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Role and approaches of agricultural extension in climate resilient agriculture

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Abstract

Climate change undeniably the biggest environmental risk whose impact is serious to combat hunger, malnutrition, disease and poverty worldwide. Climate-resilient crops are crucial for adapting to climate change, benefiting farmers by enhancing production, productivity, income, and mitigating threats of crop failure through improved soil health and temperature tolerance. The ICAR's 'National Innovations in Climate Resilient Agriculture' (NICRA) initiative strives to enhance climate resilience in the nation's vulnerable regions. Extension agents, through awareness and support, play a crucial role in helping farmers tackle diverse implications of global climate change. Small-scale producers embraced climate-resilient crops to combat abiotic stresses like drought, heat, flooding, and salinity. Analysis revealed that the primary drivers of adoption were the quality of extension services, education levels of household heads, access to inputs (especially seeds and fertilizers), and the socio-economic status of farming families. The significance of extension services in aiding smallholder farmers in overcoming agricultural challenges is paramount. Limited studies explore the development of capacities in agricultural extension agents to more effectively assist smallholders in managing climate risks. Climate change poses a critical threat to smallholder food production, necessitating increased attention. Consequently, agriculture must transition to a "climate-smart" approach, ensuring sustainable improvements in both productivity and incomes. This strategic shift is essential to alleviate the complex challenges posed by global climate change, safeguarding the livelihoods of smallholder farmers and contributing to a resilient and productive agricultural sector in the face of evolving environmental pressures. Fostering collaborative learning among farmers, researchers, and extension workers is crucial to adapt climate knowledge and disseminate Climate-Smart Agriculture practices. Conducting site-specific assessments ensures tailored technologies, promoting effective adaptation and resilience to climate challenges. Extension services play a pivotal role in assisting farmers to navigate the diverse impacts of global climate change. Through effective approaches, they raise awareness and educate farmers on various adaptation and mitigation strategies.

Keywords: Approaches, climate resilient, climate smart agriculture, extension services, mitigation

Introduction

Climate change poses a formidable challenge to addressing hunger, malnutrition, disease, and poverty on a global scale (Rupan *et al.*, 2018) [26]. Extreme weather events threaten food security and poverty reduction, particularly in rain-fed agriculture-dependent rural communities with small-scale producers, exacerbating vulnerability to climatic disruptions (Acevedo *et al.*, 2020) [1]. Climate change profoundly impacts agriculture, altering crop quantity and quality, adjusting doses of inputs like herbicides and fertilizers, and intensifying soil drainage issues. Erosion risks escalate, threatening agricultural stability. Climate-induced shifts in arable lands pose challenges to global food security. Organisms face new competitive landscapes, emphasizing the need for adaptive, sustainable agricultural strategies to mitigate climate change consequences (Dutta *et al.*, 2023) [10].

The adverse impact of climate change on agricultural income, estimated at 15-25%, underscores the pressing need for a robust embrace and rigorous implementation of the rationale behind climate-resilient agriculture (CRA). It is imperative to recognize and prioritize CRA as an essential strategy to safeguard and enhance the resilience of agricultural systems in the face of evolving climatic challenges (Srinivasarao, 2021) [31]. Over the period from 2016 to 2021, a barrage of natural disasters, including cyclones, flash floods, and landslides, inflicted extensive crop damage, affecting over 36 million hectares of land in India. This onslaught translated into substantial financial setbacks, with farmers grappling with losses totaling approximately $3.75 billion (Jena *et al.*, 2023) [14].

Anticipating a 3-16% global agricultural productivity shift by 2080, India establishes the National Adaptation Fund, demonstrating proactive commitment to support national and state-level initiatives (Dutta *et al.*, 2023) [10]. Despite recognition by GASCA and global initiatives, the widespread adoption of climate-smart technologies in agriculture remains a persistently challenging process, hindering progress in Climate-Smart Agriculture. Acknowledging climate change's impact, stakeholders,

governments, producers, and buyers must collaborate. This includes effective policies, technical and financial support for productivity, resilience, adaptation, and actively mitigating greenhouse gas emissions. (CSA) (Sala *et al.*, 2016) [27].

Extension providers play a pivotal role in advancing Climate-Smart Agriculture (CSA) by spearheading technology development, disseminating crucial information, enhancing farmers' capabilities, facilitating collaboration, and advocating for supportive policies (Rupan *et al*., 2018) [26]. In theory, farmers can embrace climate-resilient agricultural practices through a combination of external and internal factors, acknowledging the influence of both environmental and personal elements. External factors contribute to rejuvenating farmers' capabilities, empowering them to enhance adaptive skills (Jena *et al.*, 2023) [14]. This includes access to extension services like training (Tanti *et al*., 2023 & Zakaria *et al.*, 2020) [14, 36] and farm field schools (Osumba *et al*., 2021) [24]. Through demonstrations and training, farmers gain awareness and knowledge of Climate-Smart Agricultural (CSA) practices (Mgendi *et al*., 2022 & Makate *et al*., 2019) [20, 18].

Those accessing credit from public and private banks or cooperative societies are better positioned to adopt climate-resilient practices (Kangogo *et al*., 2021) [16]. As a result, agricultural extension encompasses a collective array of institutions aiding individuals in agriculture. It facilitates problem-solving, market connections, and access to knowledge, skills, and technologies for improved livelihoods (Davis, 2009 & Mukherjee *et al*., 2012) [7, 21]. India's government employs diverse strategies to address climate change, protect farmers from its impacts, and disseminate resilient technologies through public and private extension models for enhanced preparedness (Balasubraman & Dixit, 2016) [5]. Agricultural extension and rural advisory services, spanning public and private sectors, act as crucial conduits, providing information to farmers. The contemporary extensionist's role, evolving beyond production, integrates cross-sectoral functions, pivotal for Climate-Smart Agriculture (CSA) (Sala *et al*., 2016) [27]. Challenges in extending agricultural services include farmers resisting change and complicated land ownership rules hindering investment. To improve, organize workshops for agents on using technology and promote audio-visual tools (Antwi-Agyei *et al*., 2021) [3].

Climate Resilient Agriculture (CRA)

Climate Resilient Agriculture (CRA) is a farming approach that assists farmers in adjusting to and dealing with the challenges posed by a changing climate (Adams, 2023) [2]. It is a sustainable way of adjusting and transforming farming to ensure food security in the face of climate change. It involves making changes and adopting strategies to adapt and mitigate the impacts of a changing climate (Debangshi, 2021) [8]. This practice reduces hunger and poverty in the face of climate change for forthcoming generations. Climate resilient agriculture (CRA) helps decrease hunger and poverty amid climate change for future generations. These practices can improve the current situation, ensuring sustainable agricultural production from local to global levels (Srinivasarao, 2021) [31]. Intense rain or droughts, sudden hailstorms, and more frequent extreme weather are expected due to climate change. To help communities endure, we can promote climate-resilient agriculture for food security and income (Singh *et al.*, 2021) [25].

Climate change: A huge challenge

Climate change is a big, long-lasting shift in average weather conditions, like it getting warmer or wetter over many decades. It's the longer-term pattern that sets it apart from normal weather changes (Turrentine & Denchak, 2021) [34]. Climate change, periodic modification of Earth's climate which causes due to the result of shifts in the atmosphere and interactions with geological, chemical, biological, and geographical factors (Jackson, 2024) [13]. To tackle climate change, we can do things that boost the economy, make life better, and preserve the environment. By reducing greenhouse gas emission & switching to solar and wind energy reduces harmful emissions. Urgent action is needed to achieve net zero emissions by 2050, with substantial cuts by 2030 and a 6% annual fossil fuel reduction. We should help the most vulnerable people first to prepare for climate challenges, even though everyone will eventually need to adapt (Dutta *et al.*, 2023) [10].

The role of extension services in food production and climate change adaptation

Climate change will bring about severe weather events and unexpected disasters, along with new sources of diseases for humans and livestock. Many of these dangers will intersect and compound each other (Yiran and Stringer, 2017) [35]. Agricultural extension is like education, where agents share info, offer support, and fulfill farmers' needs (Maponya& Mpandeli, 2013) [19]. This includes sharing useful technologies for crops and livestock from research to smallholders (Gebrehiwot, 2015) [12]. Extension services raise awareness about climate change and help vulnerable individuals and communities build resilience. They use various methods like farmer-field schools, flyers, radio messages, and field demonstrations for education (Anyadike, 2009) [4]. Empowering small farmers in vulnerable areas to handle climate risks is crucial. Extension efforts should educate them on adaptation options for enhanced resilience (Parry, 2007) [25]. Extension plays a critical role in connecting farmers to transport, markets, and resources, especially linking with private and public institutions for disseminating adaptation technologies and funding programs (Ferris *et al.*, 2014; Mustapha *et al*.,2012) [11, 22].

Capacity building to combat climate change

Worldwide policymakers need to figure out how to tackle global warming and extreme weather while considering the well-being of people in different countries. With numerous adaptation strategies available, it's crucial to create effective training for frontline agricultural extension workers (Ogunbameru *et al.*, 2013) [23]. Generally, agricultural extension agents act as educators who provide farmers proper information, institutional support, and assistance to meet their needs.They transfer useful technologies to smallholders, mainly for crops and animals (Agyei, 2021) [3]. Adaptation of capacity building starts with raising awareness about the changing environment and also based on the prediction of current and anticipated weather- or

climate, rising temperatures, desertification, biodiversity loss etc(Dutta *et al.*, 2023) [10].

Extension Approaches used in CSA

Climate-Smart Agriculture (CSA) is a globally embraced solution, addressing climate change by ensuring sustainable food production. Countries adopt it rapidly due to its capacity to tackle climate challenges and aid farmers. This success story centers on adapting to climate issues, supporting farmers, and securing abundant food, creating a smart and effective farming approach that benefits both people and the planet.To solve big global problems, we need to create, adjust, and use new knowledge. Many different organizations must work together to help with this. Solving these new challenges means that support systems must do more than just share new technologythey need to achieve a variety of goals. Extension systems play a vital role in Climate-Smart Agriculture (CSA). The way they work, whether demand- or supply-led, one-on-one or mass communication, affects how farmers receive messages. Balancing reach and impact are crucial, as mass media suits simpler messages, while intensive interactions, like farmer field schools, are better for complex knowledge. The right approach mix influences the contribution to food security, income, adaptation, resilience, and climate change mitigation (Rupan *et al.*, 2018) [26].

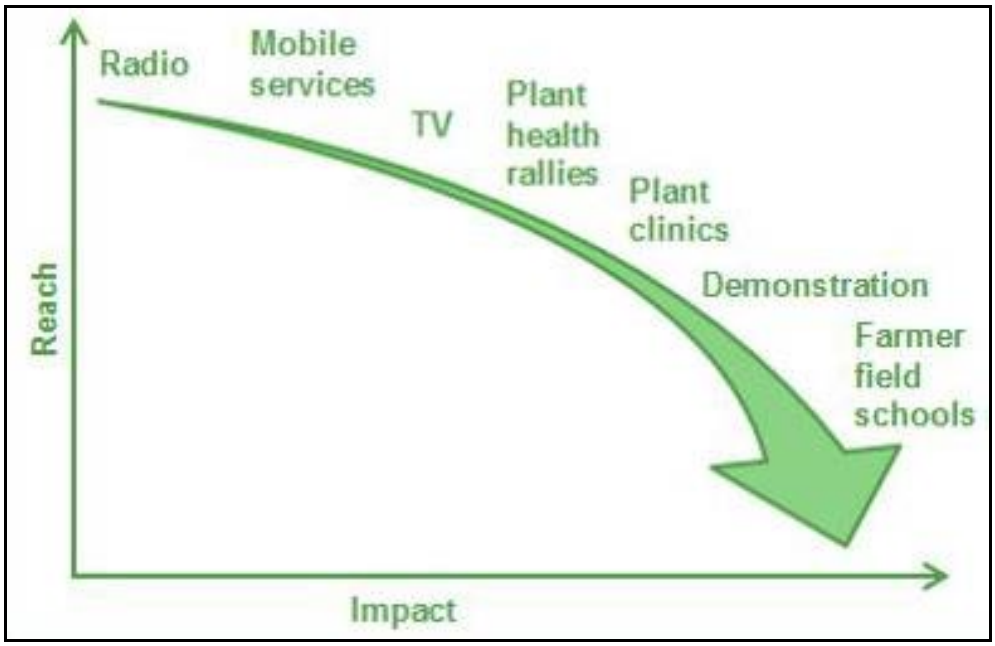

Fig 1: Impact of Extension Approaches (Sala *et al.*, 2016) [27]

Role of Rural Advisory Services

Climate change affects farming and food security. Rural Advisory Services (RAS) play a key role in helping farmers cope. They connect farmers with useful info and tools for climate-smart agriculture. RAS staff, always available to work with rural communities, understand farm life and can guide the adoption of smart farming practices. They bridge the gap between research and farmers, making sure new ideas reach the fields. During disasters, RAS assists communities, and their various approaches like demos, training, and media messages spread knowledge effectively (Jha &Singh, 2021) [30].

Tools to succeed in farmers with new knowledge

Training activities

Training intermediaries and extension personnel is crucial for updating them on global climate change and adaptation strategies. With the rise of climate-smart agriculture, focused training is essential. University education serves as the foundation, exemplified by Science Field Shops (Stigter and Winarto, 2013) [32]. Trained intermediaries, especially from Climate Field Schools, educate farmers and collaborate to establish climate services (Sala *et al.*, 2016) [27].

Plant clinics

It serves as the frontline in national extension systems, allowing direct communication between extension workers and farmers on crop issues. These clinics enable face-to-face exchanges, addressing diverse crop problems stemming from non-living factors (e.g., nutrient deficiency) or living factors (e.g., pests). Plant doctors, often trained extension workers, must understand local conditions and language, staying employed within their organizations (Boa *et al.*, 2015) [6].

The Farmer Field School (FFS)

It is a practical, non-formal learning approach where farmers experiment with new practical skills & knowledge in a low-risk setting (Settle *et al.*, 2014) [29]. It addresses global climate change, promoting improved practices like varied crops and agroforestry. In Indonesia, Climate Field Schools teach farmers to adapt to changing rainfall patterns through on-farm measurements and water harvesting (Jha &Singh, 2021) [15].

Plant Health Rally Approach

A plant health rally is a quick way to make farmers aware of risks to crops, promote better farming practices, and get their feedback. It can be spontaneous or planned, attracting

people with banners and announcements. These rallies also help in addressing global climate change, for instance, by implementing new technologies like urea deep placement to reduce greenhouse gas emissions from rice production (Jha &Singh., 2021) [15].

ICT Supported Network

Information and Communication Technologies (ICTs) are pivotal in global climate change efforts, serving as vital tools for data exchange and communication. Disparities persist in ICT supply and adoption across regions, countries, and urban-rural divides. Mobile phones, videos, and radios bridge these gaps, aiding awareness among farmers about diverse adaptation and mitigation strategies to tackle climate change challenges (Jha & Singh, 2021) [15].

Innovative extension models to boost resilient climate in Agriculture

Village Knowledge Centre

The Village Knowledge Centers (VKCs) are integral to the ClimaAdapt project, initiated by M.S. Swaminathan Research Foundation (MSSRF), with backing from NIBIO and the Norwegian Embassy. These centers employ tailored Information and Communication Technologies (ICTs) to disseminate climate-smart agro advisories and technologies to rural communities. Covering 29 villages and reaching 77,500 farmers, VKCs address gender-specific needs and offer diverse services, including weather forecasts, agricultural techniques, health, education, and government entitlements (Balasubraman & Dixit, 2016) [5]. Utilizing various communication tools like webinars and partnerships with district-level entities, VKCs empower local Knowledge Workers to manage centers, fostering community participation and sustainable knowledge transfer for informed decision-making and economic benefits (Dutta *et al*., 2023) [10].

Extension model adopted under NICRA

The NICRA extension model focuses on enhancing agricultural resilience to climate change. Objectives include developing advanced production and risk management technologies, showcasing tailored technological solutions for climate challenges on farmers' land, and elevating researchers' expertise in climate-resilient agriculture. The program's potential continuation in the XII plan involves strategic analysis for mitigation and adaptation, widespread technology dissemination in 100 vulnerable districts to address current climate variability, competitive sponsored research to address key gaps, and capacity building initiatives. This comprehensive approach aims to empower farmers, researchers, and stakeholders, fostering sustainable practices and addressing the pressing challenges posed by climate change in agriculture (Dutta *et al*., 2023) [10].

HARITA-PRIYA: A Wireless Sensor Networks (WSN) based Disease Forewarning and Crop Advisory Model

The HARITA-PRIYA initiative, a Precision Agriculture pilot study by the Centre for Development of Advanced Computing (C-DAC) and the Government of Andhra Pradesh, marks a transformative agenda in agriculture. It employs Wireless Sensor Networks (WSN) to gather real-time micro-climate information from farmers' fields. In 2015, 74 WSN nodes were deployed across five villages in Anantapur District, covering approximately 450 acres of groundnut crop. These nodes collect crop canopy-level micro-climate data, transferred to a remote server for analysis using crop-centric Decision Support Models. The system generates alerts for pest/disease forewarning or irrigation scheduling. Agriculture officers then send personalized advisories to farmers in Telugu via SMS. During the Kharif season, the system issued 41 forewarning alerts, allowing timely advisories for groundnut leaf spot disease outbreaks (Balasubraman & Dixit, 2016) [5]. HARITA-PRIYA increased advisories to individual farmers, with an average of 18 per farmer, enhancing reachability and adoption. Personalized SMS advisories in Telugu proved more effective than traditional methods, reducing fungicide/pesticide use and cutting input costs. This innovative model exemplifies the potential of Precision Agriculture to revolutionize farming practices, improve resource efficiency, and empower farmers with timely, personalized information for better decision-making (Kathiresan, C. 2016).

e-Arik (e-Agriculture)

Using ICTs to Facilitate "ClimateSmart Agriculture" among Tribal Farmers of North East India. The e-Arik project, aimed at promoting Climate-Smart Agriculture among tribal farmers in North East India, established a Village Knowledge Centre in Yagrung village, Pasighat, Arunachal Pradesh. Equipped with a computer, internet, printer, scanner, phone, and TV, this center facilitated innovative extension models. Project staff conducted field visits, digitally documenting crop conditions, pest issues, and nutrient deficiencies using ICTs. The information was communicated to the eArik Research Laboratory at the Central Agricultural University, where experts analyzed the problems and provided recommendations to the Village Knowledge Centre, eventually reaching farmers through various channels. The project also employed farmer-to-farmer communication and local self-help groups for information dissemination. Additionally, a dedicated portal (www.earik.in) offered agricultural information, government schemes, and market forecasts. Covering 12 villages and 500 farmers, the project reported significant impacts, with 44% and 92% of farmers implementing climate-smart practices on rice and mandarin crops, respectively (Drishti, 2011) [9]. Notably, 55% of farmers transitioned from slash-and-burn to settled cultivation, with increased production reported for rice and khasi mandarin crops. The eArik approach demonstrated cost-effectiveness, being 3.6 times cheaper than conventional agricultural extension systems, enabling faster access to information and services. Success factors included local intermediaries, diverse ICT tools, and multi-stakeholder partnerships. Challenges included technological issues, skepticism, and the demand for holistic development assistance from farmers (Adopted from Saravanan, 2011).

Conclusion

Climate-smart agriculture tackles India's food challenge amid climate change. Village Climate Clubs promote knowledge exchange; incentives drive resource conservation, securing Village Knowledge Centers' survival.

Key in CSA, extension services vary based on message complexity, target population, tech, data, and funds. On-ground action aligns with advocacy for climate-aware agriculture. Effective grassroot extension training is crucial for CSA adoption in India. Extension staff must grasp CSA technologies, staying updated on evolving practices. Government subsidies are vital, but addressing adverse selection and moral hazard is tricky. Targeting subsidies to committed, progressive farmers is key. Financing CSA requires funding government schemes and resilient infrastructure like micro-irrigation in semi-mountainous regions with inadequate rainfall, watershed projects connecting water sources to hills via canals and efficient farming machines like drip irrigation enhance agriculture.

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