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Pooja VS
Ph.D. Scholar, Department of
Agricultural Extension, University
of Agricultural Sciences, GKVK
Campus – Bengaluru, Karnataka,
India

Amogh CN
Ph.D. Scholar, Department of
Agricultural Extension, University
of Agricultural Sciences, GKVK
Campus – Bengaluru, Karnataka,
India

Corresponding Author:
Pooja VS
Ph.D. Scholar, Department of
Agricultural Extension, University
of Agricultural Sciences, GKVK
Campus – Bengaluru, Karnataka,
India

Designing instructional aids for climate-smart agriculture and assessing impacts on farmers' adaptive capacity

Pooja VS and Amogh CN

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Abstract

The increased climatic unpredictability, enhanced extreme weather events and higher production hazards for farmers are making global agriculture more at danger from climate change. Over time a major paradigm of 'climate-smart agriculture' (CSA) has emerged with the aim of improving agricultural production, resilience and adaptive capacity while at the same time reducing greenhouse gas emissions. However, the effectiveness of CSA initiatives depends largely on the way knowledge and practices are communicated to farmers via appropriate teaching approaches. This research synthesises peer-reviewed literature and official institutional reports to analyse the design, implementation, and impact of instructional aids used to promote CSA practices. The project explores a range of teaching materials, including digital advisory platforms, radio and audio advisories, video-based extension, printed manuals and visual work aids, and interactive learning approaches like farmer field schools. Research demonstrates that teaching techniques that are based on adult learning principles, including experiential learning, peer interaction and context-specific problem solving considerably improve farmers' understanding and implementation of climate-resilient practices. Multi-channel communication approaches including digital, audio and visual media are especially beneficial in improving farmer engagement, behavioural change and knowledge retention. The research also emphasises the need of inclusive and regionally specific instructional design that addresses the socioeconomic hurdles that affect farmers' access to information, gender inequality and literacy gaps. The research emphasises the need for multiple approaches of measuring farmers' adaptive capacity using factors associated with knowledge, use of information, practice adoption, livelihood assets, institutional participation, and resilience outcomes to measure program impact. The research concludes that the integration of digital advisory systems, evidence-based assessment frameworks and participatory extension approaches can greatly improve the adaptive capacity of the farmers and contribute to long-term sustainability and climate resilience of agricultural systems.

Keywords: Agricultural extension, climate-smart agriculture, digital advisory systems, farmers' adaptive capacity, instructional aids, participatory learning

Introduction

Climate-smart agriculture (CSA) has become a popular approach for reorienting agri-food systems towards three interlinked goals: mitigation and/or removal of greenhouse gas (GHG) emissions where possible; enhancement of adaptation and resilience to climate variability and change; and sustainable increases in productivity and incomes (Lipper *et al.*, 2014) ^[47]. But its success has also brought constant criticism: CSA may be so adaptable that it is employed as a policy "umbrella" sometimes masking power dynamics, trade-offs and the distinction between more important change and minor "smart" solutions (Chandra *et al.*, 2018; Newell & Taylor, 2018) ^[16, 54]. This topic is crucial for instructional aid design since training materials impact which CSA approaches are embraced, who gets to define "smartness," and how farmers assess the pros, cons, and labour costs. The learning settings of farmers are not neutral classrooms. Adult farmers often learn under conditions of time pressure, seasonal labour peaks, vulnerability to financial risk and uneven access to advising services. These considerations underscore the importance of adult-learning concepts (Knowles, 1980) ^[40] and the design of education to reduce cognitive overload, increase relevance, and allow for practice and feedback (Sweller, 1988;

Mayer, 2009) [50, 62]. Studies and evaluations of extension effect demonstrate that “information” alone seldom impacts outcomes unless it is accompanied with locally practicable action measures, repeated across complementary channels and established in credible connections (Fabregas *et al.*, 2019; Cole & Fernando, 2021) [19, 27]. Moreover, women typically have a range of mobility, time, asset, and phone access limitations and are often excluded from male-dominated delivery channels. Instructional aids that do not take gendered constraints into account might inadvertently exacerbate inequalities (Kondylis *et al.*, 2016; Alkire *et al.*, 2013) [7, 42].

CSA definitions, scope, and contested framings

CSA is often defined by the Food and Agriculture Organization of the United Nations as an approach that “transforms and reorients” agricultural systems to support food security in the context of climate change, seeking synergies across productivity, adaptation and mitigation (FAO, 2013; Lipper *et al.*, 2014) [28, 47]. The Intergovernmental Panel on Climate Change does not prescribe CSA as a single plan, but synthesises substantial evidence that climate change is already affecting agriculture and that adaptation alternatives exist, but face restrictions that worsen with warming (IPCC, 2022) [35]. These syntheses suggest that CSA learning materials cannot be static “best-practice” sheets, but rather allow for ongoing decision-making as biophysical and socio-economic factors change. The scope of CSA is deliberately broad: it includes agronomic practices (e.g. soil and water conservation, integrated nutrient management, climate-resilient varieties), landscape approaches (e.g. agroforestry, restoration), and enabling services (e.g. climate information services, insurance, risk finance, advisory systems) (FAO, 2013; IPCC, 2022) [28, 35]. But breadth allows for interpretative liberty. In policy, CSA can function as a “boundary concept” that connects the agriculture and climate communities, but in practice this can diffuse accountability, mask trade-offs, and allow rhetorically “smart” interventions that do not address structural vulnerability (Chandra *et al.*, 2018; Newell & Taylor, 2018) [16, 54]. Reviews in Climate Policy and political economy assessments note that CSA narratives tend to favour technical packages and market-oriented framings, often sidelining agro ecology and farmer-led innovation systems (Chandra *et al.*, 2018; Newell & Taylor, 2018) [16, 54].

Definitional clarity for instructional materials: By explicitly stating which CSA dimension(s) a learning module addresses, a programme might avoid misunderstanding and abuse. For example, a module on alternating wetting and drying or system of rice intensification may concentrate on adaptability to water shortages and mitigation co-benefits while a module on drought resistant cultivars may focus on risk management and yield stability. Manuals should specify: predicted benefits, important enabling circumstances, potential trade-offs and monitoring indicators (Thornton *et al.*, 2018; FAO, 2013) [28, 63].

Context-specific “climate-smartness: The peer-reviewed study emphasises that what is climate-smart varies on the agro ecological zone, family assets, labour availability and market/institutional contexts; so training should not consider CSA as universal (Autio *et al.*, 2021; Kpadonou *et al.*, 2017) [9, 44]. The availability of CSA prioritisation frameworks and portfolio techniques shows that the selection is a multi-criteria decision issue (Andrieu *et al.*, 2017; Thornton *et al.*, 2018) [8, 63]. Instructional aids should thus be modular and enable farmers and extension workers to adapt sequences.

Systems orientation and learning goals: Instructional aids should go beyond “do X” and incorporate learning goals that

include diagnostic skills, risk reasoning, resource budgeting (labour, cash), iterative adaptation if CSA is to be more than input adoption checklists (FAO, 2013; IPCC, 2022) [28, 35]. The most important conceptual conclusion is that the “core competency” is not one practice but the capacity to learn and adapt.

Policy embeddedness: Climate governance and agricultural policy pathways affect CSA. These include agriculture work streams under UNFCCC and alliances such as Global Alliance for Climate-Smart Agriculture (UNFCCC, 2017–2022; FAO, 2014/2015) [64]. Training material that does not pay attention to policy instruments (subsidies, extension requirements, climate services supply) may overlook institutional restrictions that shape farmer choices.

Designing instructional aids for adult farmers learning CSA

Instructional aids are not only “formats” (leaflets, videos, apps); they represent beliefs about how people learn, whose information matters, and what behaviour change routes are possible. Effective CSA training for adult farmers needs the integration of adult learning theory, cognitive science, and agricultural innovation diffusion evidence.

Adult learning foundations

Andragogy emphasises that adults are self-directed, have experience, and want to learn that is immediately useful in solving their issues ([40] Knowles, 1980) [40]. Experiential learning cycles (experience reflection conceptualisation experimentation) are especially suited to agronomic decision-making, since farmers learn in the field and by seasonal feedback (Kolb, 1984) [41]. Farmer field schools put this reasoning into practice by means of group experimentation and debate based on observation, with facilitators acting as guides rather than lecturers (Davis *et al.*, 2012; FAO, 2001/FFS guideline) [23]. This is important for CSA since climate risk management is experiential and iterative by nature; instructional tools should promote practice, reflection and adaptation rather than one-time exposure. There is evidence of social learning in agriculture, where farmers learn from the outcomes of their peers and trusted network linkages, with dissemination depending on observability, trustworthiness and possibilities for engagement (Foster & Rosenzweig, 1995; Conley & Udry, 2010; [11, 20, 31] Bandiera & Rasul, 2006) [11, 20, 31]. This promotes instructional designs that include “seen” outcomes: demonstration plots, farmer testimonials (video/audio), peer comparison tools, and community level discussion. Behavioural intention theories (e.g. Theory of Planned Behaviour) include attitudes, perceived norms and perceived behavioural control as determinants of intention however intention is not always translated into action when there are restrictions (Ajzen, 1991) [4]. Therefore, CSA teaching aids should not be framed just in motivating terms but incorporate constraint navigation: “What if labour is not available? What if input credit does not work? “What if confidence in the forecast is low?”

Cognitive science and message design

The fundamental design risk in low-resource extension contexts is not that messages are overly “technical,” but that they overwhelm attention and working memory, or lack connections to meaningful activities. Sweller (1988) [62] differentiates between intrinsic load (difficulty of the content), extraneous load (unnecessary difficulty due to bad design), and germane burden (effort leading to schema construction). High intrinsic load is

associated with CSA subjects such as soil organic matter, integrated pest management, and interpretation of climatic forecasts. Instructional aids should therefore: sequence material, reduce distractions and externalise complicated linkages using images or structured tales. According to principles of multimedia learning, appropriate pairings of words and visuals may promote knowledge, yet clutter and duplication can impair learning (Mayer, 2009) [50]. Design implications for farmers Short portions Close alignment of narrative with images Highlighting essential processes Progressive disclosure (first “why,” then “how,” then troubleshooting)

Instructional design process tailored to CSA

An evidence-aligned process can be expressed as a cycle with explicit checkpoints.

Needs assessment and performance analysis: Start by describing the performance issue, for example late fertiliser application, maladaptive drought reaction (e.g., distress sale of assets), or poor uptake of water harvesting. A needs assessment should map: farmer decision points, restrictions, current knowledge, and trusted information sources (Aker, 2011; Steinke *et al.*, 2020) [5, 61].

Learning objectives that connect to adaptive capacity: CSA training should specify objectives in terms of practice adoption as well as in terms of adaptive capacity: increased climate risk diagnosis, increased access to and use of climate information services, diversification of livelihood strategies or enhanced collective action by groups/cooperatives (Smit & Wandel, 2006; Engle, 2011) [25, 60].

Design for transfer and maintenance: Many extension projects produce short-term knowledge improvements, but have difficulty with sustainable practice change. Evidence from digital advisory services indicates that reinforcement (repeat exposure), interaction (two-way channels) and credible local mediation improve intermediate outcomes; impacts on yields may depend on complementary inputs and local feasibility (Fabregas *et al.*, 2019; Cole & Fernando, 2021; Singh *et al.*, 2023) [19, 27, 59].

Co-design and participatory testing: Participatory design literature in ICT for agriculture highlights that user-centredness and issue orientation diminish the usual failure pattern of “pushing technologies” away from farmer demands (Steinke *et al.*, 2020; Ortiz-Crespo *et al.*, 2021) [56, 61]. Print materials have benefited from intense participatory editing with women farmers, yielding teachings that better circumvent literacy obstacles and correspond with local meaning (Devkota *et al.*, 2020) [24]. Co-design is also a protection for cultural-appropriateness and gender-sensitivity.

Delivery planning as an instructional variable: A film may be used as a “broadcast object” or as a facilitation tool with pauses, discussion prompts and field practice activities. From the empirical literature on video/podcast extension, perceived credibility, legitimacy, accessibility and relevance are factors influencing engagement, and they are determined as much by the delivery setting as the content (Chivers *et al.*, 2021/2023) [17].

Instructional aid typologies and design specifications

Instructional aids for CSA can be grouped into a functional typology: (i) explanatory aids (build understanding), (ii) procedural aids (enable steps), (iii) diagnostic aids (support

judgement), (iv) motivational/social proof aids (shift norms and confidence), and (v) feedback aids (monitoring and learning loops). This section analyzes main assistance categories and design criteria, with focus to evidence on efficacy and equity.

Print and pictorial materials

Printed material is still popular since it is cheap, portable and doesn’t need electricity or connection. The main restriction is the literacy and the possibility of misunderstanding when diagrams are not relevant locally. A significant counter-example is collaborative production of picture-based extension classes with smallholder women farmers, where iterative testing and editing increased understanding and intention pathways defined by behavioural theory (Devkota *et al.*, 2020) [24]. For CSA, print is especially useful for seasonal calendars, step-by-step guidelines to composting, seed storage and simplified decision trees for insect scouting. Design specs: - Use visual step sequences (no text), with “what to do” + “common mistakes” - Whenever possible, provide local measuring signals (e.g., “handful,” “bottlecap,” “rope length”) rather than abstract units. Use with guided sessions or community conversations to eliminate uncertainty.

Audio and radio

Audio forms include community radio programs, interactive radio and interactive voice response (IVR) hotlines. They have a comparative benefit of removing literacy obstacles and allowing repetition. Large-scale tests with voice-based services have shown strong demand and confidence, and may change sources of information and adoption of suggested behaviors (Cole & Fernando, 2021) [19]. Radio based extension is context sensitive and success depends on the credibility of the show, relevance of the time of the material and the capacity to relate messages to local support. Design specs: - Break down messaging into small “micro-lessons” that refer to seasonal decision points. - Use regionally familiar voices (women and men), and include call-in queries when feasible. - Offer suggestions for action (“this week, check X”) and enable peer discussion.

Video and audio-visual aids

Video extension has two main models: broadcast (mass distribution) and moderated group learning (screenings guided by extension workers or community mediators). An example of the mediated paradigm is participatory video initiatives that combine local content development with organized distribution (Gandhi *et al.*, 2009) [32]. Multiple contexts provide rigorous evidence that video/audiovisual approaches typically improve intermediate outcomes such as knowledge and adoption; impacts on yield and income are more variable and contingent on complementary constraints (Van Campenhout *et al.*, 2021; Singh *et al.*, 2023; Abate *et al.*, 2023) [1, 59, 67]. Importantly, data also indicates gender-differentiated effects: video-based supplements targeting women may enhance retention and adoption, but may not necessarily lead to productivity improvements, especially when implementation hurdles (inputs, control over resources) remain (Baul *et al.*, 2024) [12]. Design specs: - Keep films brief (typically <10 minutes), concentrate on 1–3 essential techniques. - Select local farmers as protagonists to help with credibility and social proof. - Include “pause points” with facilitator prompts: “What would stop you from doing this?” “How could the group fix it?” - Demonstrate the process (hands, tools, sequencing) not just the product.

Mobile messaging, apps, and digital advisory systems

The digital advisory comprises SMS/USSD, IVR/push calls,

smartphone applications and integrated platforms that combine local data with personalized advice. The meta-level syntheses suggest that digital guidance is more likely to be beneficial when incorporated in institutions and decision routines rather than as “technology alone” (Fabregas *et al.*, 2019) ^[27]. High quality experiments reveal mixed results: tailored smartphone advice on nutrient management enhanced yields/profits in certain situations (Arouna *et al.*, 2021), but adding other channels (IVR/SMS) beyond video did not necessarily provide incremental benefits (Van Campenhout *et al.*, 2021) ^[67]. Digital extension may have a large impact on the uptake of adaptation technologies, via processes such as enhanced access to information and, in certain cases, links to loans (Mao, 2024) ^[48]. Design specs: - Design for minimal friction interaction (limited number of menu levels, local language, brief instructions). - Build trust by being transparent about who is giving the advice, how the suggestions are derived, and the uncertainties involved. - Add feedback loops (questions, ratings) while being aware of selection bias (Steinke *et al.*, 2020) ^[61]. - Facilitate access for people with limited literacy: audio, iconography, mediated access points.

Participatory tools and group-based decision aids

Tools like participatory rural appraisal (PRA), participatory

learning and action (PLA), scenario planning and citizen-science/on-farm experimentation are important because CSA necessitates local adaptation, not just compliance. Participatory learning may boost confidence and problem-solving orientation, including gender involvement when responsive, in mixed-method CSA adoption work in dryland situations (Jellason *et al.*, 2021) ^[36]. Digital-supported citizen science techniques, such as triadic comparisons in crop variety selection, demonstrate how participatory experimentation may be scaled without loss of farmer agency and context sensitivity (van Etten *et al.*, 2019). Design parameters: - Use structured facilitation guides translating scientific concepts into locally tested questions. - Use “reflection instruments” (basic logs, picture diaries, group grading) to document learning and adaptation. - Design for disputed knowledge: let farmers evaluate conventional approaches and new possibilities without shame.

Comparative table of instructional aid types

The table below compares instructional assistance kinds by design, inclusion, and assessment aspects. Selection is supported by peer-reviewed research on video/digital extension and participatory print development, extension design guidelines, and CSA policy sources (Gandhi *et al.*, 2009; Devkota *et al.*, 2020; Steinke *et al.*, 2020; FAO, 2013) ^[24, 28, 32, 61].

Table 1: Effective tools for climate-smart agricultural learning

Instructional aid type	Core strengths	Key risks/limitations	Inclusion & gender considerations	Best-fit CSA learning goals	Evaluation considerations
Print (text + diagrams)	Low cost, portable, repeatable	Literacy barriers; misinterpretation	Pictorial co-design can bypass literacy barriers (Devkota <i>et al.</i> , 2020)	Stepwise procedures; reminders; seasonal calendars	Measure comprehension, correct procedure, and retention
Pictorial job aids (minimal text)	Supports low literacy; rapid reference	Requires careful cultural testing	Often strong for women and marginalised groups when co-edited	“How-to” sequencing; hazard warnings	Observe practice quality; compare error rates
Audio/radio	Scales widely; bypasses literacy	Low interactivity; timing mismatch	Can reach women if access to radio/phone is ensured	Timely advisories; motivation; climate alerts	Track recall, listenership, behavioural response
IVR / push calls	Two-way potential; repeat listening	Menu complexity; phone access inequity	Gender gaps in phone ownership can exclude women	Diagnostics + Q&A; tailored advice	Log data enables usage analytics; evaluate selection bias
Video (mediated group screening)	Makes tacit practices visible; high credibility via local actors	Requires equipment/facilitation; may privilege accessible groups	Women-only screenings can help, but resource constraints remain	Complex practices; peer discussion; confidence building	Knowledge/adoption indices; facilitator quality; cost per adoption
Video (self-viewed)	On-demand access	Data/phone constraints; lower discussion	Often skews to younger/wealthier users	Refreshers; troubleshooting	App analytics + periodic survey validation
Smartphone apps (personalised)	Can tailor recommendations	Digital literacy; app maintenance; trust	Needs proactive inclusion or mediated access	Nutrient/planting decisions; climate services integration	RCT/quasi; quality of personalisation; uptake persistence
Participatory tools (FFS/PLA/PRA/citizen science)	Builds agency and systems reasoning	Higher facilitation cost; variable fidelity	Can be gender-transformative with design safeguards	Adaptive management; experimentation skills; collective action	Mixed methods + process evaluation; measure empowerment/agency

Inclusive localisation: culture, language, and gender equity

CSA educational aids are not failing because “farmers resist change,” but because they assume a generic farmer with time, liberty, and resources. Equity-oriented design demands intentional consideration to culture, language, gender norms and power within homes and communities.

Cultural appropriateness and localisation

Localisation is not translation. It involves localizing metaphors,

images, measuring systems and examples to local ecologies and livelihoods. In Indonesia, climate field schools demonstrate the value of incorporating climate prediction principles into culturally relevant learning modules and activities to help farmers use probabilistic information to make agricultural choices (Siregar & Crane, 2011) ^[58]. These schemes are about farmers as translators, not passive beneficiaries. Decision point mapping is a fundamental element of localization. Rather than teach a technique as a stand-alone module, link education to the

specific choices farmers are making: the beginning of land preparation, the procurement of seed, the onset of rains, the emergence of pests. The result is seasonal sequential “decision companions” for instructional aids that reinforce the passage from knowledge to practice.

Gender-sensitive and gender-transformative design

When extension networks are controlled by males, evidence shows the existence of gender bias in dispersion and access to services. In a randomized trial in Mozambique, the addition of trained female messengers decreased gender bias in knowledge and implementation of sustainable land management methods among women farmers (Kondylis *et al.*, 2016) ^[42]. This means that instructional aids alone cannot “fix” gender inequalities if delivery channels exclude women; design needs to include who delivers and how sessions are designed. Studies on advisory systems also reflect gendered access to information: women may access fewer sources, and face institutional barriers. This implies that inclusive CSA learning should have diversified channels, women-friendly scheduling, and be aware of intra-household dynamics. Another lesson learnt from the design is that “women-only” targeting is not enough when women do not have the resource control to execute practices. Couple-based or household choice modules, negotiation prompts, and ties to input/finance access are therefore increasingly included in instructional assistance suites. Practical spec: Gender-sensitive design check: Representation: women are shown as skilled practitioners and decision makers visually and narratively. - Scheduling: Modules accommodate women’s schedule restrictions; childcare friendly environments. - Access: phone sharing rules, alternatives such as IVR, and group hubs are envisaged. - Agency outcomes: Measure not only knowledge/adoption but participation/empowerment in decisions (Alkire *et al.*, 2013) ^[7].

Language, literacy, and accessibility

Low literacy is not a deficiency that can be “fixed” by throwing more text on them. Pictorial, audio and aided video approaches may, by design, circumvent literacy limitations, but only if visuals are evaluated. Participatory editing with women farmers in Nepal indicated that co-developed graphical lessons may improve the understanding and behavioral intention pathways (Devkota *et al.*, 2020) ^[24]. Likewise, video-mediated techniques are more credible when they include local farmers and local language narrative, which contributes to legitimacy and accessibility (Gandhi *et al.*, 2009; Chivers *et al.*, 2021;2023) ^[17, 32].

Training delivery architectures in pluralistic advisory systems

Instructional aids do not operate in a vacuum; their effect depends on delivery architectures how training is organised, who facilitates, which institutions sustain it, and how learning is reinforced.

Farmer field schools and experiential group learning

FFS methods are centered on group problem solving and on experience learning. Evidence from East Africa indicates that FFS may boost productivity and income, with some studies finding significant impacts on women and low-literacy participants in certain circumstances (Davis *et al.*, 2012) ^[23]. However, data from systematic reviews suggests diverse effects and emphasizes design and execution aspects – such as quality of facilitator, group dynamics and programme length – that

condition success (Waddington *et al.*, 2014) ^[69]. FFS are especially pertinent for CSA for complicated operations that need monitoring and iterative modification (integrated pest control, soil moisture management, composting and agroforestry development). One important lesson from the instructional design is that the scaffolds for FFS should be graphical field notebooks, basic measuring tools, seasonal decision calendars, and short movies to be utilized as triggers for discussion rather than substitutes.

Public and private extension in pluralistic systems

Many nations have pluralistic advice systems, which include state extension, NGOs, commercial input dealers and farmer associations. This presents potential (many channels) and hazards (inconsistent messaging, conflicts of interest). Digital and video extension models are commonly promoted as a solution to the shortage of extension workers, but evidence-based research suggest that digital technologies enhance rather than replace face-to-face services (Fabregas *et al.*, 2019; Singh *et al.*, 2023) ^[27, 59]. Even when the contact farmers themselves embrace innovations, decentralized “contact farmer” models may suffer from limited dissemination (Kondylis *et al.*, 2017) ^[43]. It indicates that delivery architectures should not presume cascading effects. Instead, methods of instructional assistance should: - conceptualize peer diffusion as an intervention component that requires incentives, facilitation, and observability (BenYishay & Mobarak, 2019) ^[13] - develop accountability systems to sustain quality - include gender-sensitive staffing and outreach.

E-learning and blended models

E-learning platforms for agricultural training have expanded over the last decade, with open course offering by international organizations and hybrid “blended” techniques for extension staff development (FAO eLearning Academy). Fully online delivery is frequently limited for farmers due to connection and device availability, however mixed models (community sessions + mobile reinforcement) are increasingly being used in digital advisory programs, especially when timely seasonal climate warnings are required. The design implication is to sequence information across channels, e.g. in-person demonstration of a water-harvesting activity followed by weekly IVR reminders and a visual troubleshooting page.

Impact assessment: adaptive capacity frameworks, indicators, instruments, and methods

The user request emphasises “impact assessment on farmers’ adaptive capacities.” This section clarifies what adaptive capacity is, how it is operationalised, and how instructional-aid impacts can be credibly measured without over-claiming.

Conceptualising adaptive capacity for CSA evaluation

The broad definition of adaptive capacity is the ability of people, families or systems to react to climatic unpredictability and change, to minimize possible harms and to deal with consequences (Smit & Wandel, 2006) ^[60]. Reviewers stress that adaptive ability is multi-dimensional and closely related to institutions, governance and knowledge systems (Engle, 2011) ^[25]. Vulnerability scholarship also defines vulnerability as susceptibility to damage that is a function of exposure, sensitivity and lack of capacity to adjust (Adger 2006) ^[2]. Scale remains a methodological challenge: indicators that work at the national level may not represent household-level reality, and vice versa (Vincent, 2007) ^[68].

Indicator domains aligned to CSA instructional interventions: Many projects use the capitals/assets framework from livelihoods approaches: human, social, environmental, physical and financial capital (DFID Sustainable Livelihoods Guidance). Instructional aids mainly focus on human capital (knowledge, skills) and social capital (learning networks) but their influence on adaptive capacity is contingent upon linkages to other capitals and institutions. A strong collection of indicators therefore includes six domains:

1. **Knowledge and skills (human capital):** CSA knowledge assessments, climate prediction interpretation, decision skills, self-efficacy to apply activities (Engle, 2011; Smit & Wandel, 2006) [25, 60].
2. **Access and usage of information:** Utilization of climate information services, advisory contacts, confidence in sources, time-to-action following advisories (Siregar & Crane, 2011; Aker, 2011) [58, 5].
3. **Quality and intensity in practice:** Not just “adopted/not adopted” but also right, consistency and adaption to local circumstances (Kondylis *et al.*, 2017) [43].
4. **Assets and buffers for livelihood:** Productive assets, savings, access to credit/insurance Income and crop diversification Proxies for soil health when possible (DFID; Kpadonou *et al.*, 2017) [44].
5. **Agency and institutions:** Group membership, access to extension services, women’s empowerment/agency indicators (WEAI/A-WEAI) Alkire *et al.*, 2013; Kondylis *et al.*, 2016) [7, 42].
6. **Outcomes on resilience:** Variability in yields Shock reaction and recovery time Scales of food security Subjective measures of resilience (Hahn *et al.*, 2009; FAO RIMA-II) [29, 33].

Measurement instruments and validated scales useful in CSA impact assessment

Because adaptive capacity is latent, measurement benefits from combining validated scales with context-specific modules. Food security outcome measures (frequently used as proxies for resilience): - Guidance on the Household Food Insecurity Access Scale (HFIAS) (Coates *et al.*, 2007) [18] - Technical paper on the Food Insecurity Experience Scale (Ballard *et al.*, 2013) [10] - Household Dietary Diversity Score (HDDS) criteria (Kennedy *et al.*, 2011). - Food Consumption Score (FCS) guideline (WFP) [70].

Resilience and vulnerability indices: Livelihood Vulnerability Index (LVI) (Hahn *et al.*, 2009) [33] - Resilience Index Measurement and Analysis II (RIMA-II), estimating resilience capability and drivers using latent variable modeling (FAO, 2016) [29]. - Local Adaptive Capacity (LAC) conceptualization (Jones *et al.*, 2010) [37] commonly operationalised via institutions, knowledge, innovation, governance and assets.

- **Gender and agency measurement:** Women’s Empowerment in Agriculture Index (WEAI) (Alkire *et al.*, 2013) [7]. - WEAI reduced (Malapit *et al.*, 2017) [49].
- **Learning outcomes and adoption:-** Standardized knowledge indicators (e.g., recall exams, comprehension checks). - Checklists to observe quality (particularly necessary for complicated CSA operations like SRI or composting).

Impact assessment methods suitable for CSA instructional aid evaluation

Different methods answer different questions. For CSA instructional aids, the evaluation design should be chosen based on (i) feasibility, (ii) ethical constraints, (iii) expected effect pathways, and (iv) scale.

RCTs are still the gold standard for causal estimation when practicable. There are few research in agricultural extension that show how RCTs may assess delivery routes and mediated learning (Kondylis *et al.*, 2016; Kondylis *et al.*, 2017; Arouna *et al.*, 2021; Singh *et al.*, 2023) [42, 43, 59]. However, RCTs alone generally under-explain processes and equitable impacts; they should be supplemented with process assessment and qualitative investigation.

If randomisation is not possible, quasi-experimental procedures are essential: difference-in-differences with panel data, propensity score matching, instrumental variables, regression discontinuity, and synthetic controls. Evidence of FFS influence has used quasi-experimental approaches in longitudinal contexts (Davis *et al.*, 2012) [23]. Participatory monitoring and evaluation may capture change that is locally significant, and generate learning feedback loops (Estrella *et al.*, 2000) [26].

Table comparing evaluation methods for instructional aids and adaptive capacity

The table summarizes main assessment methodologies and what they may credibly claim, depending on methodological sources and extended evaluation exemplars (Davis *et al.*, 2012; Estrella *et al.*, 2000; Kondylis *et al.*, 2017) [23, 26, 43].

Table 2: Evaluation methods for programme effectiveness assessment

Evaluation approach	Best for	Key strengths	Main threats/limitations	Data requirements	Fit for adaptive capacity measurement
RCT / cluster RCT	Comparing aid types or delivery modes	Strong causal identification	Spillovers/contamination; external validity; ethical constraints	Baseline + follow-up; adequate clusters	High, if multi-domain indicators collected
Encouragement design	When access can’t be controlled	Estimates effect of encouragement	Weak compliance; interpretation requires care	Uptake tracking; IV variables	Moderate to high
Difference-in-differences	Programme rollouts with comparison group	Controls time-invariant confounding	Parallel trends assumption	Panel or repeated cross-sections	High for outcomes like assets/food security
Matching (PSM)	Non-random participation	Improves comparability	Unobserved confounding remains	Rich covariates	Moderate
Regression discontinuity	Threshold-based targeting	Strong local causal inference	Limited generalisability	Precise running variable	Moderate
Mixed methods (quant + qual)	Understanding heterogeneity and mechanisms	Explains “why/for whom”	Integration complexity	Surveys + interviews/FGDs	High, especially for institutions/agency
Process evaluation	Fidelity, reach, dose, acceptability	Identifies implementation drivers	Not causal on outcomes alone	Monitoring logs + qualitative	Essential complement
Participatory	Local relevance,	Improves learning and	Risks of bias; comparability	Facilitated reflection	High for agency/collective

M&E (PM&E)	empowerment outcomes	accountability		tools	action
Cost-effectiveness analysis	Comparing value for money	Supports scaling decisions	Needs reliable effects + costs	Full cost data + impact estimates	High relevance for policy

Evidence on CSA instructional aids spans diverse contexts; four illustrative patterns emerge: Climate information learning through field schools: Siregar and Crane (2011) ^[58] showed that climate field schools in Indonesia may enable farmers to learn to evaluate forecasts and make adaptive choices for their crops in the face of monsoon unpredictability via experience learning.

The wider point is that climate services are not “plug-in”; they need interpretative training and synchronization with farmers’ decision calendars.

Video-mediated extension and mediated learning at scale

Models of participatory video and mediated instruction have demonstrated significant adoption benefits over classical extension in early trials, with later evidence from RCTs in different contexts indicating steady gains in knowledge and adoption, but with effects on yield differing (Gandhi *et al.*, 2009; Singh *et al.*, 2023; Abate *et al.*, 2023) ^[1, 32, 59]. There is also evidence that the cost per adoption may decrease with size since the expenses of content development and equipment amortise, but careful costing is necessary (Bernard, 2019; Abate *et al.*, 2023) ^[1, 14].

Digital advisory heterogeneity and the limits of more channels: Certain high-quality experiments suggest that tailored digital guidance may increase yields and revenues in certain circumstances (Arouna *et al.*, 2021).

Other research reveal modest marginal advantages from stacking more channels on successful video distribution (Van Campenhout *et al.*, 2021 ^[67]; The lesson for design is that ‘channel stacking’ should be theory-led: increase channels to address a particular constraint (timing, reinforcement, Q&A), not as a general digitalization technique.

Participatory learning and barriers in drylands: Mixed methods PLA work in the drylands of Nigeria suggests that participatory learning may boost confidence to address climate-related issues and help planning for CSA practices, but also points to challenges such as resource restrictions and institutional limitations (Jellason *et al.*, 2021) ^[36]. As adoption studies reveal, what is practicable in terms of the intensity of soil and water conservation also depends on family assets, labour and land endowment. Instructional aids thus must include “feasibility pathways” and not general prescriptions (Kpadonou *et al.*, 2017) ^[44].

Barriers, enablers, cost-effectiveness, and scalability

- Barriers consistently cited across CSA adoption and advisory systems include: resource constraints (labour, cash, land), weak enabling institutions, information credibility issues, gendered access barriers and mismatches between advice and local conditions (Autio *et al.*, 2021; Lamontagne-Godwin *et al.*, 2018) ^[9, 45]. So instructional aids need content quality, but that’s not enough. It’s systems design that makes the difference.
- Enablers include trusted intermediaries, participatory co-design, reinforcement via various aligned channels, and incentives/structures that encourage peer diffusion and accountability (Steinke *et al.*, 2020; Kondylis *et al.*, 2017; BenYishay & Mobarak, 2019) ^[13, 43, 61]. Gender-responsive personnel and delivery modalities may address access disparities (Kondylis *et al.*, 2016) ^[42].
- Cost-effectiveness research implies scaling may be associated with better unit costs for mediated digital/video models, although cost profiles vary by modality and result. Cost-effectiveness may not be linear with scale in gender-informed advisory settings. Early pilots should gather specific cost data and simulate scaling trajectories, rather than assume linearity (Mogues *et al.*, 2019) ^[52].
- Scalability is most useful as a package of conditions: Institutional ownership, content supply chains, quality assurance, sustainable finance, data governance and protections for inclusiveness. Digital Advisory evaluations also highlight institutional embeddedness as the key factor for sustained effect (Fabregas *et al.*, 201 Policy frameworks increasingly include measurement, adaptation and socio-economic factors in CSA governance activities within UNFCCC agricultural workstreams, thereby generating need for evidence-literate extension systems (UNFCCC, 2017–2022) ^[64].

Recommended implementation timeline

The schedule below offers a realistic 24-month path for building, implementing, assessing and preparing to scale CSA instructional aids assuming no national limitations and a diverse advisory environment.

Table 3: Phased implementation roadmap for CSA

Phase	Months	Core activities	Key outputs	Evidence & QA checkpoints
Diagnose & prioritise	0–3	Decision-point mapping; stakeholder analysis; gender & inclusion diagnosis; CSA practice prioritisation	Problem statements; target segments; draft theory of change	Baseline scoping; equity risk review
Co-design	3–6	Co-create prototypes (print/audio/video/mobile); localisation; participatory testing; facilitator guide drafting	Prototype aid suite; localisation glossary	Comprehension testing; usability testing
Pilot & iterate	6–10	Small pilots across contrasting agroecologies; monitor fidelity; refine messages and delivery	Version 1.0 aid suite; delivery SOPs	Process evaluation; learning assessment
Impact evaluation	10–18	RCT/quasi design implementation; mixed methods; cost tracking	Impact estimates; heterogeneity analysis	Pre-analysis plan; data quality audits
Scale preparation	18–24	Institutional embedding; training of trainers; content supply chain; M&E system integration	Scale strategy; financing plan; QA protocols	Equity monitoring plan; cost-effectiveness model

Policy and research implications

Policy makers and programme designers should see CSA

instructional aids as public-interest infrastructure: they mitigate information asymmetry, but the advantages rely on trustworthy

institutions, inclusion protections and measurement capability. Three practical implications arise.

1. Invest in design skills not just content. User-centred and participatory design techniques have been shown to increase relevance and routes to adoption, particularly for digital services (Steinke *et al.*, 2020; Ortiz-Crespo *et al.*, 2021) [56, 61].
2. Make gender equity quantifiable and enforced. employ gender-disaggregated reach and results, employ empowerment metrics (WEAI/A-WEAI), and create delivery channels that eliminate gender bias (Alkire *et al.*, 2013; Kondylis *et al.*, 2016) [7, 42].
3. Institutionalise M&E for learning. Combine causal effect assessment with PM&E to retain accountability and iteration capacity in scaling (Kondylis *et al.* 2017, Estrella *et al.* 2000) [26, 43].

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