emissions.* ii) *Low Adoption* iii) *soil fertility decline, food insecurity and climate change.*	*cover crops planting and minimum tillage practices, soil amendments, conversion of waste to compost, agro-forestry, resource conservation and use of agro-weather* *soil moisture conservation, erosion reduction, soil fertility enhancement, increasing and stabilizing crop yield and livelihoods,*	
Nigeria	i) *Involvement of extension agents* ii) *Awareness Level of Urban Farmer*	*sustainable land management*	
Ethiopia, Kenya, Tanzania, Malawi, and Mozambique	*Climate Change & Farmer Livelihood* *household food availability and greenhouse gas emissions*		
Rwanda	i) *producers' experiences with Rwanda's Crop Intensification Program (CIP)*	*CSA Policies-centric* *Intensification programs are now frequently linked to Climate Smart Agriculture (CSA), which attempts to build resilience and reduce greenhouse gas emissions while increasing crop yields.*	
Tanzania & Uganda	*locally appropriate climate smart agriculture (CSA) technologies will need to address the context-specific multi-dimensional complexity in agricultural systems.*	*The CSA-RA combines common participatory rural appraisal (PRA) and rapid rural appraisal (RRA) tools into one methodology. It takes into consideration gender differences in perceptions of climate change and its impacts.*	

Some examples of good practice reported in Ghana includes mobile phone delivery channels of weather forecasts through the ESOKO platform, and the Climate Smart Village (CSV) Lawra-Jirapa in northern Ghana. Kenya and Nigeria appear to focus on aspects of determinants of CSA adoption or engagement extension services etc. For example, Kenya, has a general focus on livelihood of farmers (income), rehabilitation & protection of soil, feed scarcity but the specific orientation and concern is towards understanding the socio-economic determinants of adoption, determinants of low adoption rate (refer to study codes 5, 7, 29 in Appendices: Table A for details of these studies). The same Nigeria's approach also focuses on determinants of engagement with extension services, determinants of awareness levels of farmers etc (refer to study codes 34 and 36 in Appendices: Table A for details of these studies). Some identifiable CSA best practices found in Kenya includes: Improved planted forages such as Brachiaria grass have been recommended as one of the strategies of alleviating feed scarcity, especially in drier agro-ecological zones. Climate Smart Social (CSS) practices (agroforestry, intercropping, liming, organic manure use, inorganic fertilizer, and improved hybrid seeds).

The impact of a major CSA aid effort (the United States Agency for International Development-funded Wellness and Agriculture for Life's Advancement (WALA) project cover crops planting and minimum tillage practices. Soil amendments, conversion of waste to compost, agro-forestry, resource conservation and use of agro-weather related initiatives. Some CSA adoption best practices found in Nigeria includes cover crops planting and minimum tillage practices, soil amendments, conversion of waste to compost, agro-forestry, resource conservation and use of agro-weather, soil moisture conservation, erosion reduction, soil fertility enhancement, increasing and stabilizing crop yield and livelihoods.

For Ethiopia CSA adoption is observed across multiple range of practices including Conservation Agriculture, Agro-forestry, & Agro-ecology. Ethiopia's orientation to CSA adoption like Malawi, also seems to be broad/pragmatic but with a clear focus on the farmer. Broadly, there is a focus on soil fertility decline, food insecurity and climate change, but more specifically tended to narrow down on concern for farmers livelihoods (including women) example improving crop and livestock production and farmer income while reducing greenhouse gas emissions, farmers willingness to adopt climate smart service (example farmers' willingness to accept payments for ecosystem services on agricultural land) and the low adoption rate etc (refer to studies codes 10, 14, 27, 56 in Appendices: Table A for details of these studies). Some examples of good practice found in Ethiopia includes: the innovations on household nutritional security, including gender-differentiated nutritional status

Payment for Ecosystem Services (PES) schemes that promote large-scale adoption of climate-smart agroforestry, improved agronomy, soil and water conservation, drought tolerant high yielding crop variety, small-scale irrigation, integrated disease, pest, and weed management, and integrated soil fertility management. Faidherbia albida trees buffer wheat against climatic extremes in the Central Rift Valley of Ethiopia. The parklands which deliver multiple benefits, including fuelwood, soil nutrient replenishment, moisture conservation, and improved crop yield underneath the canopy. Its microclimate modification may provide an affordable climate adaptation strategy which needs to be explored.

Other examples of good practices for CSA adoption are found across the continent. The following are some of the additional examples of good practice we identified in our data base. In Rwanda we find the CSA Policies-centric approach interesting. In addition, the focus on intensification programs which are now frequently linked to Climate Smart Agriculture (CSA), is enabling the development of resilience and reduction of greenhouse gas emissions while increasing crop yields in Rwanda (refer to study code 48 in Appendices: Table A for details of these study). Also, Tanzania and Uganda's approach on the CSA-RA which combines common participatory rural appraisal (PRA) and rapid rural appraisal (RRA) tools into one methodology as well as takes into consideration gender differences in perceptions of climate change and its impacts is an example of good practice (refer to study code 48 in Appendices: Table A for details of these study).

Cameroon & Liberia on the conservation of biodiversity and provision of ecosystem services across the region is an example of good practice (refer to study code 53 in Appendices: Table A for details of these study). In addition, cropland expansion and deforestation in Zambia is insightful (refer to study code 6 in Appendices: Table A for details of these study). Finally, we note Sudan's use of Integrated Technology Platform (ITP) which integrates remote sensing, Geographical Information Systems (GIS), flood forecasting models and communication platforms together as an example of good practice for African countries to learn from. Particularly, the Gash Delta of Eastern Sudan, spate irrigation (flood-recession farming) contributes substantially to rural livelihoods (refer to study code 16 in Appendices: Table A for details of these study). In view of the above, we believe there is abundance of opportunity for African countries to learn from each other's CSA practices. Thus, we state the proposition below:

Proposition 3 : The higher the opportunity to learn CSA best practice between countries in continent, the higher the likelihood for achieving plausible futures in Africa.

5.3 Why is Industry 4.0 Technology less utilised for CSA & What does it mean for Africa's Future?

TABLE 5: ***CSA Adoption: Learning from (Regional focus on Industry 4.0)***

Regions	*Contextual Background*	*Type of CSA Applied (Practice & Technology)*	*Number of Articles*
All Parts of Africa	*The connections between AI and climate change research as a whole and its usefulness in climate change adaptation efforts in particular.*	*Industry 4.0*	*4*
		Artificial Intelligence (AI) is believed to have a significant potential use in tackling climate change.	
West Africa	*Climate change-induced reduction in agricultural land suitability*	*Machine Learning*	
East Africa	*Food Security*	*Advanced Machine Learning*	
Sub-Saharan Africa	*Irrigated farmlands*	*Internet of Things (IoT)*	

Despite the significance of technology towards CSA, the utilization of advance form of technology especially the industry 4.0 appears very low across the continent (please see Table 5 above). Clearly the lower utilization rate of advance technology could be linked to lower absorptive capacity of farmers and other key actors within the Agricultural/food systems in Africa. The absorptive capacity here encompasses the whole system of digital infrastructure and knowledge architecture to enable African smallholder farmers and other actors in the food systems to be able to acquire, absorb, & retain technological knowledge.

Since value crating in the digital age is increasingly shifting towards intangibles such as R&D, IP, design, software, branding, use of data etc., it is vital for Africa to invest heavily in development of absorptive capacity to facilitate CSA adoption with advanced technological support (Africa Trade Report, 2019). Without required absorptive capacity the African countries could run the risk of being unable to leverage on the CSA opportunities that present themselves of higher value-added nature. Thus, in view of the above we state the proposition below.

Proposition 4: The higher the opportunity to develop the absorptive capacity for adopting industry 4.0 technology to the CSA practices, the higher the likelihood for achieving plausible futures in Africa.

TABLE 6: ***CSA plausible Future: Some Critical Success Factors***

Critical Success Factors (CSF)	*Authors (year and code)*	*Emerging Themes*

Training: (Awareness, & Capacity Building)	*Zakaria et al., 2020 (study code 11)* *Antwi-Agyei et al., 2021* *(Study code 18)*	*Role of Training & Capacity Building for CSA adoption (access to agricultural extension services)* *identified capacity building needs such as developing extension agents' technical skills, improving communication skills, improving knowledge and use of climate smart agricultural interventions such as soil moisture conservation methods, and training on information communication technologies (ICT) to deliver extension advice on climate change*
	Mashi et al., 2022 (Study code 36) *Autio et al., 2020 (Study code 61)* *Sarr et al., 2021 (Study code 9)*	*Determinants of awareness levels* *emphasize lack of awareness as a barrier to adoption,* *farmers with low resistance to adoption, benefit.* *the need for policies that increase climate awareness to ensure food security.*
Voices of the Women, & Youth,	*Makate et al., 2019a (Study code 3)* *Tsige et al., 2019 (study code 10)* *Pangapanga-Phiri, and Mungatana, et al., 2021 (Study code 12)*	*Access to extension services or credit enhances CSA adoption & Inclusion with disadvantage groups (youth & women)* *women smallholder's uptake is affected by limited access to credit, extension, restricted membership in cooperatives and water user associations, lack of access or user rights to land, skill training, information, and restricted mobility* *gender-targeting extension services to augment the benefits of CSA practices among female farmers*
	Teklewold, 2019 (Study code 27) *Mwongera 2017 (Study code 32)* *Makate et al., 2019 (Study code 40)* *Mutenje et al, 2019 (Study code 43)*	*Gender-disaggregation results suggest nutritional outcome differentials between male and female headed households due to both differences in household characteristics, including household resources, and differences in returns to resources* *heterogeneity across the sites in terms of vulnerability, constraints and CSA priorities among different social groups (gender) and agro-ecological zones.* *impacts of multiple adoption of the practices are not entirely uniform across different geographic regions and gender* *women's bargaining power, drought shock, and access to CSA technology information positively influenced the probability of investing in CSA technology combinations.*

Voices of small holder Farmers	*Maguire-Rajpaul 2022 (Study code 17)* *Clay and Zimmerer et al., 2020 (Study code 60)*	*smallholder voices remain marginalised and argue that corporate-led CSC schemes build upon and re-employ past sovereign powers (e.g., threatening to evict smallholders from protected forests), thus entrenching long-standing power asymmetries and overlooking critical differences between countries* *rural development policies could better promote climate-resilient livelihoods through: 1) adaptive governance that enables smallholder land use decision-making; 2) support for smallholder food producers' existing agro-ecological strategies of intensification; 3) participatory approaches to visualize and correct for inequalities in local processes of social-ecological resilience*
Socio-Economic Barriers & Constraints	*Jew et al., 2020 (Study code 57)* *Musafiri et al., 2022 (Study code 5)*	*The most significant constraints were linked to household health, with associated labour and monetary impacts, in addition to the availability of external inputs of fertiliser and improved seed varieties.* *relevant stakeholders should consider farmer, institutional, and biophysical factors in upscaling or promoting the adoption of CSAPs.*

One of the key issues affecting the adoption and scaling-up of the CSA in Africa is the negative perception and farmers resistance to change especially the smallholder farmers (Nyang'au et al., 2021; Antwi-Agyei et al et al., 2021). This negative perception and resistance have led to negative impacts including deepening the impacts of climate change, declining productivity, and food insecurity (Nyang'au et al., 2021). On the other hand, farmers with positive perceptions – thus low resistance to CSA adoption benefits from improved yield (Sarr et al., 2021). In view of the above, some vital issues identified as the critical success factors for Africa's CSA plausible future includes training (awareness & capacity building), voices of women/youth, voices of smallholder farmers, and overcoming socio-economic barriers (livelihoods). The critical success factors are discussed as below.

5.4 Training: (Awareness, & Capacity Building) is a key pillar to Africa's CSA plausible Futures – but who and how to train is still a puzzling concern?

There are generally two streams of capacity building related issues identified in our data set namely the role of training for capacity building of farmers and extension workers on one hand (please see Table 6: Zakaria et al., 2020 study code 11 and Antwi-Agyei et al., 2021., 2021 Study code 18), and the role of general awareness levels among extension workers and farmers (please see Table 6: Mashi et al., 2022 Study code 36; Autio et al., 2020 Study code 61; and Sarr et al., 2021 Study code 9). According to Zakaria et al. (2020), participation in capacity building trainings positively correlates with adoption of CSA practices and is mainly influenced by the farmers access to range of services (extension & insurance) services, as well as membership of a certain farm-based organisation. However, Antwi-Agyei et al., (2021) note that, the capacity of the extension workers themselves needs building significantly. They identified several capacity building needs of the extension workers such as "technical skills, improving communication skills, improving knowledge and use of climate smart agricultural interventions such as soil moisture conservation methods, and training on information communication technologies (ICT) to deliver extension advice on climate change. Other needs included developing skills in field demonstration and project monitoring and evaluation) (Antwi-Agyei et al., 2021). In addition, they identified additional barriers that extension workers face including: "transportation facilities for extension agents, lack of appropriate extension materials, high agricultural extension agent to farmer ratios, and inadequate funds to implement adaptation practices, farmer resistance to change and complex land tenure arrangements that do not allow investment.

5.5 A CSA Plausible Future respect voices of the women, youth,

Given the significance of the extension work, we are surprised to find in our data set that, women and youth have been systematically marginalised from gaining access to extension training and related services. In our data set we note that, the systematic marginalisation of the disadvantaged group of women/youth is visible given the limited access or restrictions to extension and other valuable services/opportunities (please see Table 6: Tsige et al., 2019 study code 10, Pangapanga-Phiri, and Mungatana, et al., 2021 Study code 12, and Makate et al., 2019 (Study code 3). This is very alarming if one considers the Africa's youthful population as well as the potential crucial role women could play in enhancing the productivity of Agriculture through CSA adoption (Makate et al., 2019a). In addition to lack or restricted access to extension services women farmers in Africa continue to suffer gender unequal access to CSA technological information – deepened by nutritional outcome differentials, household resources etc (please see Table 6: Teklewold, 2019 Study code 27; Mwongera, 2017 Study code 32; Makate et al., 2019b Study code 40; and Mutenje et al, 2019 Study code 43)

5.6 A CSA Plausible Future must be inclusive & respect the voices of small holder farmers

A central issue of concern which has been under-represented in the literature is the issue of smallholder farmers voices. The under-representation of smallholder farmers is apparent both in the literature reviewed and in practice. According to Maguire-Rajpaul., (2022) the "smallholder voices remain marginalised and argue that corporate-led CSC schemes build upon and re-employ past sovereign powers (e.g., threatening to evict smallholders from protected forests), thus entrenching long-standing power asymmetries and overlooking critical differences between countries". In addition, they stated that "smallholders in Côte d'Ivoire and Ghana supply over 60% of the cocoa to the $120bn global chocolate industry. Like colonialists and multilateral banks before them, foreign chocolate corporations today attempt to govern the behaviour of smallholders in Ivorian and Ghanaian forests via a recent proliferation of 'climate-smart' cocoa (CSC) schemes" (please see Table 6: Maguire-Rajpaul., Study code 17).

The above concern raised by smallholder farmers could not be ignored as it could inhibit the CSA adoption through aggravating the already negative perceptions, lack of awareness, and resistance that is prevalent among the smallholder farmers group in Africa (Nyang'au et al., 2021). This scepticism is beginning to grow and is attracting criticism from civil society organisation. For example, in Kenya in 2022 various civil society organisations argued and criticised the application of genetically modified cassava to avoid interference with seed systems suitable and well-adapted to the conditions of small-scale farmers (Maina et al. 2020). Also in Uganda a GM sceptic worried that smallholder farmers may not have control over the seeds, thus should not enter in to relationship or agreements which does not guarantee their rights (Doucleff 2013). Going forward, an African plausible future for CSA must take in to consideration the flight and voice of the smallholder farmers – through guaranteeing among other things respect for their opinions as well as compatibility/integration of a systems which preserves local farming practices utilised for over a millennia (Ashton 2012). Clay and Zimmerer, (2020) suggested that "rural development policies could better promote climate-resilient livelihoods through: 1) adaptive governance that enables smallholder land use decision-making; 2) support for smallholder food producers' existing agro-ecological strategies of intensification; 3) participatory approaches to visualize and correct for inequalities in local processes of social-ecological resilience Such considerations are paramount for meeting the United Nations Sustainable Development Goals and building climate-resilient food systems".

5.7: Overcoming the Socio-Economic Barriers & Constraints (livelihoods)

The African CSA and associated crop technologies under the guise of green revolution have become subject to so many expectations (Fischer et al., 2016). However, several studies have demonstrated that the CSA adoption and scaling in Africa have been negatively affected by many barriers and constraints. Scholars identified institutional, biophysical, household health, monetary impacts, availability of external inputs of fertiliser and improved seed varieties as some of the many barriers/constraints to CSA adoption and scaling (please see Jew et al., 2020 Study code 57 and Musafiri et al., 2022 Study code 5). Going forward, some studies have suggested that the focus should not be just bio-physical and socio-technical factors but also shall encompass policy analysis and mapping of regions into favourable, intermediate, and unfavourable (Andriew et al., 2021).

In view of the importance of all the critical success factors discussed, we state the following proposition.

> *Proposition 5: The higher the opportunity to strengthen the development of some critical success factors like (training/awareness/capacity building; gender/youth mainstreaming; voice of small holder farmers; & socio-economic barriers) , the higher the likelihood for achieving plausible futures in Africa.*

Conclusion:

Given the growing interest on Climate Smart Agriculture (CSA) in Africa, the study started by setting the context of growing relevance of CSA and its implication for African agriculture. The context was developed based on general lack of understanding of direction for Africa's CSA plausible futures regarding the slow adoption rate of CSA in Africa. Afterwards, the study establishes an operational definition which encompasses learning in hindsight as a precondition to understanding the plausible futures in Africa. Afterwards, literature review focuses on reviewing relevant streams of literature particularly linked to attitude behaviour gap and awareness for CSA adoption in Africa.

The study utilises a secondary desk-based exploratory systematic review and analysis leading to the development of a summary of the current state of research on CSA plausible futures in Africa. A comprehensive systematic secondary search was conducted using a single source 'the Science Direct'. After sorting and identifying relevant literature, the study maps out CSA foresight studies using the six foresight frames typology. In so doing, the study develops insights about the nature and direction of CSA foresight studies published. Particularly, the study finds that most CSA foresight in Africa focused on utilising planning and scenaric frames as lens for generating insights about the future, while the critical, and transformative frames – appeared to be under-utilised.

Despite the numerous CSA best practices across the continent, there are no sufficient sharing and learning from each other hence hindering advances to CSA plausible futures across Africa. Also, the study finds that there is limited application of industry 4.0 for CSA across the continent of Africa, perhaps this could be due to low absorptive capacity. Finally, the study identified some four emerging CSA critical success factors necessary for developing a plausible future in Africa including the need for more training (awareness & capacity building), gender and youth mainstreaming, accommodating the voice of the smallholder farmers, and going beyond socio-economic barriers. Each of the four critical success factors have been discussed in detail and subsequently led to the stating of five baseline propositions – each with clear implications to policy to facilitate debates and actions on plausible futures of CSA in Africa.

The main shortcoming of the study is on reliance on single source 'the Science Direct'. Going forward, the single source will expand to particularly include relevant studies from 'Scopus' and 'Web of Science' sources. Once the data sources are expanded accordingly, the future study will utilise the additional findings to state more propositions about CSA plausible futures as well as utilise that as basis to developing a 'futures mapping canvass'. The goal is to develop a tool that will enable practitioners across the continent of Africa to engage in stakeholder workshops on how to address the identified critical success factors and mitigate any potential inhibiting issues to arise. This will help in developing the role of foresight competences for CSA in Africa.

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1. APPENDICES - TABLE A: CSA Adoption : Codes, Themes, Contexts, & Learning in Hindsight

JOURNAL	COD-ING	AUTHORS & TITLE	TYPE OF CSA ADOPTED & WHY?	FORESIGHT ANALYTICAL FRAMES	CONTEXT APPLIED	LEARNING IN HIND-SIGHT (FACTORS FOR MAPPING PLAUSIBLE FUTURES)
Agricultural Water Management, *Volume 178,* *2016,*	*1*	*Olawale Emmanuel Olayide, Isaac Kow Tetteh, Labode Popoola, (2016)* *Differential impacts of rainfall and irrigation on agricultural production in Nigeria: Any lessons for climate-smart agriculture?,*	*CSA technologies Impacts to productivity of more arable lands*	*Quant (Econometrics)*	*Rain fed Agriculture & irrigation in Nigeria.* *Irrigation would also enhance complementary agricultural water management for the development of all the sub-sectors of agriculture, thereby enhancing food security and sustainable agricultural production under prevailing climate change and variability.*	*Variation of Impacts (No one measure fits all) – for productivity* *impact may also vary by aggregate and sub-sectoral levels of agricultural production*
Ecological Economics, *Volume 163,* *2019,* *Pages 126-137,*	*2*	*Munyaradzi Junia Mutenje, Cathy Rozel Farnworth, Clare Stirling, Christian Thierfelder, Walter Mupangwa, Isaiah Nyagumbo, (2019)* *A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology,*	*(CSA) technologies Cost-benefit analysis (CBA) and a mixed methods approach were used to assess the likelihood of investment in various CSA options that combined soil and water conservation management practices based on the principles of conservation agriculture (CA), improved varieties, and associations of cereal-legume crop species were economically viable and worth implementing for ri*	*Mixed method (Cost & Benefit Analysis)* *The cost-benefit analysis and stochastic dominance results showed that* *Cost-benefit analysis (CBA) and a mixed methods approach were used to assess the likelihood of investment in various CSA options*	*CSA technology combinations. The data were drawn respectively from 1440, 696, and 1448 sample households in Malawi, Mozambique and Zambia, covering 3622, 2106 and 5212 maize-legume plots in these countries over two years.*	*CSA for Climate change adaptations effectively/ mitigationg risks* *comprise a suite of interventions that aim to sustainably increase productivity whilst helping farmers adapt their farming systems to climate change and to manage risk more effectively.*

Environ-mental Development, *Volume 32,* *2019,*	*3*	*Clifton Makate, Marshall Makate, Munyaradzi Mutenje, Nelson Mango, Shephard Siziba, (2019)* *Synergistic impacts of agricultural credit and extension on adoption of climate-smart agricultural technologies in southern Africa,*	*Impact of extension and credit services to CSA adoption*	*Quant (Probability)* *inverse-probability weighting regression adjustment and propensity score matching*	*Using household level survey data from Zimbabwe and Malawi,*	*Access to extension services or credit enhances CSA adoption & Inclusion with disadvantage groups (youth & women)* *access to either extension or credit significantly progresses CSA technology adoption. However, access to extension services only proved to be more effective in enhancing CSA technology adoption than access to credit alone* *joint impacts of credit and extension on adoption were found to be less pronounced in youthful and women farmer groups compared to their old and male farmer group counterparts respectively.*

Ecological Economics, *Volume 167,* *2020,*	*4*	*Festus O. Amadu, Daniel C. Miller, Paul E. McNamara, (2020)* *Agroforestry as a pathway to agricultural yield impacts in climate-smart agriculture investments: Evidence from southern Malawi,*		*Quant (Survey/ Model)* *Using original survey data from 808 households across five districts, we apply a double hurdle specification with a control function approach to account for the endogeneity of CSA program participation and the intensity of agroforestry fertilizer trees (as a proxy for agroforestry adoption) in the study area.*	*insights about the future of agriculture and food security under a range of future drivers including climate change* *in interaction with stakeholder-generated narratives and scenario trends and SSP assumptions. We present this process as an example of linking comparable scenarios across levels to increase coherence with global contexts,*	*Enhancement of Yield* *productivity among smallholder farmers in sub-Saharan Africa and elsewhere. More broadly,* *More broadly, our results show that incorporating agroforestry into CSA interventions could enhance agricultural yields among smallholder farmers in the face of climate change — a crucial aspect of sustainable development goals on hunger and climate adaptation.*
Heliyon, *Volume 8, Issue 1,* *2022,*	*5*	*Collins M. Musafiri, Milka Kiboi, Joseph Macharia, Onesmus K. Ng'etich, David K. Kosgei, Betty Mulianga, Michael Okoti, Felix K. Ngetich, (2022)* *Adoption of climate-smart agricultural practices among smallholder farmers in Western Kenya: do socioeconomic, institutional, and biophysical factors matter?,*	*Rigorous efforts should be channeled to the current low adoption of climate-smart agricultural practices (CSAPs) in sub-Saharan African countries to improve food production*	*Quant (The ordered probit model)*	*What determinants of CSAPs among smallholder farmers in Kenya?.*	*Determinants of low CSA adoption rate in SSA* *revealed that gender, arable land, livestock owned, soil fertility, and constant soil erosion were crucial determinants of CSAPs adoption. The findings implied that policymakers and relevant stakeholders should consider farmer, institutional, and biophysical factors in upscaling or promoting the adoption of CSAPs.*

Land Use Policy, *Volume 107,* *2021,*	*6*	*Hambulo Ngoma, Johanne Pelletier, Brian P. Mulenga, Mitelo Subakanya, (2021)* *Climate-smart agriculture, cropland expansion and deforestation in Zambia: Linkages, processes and drivers,*	*Climate-smart agriculture (CSA) is considered an important option to increase agricultural productivity and resilience, intensify agricultural production, and possibly reduce cropland expansion.*	*Quant: Survey* *This paper uses nationally representative survey data to assess the extent, intensity and drivers of cropland expansion, and applies an instrumental variable approach to determine the extent to which CSA reduced cropland expansion in Zambia.*	*Urgent need to increase production for subsistence farmers and avoid cropland expansion to forest* *There is an urgent need to increase agricultural production to meet increasing food demands driven in part by population growth and changing dietary preferences. Doing so by expanding area cultivated into forests has important environmental consequences, including engendering climate change.*	*No statistically significant association is found between CSA and cropland expansion to forests* *Most households expanded cropland because they needed to meet subsistence food requirements and a few others in response to market opportunities. We did not find statistically significant associations between adopting CSA and cropland expansion in our national sample.*

Heliyon, *Volume 7, Issue 4,* *2021,*	*7*	*Jared O. Nyang'au, Jema H. Mohamed, Nelson Mango, Clifton Makate, Alex N. Wangeci, (2021)* *Smallholder farmers' perception of climate change and adoption of climate smart agriculture practices in Masaba South Sub-county, Kisii, Kenya,*	*Many countries experience the negative impacts of climate change especially in the decline of agricultural productivity leading to decreased national and household food security.* *The major climate-smart agriculture practices adopted by farmers in the area included; diversification of crops, change of planting time and crop rotation/mixed cropping.*	*Mixed (Quant & Qual)* *A multi-stage sampling technique was used to collect data from 196 smallholder farmers. Additionally, focused group discussions and key informant interviews were used.*	*This study assessed smallholder farmers' perception of climate variability and change and their adaptation strategies in Masaba South Sub-County, Kisii County, Kenya.*	*Determinants of CSA adoption & perception matters* *The adoption of climate-smart agriculture practices significantly correlated with the household size, monthly income, access to credit and farmers' perception of climate change. The study recommends the incorporation and prioritization of climate change in the county and government development agenda as a means of enhancing the uptake of climate-smart agricultural practices.* *Keywords: Climate-smart agriculture; Climate variability and change; Perception; Adaptation*

Environmental Challenges, *Volume 8,* *2022,*	*8*	*Emmanuel K. Derbile, Samuel Ziem Bonye, Gordon Yenglier Yiridomoh, (2022)* *Mapping vulnerability of smallholder agriculture in Africa: Vulnerability assessment of food crop farming and climate change adaptation in Ghana,*	*This study, conducted in the Upper West Region of Ghana, assessed the crop specific vulnerability to climate change induced extremes and the implications for climate change adaptation planning.*	*Mixed* *A mixed study design involving a survey of 540 crop farmers and 24 Focus Group Discussions (FGDs) were conducted across twelve (12) rural communities for data collection and analysis* *Foresight Frame: it is imperative that efforts at climate change adaptation planning should promote Climate Smart Agriculture (CSA)*	*Vulnerability assessment of food crop farming and climate change adaptation in Ghana,*	*Recommendations - CSA adaptations for reduction of vulnerability to climate extremes.* *The results showed that although farmers were vulnerable to multiple climatic extremes, drought was the most frequently occurring and negatively impacting extreme event that impacted crop production negatively.* *To reduce vulnerability to climate extremes, especially, drought, it is imperative that efforts at climate change adaptation planning should promote Climate Smart Agriculture (CSA) if rural livelihoods that largely depend on the smallholder crop sector are to be sustained in rural Ghana and SSA at large.*

World Development, Volume 138, 2021,,	*9*	*Mare Sarr, Mintewab Bezabih Ayele, Mumbi E. Kimani, Remidius Ruhinduka, (2021)* *Who benefits from climate-friendly agriculture? The marginal returns to a rainfed system of rice intensification in Tanzania,*	*Agricultural production in sub-Saharan Africa faces a multitude of challenges arising from land degradation, climate change, and limited access to improved technology. In this context, technologies that raise farmers' crop productivity while mitigating risk exposure are particularly valuable* *While the uptake of SRI has been considerable in Asia, the limited uptake in Africa is puzzling, particularly given its suitability for the African setting.*	*Quant (estimation model)* *Our empirical strategy relies on the estimation of marginal treatment effect (MTE) models.*	*This study assesses the impacts of a modified, rainfed variant of the system of rice intensification (SRI) on expected yields, yield variance (variability) and yield skewness (exposure to downside risk) in Tanzania.* *The appeal of the technology lies in its yield-enhancing potential, its low demand for complementary external inputs as well as its drought resistance features.*	*CSA low adoption: perception (level of resistance, & awareness) of farmers to adopt matters* *We find that, while the average effects on adopters suggest that SRI enhances yield and reduces the downside risk of crop failure, the marginal treatment effects indicate that only farmers with low resistance to adoption, benefit.* *the need for policies that increase climate awareness to ensure food security.*

Scientific African, *Volume 7,* *2020,*	*10*	*Meseret Tsige, Gry Synnevåg, Jens B. Aune, (2020)* *Gendered constraints for adopting climate-smart agriculture amongst smallholder Ethiopian women farmers,*	*Although Climate-smart agriculture (CSA) can offer economic and food security opportunities for women farmers, success in the uptake of these technologies is contested by gendered constraints.*	*Mixed (Quant Vs Qual)* *Qualitative and quantitative data collections were applied using survey, in-depth interviews and focus group discussions. Quantitative data were analyzed using descriptive statistics, Pearson's chi-square test and binary logistic regression using statistical software for the social sciences (SPSS) version 24. Thematic and narrative analysis methods were used to analyze qualitative data.*	*This study uses 344 women and men survey respondents involved in conservation agriculture (CA) and small-scale irrigation schemes (SSIS) as data sources for examining the effect of gendered constraints for adopting climate-smart agriculture amongst women in three areas in Ethiopia.*	*Inclusion for Gendered Constraints* *The findings show that women smallholders uptake is affected by limited access to credit, extension, restricted membership in cooperatives and water user associations, lack of access or user rights to land, skill training, information, and restricted mobility. Agricultural development interventions should be implemented by accepting and considering individual farmer's entitlement to development. Expanding off-farm diversification and rural employment opportunities through changing the land tenure system, which is currently state-owned, are essential to enhance women smallholders' access to land and other agricultural inputs.*

Technology in Society, *Volume 63,* *2020*	*11*	*Abraham Zakaria, Shaibu Baanni Azumah, Mark Appiah-Twumasi, Gilbert Dagunga, (2020)* *Adoption of climate-smart agricultural practices among farm households in Ghana: The role of farmer participation in training programmes,*	*Climate Smart Agriculture (CSA) is being promoted among farmers as a way of adapting to the effect of climate change on agricultural systems.*	*Quant (Regression)* *We fitted an Endogenous-Switching Poisson regression model to determine the drivers of farmers' participation in climate change capacity building programmes and the concomitant effect of participation on adoption intensity of Climate Smart Agricultural Practices (CSAPs).*	*This study used primary data from 300 farmers in the Zabzugu and South Tongu districts of Ghana.*	*Role of Training & Capacity Building for CSA adoption (access to agric extension services)* *The study found that participation in climate change capacity building training is endogenous and is positively influenced by farmers' access to agricultural extension services and membership of farmer-based organisations (FBOs). Consequently, participation in capacity building training, family labour, and agricultural insurance significantly influenced farmers' CSAPs adoption intensity. We recommend, based on these findings, that climate change and agricultural projects incorporate farmer training on CSAPs in their programming, in order to guide the adoption of multiple practices. Here, extension agents and FBOs should be targeted to disseminate information to farmers. An important finding from this study relates to the significant effect of agricultural insurance on adoption intensity of CSAPs. We argue that farm insurance reduces the risk of investing in climate mitigation practices for smallholder farmers and for that matter, national agricultural policies should facilitate farmers' subscription to crop insurance as a mechanism to increase resilience to climate risks and shocks.*

International Journal of Disaster Risk Reduction, Volume 61, 2021,	*12*	*Innocent Pangapanga-Phiri, Eric Dada Mungatana, (2021) Adoption of climate-smart agricultural practices and their influence on the technical efficiency of maize production under extreme weather events,*	*This study examines the drivers of CSA practices' adoption and their influence on the technical efficiency of maize production among drought-affected households.*	*Quant -Logit Based on a conditional logit model, the study finds drought episodes substantively enhancing the adoption of organic manure by 76% and soil and water conservation by 29%. The Cobb-Douglas Stochastic Frontier*	*Malawi experiences frequent and intense extreme weather events that affect rain-fed household maize production. Thus, households have adopted various climate-smart agriculture (CSA) practices to cushion maize production from the adverse effects of extreme weather events, particularly drought episodes.*	*Gendered targeting of extension services & technical efficiency of production advocated Besides, the study recommends championing gender-targeting extension services to augment the benefits of CSA practices among female farmers. Ultimately, the study results contribute to the existing literature on improving agricultural productivity under varying weather conditions. This study, therefore, advocates for simultaneous adoption of organic and inorganic fertilizers to enhance the effect of CSA practices on the technical efficiency of maize production under intensifying drought episodes.*

Agriculture, Ecosystems & Environment, *Volume 277,* *2019*	*13*	*Peter R. Steward, Christian Thierfelder, Andrew J. Dougill, Ivy Ligowe, (2019)* *Conservation agriculture enhances resistance of maize to climate stress in a Malawian medium-term trial,*	*There are a range of climate-smart systems that have been proposed and conservation agriculture (CA) based on minimum soil disturbance, crop residue retention and crop rotation is one of them.* *Crop diversification improved the resistance of CA systems to climate stress, more so when diversification was over time (rotation) than in space (intercropping). In all years CA systems substantially outyielded conventional practice, this highlights the benefits of medium-term (eight years) CA management before the rainout shelter experiment started.*	*Quant-Trial (Pilot)* *A CA trial established in 2007 in Malawi was used during cropping -seasons 2015–2016 (El Niño) and 2016–2017 (La Niña) to assess the performance and resistance of different CA maize systems under climate-related stress at anthesis, a climate sensitive growth stage. Large in-situ rainout shelters were used to simulate increased daytime temperatures and in-season droughts of 18–19 days and 27 days.*	*Smallholder farming in southern African needs climate-smart agricultural approaches to adapt to current climate stress and climate variability, and increasing risk of these under future global climate change.*	*CSA adaoption enhances CA systems (adaptive capacity)* *Our results from natural and simulated drought conditions confirm that CA systems can increase adaptive capacity to an increased risk of climate stress associated with projected global climate change. We show that large-scale rainout shelters are a useful means of accelerating our understanding of how long-term agricultural management practices can enhance resistance to climate stresses.* *CA systems better resisted climate stress around anthesis than conventional tillage practices as CA systems showed greater resistance to drought than conventional practice. This was expressed by higher CA maize grain yields, biomass yields or harvest index under conditions of natural (El Niño) or 19 day simulated drought.*

Ecosystem Services, *Volume 39,* *2019,*	*14*	*Kaleab K. Haile, Nyasha Tirivayi, Wondimagegn Tesfaye, (2019)* *Farmers' willingness to accept payments for ecosystem services on agricultural land: The case of climate-smart agroforestry in Ethiopia,*	*This study examines smallholder farmers' preferences for the uptake of contractual climate-smart agroforestry, which yields economic and ecosystem benefits.*	*Quant- Experiment/Pilot* *A discrete choice experiment was conducted with smallholder farmers in Ethiopia to elicit their willingness to participate in a payment for ecosystem services (PES) scheme that incentivizes integrating faidherbia albida (a fertilizer tree) in their mono-cropping farming system.*	*Attributes evaluated are "number of planted trees", "payment amount", "payment type", and "contract period". The presence of heterogeneity in the choice behavior of farmers warrants the use of the generalized multinomial logit and latent class conditional logit models to allow for farmer- and class-specific preferences, respectively* *These findings shed light on the considerations that must be accounted for when designing and implementing environmental policies such as PES schemes that promote large-scale adoption of climate-smart agroforestry, which would transform smallholder agriculture into a sustainable farming system.* *Ethiopia*	*Contractual Adoption of CSA Agro forestry (Preferences)* *The results show that farmers derive higher utility from up-front payments. Farmers also strongly prefer food as the mode of payment than cash. Moreover, low numbers of mandatory planted trees and short-term contracts are found to be essential attributes that positively affect farmers' decisions to take-up a contractual arrangement to grow trees on their agricultural land.* *Our analysis also shows the presence of heterogeneity in preferences across segments of farmers in conjunction with differences in household characteristics.*

World Development Perspectives, Volume 18, 2020,	*15*	*Maurice Juma Ogada, Elizaphan J.O. Rao, Maren Radeny, John W. Recha, Dawit Solomon, (2020) Climate-smart agriculture, household income and asset accumulation among smallholder farmers in the Nyando basin of Kenya,*	*In this article, we assess the impacts on livelihood outcomes, of climate smart agricultural (CSA) practices that are promoted as adaptive strategies against effects of climate change.*	*Quant – with foresight (adaptive pathways/scenarios) Using data from a survey of households in Nyando basin in Kenya, we combine statistical matching and simultaneous equation econometric modelling, to evaluate pathways through which CSA practices impact on household asset accumulation and income.*	*For smallholder households that heavily depend on agriculture, adaptation and mitigation measures, including coping strategies are therefore needed to secure household livelihoods and incomes.*	*We find that uptake of multiple stress-tolerant crops improves household income by 83%, which in turn improves household asset accumulation. Impact pathway modelling also show that adoption of improved livestock breeds significantly reduces household income by 76%. For improved livestock, however, household income does not impact on asset accumulation, possibly because income is invested in form of livestock rather than household assets. These findings show that adoption of multiple stress-tolerant crops improves household assets accumulation via the income pathway. However, given an option, households would invest increased incomes in livestock assets, confirming that livestock are a form of savings, which can be liquidated to bridge household income gaps. This is a better resilience measure as compared to investment in domestic household assets.*

Climate Risk Management, *2018,*	*16*	*Amarnatha,* , G.W.H. Simonsb,c , N. Alahacoona , V. Smakhtind , B. Sharmae , Y. Gismallaf , Y. Mohammedf , M.C.M. Andriessenb (2018)* *Using smart ICT to provide weather and water information to smallholders in Africa: The case of the Gash River Basin, Sudan G.*	*This paper shows how integrating remote sensing, Geographical Information Systems (GIS), floodforecasting models and communication platforms can, in near real time, alert smallholder farmers and relevant government departments about incoming floods, using the Gash basin of Sudan as an example.* *.*	*Case Study : Foresight Frame Planning & transformationall* *The Ministry of Water Resources of Sudan used the findings of this study to transform farmers' responses to flood arrival from being 'reactive', to planning for the flood event. Intensive on-site and institutional efforts to build the capacity of farmers, farmer organizations, development departments and officers of the Ministry helped to develop the initiative from simply sending 'emergency alerts' to enabling stakeholders to visually see the flood event unfolding in the region and to plan accordingly for storing water, operating spate-irrigation systems and undertaking cropping activities.*	*The research, initially conducted on a 60 × 60 km site, was later extended to the entire Gash basin.* *In the Gash Delta of Eastern Sudan, spate irrigation (flood-recession farming) contributes substantially to rural livelihoods by providing better yields than rainfed dryland farming. However, spate irrigation farmers are challenged by the unpredictability of flooding. In recent decades, the number of farmers practicing spate irrigation has decreased, due to varying rainfall intensity and frequency, insufficient infrastructure and farmers' limited capacity to manage such variations. One solution that may help farmers face such challenges is for them to access real-time waterrelated information by using smart Information and Communication a Technology (ICT).*	*CSA Adoption: Transformational * integrated ICT stms* *The paper outlines how to develop tools that can monitor plot-specific information from satellite measurements, and supply detailed and specific information on crops, rather than providing very general statements on crop growth. Farmers are able to use such tools to optimize their farm profits by providing water to their crops in the right place, at the right time and in the right quantity. Finally, the work demonstrates the high potential of combining technology, namely remote sensing data and simple a agro-meteorological model with limited parameters, for large-scale monitoring of spate irrigation systems and information sharing to advise farmers as to how to apply this information to their managerial decisions*

Geoforum, Volume 130, 2022,	17	Victoria A. Maguire-Rajpaul, Chris Sandbrook, Constance McDermott, Mark A. Hirons, (2022) Climate-smart cocoa governance risks entrenching old hegemonies in Côte d'Ivoire and Ghana: a multiple environmentality analysis,	In this article, we seek to understand what is new and different – if anything – about contemporary, climate-smart governance of cocoa and forests.	Qual – Interview and Documentary analysis To do this, we apply and temporally extend Fletcher's 'multiple environmentalities' framework to classify the various techniques by which smallholder behaviour has been steered throughout the history of cocoa and forest governance, comparing the cases of Côte d'Ivoire and Ghana by drawing on interviews with 200 smallholders and documentary analysis	Smallholders in Côte d'Ivoire and Ghana supply over 60% of the cocoa to the $120bn global chocolate industry. Like colonialists and multilateral banks before them, foreign chocolate corporations today attempt to govern the behaviour of smallholders in Ivorian and Ghanaian forests via a recent proliferation of 'climate-smart' cocoa (CSC) schemes. . This framework parses diverse 'techniques of government' used to shape subjects' behaviour, including: sovereign (imposing laws), disciplinary (internalising norms), neoliberal (constructing material incentives), and liberation (emancipatory self-rule).	CSA Adoption- Marginalised small farmer voices We show that across all eras and in both countries – despite divergent political economies – smallholder behaviour has been predominantly governed by overlapping neoliberal and sovereign governmentalities, whose legitimacy has increasingly relied on reframing smallholders as environmental subjects. We demonstrate how smallholder voices remain marginalised and argue that corporate-led CSC schemes build upon and re-employ past sovereign powers (e.g., threatening to evict smallholders from protected forests), thus entrenching long-standing power asymmetries and overlooking critical differences between countries. Notably, cross-border corporate governance schemes ignore, and thereby (unwittingly) inflame, Ivorian violence and ethnoreligious strife.

Climate Risk Management, Volume 32, (2021)	*18*	*Philip Antwi-Agyei, Lindsay C. Stringer, (2021) Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana,*	*This paper aims to identify how agricultural extension agents in Ghana can better support smallholder farmers in navigating and addressing the effects of climate change on food production. It asks: (i) what are the sources of information used by agricultural extension agents in Ghana's Upper East region? (ii) what are the capacity building needs of agricultural extension agents for effective communication of climate information for building resilient agricultural systems? (iii) what are the key barriers to successful extension outcomes for climate change adaptation?*	*Mixed: Interviews & Surveys The paper uses a mixed methods approach including three regional stakeholder orkshops, expert interviews and surveys with 32 agricultural extension agents in northeastern Ghana. Results addressing question (i) indicated that radios and television are the dominant sources of climate information for agricultural extension agents in the Upper East region.*	*Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana,*	*CSA Adoption Training & Capacity Building for the extension workers (farmer resistance to change) Findings targeting question (ii) identified capacity building needs such as developing extension agents' technical skills, improving communication skills, improving knowledge and use of climate smart agricultural interventions such as soil moisture conservation methods, and training on information communication technologies (ICT) to deliver extension advice on climate change. Other needs included developing skills in field demonstration and project monitoring and evaluation. Addressing question (iii), key barriers confronted by agricultural extension agents in the delivery of extension on climate change included lack of transportation facilities for extension agents, lack of appropriate extension materials, high agricultural extension agent to farmer ratios, and inadequate funds to implement adaptation practices. Wider barriers reducing the effectiveness of extension efforts included farmer resistance to change and complex land tenure arrangements that do not allow investment. Periodic workshops should be organised for agricultural extension agents on the use of ICT to deliver extension services, whilst encouraging the use of audio-visuals in extension delivery. These efforts should be supported by regular assessments of extension agents' capacity building needs.*

Environmental Development, Volume 37, 2021,	*19*	*Nadine Andrieu, Patrice Dumas, Emma Hemmerlé, Francesca Caforio, Gatien N. Falconnier, Mélanie Blanchard, Jonathan Vayssières, (2021)* *Ex ante mapping of favorable zones for uptake of climate-smart agricultural practices: A case study in West Africa,*	*Developing relevant decision-support tools for policymakers to support large-scale implementation of climate-smart agriculture in the Global South is challenging given the great diversity in biophysical, socio-technical, and organizational conditions.* *The policy documents considered were investment plans, adaptation plans for climate change, nationally determined contributions, and Technology Needs Assessments project reports. Sixteen policy documents for four countries were thoroughly reviewed and classified as unfavorable, intermediate, and favorable for the four selected practices, based on a decision tree built for that purpose*	*Pilot- Policy analysis (pilot exercise)- Mapping* *This article describes a pilot exercise inspired by the recommendation domain literature that aimed at mapping, beyond "classical" biophysical and socio-technical variables, the institutional variables (i.e., the existence of policy incentives in national policy documents) that could influence the large-scale implementation of climate-smart agricultural practices* .	*Four practices were considered: cereal-legume intercropping, fodder legume cultivation, farmer managed natural regeneration (FMNR) of Parkia biglobosa, and crop residue mulching. The biophysical and socio-technical variables were classified based on thresholds identified in the literature and mapped with a geographic information system* *ur analysis shows that areas where biophysical, socio-technical, and institutional variables are aligned for the four practices considered are small, particularly for fodder legume cultivation and crop residue mulching. For cereal-legume intercropping, incentives from national policies strongly differ from one country to another while for FMNR of Parkia biglobosa policies are more homogeneously conducive across countries.*	*CSA Adoption/implementation with policy (decision support tools for policy makers at local and national levels)* *Nonetheless, it was possible to identify areas where biophysical, socio-technical, and institutional dimensions of the transition toward climate-smart agriculture (CSA) were aligned, for example, cereal-legume intercropping in southern Mali. The delineating of favorable and unfavorable areas allows specific recommendations to be made for policymakers as levers for action differ in favorable, intermediate, and unfavorable zones. Based on the exploration made for the four practices, this study highlights the need for further articulations from local to national scale to implement CSA.*

Food Policy, Volume 92, 2020,	*20*	*Festus O. Amadu, Paul E. McNamara, Daniel C. Miller,* *Yield effects of climate-smart agriculture aid investment in southern Malawi,*	*To help mitigate such risk and increase food security, international development agencies have invested billions of dollars in climate-smart agriculture (CSA) programs over the past decade. However, rigorous evidence on the food security impacts of CSA aid through crop yields remains scant generally, and specifically in sub-Saharan Africa.*	*Quant – regression estimates* *Based on primary survey data from a sample of 808 households in the project area, we use endogenous switching regression and a control function approach to estimate CSA adoption and impacts on maize yield in 2016, controlling for potential program placement bias, selection bias in CSA adoption, and endogeneity issues.*	*Most studies have not explicitly linked CSA adoption and yield impacts with CSA aid interventions among smallholder farmers.* *Here, we respond to this knowledge gap by estimating the impact of a major CSA aid effort (the United States Agency for International Development-funded Wellness and Agriculture for Life's Advancement (WALA) project) on agricultural yields in Southern Malawi.*	*CSA adoption – increase in crop yield for food security* *We found a 53% increase in maize yield among CSA adopters in the drought year of 2016. Results demonstrate that policies and funding streams supporting CSA in low-income, dryland contexts such as southern Malawi can have important impacts on food security by boosting crop yields in the face of increasing climate uncertainty and extreme weather shocks.*

JOURNAL	COD-ING	AUTHORS & TITLE	TYPE OF CSA ADOPTED & WHY?	FORESIGHT ANALYTICAL FRAMES	CONTEXT APPLIED	LEARNING IN HINDSIGHT (FACTORS FOR MAPPING PLAUSIBLE FUTURES)

Technological Forecasting and Social Change, *Volume 180,* *2022,*	*21*	*Walter Leal Filho, Tony Wall, Serafino Afonso Rui Mucova, Gustavo J. Nagy, Abdul-Lateef Balogun, Johannes M. Luetz, Artie W. Ng, Marina Kovaleva, Fardous Mohammad Safiul Azam, Fátima Alves, Zeus Guevara, Newton R Matandirotya, Antonis Skouloudis, Asaf Tzachor, Krishna Malakar, Odhiambo Gandhi, (2022)* *Deploying artificial intelligence for climate change adaptation,*	*This paper shows the various means via which AI can support research on climate change in diverse regions, and contribute to efforts towards climate change adaptation.*	*Quant: Questionnaire & systematic review* *Using a systematic review of the literature on applications of AI for climate change adaptation and a questionnaire survey of a multinational and interdisciplinary team of climate change researchers,*	*Artificial Intelligence (AI) is believed to have a significant potential use in tackling climate change. This paper explores the connections between AI and climate change research as a whole and its usefulness in climate change adaptation efforts in particular.* *The surveyed articles are classified under nine areas, e.g., Global/ Earth Related; Water-related Issues and agriculture, 95% of which are related to adaptation. The areas that have attracted the most studies about AI applications are water-related management issues (38%).*	*CSA adoption (AI based) (governance & capacity of digitisation)* *Evidence gathered in the study suggests that, provided that due care is taken, the use of AI can provide a welcome support to global efforts to better understand and handle the many challenges associated with a changing climate.* *In terms of the survey results, the most robust agreements were noted concerning the capacity of digitisation and AI to strengthen governance practices and afford policy coherence in climate change.*

Agricultural Systems, Volume 154, 2017,	*22*	*N. Andrieu, B. Sogoba, R. Zougmore, F. Howland, O. Samake, O. Bonilla-Findji, M. Lizarazo, A. Nowak, C. Dembele, C. Corner-Dolloff, (2017) Prioritizing investments for climate-smart agriculture: Lessons learned from Mali,*	*The Climate-Smart Agriculture (CSA) concept arises from a need to provide innovative solutions towards the complex and integrated goals of increasing yields, improving resilience, and promoting a low emissions agricultural sector.*	*Pilot This paper presents the process, results, and lessons learned from a yearlong pilot of the Climate-Smart Agriculture Prioritization Framework (CSA-PF) in Mali.*	*Agricultural productivity and growth in Mali are under threat from erratic rainfall, resulting in more frequent dry years. The national economy is vulnerable to climate change due to 50% of the gross domestic product coming from the agricultural sector and 75% of the population living in rural areas. A major challenge for policymakers to operationalize CSA is the identification, valuation (cost-benefit), and subsequent prioritization of climate-smart options and portfolios (groups of CSA options) for investment.*	*CSA adoption – learning from pilot scheme Key national and international stakeholders participated in the co-development and prioritization of two CSA portfolios and related action plans for the Malian Sudanese zone. Initial steps towards outcomes of the process include inclusion of prioritized CSA practices in ongoing development projects and prompting discussion of modifications of future calls for agricultural development proposals by regional donors.*

Technology in Society, *Volume 64,* *2021,,*	*23*	*Edward Martey, Prince M. Etwire, Jonathan Mockshell, (2021)* *Climate-smart cowpea adoption and welfare effects of comprehensive agricultural training programs,*	*With persistent low agricultural productivity in Sub Saharan Africa (SSA), the content, effectiveness, and mode of delivery of training programs remain a debate.*	*Quant (regression)* *In this paper, we examine the adoption, productivity, and income effects of participating in a novel comprehensive agricultural training program (CATP) involving cowpea farmers in northern Ghana by using the endogenous switching regression (ESR) model. The CATP requires farmers to complete a set of modules on good agronomic practices to gain informal certification.*	*Agricultural training programs remain one of the primary mechanisms for disseminating modern and climate-smart technologies with the aim to improve the welfare outcomes of smallholder farmers.*	*For CSA adoption & participation in training matters* *The results indicate that participating in the CATP increases the adoption of climate-smart cowpea varieties, productivity, and cowpea income by 75, 15, and 24% points, respectively, compared to their mean levels. These positive welfare effects of participating in the CATPs confirm the need to increase capacity-enhancing activities in agricultural development projects, and design mechanisms to eliminate barriers to participation among rural farm households.*

Journal of Cleaner Production, Volume 2020,,	*24*	*Giacomo Branca, Chiara Perelli, 'Clearing the air': common drivers of climate-smart smallholder food production in Eastern and Southern Africa,*	*This research is an innovative contribution to that effort. It uses a unique household dataset where data is scarce; it considers the impact of smallholders' conditioning factors on technology climate-smartness level; and it estimates the correlations among a wide range of practices, agro-ecologies and geographical contexts.*	*Quant (econometric) Here, a cross-sectional econometric analysis using primary data on sustainable farming practices in the cereal-legume farming systems of Ethiopia, Malawi, South Africa and Tanzania is applied to analyse the drivers and intensity of innovation adoption.*	*African smallholders should adopt climate-smart agriculture to make a sustainable transition towards cleaner, circular and more productive food systems. Farmers must play a key role in that process. However, the adoption and diffusion of climate-smart technologies have been slow. While national climate policies already include climate-smart agriculture as an adaptation blueprint, policy makers need empirical evidence to support large-scale adoption.*	*CSA adoption & diffusion (slow) (Socio-economic barriers) Socio-economic barriers reduce adoption intensity among marginalised farmers, and proper incentives are needed to overcome them. Business links between technology-ready smallholders and small-to-medium enterprises must be created to enable the uptake and scaling-up of innovations and the development of industrial application models. Such results can support the design of evidence-based strategies for the sustainable transformation of production systems.*

Heliyon, *Volume 7, Issue 4,* *2021,,*	*25*	*Stanley Karanja Ng'ang'a, Vail Miller, Evan Girvetz,* *Is investment in Climate-Smart-agricultural practices the option for the future? Cost and benefit analysis evidence from Ghana, (2021)*	*Over the recent decades, however, there has been advancement by programs channelling resources into Climate-Smart Agricultural (CSA) practices to improving smallholder livelihoods and food security.* *The interest in advancing investment in CSA practices is a key pathway that has the potential to significantly reduce the negative effect of climate change and variability risks on smallholder farmers livelihoods. Investing in CSA practices is also a key pathway to improving farm yield per unit area. Consequently, smallholder farmers are adopting and implementing CSA practices.*	*Quant (Cost Benefit Analysis) : Future Options & Discounted Cashflows* *On this basis, the present study undertook a detailed cost-benefit analysis (CBA) of seven CSA practices identified with smallholder farmers in the coastal savannah agro-ecological zone of Ghana. A total of 48 smallholder farmers that had adopted these practices were studied. Three CBA indicators namely the net present value (NPV), internal rate of return (IRR) and payback period (PP) were assessed for each of the seven CSA practices.*	*A majority of smallholder farmers in sub-Saharan Africa (SSA) countries depend to a large extent on agriculture for food security and income. Efforts aimed at improving farm-related profitability are therefore important to improving livelihoods among smallholder farmers. In Ghana, for example, smallholder farmers that depend on agriculture face serious risks especially those related to climate change and variability and soil degradation. Notwithstanding these dangers, evidence of the published literature on how best to tackle these challenges is limited.*	*CSA adoption (suitability for scaling up) for livelihoods* *The finding from this study, therefore, fill the current information gap in the literature on the costs and benefits of adopting CSA practices on household livelihoods in Ghana. Such a finding is critical to the promotion and scaling up the adoption of CSA practices by smallholder farmers and serve as a basis of formulating appropriate guidelines and policies for supporting CSA practices.* *The results showed that out of the seven CSA practices examined, six of them were profitably suitable for adoption and scaling up from the perspective of smallholder farmers as well as the public perspective.*

Agricultural Systems, *Volume 151,* *2017*	*26*	*James Hammond, Simon Fraval, Jacob van Etten, Jose Gabriel Suchini, Leida Mercado, Tim Pagella, Romain Frelat, Mats Lannerstad, Sabine Douxchamps, Nils Teufel, Diego Valbuena, Mark T. van Wijk, (2017)* *The Rural Household Multi-Indicator Survey (RHoMIS) for rapid characterisation of households to inform climate smart agriculture interventions: Description and applications in East Africa and Central America,*	*Achieving climate smart agriculture depends on understanding the links between farming and livelihood practices, other possible adaptation options, and the effects on farm performance, which is conceptualised by farmers as wider than yields.* *The balance of indicators selected gave an adequate snap shot picture of the two sites, and allowed us to appraise the 'CSA-ness' of different existing farm strategies, within the context of other major development objectives.*	*Quant - Survey* *TRHoMIS is a household survey tool designed to rapidly characterise a series of standardised indicators across the spectrum of agricultural production and market integration, nutrition, food security, poverty and GHG emissions. The survey tool takes 40–60min to administer per household using a digital implementation platform. This is linked to a set of automated analysis procedures that enable immediate cross-site bench-marking and intra-site characterisation. We trialled the survey in two contrasting agro-ecosystems, in Lushoto district of Tanzania (n=150) and in the Trifinio border region of Guatemala, El Salvador and Honduras (n=285).*	*Reliable indicators of farm performance are needed in order to model these links, and to therefore be able to design interventions which meet the differing needs of specific user groups. However, the lack of standardization of performance indicators has led to a wide array of tools and ad-hoc indicators which limit our ability to compare across studies and to draw general conclusions on relationships and trade-offs whereby performance indicators are shaped by farm management and the wider social-environmental context.*	*CSA Adoption (Farmers livelihoods strategies)* *Our results suggest that at both sites the climate smartness of different farm strategies is clearly determined by an interaction between the characteristics of the farm household and the farm strategy.* *In general strategies that enabled production intensification contributed more towards the goals of climate smart agriculture on smaller farms, whereas increased market orientation was more successful on larger farms.* *On small farms off-farm income needs to be in place before interventions can be promoted successfully, whereas on the larger farms a choice is made between investing labour in off-farm incomes, or investing that labour into the farm, resulting in a negative association between off-farm labour and intensification, market orientation and crop diversity on the larger farms, which is in complete opposition to the associations found for the smaller farms.*

World Development, *Volume 122,* *2019,,*	*27*	*Hailemariam Teklewold, Tagel Gebrehiwot, Mintewab Bezabih,* *Climate smart agricultural practices and gender differentiated nutrition outcome: An empirical evidence from Ethiopia,*	*Since the beginning of the decade, climate resilient green economy strategies have been proposed in many African countries. One of the pillars of the strategies is the adoption and diffusion of various climate smart agricultural practices for improving crop and livestock production and farmer income while reducing greenhouse gas emissions.* *.*	*Quant* *We examine the determinants of adoption of combinations of multiple climate smart agricultural innovations and their impact on different nutrition outcomes.*	*The effects of these innovations on household nutritional security, including gender-differentiated nutritional status, have hardly been analyzed*	*CSA adoption Gendered and dietary perspective are critical* *The study provides insight into the interaction between climate change adaptation and nutrition security among male and female headed households, with implication for the Sustainable Development Goals of ending hunger, achieving gender equality, and taking action on climate change.* *We find that adoption of climate smart innovations increases dietary diversity and improves calorie and protein availability. These benefits increase with adoption of combinations of innovations, relative to adopting an innovation in isolation.* *Gender-disaggregation results suggest nutritional outcome differentials between male and female headed households due to both differences in household characteristics, including household resources, and differences in returns to resources.*

Journal of Environ-mental Economics and Man-agement, *Volume 93,* *2019,,*	*28*	*Jeffrey D. Michler, Kathy Baylis, Mary Arends-Kuenning, Kizito Mazvima-vi,(2019)* *Conservation agri-culture and climate resilience,*	*Agricultural productivity growth is vital for economic and food security outcomes which are threatened by climate change. In response, governments and development agencies are encouraging the adoption of 'climate-smart' agricultural technologies, such as conserva-tion agriculture (CA).*	*Quant* *Using panel data from Zimbabwe, we test how CA performs during extreme rainfall events - both shortfalls and surpluses. We control for the endogenous adop-tion decision and find that use of CA in years of average rainfall results in no yield gains, and in some cases yield loses.*	*However, there is little rigorous evidence that demonstrates the effect of CA on pro-duction or climate resilience, and what evidence exists is ham-pered by selection bias.*	*CSA Adoption – effective for production/resilience* *CA is effective in mitigating the negative impacts of deviations in rainfall. We conclude that the lower yields during normal rainfall seasons may be a proxi-mate factor in low uptake of CA. Policy should focus promotion of CA on these climate resilience benefits.*

Heliyon, *Volume 6, Issue 6,* *2020,*	*29*	*Mare Sarr, Mintewab K.W. Maina, C.N. Ritho, B.A. Lukuyu, E.J.O. Rao, (2020)* *Socio-economic determinants and impact of adopting climate-smart Brachiaria grass among dairy farmers in Eastern and Western regions of Kenya,*	*Therefore, there is a need to develop feasible cost-effective strategies for improving the year-round feed supply. Improved planted forages such as Brachiaria grass have been recommended as one of the strategies of alleviating feed scarcity, especially in drier agro-ecological zones.* *holistic policy approaches that promote the widespread adoption of Brachiaria grass. There is also a need for an effective information dissemination pathway for Brachiaria grass.*	*Quant* *This study analyses the socio-economic determinants of adoption and the impact of adopting Brachiaria grass for feed sufficiency and increased milk production. Propensity Score Matching (PSM) method was used to assess the determinants and impact of the adoption of Brachiaria grass.*	*he sustainability of the livestock sector in sub-Saharan Africa is negatively affected by limited access to high-quality fodder in adequate quantities.* *This study assesses the impacts of a modified, rainfed variant of the system of rice intensification (SRI) on expected yields, yield variance (variability) and yield skewness (exposure to downside risk) in Tanzania.* *The appeal of the technology lies in its yield-enhancing potential, its low demand for complementary external inputs as well as its drought resistance features.*	*CSA adoption of non-tech practices like (Bacharia grass)* *Empirical results indicate that the adoption of Brachiaria grass led to a significant increase in milk production by 27.6% and feed sufficiency by 31.6%. The positive impact of Brachiaria grass is consistent with the role of agricultural technologies in improving the productivity, income, and welfare of smallholder farmers. The adoption of Brachiaria grass is influenced by age of farmer, tropical livestock unit (TLU), type of animal breed, perceived benefits of the technology, access to extension, and farmer group membership. The study recommends*

Climate Services, *Volume 26,* *2022,*	*30*	*Bwema Ombati Mogaka, Stanley Karanja Ng'ang'a, Hillary Kiplangat Bett,* *Comparative profitability and relative risk of adopting climate-smart soil practices among farmers. A cost-benefit analysis of six agricultural practices,*	*This study assessed the comparative profitability and relative risk of implementing CSS practices among farmers in Kakamega, Siaya, and Bungoma counties in Western Kenya. The prioritization of these CSS practices (agroforestry, intercropping, liming, organic manure use, inorganic fertilizer, and improved hybrid seeds) was based on the climate-smart agriculture (CSA) pillars (production, adaptation, and mitigation) and their benefits.*	*Quant (Cost and Benefit)* *A deterministic cost-benefit analysis model that incorporates sensitivity and scenario analysis assessed these factors.*	*The adoption of climate-smart soil (CSS) practices among farmers have the potential to rehabilitate and protect the soil. Proponents have not fully addressed factors such as; profitability and the relative risk that farmers face during the adoption and implementation of these CSS practices. These factors determine the adoption and sustainability of these practices.*	*CSA Adoption – critical factors (minimum interest loan, input subsidies, skilled personnel etc)* *The findings showed that agroforestry was the most profitable having a net present value of US$ 16,071 ha−1, followed by intercropping (US$ 10,487 ha−1), and the use of improved hybrid seeds was the least profitable (US$ 881 ha−1).* *In terms of relative risk, all the practices were more sensitive to the product price and output than the lifespan, discount rate, and labour cost.* *The result implies that exposure of these practices to climatic and economic shocks will result in high-profit risk. Therefore, national and county governments should place micro-credit loans with minimum interest, input subsidies, and skilled personnel to promote increased adoption of agroforestry and intercropping. Agricultural extension officers should also demystify farmers' mentality that improved hybrid seeds can guarantee increased productivity.*

Heliyon, *Volume 8, Issue 5,* *2022,*	*31*	*Abdul-Fatah Alidu, Norsida Man, Nurul Nadia Ramli, Nur Bahiah Mohd Haris, Amin Alhassan, (2022)* *Smallholder farmers access to climate information and climate smart adaptation practices in the northern region of Ghana,*	*Climate information could be a vital resort for smallholder farmers' adoption of climate smart adaptation strategies in order to better manage climate risk. This study is aimed at investigating factors that influence smallholder farmers' joint decision to access climate information as well as adopt climate smart adaptation practices in the Northern Region.*	*Quant (Regression)* *Data used was collected from a cross-sectional survey of 475 smallholder farmers'. The joint decision of smallholder farmers to access climate information and also adopt climate smart adaptation practices was analysed by using bivariate probit regression model.* *The econometric estimates reveal that age, household size, farm income, access to agricultural extension services and assets are the key drivers of smallholder farmers joint decision to access climate information and adopt climate smart adaption practices.*	*In Ghana over 70% of people who are employed in the agricultural sector are smallholder farmers' living in less developed communities engaging in rudimentary agriculture. Climate change poses a serious threat to smallholder farmers which impacts on their income, food security and wellbeing.*	*CSA Adoption (literacy , knowledge including formal, informal, extension education et).* *Government, district assemblies and non-governmental organisations supporting smallholder farmers' adoption of climate smart adaptation strategies in order to overcome climate risk should also assist in the accessibility of climate information since they complement one another. Smallholder farmers literacy and knowledge level should be increased through non-formal and informal educational programmes, and extension education using the farmer-field schools method.*

Agricultural Systems, Volume 151, 2017,	32	Caroline Mwongera, Kelvin M. Shikuku, Jennifer Twyman, Peter Läderach, Edidah Ampaire, Piet Van Asten, Steve Twomlow, Leigh A. Winowiecki, (2017) Climate smart agriculture rapid appraisal (CSA-RA): A tool for prioritizing context-specific climate smart agriculture technologies,	This is an imperative if countries are to respond to the COP21 agreement and meet their intended nationally determined contributions (INDCs). The CSA-RA is designed to assess biophysical including climatic, socio-cultural, economic and technological characteristics at the household, farm and community/regional level. The tool collects qualitative and quantitative data from various stakeholders (farmers, local leaders, researchers, local-level agricultural experts, private sector actors, donor organizations, and policy implementers), allowing expansive analysis, triangulation and validation	Mixed Method: Key informant Interviews & Pairwise The CSA-RA employs gender-disaggregated methods, including gender differences in perceptions of climate change and its impacts. The CSA-RA combines common participatory rural appraisal (PRA) and rapid rural appraisal (RRA) tools into one methodology, that disaggregates the gender dimension, and includes resource mapping; climate calendars; historical calendars; cropping calendars; organization mapping; transect walks; key informant interviews; farmer interviews; and pairwise ranking matrix.	Approaches that aim to identify and prioritize locally appropriate climate smart agriculture (CSA) technologies will need to address the context-specific multi-dimensional complexity in agricultural systems. The climate smart agriculture rapid appraisal (CSA-RA) is a mixed method approach that draws on participatory bottom-up, qualitative, and quantitative tools to assess the heterogeneity of local contexts, and prioritize context-specific CSA options.	CSA Appraisal Tool (priorities in gender, vulnerabilities & other constraints) etc Application of the CSA-RA in Tanzania and Uganda reveals heterogeneity across the sites in terms of vulnerability, constraints and CSA priorities among different social groups (gender) and agro-ecological zones. Thus, the CSA-RA allows stakeholders to simultaneously take into account biophysical and socio-economic aspects to target and implement CSA.

Journal of Cleaner Production, Volume 172, 2018	33	Mmapatla Precious Senyolo, Thomas B. Long, Vincent Blok, Onno Omta, (2018) How the characteristics of innovations impact their adoption: An exploration of climate-smart agricultural innovations in South Africa,	Climate-smart agriculture provides a response to climate change whilst enhancing livelihood of farmers. Climate-smart agricultural technological innovations at farm level have the potential to address climate-related challenges.	Qual : Interviews with expert stakeholders An overview of climate change risks and variability in South Africa and a framework to classify the technological innovations is established based on a literature review. Interviews with expert stakeholders are used to characterise and collect information on available technologies. This study serves as an initial assessment through the exploration of the available climate-smart agricultural technologies in South Africa. This is essential given that the agricultural sector is faced with the dilemma of responding to climate change related challenges whilst increasing the productivity of farmers.	Climate change threatens agricultural production and the food security of developing countries in complex ways that demand environmentally friendly innovations. However, inadequate adoption of these technologies remains a problem. This paper identifies available climate-smart agricultural technological innovations in South Africa and explores their characteristics and context of use using an exploratory research approach.	CSA Adoption (prospects, priority, and Agric tech innovations) Results indicate that Conservation Agriculture, Rainwater Harvesting and Seed Varieties that are Drought Tolerant and Early Maturing may be the most suited technologies for climate-smart agriculture in South Africa, particularly for smallholder farmers. However, high initial investment costs, additional labour requirements and management intensity associated with conservation agriculture and rainwater harvesting may pose problems within the South African context. Drought Tolerant and Early Maturing Seed Varieties were noted as less costly and less management intensive, creating better prospects for adoption.

Journal of the Saudi Society of Agricultural Sciences, *Volume 19, Issue 4,* *2020,,*	*34*	*T.O. Olorunfemi, O.D. Olorunfemi, O.I. Oladele, (2020)* *Determinants of the involvement of extension agents in disseminating climate smart agricultural initiatives: Implication for scaling up,*	*Globally, the role of extension agents in scaling up the utilization of Climate Smart Agricultural Initiatives (CSAI) by farmers remains very crucial. This study examined the determinants of the involvement of extension agents in the dissemination of CSAI to farmers.*	*Quant- survey* *A two-staged random sampling technique was used to elicit information from 277 extension agents in South West Nigeria using a structured questionnaire. Data were analysed using frequency counts, percentage and linear regression analysis..*	*Significant factors influencing extension agents' involvement in the dissemination of CSAI are educational qualification ($t = 2.57$; $p = 0.011$), years of experience ($t = 5.11$; $p = 0.000$), participation in CSA training ($t = 1.77$; $p = 0.077$) and numbers of community covered ($t = -2.30$; $p = 0.022$). The study concludes that although extension agents are involved in the dissemination of some CSAI, there are still a wide range of initiatives that are not adequately disseminated to the rural farmer. It was therefore recommended that extension agents should be trained especially on the wide range of CSAI identified not to be predominantly disseminated so as to scale-up their adoption by farmers to enhance sustainable agricultural productivity and food security for all.* *Keywords: Climate smart agricultural initiatives; Determinants; Extension agents; Involvement; Nigeria.*	*CSA Adoption relevance of extension workers knowledge and experiences* *The findings revealed that prominent initiatives extension agents disseminated were cover crops planting and minimum tillage practices.* *However, extension agents had low involvement in the dissemination of use of soil amendments, conversion of waste to compost, agro-forestry, resource conservation and use of agro-weather related initiatives.*

Climate Risk Management, *Volume 32,* *2021,*	*35*	*Abdoulaye Djido, Robert B. Zougmoré, Prosper Houessionon, Mathieu Ouédraogo, Issa Ouédraogo, Ndeye Seynabou Diouf, (2021)* *To what extent do weather and climate information services drive the adoption of climate-smart agriculture practices in Ghana?,*	*This study examines this nexus by focusing on mobile phone delivery channels of weather forecasts through the ESOKO platform in the Upper West Region of Ghana.* .	*Quant-probit model with future pathway insights* *We employ a simultaneous equation system with a recursive bivariate probit model in which both the outcome (CSA practices) and the endogenous treatment variable (WCIS) are binary.* *Pathways for promoting CSA practices should address the adoption barriers inherent to farmers' characteristics and their livelihood strategies (e.g. livestock, income diversification).*	*There is a growing interest in understanding the linkages between the use of weather and climate information services (WCIS) and the adoption of climate-smart agricultural (CSA) practices. At present, however, there is little guidance on the impact of the use of WCIS on the adoption of CSA practices.*	*CSA Adoption by WCIS (Sources of info matters)* *The use of WCIS significantly increases the adoption of water management and multiple cropping practices by 6.8% and 5.6% respectively.* *We found, however, no statistical significance on the effects of WCIS on the adoption rates of erosion control, pest-resistant crops, and integrated pest management. Our findings underscore the importance of the source of information on agricultural practices (e.g. radio, TV), farmers' characteristics (e.g. gender, age) and their perceptions of climate change in the decision to use WCIS.*

Technology in Society, *Volume 70,* *2022,*	*36*	*Sani Abubakar Mashi, Amina Ibrahim Inkani, Dominic Oghenejeabor Obaro, (2022)* *Determinants of awareness levels of climate smart agricultural technologies and practices of urban farmers in Kuje, Abuja, Nigeria,*	*Climate smart agriculture (CSA) technologies and practices are important for achieving soil moisture conservation, erosion reduction, soil fertility enhancement, increasing and stabilizing crop yield and livelihoods, enhancing ecosystem services, achieving food security, tackling climate change problems, and improving the climate change resilience of farming ecosystems.*	*Quant* *This paper evaluates the factors that influence levels of awareness of CSA technologies among urban farmers in Kuje town (Nigeria), using data collected from 491 farming households.*	*Awareness (and subsequent adoption) of these technologies by farmers depends heavily upon a number of factors related to the farmer and the farming environment.* *There are very few studies that investigate how such factors influence awareness levels of CSA technologies in urban farming households, as most completed studies are on determinants of adoption of the technologies, especially by rural farmers.* *Yet urban agriculture is an important economic activity in many cities, especially in developing countries.*	*CSA Adoption – Socio economic barriers as Critical Futures for farmers awareness levels* *The results showed that the farmers that are more educated; older; having larger family sizes, income sources and economic assets; with greater climate change experience and local knowledge; and having farmlands with better physical conditions have more awareness of CSA adaptation strategies. Eleven other factors (namely marital status, tribal inclination, gender, religion, extension service, capacity building, security of tenure, institutional support, farmer organisational affiliation, distance to farmlands, and availability of loans and incentives) have no significant influence on the farmers' awareness levels of CSA adaptation strategies in the study area. Some ideas were given on how to improve these explanatory factors to help more awareness in the area learn about the CSA.* .

Heliyon, Volume 8, Issue 7, 2022,,	*37*	*Mebratu Negera, Tekie Alemu, Fitsum Hagos, Amare Haileslassie, Determinants of adoption of climate smart agricultural practices among farmers in Bale-Eco region, Ethiopia,*	*This study examines factors that influence adoption and the level of adoption of multiple CSA practices, including improved agronomy, soil and water conservation, drought tolerant high yielding crop variety, small-scale irrigation, integrated disease, pest, and weed management, and integrated soil fertility management,*	*Quant – Survey Multivariate Probit Model using survey data from 404 farm households in Bale-Eco Region (BER), Ethiopia. The study applied a multivariate probit model for analyzing the simultaneous adoptions of multiple CSA practices, and ordered probit model for examining the factors influencing the level of adoption. The CSA practices are found to be complementary.*	*Adoption of climate smart agricultural (CSA) practices has been widely recognized as a promising and successful alternative to minimize the adverse impacts of climate change. However, their adoption among smallholder farmers remains low in developing countries, including Ethiopia.*	*CSA Adoption multiple factors (socio-economic) for policy makers to note Moreover, farmers' adoption of multiple CSA practices, as well as their intensity of adoption, is significantly influenced by the age of the household head, education, land size, household total asset value, frequency of extension contacts, farmer awareness of climate change, farmer experience with climatic shocks, parcel fertility, slope, and severity of soil erosion. The study's findings suggest that agricultural policy makers and implementers of CSA should recognize the complementarity among CSA practices in order to intensify their adoption among BER farmers and disseminate CSA practices in other parts of the country. Moreover, policymakers should consider household socio-economic, institutional, and parcel-specific factors that positively influence CSA adoption.*

Environmental Challenges, *Volume 3,* *2021,*	*38*	*Dil Bahadur Rahut, Jeetendra Prakash Aryal, Paswel Marenya, (2021)* *Ex-ante adaptation strategies for climate challenges in sub-Saharan Africa: Macro and micro perspectives,*	*In light of these growing challenges, we used data collected in 2018 from farm households in Ethiopia, Kenya, Tanzania, Malawi, and Mozambique to investigate the climate threats encountered by farmers and the ex-ante climate risk adaptation strategies they adopted. Drought, floods, hailstorms, and crop pests and diseases were the most common climate threats in these countries.*	*Quant-Multivariate* *Unlike previous studies, we also assessed the adaptive capacity at the macro level by using secondary data. We reviewed the factors that affect the adaptive capacity of each nation to address climate risks. At the micro-level, we assessed the factors influencing the choice of ex-ante adaptation measures by using primary data collected from 4351 farm households. Micro-level data also include the variables that indicate the adaptive capacity of farm households, such as asset ownership, demographic characteristics, and participation in local institutions.* *We used a multivariate probit model to investigate the factors explaining the choice of ex-ante climate risk adaptation strategy.*	*Farmers in sub-Saharan Africa are facing serious consequences from climate change, which pose obstacles to meeting UN Sustainable Development Goals (SDGs) such as zero hunger, ending poverty, ensuring Results showed five major ex-ante climate risk adaptation strategies – change in farming practice, sustainable land management, seek alternative livelihood, saving, and other unspecified strategies – are prevalent in the region.* *In comparison to farmers in Mozambique's northern region, farmers in all other locations were more likely to apply agricultural measures such as change in farming practice and sustainable land management, while they were more likely to apply non-agricultural measures to adapt to risk. Macro-level indicators show that national adaptive capacity is substantially low in all countries, but considerably varies across them.*	*CSA Adoption – country level adaptation strategies) (socio-economic)* *Findings targeting question (ii) identified capacity* *Results showed that female-headed households and households with married heads were more likely than male-headed households to change farming practices to adapt to climate risk. Surprisingly, land ownership was found to be insignificant in all cases. Relatively rich families tended to apply either change in farming practice or saving as a measure to adapt to climate risks. Training on climate-smart agriculture was found to enhance the adoption of sustainable land management as adaptation strategies by farm households. Our findings exhibit substantial differences within and among countries regarding the adoption of ex-ante climate adaptation strategies by farm households.*

Heliyon, *Volume 8, Issue 4,* *2022,,*	*39*	*Mumo Elijah Musyoki, John Ronoh Busienei, John Kamau Gathiaka, George Njomo Karuku,* *Linking farmers' risk attitudes, livelihood diversification and adoption of climate smart agriculture technologies in the Nyando basin, South-Western Kenya,*	*This study, focused on determining how farmers' risk attitudes and household livelihood diversification influenced the adoption of CSA technologies in the Nyando basin.*	*Quant-Multivariate Probit Model* *The study utilized primary data from 122 households from two administrative regions of Kisumu and Kericho counties in Kenya. The study employed the multivariate probit (MVP) and ordered probit (OP) models and descriptive statistics in data analysis using Stata 14.0..*	*Climate smart agriculture (CSA) technologies are innovations meant to reduce the risks in agricultural production among smallholder farmers. Among the factors that influence farmer adoption of agricultural technologies are farmers' risk attitudes and household livelihood diversification.*	*CSA Adoption- Risks and livelihoods – recommended use of insurance)* *Results from the study indicated that farmers' risk attitudes had a significant negative influence in the adoption of terraces, ridges and bunds as well as the intensity of adoption of given CSA technologies.* *Household livelihood diversification had a significant negative influence in the adoption of stress tolerant livestock but did not have a significant effect on the intensity of adoption of given CSA technologies. The study recommends that relevant stakeholders should introduce an appropriate agricultural index insurance product to Nyando basin farmers to encourage the broader adoption of CSA technologies.* *Keywords: Risk*

Journal of Environmental Management, *Volume 231,* *2019,*	*40*	*Clifton Makate, Marshall Makate, Nelson Mango, Shephard Siziba,* *Increasing resilience of smallholder farmers to climate change through multiple adoption of proven climate-smart agriculture innovations. Lessons from Southern Africa,*	*This study evaluates factors explaining individual and multiple adoption of climate change management strategies and their differential impacts on productivity and income using a sample of 1172 smallholder farmers from Malawi and Zimbabwe.* *The results show that multiple adoption of innovations is mostly explained by access to key resources (credit, income and information), level of education and size of land owned by the farmer.*	*Quant – multinomial regression* *The study employs multinomial logistic regression to evaluate factors of individual and multiple adoption and regression adjustment with inverse probability weighting to evaluate impacts of the different adoption regimes on farm productivity and income.*	*Conservation agriculture, drought tolerant maize, and improved legume varieties are key climate change management strategies for smallholder farmers in southern Africa. Their complementary efforts in adaptation to climate change are sternly important for farm productivity and income.*	*CSA multiple adoptions of innovations (socio-economic & gender issues)* *More so, the concurrent adoption of conservation agriculture, stress adapted legume varieties and drought tolerant maize has far greater dividends on productivity and income than when considered individually. However, impacts of multiple adoption of the practices are not entirely uniform across different geographic regions and gender. Results suggest that effective institutional and policy efforts targeted towards reducing resource constraints that inhibit farmers' capacity to adopt complementary climate-smart agriculture packages such as conservation agriculture, drought tolerant maize and improved legume varieties must be gender sensitive and context specific.*
JOURNAL	**CODING**	**AUTHORS & TITLE**	**TYPE OF CSA ADOPTED & WHY?**	**FORESIGHT ANALYTICAL FRAMES**	**CONTEXT APPLIED**	**LEARNING IN HINDSIGHT (FACTORS FOR MAPPING PLAUSIBLE FUTURES)**

Regional Sustainability, Volume 2, Issue 4, 2021,,	*41*	*Philip Antwi-Agyei, Emmanuel Mawuli Abalo, Andrew John Dougill, Frank Baffour-Ata, (2021)* *Motivations, enablers and barriers to the adoption of climate-smart agricultural practices by smallholder farmers: Evidence from the transitional and savannah agroecological zones of Ghana,*	*This paper examined the prioritized climate-smart agricultural practices by smallholder farmers, the motivations of adopting climate-smart agricultural practices, the enablers to the successful adoption of climate-smart agricultural practices, and the barriers to the successful adoption of climate-smart agricultural practices in the transitional and savannah agroecological zones of Ghana.* *Smallholder farmers; Food security; Climate change; Weighted average index; Problem confrontation index; Ghana*	*Mixed : Ethnography & Weighted Average Index ranking* *Specifically, we employed ethnographic research using participatory approaches, including two stakeholder workshops and household surveys with 1061 households in the transitional and savannah agroecological zones of Ghana. The weighted average index (WAI) and problem confrontation index (PCI) were used to rank smallholder farmers' perceived enablers to the adoption of climate-smart agricultural practices and the barriers affecting climate-smart agricultural practices, respectively.*	*Results suggest that the majority of the respondents used a suite of climate-smart agricultural practices, including the timely harvesting of produce and storage, emergency seed banking, appropriate and timely weed and pest control, and early planting as practices to build climate resilience* *The majority of smallholder farmers primarily employed climate-smart agricultural practices to improve household food security (96.2%), reduce pests and diseases (95.6%), and obtain higher yields and greater farm income (93.2%).*	*CSA adoption (enablers vs barriers)* *Evidence gathered in the Findings also show that secured land tenure system arrangement, understanding the effects of climate change, and access to sustainable agricultural technologies were ranked the first, second, and third most important enablers to the adoption of climate-smart agricultural practices with the WAI values of 2.86, 2.75, and 2.70, respectively. Key barriers to the successful adoption of climate-smart agricultural practices included incidences of pests and diseases (PCI = 2530), inadequate access to agricultural credit (PCI = 2502), high cost of improved crop varieties (PCI = 2334), and limited government support with farm inputs (PCI = 2296). Smallholder farmers need to be better supported through the provision of appropriate institutional and policy arrangements together with improved land management extension advice to overcome these barriers and facilitate the more effective implementation of climate-smart agricultural practices in Ghana.*

Agricultural Systems, Volume 151, 2017,	*42*	*An Notenbaert, Catherine Pfeifer, Silvia Silvestri, Mario Herrero, (2017) Targeting, out-scaling and prioritising climate-smart interventions in agricultural systems: Lessons from applying a generic framework to the livestock sector in sub-Saharan Africa,*	*A variety of promising climate-smart interventions have been identified. However, what remains is the prioritization of interventions for investment and broad dissemination. The suitability and adoption of interventions depends on a variety of bio-physical and socio-economic factors. Also their impacts, when adopted and out-scaled, are likely to be highly heterogeneous. This heterogeneity expresses itself not only spatially and temporally but also in terms of the stakeholders affected, some might win and some might lose.*	*Framework Development for CSA future planning & priority setting Through examples, related to livestock production in sub-Saharan Africa, we demonstrate each of the steps and how they are interlinked. The framework is applicable in many different forms, scales and settings. It has a wide applicability beyond the examples presented and we hope to stimulate readers to integrate the concepts in the planning process for climate-smart agriculture, which invariably involves multi-stakeholder, multi-scale and multi-objective decision-making.*	*As a result of population growth, urbanization and climate change, agricultural systems around the world face enormous pressure on the use of resources. There is a pressing need for wide-scale innovation leading to development that improves the livelihoods and food security of the world's population while at the same time addressing climate change adaptation and mitigation.*	*CSA adoption –Framework for planners and priority setters In this paper we provide climate smart agriculture (CSA) planners and implementers at all levels with a generic framework for evaluating and prioritising potential interventions. This entails an iterative process of mapping out recommendation domains, assessing adoption potential and estimating impacts. A mechanism that can facilitate a systematic, holistic assessment of the likely spread and consequential impact of potential interventions is one way of improving the selection and targeting of such options.*

Ecological Economics, Volume 163, 2019,	43	Munyaradzi Junia Mutenje, Cathy Rozel Farnworth, Clare Stirling, Christian Thierfelder, Walter Mupangwa, Isaiah Nyagumbo, (2019) A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology,	The cost-benefit analysis and stochastic dominance results showed that CSA options that combined soil and water conservation management practices based on the principles of conservation agriculture (CA), improved varieties, and associations of cereal-legume crop species were economically viable and worth implementing for risk averse smallholder farmers.	Mixed: Cost and Benefit Analysis Cost-benefit analysis (CBA) and a mixed methods approach were used to assess the likelihood of investment in various CSA technology combinations. The data were drawn respectively from 1440, 696, and 1448 sample households in Malawi, Mozambique and Zambia, covering 3622, 2106 and 5212 maize-legume plots in these countries over two years.	Defn: Climate change and extreme weather events undermine smallholder household food and income security in southern Africa. Climate Smart Agriculture (CSA) technologies comprise a suite of interventions that aim to sustainably increase productivity whilst helping farmers adapt their farming systems to climate change and to manage risk more effectively.	CSA adoption cultural & social context matters- gender roles A dynamic mixed multinomial logit demonstrated that women's bargaining power, drought shock, and access to CSA technology information positively influenced the probability of investing in CSA technology combinations. This study provides evidence of the importance of cultural context, social relevance and intra-household decision-making in tailoring suitable combinations of CSA for smallholder farmers in southern Africa. Keywords: Gender; Intra-household decision-making; Climate-smart agriculture; Cost-benefit analysis; Southern Africa

Climate Services, *Volume 22,* *2021,*	*44*	*Philip Antwi-Agyei, Andrew J. Dougill, John Doku-Marfo, Robert C. Abaidoo, (2021)* *Understanding climate services for enhancing resilient agricultural systems in Anglophone West Africa: The case of Ghana,*	*The paper addresses the questions: (i) to what extent is climate change recognised as a threat to agricultural development in national climate facing policies of Anglophone West African states? (ii) to what extent have climate information services been incorporated into national and regional policy frameworks of Anglophone West African states for resilient agricultural systems? (iii) what are the key challenges in mainstreaming climate information services into national policies for resilient agricultural building in Ghana?*	*Mixed: Thematic content analysis & expert interviews* *The study employed thematic content analysis, multi-stakeholder workshops and expert interviews to understand climate discourses around climate services.*	*Whilst the capability of climate services to reduce climate impacts is alluring, empirical evidence on how best to mainstream climate information services in Africa is lacking. This paper determines how climate information services have been incorporated into national policies by Anglophone West African states for building agricultural resilience and provides a detailed analysis of issues facing Ghanaian agricultural systems.* *For the case of Ghana, the study reveals low awareness of climate change among policy-makers, human and institutional capacity constraints as some of the key factors militating against the mainstreaming of climate information services. Capacity building of policy makers and institutional strengthening are both vital for more effective mainstreaming of climate services across West Africa.*	*CSA adoption (Climate information services & policy framework not sufficiently integrated at various national levels): Low awareness * capacity building of policy makers, institutional strengthening required* *Findings show that climate change is highlighted in national and regional level policies as a serious threat to socioeconomic development and agricultural productivity in West Africa.* *Anglophone West Africa countries are at various stages in establishing a National Framework for Climate Services to help guide future adaptation planning. This study shows that Anglophone West African states have not yet incorporated climate information services into strategic national and regional climate facing policies that are critical in shaping efforts aimed at managing climate risks.*

Environmental Development, *Volume 32,* *2019,*	*45*	*Clifton Makate, Marshall Makate, Munyaradzi Mutenje, Nelson Mango, Shephard Siziba,* *Synergistic impacts of agricultural credit and extension on adoption of climate-smart agricultural technologies in southern Africa,*	*Institutional credit and extension services are critical inputs that can reduce scaling challenges in agricultural development interventions if accessed by farmers.* *A majority of smallholder farmers in sub-Saharan Africa (SSA) countries depend to a large extent on agriculture for food security and income. Efforts aimed at improving farm-related profitability are therefore important to improving livelihoods among smallholder farmers.* *In Ghana, for example, smallholder farmers that depend on agriculture face serious risks especially those related to climate change and variability and soil degradation. Notwithstanding these dangers, evidence of the published literature on how best to tackle these challenges is limited.*	*Quant: Regression* *Using household level survey data from Zimbabwe and Malawi, this article seeks to contribute to the existing literature by examining impacts of separate and joint access to credit and extension services on climate-smart agricultural (CSA) technologies adoption.* *Using inverse-probability weighting regression adjustment and propensity score matching*	*Results call for prudent policy and institutional strategies in improving access to credit and extension services in Malawian and Zimbabwean smallholder farming that are mindful of disadvantaged groups such as youth and women farmer groups in order to improve adoption and upscaling of CSA technologies. Possible options include; improving number of extension workers at village level, increasing youth and women extension agent numbers, capacity building of extension personnel and institutions, and increasing financial support to national extension programs.*	*CSA adoption (Acces to credit vs access to extension services collective impact), but separately extension service proved more useful to enhancing adoption* *This study found out that access to either extension or credit significantly progresses CSA technology adoption. However, access to extension services only proved to be more effective in enhancing CSA technology adoption than access to credit alone.* *More importantly, results show enhanced collective impact of simultaneous access to credit and extension on CSA technology adoption.* *Youth & Gender marginalised groups* *Further, joint impacts of credit and extension on adoption were found to be less pronounced in youthful and women farmer groups compared to their old and male farmer group counterparts respectively.*

World Development, Volume 126, 2020,	*46*	*Festus O. Amadu, Paul E. McNamara, Daniel C. Miller, Understanding the adoption of climate-smart agriculture: A farm-level typology with empirical evidence from southern Malawi,*	*Climate-smart agriculture (CSA) is increasingly important for advancing rural development and environmental sustainability goals in developing countries. Over the past decade, the international community has committed billions of dollars to support various practices under the banner of CSA. Despite this effort, however, CSA adoption remains low in many contexts. Lack of conceptual clarity about the range of potential farm-level CSA practices across contexts impedes understanding of CSA adoption in developing countries. Here we review relevant literature to develop a typology of farm-level CSA practices to facilitate analyses of CSA adoption.*	*Quant – Probit Bivariate Regression The typology consists of six categories, organized from least to most resource intensive: (1) residue addition, (2) non-woody plant cultivation, (3) assisted regeneration, (4) woody plant cultivation, (5) physical infrastructure, and (6) mixed measures. We use the typology to generate and test hypotheses about CSA adoption using primary household survey data from a large aid-funded CSA intervention area in southern Malawi. We then use recursive bivariate probit regression (controlling for endogeneity and selection bias) to estimate the effect of program participation on adoption across CSA categories.*	*Reliable indicators of farm performance are needed in order to model these links, and to therefore be able to design interventions which meet the differing needs of specific user groups. However, the lack of standardization of performance indicators has led to a wide array of tools and ad-hoc indicators which limit our ability to compare across studies and to draw general conclusions on relationships and trade-offs whereby performance indicators are shaped by farm management and the wider social-environmental context.*	*CSA Low Adoption (support for resource intensive CSA practices is vital) We find positive and statistically significant effects of program participation on adoption of CSA practices generally with the strongest effects on resource-intensive CSA categories. Results demonstrate the potential for wider application of the typology to build knowledge of the effectiveness of CSA promotion efforts across different social and environmental contexts. Our findings also suggest the importance of external support for the adoption of more resource-intensive CSA practices among rural households and communities in Malawi and elsewhere in the developing world.*

Agriculture, Ecosystems & Environment, *Volume 251,* *2018,*	*47*	*Peter R. Steward, Andrew J. Dougill, Christian Thierfelder, Cameron M. Pittelkow, Lindsay C. Stringer, Maxwell Kudzala, Gorm E. Shackelford, (2018)* *The adaptive capacity of maize-based conservation agriculture systems to climate stress in tropical and subtropical environments: A meta-regression of yields,*	*Conservation agriculture is widely promoted across sub-Saharan Africa as a sustainable farming practice that enhances adaptive capacity to climate change. The interactions between climate stress, management, and soil are critical to understanding the adaptive capacity of conservation agriculture. Yet conservation agriculture syntheses to date have largely neglected climate, especially the effects of extreme heat.*	*Quant: Meta Regression & global soil and climate data set* *For the sub-tropics and tropics, we use meta-regression, in combination with global soil and climate datasets, to test four hypotheses: (1) that relative yield performance of conservation agriculture improves with increasing drought and temperature stress; (2) that the effects of moisture and temperature stress exposure interact; (3) that the effects of moisture and temperature stress are modified by soil texture; and (4) that crop diversification, fertilizer application* *….will enhance clime stress.*	*The effects of these innovations on household nutritional security, including gender-differentiated nutritional status, have hardly been analyzed*	*CSA adoption Gendered and dietary perspective are critical* *Our meta-regression supports the narrative that conservation agriculture enhances the adaptive capacity of maize production in sub-Saharan Africa under drought and/or heat stress. However, in very wet seasons and on clay-rich soils, conservation agriculture yields less compared to conventional practices* *Our results support the hypothesis that the relative maize yield performance of conservation agriculture improves with increasing drought severity or exposure to high temperatures.*

Agricultural Systems, Volume 163, 2018,,	48	B.K. Paul, R. Frelat, C. Birnholz, C. Ebong, A. Gahigi, J.C.J. Groot, M. Herrero, D.M. Kagabo, A. Notenbaert, B. Vanlauwe, M.T. van Wijk, (2018) Agricultural intensification scenarios, household food availability and greenhouse gas emissions in Rwanda: Ex-ante impacts and trade-offs,	Rwanda's agricultural sector is facing severe challenges of increasing environmental degradation, resulting in declining productivity. The problem is likely to be further aggravated by the growing population pressure. A viable pathway is climate smart agriculture, aiming at the triple win of improving food security and climate change adaptation, while contributing to mitigation if possible. Across all sites, 46% of households were below the 2500kcal-MAE−1yr−1 line, with lower food availability in the Southern and Eastern Rwanda. Consumed and sold food crops were the mainstay of food availability, contributing between 81.2% (low FA class) to 53.1% (high FA class). Livestock and off-farm income were the most important pathways to higher FA. Baseline GHG emissions were low, ranging between 395 and 1506kg CO_2e hh−1yr−1 per site, and livestock related emissions from enteric fermentation (47.6–48.9%) and manure (26.7–31.8%) were the largest contributors to total GHG emissions across sites and FA classes. GHG emissions increased with FA, with 50% of the total GHG being emitted by 22% of the households with the highest FA scores.	Foresight FramIng: Scenario Policy Assessements In this study, we aimed at assessing the potential impact of these policy programs on food availability and greenhouse gas (GHG) emissions of 884 households across different agro-ecologies and farming systems in Rwanda. Household level calculations were used to assess the contribution of current crops, livestock and off-farm activities to food availability and GHG emissions.	The Government of Rwanda has initiated ambitious policies and programs aiming at low emission agricultural development. Crop focused policies include the Crop Intensification Program (CIP) which facilitates access to inorganic fertilizer and improved seeds. In the livestock subsector, zero-grazing and improved livestock feeding are encouraged, and the Girinka program provides poor farm households with a crossbred dairy cow.	CSA Adoption – effective for production/resilience Scenario assessment of the three policy options showed strong differences in potential impacts: Girinka only reached one third of the household population, but acted highly pro-poor by decreasing the households below the 2500kcalMAE−1yr−1 line from 46% to 35%. However, Girinka also increased GHG by 1174kg CO_2e hh−1yr−1, and can therefore not be considered climate-smart. Improved livestock feeding was the least equitable strategy, decreasing food insufficient households by only 3%. However, it increased median FA by 755kcalMAE−1yr−1 at a small GHG increase (50kg CO_2e hh−1yr−1). Therefore, it is a promising option to reach the CSA triple win. Crop and soil improvement resulted in the smallest increase in median FA (FA by 322kcalMAE−1yr−1), and decreasing the proportion of households below 2500kcalMAE−1yr−1 by 6%. This came only at minimal increase in GHG emissions (23kg CO_2e hh−1yr−1). All policy programs had different potential impacts and trade-offs on different sections of the farm household population. Quick calculations like the ones presented in this study can assist in policy dialogue and stakeholder engagement to better select and prioritize policies and development programs, despite the complexity of its impacts and trade-offs.

Agricultural Systems, Volume 199, 2022,,	49	Alex Zizinga, Jackson-Gilbert Majaliwa Mwanjalolo, Britta Tietjen, Bobe Bedadi, Himanshu Pathak, Geofrey Gabiri, Dennis Beesigamukama, (2022) Climate change and maize productivity in Uganda: Simulating the impacts and alleviation with climate smart agriculture practices,	This study investigated the effectiveness of CSA practices (mulching at 0, 2, 4 and 6 cm thicknesses), permanent planting basins (20 and 30 cm deep), and halfmoon pits as a mitigation and adaptation strategy for improving maize productivity in rainfed production systems in the sub-humid regions of Sub-Saharan Africa.	Quant : Field experiments & Modelling (with foresight framing i.e scenario planning projections & prioritisation) We used the AquaCrop model of the Food and Agriculture Organization (FAO, 2018), AquaCrop version 6.1 to evaluate potential benefits of the CSA practices: half-moon, mulching (using different thickness) and permanent planting basins compared to a control treatment in rainfed production systems. The performance of CSA practices was evaluated using field experiments under present and future conditions. We first parameterized the model based on a three-season field experiment (2019-2020). We then run the model under projected future trends (2010–2039) using four general circulation models in each two greenhouse gas (GHG) emission representation concentration pathways (RCP4.5 and RCP8.5) for the Coupled Model Inter-comparison Project 5 (CMIP5).	Climate change continues to affect maize production, food security and livelihoods of smallholder farmers in most of the developing countries. Climate smart agriculture (CSA) practices can enhance agricultural production by alleviating adverse climate effects on maize productivity through improved soil moisture storage, water use efficiency, increased soil carbon (C) and nutrient supply with long-term resilience to climate change. Our findings highlight the key role of CSA practices in reducing the climate change effects on maize production in the sub-humid regions. Therefore, national governments should prioritize adoption of climate smart agriculture practices as a key strategy for improving and sustaining maize productivity in rainfed systems of the sub-humid region.	CSA adoption (productivity) Our results indicated that use of mulching, especially 6 cm thick mulch increased maize grain yield and water use efficiency under present and future conditions . It was noted that CSA practices would increase grain yield by 14–37% under RCP8.5 climate scenario. Projections revealed increases in mean temperature of 0.5 °C and 1.0 °C under RCP4.5 and RCP8.5, respectively, in the 30 years (2010–2039). The model also projected a decrease (4.7%) and increase (2%) of the annual averages of rainfall in the future under RCP4.5 and RCP8.5, respectively

Agricultural Systems, *Volume 190,* *2021,*	*50*	*Renata Jagustović, George Papachristos, Robert B. Zougmoré, Julius H. Kotir, Aad Kessler, Mathieu Ouédraogo, Coen J. Ritsema, Kyle M. Dittmer (2021)* *Better before worse trajectories in food systems? An investigation of synergies and trade-offs through climate-smart agriculture and system dynamics,*	*Our study aims to inform the sustainable transformation of food systems by identifying short- and long-term synergies and trade-offs in the climate-smart village (CSV) Lawra-Jirapa in northern Ghana under the current practices, technologies, policies, and trends of population growth, extreme events, and climate change impacts.*	*Foresight Frame* *Systems thinking; System dynamics modelling* *We develop a system dynamics model to simulate the food system in the CSV between 2011 and 2060. We apply the climate-smart agriculture (CSA) approach as a diagnostic tool to the CSV system to reveal the short- and long-term trade-offs and synergies between the CSA goals.*	*CONTEXT* *Food systems face multiple challenges simultaneously: provision to a growing population, adaptation to more extreme and frequent climate change risks, and reduction of their considerable greenhouse gas (GHG) emissions. Food system interventions and policies give rise to synergies and trade-offs that emerge over time due to the dynamic nature and interconnections of system elements. Analysis of an entire food system is necessary to identify synergies that bring simultaneous benefits and mitigate trade-offs, both short- and long-term.* *The simulation results reveal short-term progress towards the goal of increased productivity and income, with trade-offs in the goals of GHG removal, climate adaptation, and resilience. In the long term, post-2035, current agriculture practices, technologies, and policies inside and outside the CSV boundaries result in trade-offs across all three CSA goals, and progress made towards these goals is reversed. The CSV system behaviour, thus, exhibits a “better before worse” pattern.*	*CSA Adoption – Systems thinking with short & longterm transformations.* *The analysis demonstrates an approach, which considers simultaneously all three CSA goals, to identify synergies and mitigate trade-offs in an entire food system. The findings suggest that understanding the dynamics of food systems is a precursor to their sustainable transformation. This transformation will entail changes to the food system’s goals and structure with equal attention to short- and long-term outcomes.*

Agricultural Systems, *Volume 200,* *2022,,*	*51*	*Komlavi Akpoti, Thomas Groen, Elliott Dossou-Yovo, Amos T. Kabo-bah, Sander J. Zwart, (2022)* *Climate change-induced reduction in agricultural land suitability of West-Africa's inland valley landscapes,*	*The main objective of the study is to apply a set of machine learning models to quantify the extent of climate change impact on land suitability for rice using the presence of rice-only data in IVs along with bioclimatic indicators.* *The demand for rice in West Africa is huge. For the rice self-sufficiency agenda of the region, "where" and "how much" land resources are available is key and requires long-term, informed planning. Farmers can only adapt when they switch to improved breeds, providing that they are suited for the new conditions. Our results stress the need for land use planning that considers potential climate change impacts to define the best areas and growing systems to produce rice under multiple future climate change uncertainties.*	*Quant: Machine Learning Modelling with foresight frame scenarios* *We used a spatially explicit modeling approach based on correlative Ecological Niche Modeling. We deployed 4 algorithms (Boosted Regression Trees, Generalized Linear Model, Maximum Entropy, and Random Forest) for 4-time periods (the 2030s, 2050s, 2070s, and 2080s) of the 4 Representative Concentration Pathways (RCP2.6, RCP4.5, RCP6.0, and RCP8) from an ensemble set of 32 spatially downscaled and bias-corrected Global Circulation Models climate data.*	*Although rice production has increased significantly in the last decade in West Africa, the region is far from being rice self-sufficient. Inland valleys (IVs) with their relatively higher water content and soil fertility compared to the surrounding uplands are the main rice-growing agroecosystem. They are being promoted by governments and development agencies as future food baskets of the region. However, West Africa's crop production is estimated to be negatively affected by climate change due to the strong dependence of its agriculture on rainfall.*	*CSA Adoption (strong adaptation measures required with tech advances)* *The overall trend showed a decrease in suitable areas compared to the baseline as a function of changes in temperature and precipitation by the order of 22–33% area loss under the lowest reduction scenarios and more than 50% in extreme cases. Isothermality or how large the day to night temperatures oscillate relative to the annual oscillations has a large impact on area losses while precipitation increase accounts for most of the areas with no change in suitability. Strong adaptation measures along with technological advancement and adoption will be needed to cope with the adverse effects of climate change on inland valley rice areas in the sub-region.*

Soil and Tillage Research, *Volume 188,* *2019,,*	*52*	*Rattan Lal, (2019)* *Promoting "4 Per Thousand" and "Adapting African Agriculture" by south-south cooperation: Conservation agriculture and sustainable intensification,*	*The objective of this article is to discuss the merits and challenges of South–South Cooperation (SSC) in promoting the adoption of best management practices (BMPs) such as conservation agriculture (CA) and sustainable intensification (SI). Basic principles of CA are: retention of crop residue mulch, incorporation of cover crops and complex rotations, integrated nutrient management and elimination of soil disturbance.* *The strategy of SSC is pertinent because of the ten basic principles or tenets: lack of hierarchy, equal participation in all decision-making processes along with transparency, trust, mutual respect, and accountability. However, several concerns have been raised regarding issues such as land grab, and access to resources etc.*	*Mixed Method* *The CSA-RA employs gender-disaggregated methods, including gender differences in perceptions of climate change and its impacts. The CSA-RA combines common participatory rural appraisal (PRA) and rapid rural appraisal (RRA) tools into one methodology, that disaggregates the gender dimension, and includes resource mapping; climate calendars; historical calendars; cropping calendars; organization mapping; transect walks; key informant interviews; farmer interviews; and pairwise ranking matrix.*	*The "4 per Thousand" and "Adapting African Agriculture" are bold and innovative initiatives adopted at COP21 in Paris and COP22 in Marrakesh, respectively. These initiatives are soil-centric and based on adoption of soil-restorative and improved agricultural practices.* *The strategy of SI is to produce more from less by enhancing the eco-efficiency, reducing waste, and restoring soil health. Whereas CA has been successfully adopted in Brazil, Argentina, Chile and other regions of South America, its potential of harnessing agronomic and ecologic benefits has not been realized in Sub-Saharan Africa, South Asia, and elsewhere in The Global South.*	*CSA Adoption – UNSDG- South South Cooperation challenges (producing more from less)* *Based on the scientific concepts of SI, producing more from less, even a triangular cooperation (TAC) or South-South-North (SSNC) cooperation can be developed to achieve adaptation and mitigation of climate change, advance food security, improve degraded soils and restore soil health through soil organic carbon (SOC) sequestration, and advance Sustainable Development Goals (SDGs) of the U.N. A widespread adoption of CA and SI through SSC, TAC or SSNC can advance SDGs including #1 (end poverty), #2 (eliminate hunger), #6 (clean water), #13 (climate action), and #15 (life on land). Of the global cropland area under CA estimated at 180 million hectare (Mha) in 2015–16, land area under CA is only 2.7 Mha in Africa and 13.2 Mha in Asia. SSC, TAC and SSNC can build upon the existing and on-going initiatives by national and international organizations.* *Keywords: Soil restoration; Multilateral cooperation; Food security*

Land Use Policy	*53*	*Marieke Sassen, Arnout van Soesbergen, Andrew P. Arnell, Emma Scott, (2018)* *Patterns of (future) environmental risks from cocoa expansion and intensification in West Africa call for context specific responses,* *Land Use Policy,* *Volume 119,* *2022,*	*To inform efforts to prevent further cocoa-driven deforestation in the West African cocoa zone, we mapped areas that are important for biodiversity and ecosystem services (carbon, water, forest products) and potentially most at risk from further cocoa expansion based on climatic suitability, a continuation of past deforestation trends and the potential role of cocoa therein.*	*Foresight Frame: Future Mapping & Planning* *, the approach used in this study can help identify areas with the highest biodiversity and ecosystem services values and inform planning of future cocoa development to maximise cocoa system productivity potential, biodiversity and ecosystem services from the national to local scale.*	*Cocoa is an important historical driver and direct cause of forest loss and degradation in the West African Upper Guinean biodiversity hotspot.* *In countries with large areas of remaining forests (e.g., Liberia and Cameroon) that are highly suitable for cocoa and where cocoa is expanding* *Adaptation strategies are required to avoid the loss but also improve the conservation of biodiversity and provision of ecosystem services across the region.*	*CSA Adoption (prospects, priority, and Agric tech innovations)* *We found that cocoa expansion and intensification risks further impacting ecologically important areas in West Africa, but that patterns vary in space, may be compounded by climate change and demand context specific responses. In Ghana and Côte d'Ivoire, remaining forests should be better protected, degraded forests should be restored, and agroforestry systems should be supported where possible to maintain or enhance biodiversity and ecosystem services provision in cocoa landscapes.*

Climate Services, *Volume 20,* *2020,*	*54*	*Obed M. Ogega, Benjamin A. Gyampoh, Christopher Oludhe, James Koske, James B. Kung'u, (2020)* *Building on foundations for climate services for sustainable development: A case of coastal smallholder farmers in Kilifi County, Kenya,*	*Globally, the role of extension agents in scaling up the utilization of Climate Smart Agricultural Initiatives (CSAI) by farmers remains very crucial. This study examined the determinants of the involvement of extension agents in the dissemination of CSAI to farmers.*	*Quant- survey* *A two-staged random sampling technique was used to elicit information from 277 extension agents in South West Nigeria using a structured questionnaire. Data were analysed using frequency counts, percentage and linear regression analysis..*	*Significant factors influencing extension agents' involvement in the dissemination of CSAI are educational qualification ($t = 2.57$; $p = 0.011$), years of experience ($t = 5.11$; $p = 0.000$), participation in CSA training ($t = 1.77$; $p = 0.077$) and numbers of community covered ($t = -2.30$; $p = 0.022$). The study concludes that although extension agents are involved in the dissemination of some CSAI, there are still a wide range of initiatives that are not adequately disseminated to the rural farmer. It was therefore recommended that extension agents should be trained especially on the wide range of CSAI identified not to be predominantly disseminated so as to scale-up their adoption by farmers to enhance sustainable agricultural productivity and food security for all.* *Keywords: Climate smart agricultural initiatives; Determinants; Extension agents; Involvement; Nigeria.*	*CSA Adoption relevance of extension workers knowledge and experiences* *The findings revealed that prominent initiatives extension agents disseminated were cover crops planting and minimum tillage practices.* *However, extension agents had low involvement in the dissemination of use of soil amendments, conversion of waste to compost, agro-forestry, resource conservation and use of agro-weather related initiatives.*

Environmental Challenges, *Volume 4,* *2021,*	*55*	*Anja du Plessis, (2021)* *Necessity of making water smart for proactive informed decisive actions: A case study of the upper vaal catchment, South Africa,*	*SWM can enable improved integrated water resource management by increasing sharing and effective use of real-time data of acceptable quality to promote proactive unambiguous strategies and decisions focused on overall improved water management and the evasion of a future water predicament.*	*Case Study: Foresight Frame – Evasion of future predicament* *The quality of available government data is mostly of an acceptable standard according to the evaluated data dimensions and elements.*	*The need for informed management of water resources has been continuously highlighted worldwide. Societies are increasingly faced with water quality challenges globally which directly translate into multifaceted challenges. South Africa has acknowledged that water is not receiving the attention and status it deserves. Wastage is rife and degradation widespread. The sustainability of South Africa's freshwater resources has reached a critical point and requires decisive action. Vast amounts of water quality data, varying in quality, is available however the seemingly lack of integrative data management has led to reactive planning and questionable decisions.*	*CSA Adoption (SWM – water quality & value)* *The paper highlights the necessity for making water smart through a case study of the Upper Vaal catchment.* *The practical application of determining hydrological responses to predict possible water quality changes towards land cover change in the Vaal river catchment emphasises that there is suitable data available and highlights the value of Smart Water Management (SWM).*

Agricultural and Forest Meteorology, Volume 248, 2018,	*56*	*Tesfaye Shiferaw Sida, Frédéric Baudron, Haekoo Kim, Ken E. Giller, (2018)* *Climate-smart agroforestry: Faidherbia albida trees buffer wheat against climatic extremes in the Central Rift Valley of Ethiopia,*	*Model-based sensitivity analysis showed that under moderate to high rates of N, wheat yield responded positively to a decrease in temperature caused by F. albida shade. Thus, F. albida trees increase soil mineral N, wheat water use efficiency and reduce heat stress, increasing yield significantly. With heat and moisture stress likely to be more prevalent in the face of climate change, F. albida, with its impact on microclimate modification, maybe a starting point to design more resilient and climate-smart farming systems.*	*Quant: Experiment, Test, & Modelling* *We carried out an on-farm experiment for three consecutive seasons in the Ethiopian Central Rift Valley with treatments of Faidherbia trees with bare soil underneath, wheat grown beneath Faidherbia and wheat grown in open fields. We tested the sensitivity of wheat yield to tree-mediated variables of photosynthetically active radiation (PAR), air temperature and soil nitrogen, using APSIM-wheat model.*	*Faidherbia albida parklands cover a large area of the Sudano-Sahelian zone of Africa, a region that suffers from soil fertility decline, food insecurity and climate change. The parklands deliver multiple benefits, including fuelwood, soil nutrient replenishment, moisture conservation, and improved crop yield underneath the canopy. Its microclimate modification may provide an affordable climate adaptation strategy which needs to be explored.*	*CSA Adoption (practices other than technology):* *Trees Buffer against extreme weather* *Results showed that soil moisture in the sub-soil was the least for wheat with tree, intermediate for sole tree and the highest for open field. Presence of trees resulted in 35–55% larger available N close to tree crowns compared with sole wheat. Trees significantly reduced PAR reaching the canopy of wheat growing underneath to optimum levels. Midday air temperature was about 6°C less under the trees than in the open fields. LAI, number of grains spike−1, plant height, total aboveground biomass and wheat grain yield were all significantly higher (P<0.001) for wheat associated with F. albida compared with sole wheat.*

Land Use Policy, *Volume 95,* *2020,*	*57*	*Eleanor K.K. Jew, Stephen Whitfield, Andrew J. Dougill, David D. Mkwambisi, Peter Steward, (2020)* *Farming systems and Conservation Agriculture: Technology, structures and agency in Malawi,*		*Evaluation: Group Exercises & Focus Group* *Agricultural system constraints experienced by farming households are identified, and in response the technologies, structures and agency associated with CA are evaluated. The most significant constraints were linked to household health, with associated labour and monetary impacts, in addition to the availability of external inputs of fertiliser and improved seed varieties.*	*Conservation Agriculture (CA) is advocated as an agricultural innovation that will improve smallholder famer resilience to future climate change. Under the conditions presented by the El Niño event of 2015/16, the implementation of CA was examined in southern Malawi at household, district and national institutional levels.* *Our findings show that such constraints are not adequately addressed through current agricultural system support structures, with the institutions surrounding CA (in both Government extension services and NGO agricultural projects) focusing attention predominantly at field level practice, rather than on broader system constraints such as education and health support systems. Limited capacity within local institutions undermines long term efforts to implement new technologies such as CA.*	*CSA Adoption – Holistic approach to Constraints (Household Health, education, limited capacity)* *It is vitally important that the flexibility of farmers to adapt new technologies in a locally-appropriate manner is not closed down through national and institutional aims to build consensus around narrow technical definitions of a climate-smart technology such as CA. To enable farmers to fully utilise CA programmes, interventions must take a more holistic, cross-sectoral approach, understanding and adapting to address locally experienced constraints. Building capacity within households to adopt new agricultural practices is critical, and integrating healthcare support into agricultural policy is a vital step towards increasing smallholder resilience to future climate change.*

Heliyon, Volume 8, Issue 4, 2022,	*58*	*Devinia Princess Akinyi, Stanley Karanja Ng'ang'a, Margret Ngigi, Mary Mathenge, Evan Girvetz, (2022) Cost-benefit analysis of prioritized climate-smart agricultural practices among smallholder farmers: evidence from selected value chains across sub-Saharan Africa,*	*Prioritization of adaptation options is complex. This study presents a multi-dimensional framework to evaluate how to allocate resources among competing alternatives. The main objectives of the study were to identify the prioritized climate-smart agricultural practices adopted among smallholder farmers in different value chains across sub-Saharan Africa (SSA) and to assess the economic feasibility of the practices using Cost-Benefit Analysis (CBA) to develop a portfolio of viable and cost-effective options.*	*Cost Benefit Analysis (CBA) & Interviews This study focused on selected five SSA countries and selected value chains. 153 smallholder farmers and stakeholders were interviewed. The Climate Smart Agriculture Prioritization Framework was applied for the assessment of economically viable adaptation options. The prioritization was based on standard ranks on the ability of the practice to improve productivity, increase resilience, and mitigation. Spearman's rank-order correlation was used to assess the independence of the ranks. A CBA was conducted as the final step.*	*Farmers in sub-Saharan Africa are facing serious consequences from climate change, which pose obstacles to meeting UN Sustainable Development Goals (SDGs) such as zero hunger, ending poverty, ensuring Results showed five major ex-ante climate risk adaptation strategies – change in farming practice, sustainable land management, seek alternative livelihood, saving, and other unspecified strategies – are prevalent in the region. In comparison to farmers in Mozambique's northern region, farmers in all other locations were more likely to apply agricultural measures such as change in farming practice and sustainable land management, while they were more likely to apply non-agricultural measures to adapt to risk. Macro-level indicators show that national adaptive capacity is substantially low in all countries, but considerably varies across them.*	*CSA Adoption – country level adaptation strategies) Smallholder farmers in the study areas prioritized the adoption of improved seed, good agricultural practices, and conservation agriculture practices. In the sweet potato value chain in Kenya, good agricultural practices was viable with an NPV of US$ 28,044, an IRR of 328%, and a one-year payback period. This is in comparison to the improved seed varieties (US$ 8,738, 111%, and two years payback period) respectively. In Nigeria, the most viable option was the improved seed in the potato value chain and good agricultural practices in the rice value chain. In Malawi, Ethiopia, and Zambia, the most viable practices were improved seed, and conservation agriculture in the soybean, faba beans, and peanut value chains respectively. The NPV was highly sensitive to changes in the discount rate, moderately to price, yield, and practice lifecycle, and least to changes in annual labour costs. The results elaborate on the most feasible adaptation practices that enable smallholder farmers to increase productivity and be economically efficient. The use of the CSA-PF consecutively with the CBA tool allows for the proper identification of best-bet CSA options.*

Journal of Cleaner Production, *Volume 278,* *2021,*	*59*	*Giacomo Branca, Ademola Braimoh, Yuxuan Zhao, Motselisi Ratii, Puseletso Likoetla,* *Are there opportunities for climate-smart agriculture? Assessing costs and benefits of sustainability investments and planning policies in Southern Africa,*		*Cost and Benefit Analysis & policy planning* *The paper presents a cost-benefit analysis of the public investment program to promote climate-smart agriculture in Lesotho. Economic profitability of investing in such program in nationwide crop, livestock and aquaculture smallholders' production is assessed, considering costs and benefits at private level and those that accrue to society.* *Foresight Frame* *Given uncertainty about the future, a development pathway commercially oriented is compared with a pathway aimed at increasing households' capacity to adapt their farming systems to the changing climate.*	*Transformation in the smallholder agricultural sector towards more sustainable and cleaner production systems is needed in Southern Africa. Climate-smart agriculture could be an opportunity in this respect.*	*CSA Adoption-Investment Returns)* *Investment returns are above the opportunity cost of capital, under both pathways, indicating the convenience for farmers and the whole society in investing in climate-smart agriculture. The program also leads to a decrease in the greenhouse gas emissions' intensity, positively contributing to climate change mitigation. The economic evaluation of the carbon-balance increases societal profitability of the investment program.*

Land Use Policy, *Volume 97,* *2020,,*	*60*	*Nathan Clay, Karl S. Zimmerer,* *Who is resilient in Africa's Green Revolution? Sustainable intensification and Climate Smart Agriculture in Rwanda,*	*This article considers who and what is resilient in Africa's Green Revolution. We report on a multi-season study of smallholder food producers' experiences with Rwanda's Crop Intensification Program (CIP) and related policies that aim to commercialize subsistence agriculture while implementing CSA. . We suggest that there are fundamental limits to the climate resilience afforded by CSA and development efforts rooted in Green Revolution thinking.*	*Quant – multinomial regression* *The study employs multinomial logistic regression to evaluate factors of individual and multiple adoption and regression adjustment with inverse probability weighting to evaluate impacts of the different adoption regimes on farm productivity and income.*	*Under the banner of a "New Green Revolution for Africa," agricultural intensification programs aim to make smallholder agriculture more productive as well as "climate smart". As with Green Revolutions in Asia and Mexico, agricultural innovations (hybrid seeds, agronomic engineering, market linkages,and increased use of fertilizer and pesticides) are promoted as essential catalysts of agriculture-led economic growth. Intensification programs are now frequently linked to Climate Smart Agriculture (CSA), which attempts to build resilience and reduce greenhouse gas emissions while increasing crop yields.*	*CSA adoptions (Resilience , smallholder farmer vulnerability & inequality in local practices* *Our findings illustrate that such efforts foreground technology and management adjustments in ways that have reduced smallholder resilience by inhibiting sovereignty over land use, decreasing livelihood flexibility, and constricting resource access.* *We put forth that rural development policies could better promote climate-resilient livelihoods through: 1) adaptive governance that enables smallholder land use decision-making; 2) support for smallholder food producers' existing agro-ecological strategies of intensification; 3) participatory approaches to visualize and correct for inequalities in local processes of social-ecological resilience Such considerations are paramount for meeting the United Nations Sustainable Development Goals and building climate-resilient food systems.*

JOURNAL	CODING	AUTHORS & TITLE	TYPE OF CSA ADOPTED & WHY?	FORESIGHT ANALYTICAL FRAMES	CONTEXT APPLIED	LEARNING IN HINDSIGHT (FACTORS FOR MAPPING PLAUSIBLE FUTURES)
Agricultural Systems, *Volume 194,* *2021,*	*61*	*Antti Autio, Tino Johansson, Lilian Motaroki, Paola Minoia, Petri Pellikka, (2021)* *Constraints for adopting climate-smart agricultural practices among smallholder farmers in Southeast Kenya,*	*Understanding how biophysical and socio-economic constraints affect the adoption of CSA practices and technologies plays an essential role in policy and intervention planning. Our objective was to identify these constraints among smallholder farmers in Taita Taveta County of Southeast Kenya across varying agro-ecological zones.* *SIGNIFICANCE* *This study contributes to existing climate change adaptation research by increasing our understanding of how physical and socio-economic constraints can affect the adoption of new farm and land management practices, and how CSA-based intervention strategies could be restructured by local stakeholders to be more inclusive.*	*Mixed : Appraisal, Survey, & Interview* *We conducted a Climate-Smart Agriculture Rapid Appraisal that consisted of four mostly gender-disaggregated smallholder farmer workshops (102 participants), a household survey (65 participants), key-informant interviews (16 informants), and four transect walks.*	*Climate uncertainty challenges the livelihoods of smallholder farmers in sub-Saharan Africa. Awareness of climate-smart agricultural (CSA) practices and access to climate-smart technologies are key factors in determining the utilization of farm and land management practices that may simultaneously decrease greenhouse gas emissions, increase the adaptive capacity of farmers, and improve food security.* *Our research findings are based on the contextual settings of Taita Taveta County, but the results indicate that adopting CSA practices and utilizing technologies, especially in sub-Saharan regions that are heavily based on subsistence agriculture with heterogenous agro-ecological zones, require localized and gender-responsive solutions in policy formation and planning of both agricultural extension services and development interventions that take into account the agency of the farmers.*	*CSA adoption (Awareness and Access): Food security & adaptive capacity* *Our results indicate a dissonance in the perceived awareness of CSA practices and utilization of CSA technologies between state actors and farmers. State actors emphasize lack of awareness as a barrier to adoption, while farmers express knowledgeability regarding environmental change and climate-smart practices but are confined by limitations and restrictions posed by e.g. market mechanisms, land tenure issues, and lack of resources. These restrictions include e.g. uncertainty in product prices, lack of land ownership, scarcity of arable land, and simply lack of capital or willingness to invest. Farmers are further challenged by the emergence of new pests and human–wildlife conflicts.*

Smart Agricultural Technology, *2022,*	*62*	*Agricultural decision system based on advanced machine learning models for yield prediction: Case of East African countries (2022)* *Rubby Aworkaa , Lontsi Saadio Cedric a , Wilfried Yves Hamilton Adoni b, , Jérémie Thouakesseh Zoueuc,d , Franck Kalala Mutomboa,e , Charles Lebon Mberi Kimpoloa , Tarik Nahhal f , Moez Kricheng,h*	*Machine learning has become an impressive predictive analytical tool for large volume of data. It has been used in many domains such as medicine, finance, sport, and recently in agriculture. In this work, we propose three crop prediction models : Crop Random Forest, Crop Gradient Boosting Machine and Crop Support Vector Machine.* *.*	*Quant: Experiment with Machine Learning : Foresight Frame: Predictions* *We combine climate data, crop production data, and pesticides data to develop a decision system based on advanced machine learning models. Despite the poor availability of data related to agriculture in Africa, we were able to propose a decision system able to predict the crop yield at the country level in fourteen East African countries.*	*Food security has become a real challenge for some organizations in charge of the food program and for the majority of countries, especially African countries. The United Nations Organizations' has recently defined the end of hunger and the improvement of food security in 2030 as its primary goal. Improving food security could also pass through the handling of agricultural yield. Agricultural yield is affected by climate changes since this latest decade. Climate change is considered one of the major threats to agricultural development in Africa. Decisionmaking level and farmers need efficient analytical tools to help them in decision making.*	*CSA adoption -Advanced Machine Learning* *Our experimental results show that the three proposed machine learning models fit well the crop data with a high accuracy 2. The Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) associated to our models are very minimal because the agricultural prediction values are very close to reality. Our proposed models are reliable and generalize well the agricultural predictions in East Africa*

Heliyon (2021)	*63*	*Andrew Waaswa a,* , Agnes Oywaya Nkurumwa a , Anthony Mwangi Kibe b , Ng'eno Joel Kipkemoi c (2021)* *Communicating climate change adaptation strategies: climate-smart agriculture information dissemination pathways among smallholder potato farmers in Gilgil Sub-County, Kenya*	*This study investigated the information dissemination pathways used by different categories of smallholder potato farmers for and practice of CSAPs.*	*Quant- Statistics%* *It found a difference between information sources and practice of CSAPs at a 5% level of significance (X2 ¼ 100.12139, df ¼ 2, p < 0.05, Cramer's V ¼ 1.0), and a difference in the use of the three information dissemination pathways between men and women at a 5% level of significance (X2 ¼ 6.05949, df ¼ 2, p < 0.05, Cramer's V ¼ 0.17406).*	*Proven and sustainable practices like climate-smart agricultural practices (CSAPs) need to be prioritized and promoted for uptake especially by the farmers to achieve sustainable development. These are capable of contributing to the realization of sustainable development goals through averting food and nutritional insecurity, increasing and sustaining yields that translate into increased incomes and later reduced poverty. This is because CSAPs enable farmers to adapt and mitigate climate change effects. However, due to inappropriate communication of CSAPs to the farmers, to date, some farmers still see no escape route from the frightening effects of climate change and they are currently adopting a rather fatalistic attitude.*	*CSAP Adption Pathways (Nighburs, friends, & extension officiers)* *The three information dissemination pathways included media, neighbours and friends, and extension officers. Generally, farmers were aware and practiced the CSAPs investigated in this study except for irrigation with high awareness yet with low uptake percentage and potato seedlings and minitubers both with low awareness and practice respectively. This study recommended mainstreaming of CSAPs information*

Procedia Computer Science 177 (2020),	*64*	*Ethiopia Nigussiea,*, Thomas Olwalb , George Musumbac , Tesfa Tegegned , Atli Lemmae , Fisseha Mekuria (2020)* *IoT-based Irrigation Management for Smallholder Farmers in Rural Sub-Saharan Africa*	*Indigenous farming and expert knowledge, regional weather information, crop and soil specific characteristics are also provided to the system for informed-decision making and efficient operation of the irrigation management system. In SSA, broadband connectivity and cloud services are either unavailable or expensive.*	*Case Study* *In this work, IoT-based irrigation management system is proposed after investigating problems of irrigated farmlands in three SSA countries, Ethiopia, Kenya, and South Africa as case studies. Resource-efficient IoT architecture is developed that monitors soil, microclimate and water parameters and performs appropriate irrigation management.*	*Ensuring food security has become a challenge in Sub-Saharan Africa (SSA) due to combined effects of climate change, high population growth, and relying on rainfed farming. Governments are establishing shared irrigation infrastructure for smallholder farmers as part of the solutions for food security. However, the irrigated farms often failed to achieve the expected crop yield. This is partly due to lack of water management system in the irrigation infrastructure.*	*CSA adoption : IoT(minimum resource consumption, bio-diversity, & yield)* *To tackle these limitations, data processing, network management, irrigation decisions and communication to the farmers are carried out locally, without the involvement of any back-end servers.* *Furthermore, the use of green energy sources and resource-aware intelligent data analysis algorithm is studied. It is expected that an intelligent data analysis will help to discover new knowledge that support further development of agricultural expertise.* *The proposed IoT-based irrigation management system is expected to contribute towards long term and sustainable high* *crop yield with minimum resource consumption and impact to the biodiversity around the case farmlands.*

World Development *2021,*	*65*	*Antonio Scognamillo a, , Nicholas J. Sitko b, (2021)* *Leveraging social protection to advance climate-smart agriculture: An empirical analysis of the impacts of Malawi's Social Action Fund (MASAF) on farmers' adoption decisions and welfare outcomes*	*This article assesses the interactions between participation in Malawi's largest public works programme, the Malawi Social Action Fund (MASAF), and three widely promoted climate smart agriculture (CSA) practices.*	*Survey* *Drawing on three waves of national panel household survey data, we find that participation in MASAF significantly increases the probability that farm households adopt the resource intensive CSA practices of building soil water conservation structures and applying organic fertilizers. Moreover, participation in MASAF contributes to a sustained adoption of these practices over multiple agricultural seasons.*	*We empirically demonstrate that the standalone impact of the CSA practices on maize productivity and the value of crops harvested under normal and dry conditions is, in most cases, not significantly different from zero. However,*	*CSA adoption (Integration with other interventions – example the social security)* *we find a reduction in sensitivity to low precipitation when MASAF participation occurs in the previous agricultural season. Moreover, the joint treatment effect of MASAF participation with sustained adoption of soil water conservation structures substantially increases households' productivity and welfare. This synergistic benefit is likely driven by the transfer of skills learned during MASAF public works to farmers' own fields. Results suggest that the CSA agenda can be enhanced by explicitly integrating existing social protection interventions with the promotion of CSA practices*

Environmental Science and Policy, *2018,*	*66*	*Marije Schaafsmaa,b,*, Henri Utilac, Mark A. Hirons (2018)* *Understanding trade-offs in upscaling and integrating climate-smart agriculture and sustainable river basin management in Malawi*	*This paper presents an assessment of the potential trade-offs between social, economic and environmental objectives when upscaling and integrating climate-smart agriculture (CSA) with integrated catchment management (ICM) at landscape level, with a case study in Malawi.*	*Scenario Planning* *In a workshop, government and NGO representatives and experts assessed trade-offs between the goals of ICM and CSA under four different scenarios of climatic and economic changes. The paper presents a novel combination of scenarios and a trade-off matrix exercise to critically evaluate trade-offs between CSA and ICM and link these to policy challenges and interventions.*	*Reliable indicators of farm performance are needed in order to model these links, and to therefore be able to design interventions which meet the differing needs of specific user groups. However, the lack of standardization of performance indicators has led to a wide array of tools and ad-hoc indicators which limit our ability to compare across studies and to draw general conclusions on relationships and trade-offs whereby performance indicators are shaped by farm management and the wider social-environmental context.*	*CSA Adoption (Trade-offs when integrating or upscaling CSA, but doesn't have effect on reducing inequality)* *Our analysis shows that the compatibility of CSA and ICM policies depends on future climatic and economic developments, with a higher prevalence of perceived trade-offs in futures with low economic growth and high climate change. CSA was expected to have limited effect on reducing inequalities and investment in literacy and skills development are critical to ensure that marginalised groups benefit from CSA*