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Climate-smart agriculture (CSA) and extension advisory service (EAS) stakeholders' prioritisation: a case study of Anantapur district, Andhra Pradesh, India

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ABSTRACT

Several climate-smart agriculture (CSA) interventions are promoted by public, private and civil societies in India. However, there is a considerable variation among them. Therefore, to understand the different CSA interventions supported and prioritised by the public and non-governmental organisations (NGOs) as well as their impacts at the farmer level, a case study was undertaken in Anantapur district, as it is highly vulnerable to climate change risks due to the increase in temperature, delayed monsoon, erratic rainfall and frequent occurrence of droughts. A case study research method was followed to assess the CSA interventions promoted by Krishi Vigyan Kendra (KVK), Department of Agriculture, Accion and Adarsha. The findings showed that KVK has focused its extension advisory services on the promotion of field crop (e.g. groundnut)-based CSA. The extension services of NGO-Accion were aimed at promoting horticulture, and Adarsha was prioritised promoting millet-based CSA interventions. Whereas the CSA priority of the department of agriculture was driven by the prevailing zero-budget natural farming project. However, interventions of KVK and NGOs were implemented on a limited scale. Therefore, the recommendations that emerged from the study will help the stakeholders to ensure convergence and foster synergy in implementing CSA interventions at scale. Some challenges faced during the research study were difficulties in the identification of the right stakeholders who were promoting CSA, also their technologies and services related to CSA. However, after a thorough discussion with the extension officers of Anantapur district, the stakeholders were identified and their CSA interventions were ascertained through focus group discussions and secondary data reviewed from magazines and other publications. Furthermore, the present study focused only on the CSA interventions promoted by two public sectors and two NGOs, and there is a wider scope for identifying more stakeholders, e.g. private sector, FPOs and entrepreneurs, and assessing their extent of involvement in the promotion of CSA and prioritisation.

Key words: climate-smart agriculture, climate change, extension advisory services, prioritisation, stakeholders

HIGHLIGHTS

- The study highlights the variations among the extension stakeholders in promoting climate-smart agriculture (CSA) technologies, practices and innovations.
- It identifies the strength and gaps of public and non-governmental organisations in promoting CSA among farmers.
- The study elucidates the major CSA interventions and their impacts at the farmer level.
- Also, factors influence each stakeholder in the promotion of CSA technologies.

1. INTRODUCTION

In the recent past, climate change has prompted various international and national organisations, public, private, non-governmental organisations (NGOs) and the like to invest in climate-smart agriculture (CSA) technologies, practices and innovations that can help farmers to mitigate the effects of, and adapt to, climate change, both in the short and long term. Several studies show that agriculture is severely impacted by the changes in climate and has affected the income of farmers globally. About 800 million people in South Asia would be prone to climate change scenarios such as floods, cyclones, droughts and heatwaves, including India. In India, gross domestic product (GDP) per capita is estimated to decline to 9.8% by 2050 under carbon-intense climate change, and climate-induced yield loss would be anywhere between 4.5 and 9%, which will lead to a loss of 1.5% of GDP on an annual basis (Vijayan & Viswanathan 2018). Indian farmers might have to incur about a 3% net income loss if the temperature rises by 2 °C and +7% change in average precipitation (Kumar 2011). Also, they are likely to face around a 10% rise in cereal price and 3–4% increased poverty after 30 years than at the present time due to an increase in temperature and aberrations in weather (Jacoby *et al.* 2011). Therefore, it might need to produce 70 million more food grains by 2030 to feed the burgeoning population (The Economic Times 2017).

According to the Food and Agriculture Organization (FAO), CSA provides the means to help stakeholders identify agricultural strategies suitable to their local conditions, therefore sustainably increasing agricultural productivity and income; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible. The FAO believes in integrated and holistic approaches for agriculture to be climate-smart. It aims to improve the capacity of all stakeholders for the adoption of CSA at the field level. In this context, the participation of the public, private, NGOs, civil society organisations (CSO) and donor agencies in the promotion of CSA has become pivotal. However, their priorities on CSA interventions vary from region to region.

Most of the international organisations' efforts on CSA are project- or programme-based, and most of them aim at enhancing the adaptive capacity of farmers to risks and uncertainties posed by climate change. Some of these projects are the Mitigation of Climate Change in Agriculture (MICCA) Programme of the FAO, Climate-Smart Agriculture Support Project of World Bank, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), WBCSD CSA Initiative, Global Alliance for Climate-Smart Agriculture (climate-smart coalition of 140 members), etc. (Dinesh *et al.* 2017). For example, the Drought Tolerant Maize for Africa (DTMA) implemented by the International Maize and Wheat Improvement Center (CIMMYT) and the International Institute for Tropical Agriculture (IITA) in sub-Saharan Africa have enhanced the adaptive capacity of maize farming systems owing to their facilitative roles such as convergence and coordination with the National Agricultural Research Systems (NARS) and local agro-service providers. As of 2013, in sub-Saharan Africa, 3 million ha of maize lands were brought under drought-tolerant (DT) maize varieties, benefiting around 53 million people (Sulaiman *et al.* 2018).

Each country has a certain policy framework, strategy and priority that guide its CSA. In South Asian countries, agricultural policies are governed by provincial and national governments, and also they integrate CSA into their existing policies and initiatives (Pound *et al.* 2018). In Africa, the public sectors continue to be the major CSA promoters, and they prioritise their policy frameworks to finance CSA. In 2014, at the 23rd ordinary session of the African Union, the government of Malabo, Equatorial Guinea and Africa included CSA in the New Partnership for Africa's Development (NEPAD) programme and evolved the African Climate-Smart Agriculture Coordination Platform for promoting convergence among CSA stakeholders and capacity of them to CSA (Williams *et al.* 2015). China has extensively promoted China's 'Grain for Green' programme among farmers as a way of reducing erosion in river catchments. It incentivised farmers with tree seedlings, annual grain and cash payments for each hectare that was set aside for tree plantation. In Vietnam, the Plant Protection Department has focused more on the promotion of low input rice cultivation (e.g. less seed, less nitrogen fertiliser and water). The country has followed farmer field schools and farmer-to-farmer training approaches for the wide-scale promotion of the rice-based CSA technique. This has helped around 1 million rice growers in 22 provinces to reduce the use of inputs on about 0.18 million ha and get a better yield of up to 15% compared to the conventional method of rice cultivation (Neate 2013). In Nepal, the National Climate Change Policy was enacted in 2011 to promote good agricultural practices, livelihood diversification and capacity-building activities (Paudel *et al.* 2017). In India, the National Innovations on Climate Resilient Agriculture (NICRA) was launched by the Government of India under the Indian Council of Agricultural Research (ICAR) for enhancing the resilience of agriculture to the distress caused by climate change. The NICRA is implemented by the Krishi Vigyan Kendras (KVKs), and therefore, most of the extension advisory services of KVKs are driven by the CSA components of the NICRA (Vijayan & Viswanathan 2018). KVKs at Babhaleshwar (Ahmednagar) and Baramati (Pune district) of Maharashtra state have enhanced the resilience of agricultural systems/patterns to climate change through technological interventions under the NICRA. These interventions have helped farmers to get assured income due to the diversification of the farming system with dairy and poultry (Rupan *et al.* 2018). In Punjab state (India), cooperatives and service providers are organising demonstrations on CSA technologies (e.g. zero multi-crop planter) in farmers' fields by creating a trustworthy network with the research stations, Punjab Agricultural University, the Department of Agriculture, CIMMET and other CSA technology producers in the state. It was found that good partnerships and customer relationships facilitated both cooperatives and service providers to demonstrate the CSA technologies at scale (Groot *et al.* 2019). The majority of the Indian states have different priorities on CSA projects, and most of them are funded by external organisations. Some of them are the 'Climate Resilient Agricultural Practices – Climate Smart Villages' Project of Haryana state, Zero-Budget Natural Farming (ZBNF) of Andhra Pradesh (Rajani 2019), the Tamil Nadu Irrigated Agriculture Modernization Project (TNIAM) of Tamil Nadu, the Maharashtra Project on Climate Resilient Agriculture, Climate Change Knowledge Network in Indian Agriculture (CCKN-IA) project of Maharashtra, Jharkhand and Odisha, among others (Rupan *et al.* 2018).

Apart from public sectors, the private sectors, financial institutions and civil society have an important role to play in climate-smart food systems (FAO 2013). Hence, they have the potential to respond to long-term climate change by initiating need-based CSA interventions in agriculture and allied sectors (Quail *et al.* 2016; Zougmoré *et al.* 2016; Olorunfemi *et al.* 2020). In Nepal, private business firms such as Golchha Group, Sharda Group and Probiotech-Nimbus Group have committed to educating farmers on the improved agronomic practices and facilitating their access to stress-resilient seeds, irrigation technologies and fertilisers. Furthermore, the Golchha Group has initiated a pilot programme for CSA with the help of the International Finance Corporation (IFC). The project aimed at increasing the adoption rates of climate-resilient practices (i.e. mulching, planting stress-tolerant seeds and integrated pest management) in sugarcane crops through a combination of extension methods such as demonstration, training, technical skilling and model lead farmers. Around 6,000 farmers, including 2,400 women, benefited from this CSA initiative of the Golchha Group. It is expected that sugarcane yield would increase by 20%, and also income of the beneficiary farmers (Trabacchi & Stadelmann 2013; IFC n.d.).

Coffee companies such as Co-op Coffee, JDE, Keurig Green Mountain, Lavazza and Nestlé were promoting CSA across their supply chains through training. However, these private firms focus their interventions on being more climate-smart than creating new CSA practices/technologies (Sloan *et al.* 2019). In East Africa, an insurance surveyor and an agent company ACRE Africa (Agriculture and Climate Risk Enterprise Ltd) were promoting crop insurance among farmers against the risks and damages caused by changes in rainfall and increases in droughts. Its extension services such as farmer-centric education and capacity-building programmes have influenced the farmers to insure their crops against climate-induced risks before planting. Around 0.23 million farmers had benefited up until 2014 in East Africa. As an insurance surveyor, its priorities were mostly on surveying the damaged lands (farm-specific) using the index (e.g. historical rainfall) and facilitating credit-linked insurance through microfinance institutions, and thereby helping the farmers to get the assured compensation for climate-induced crop/livestock damages (Sulaiman *et al.* 2018). In Cote d'Ivoire, Ben & Jerry's (a US ice cream company) developed a producer development initiative (PDI) by partnering with Fairtrade International, Barry Callebaut and the Sustainable Food Lab for renovating cocoa farms. This company has provided financial assistance under the climate-smart cocoa programme to farmers for renovating their Cocoa farms (tree stocks) and diversifying their farms with banana, maize and coffee, and thereby making the cocoa farms more climate-resilient (https://sustainablefoodlab.org/).

In Ghana, Olam (a globally integrated supply chain manager of agricultural products and food ingredients) has fostered its partnership with the Rainforest Alliance for enabling the farmers to adopt cocoa plantations within the forest lands and thereby enhancing the resilience of farming systems to the changes in moisture and temperature level (Brasser 2013). In India, as well, the private companies/corporates have increasingly been participating in CSA. The majority of the private organisations have spent a large amount of their Corporate Social Responsibility (CSR) funds on Natural Resource Management (NRM), technological innovations, extension advisory models, institutional approaches and marketing linkages. Also, they invest in watershed management in climate-vulnerable regions as a way of ensuring round-the-clock water availability for crop production and livestock management (Balasubramani & Vincent 2019). In Uttar Pradesh state, DCM Shriram' (a private business firm with a stake in agriculture, chemicals, power and cement) initiative on CSA, i.e. climate-smart sugarcane agronomy package of practices (PoP) or 'Meetha Sona' programme have enabled their contract farmers to get an increased yield of sugarcane up to 20%, which is higher than the present yield (45 tonnes/hectare). Extension approaches such as continuous training and capacity-building measures have supported farmers to adopt CSA technologies of sugarcane production such as climate-resilient/high-yielding varieties; soil health improvement/water-use efficient practices/technologies, namely mulching, furrow irrigation, land levelling and drip irrigation systems. Around 80,000 contract farmers of DCM Shriram benefited from Meetha Sona, with a 20% increase in their income (IFC n.d.).

NGOs can also support the testing and scaling up of CSA. In developing countries, public institutions have a major stake in providing advisory services to farmers, while extension advisory services of NGOs such as participatory approach, localised farmers' institutions and climate field schools have increasingly become important in addressing the issues related to climate change (Sala *et al.* 2016; Deepika *et al.* 2018). Five international NGOs, namely World Vision, Catholic Relief Services, CARE International, Concern Worldwide and OXFAM, were found to play a major role in making African agriculture climate-smart. For instance, Vi Agroforestry, a Swedish NGO founded in 1983, has its presence in four African countries – Kenya, Uganda, Tanzania and Rwanda. It promotes several CSA practices (e.g. composting, crop rotation and mulching) and technologies (tree planting along with soil erosion control structures) among farmers (especially small farmers) in these four countries. The farmers' group capacity development approach was its major extension strategy for promoting CSA. The Kenya Agricultural Carbon Project (KACP) implemented by Vi Agroforestry seeks to enhance the soil organic matter, improve soil water retention, enhance the nutrient supply, as well as sustain biodiversity through community-level agroforestry. This project has benefited about 60,000 farmers on 45,000 ha in Kenya since 2008. Similarly, the Environmental Conservation Trust of Uganda (ECOTRUST), an NGO in Uganda, trained the farmers in 'on-farm' tree planting under Plan Vivo system with its major CSA project 'trees for global benefits' (TFGB). Around 400 farmers were involved in this project, and they have planted about 35,000 trees to date. As a result, around 25,000 tons of CO_2 is expected to be sequestered over the 20-year agreement period (World Bank 2014; Shames *et al.* 2016; Hughes *et al.* 2020). In India, several NGOs are working towards CSA. For example, CECOEDECON, an NGO from Rajasthan, has been promoting community-based CSA and aims at promoting water-smart practices such as the construction of bunds, gully plugs, digging feeder channels and deepening wells. These water-conserving sustainable practices have ensured the year-round availability of water for farming, fisheries and livestock. In Anantapur district (Andhra Pradesh), the NGO – Center for Sustainable Agriculture (CSA) – has been promoting farmer-centric CSA practices and technologies such as the production of bio-pesticide, the conservation of seeds from traditional varieties and the installation of vermicompost facilities. These CSA interventions have the potential to reduce input costs and therefore minimise the farmers' vulnerability to external risks posed by climate change (Pande & Akermann 2009). However, scaling up of CSA technologies/practices is dependent on conducive policies and efficient institutional actions, which will help the multi-stakeholders to establish responsibilities in upscaling the CSA technologies and minimise the challenges and constraints faced by farmers in the adoption of CSA interventions that not only have the resilience to climate change but also have co-benefits for social, economic and environmental sustainability (Westermann *et al.* 2015; Winter *et al.* 2017; Makate 2019).

Challenges and limitations

Some challenges faced during the research study were difficulties in the identification of the right stakeholders who were promoting CSA, their technologies and services related to CSA. Also, the project village or areas of each identified stakeholder were located in different geographies, which has posed challenges in travelling to and fro for the observation of stakeholders' project locations. However, after a thorough discussion with the extension officers of Anantapur district and reviews of secondary data, the stakeholders were identified, and their CSA interventions were ascertained through focus group discussions and secondary data such as magazines and other publications. Furthermore, the present study focused only on the CSA interventions promoted by two public sectors and two NGOs, and there is a wider scope for identifying more stakeholders, e.g. private sector, FPOs and entrepreneurs, and assessing their extent of involvement in the promotion of CSA and prioritisation. Furthermore, the study collected information only from the beneficiary farmers. Future studies may consider non-beneficiary farmers in the same geographic area to compare and contrast the benefits.

Study objectives

The major objective of the present study is to understand the important CSA technologies, practices and services promoted by the four agricultural stakeholders, namely public sectors: (i) KVK; (ii) the Department of Agriculture; NGOs such as (iii) Accion Fraterna Ecology Centre and (iv) Adarsha Rural Development and Training Society. The second objective is to assess and understand the major extension approaches adopted by these stakeholders for promoting CSA. Thirdly, to assess the benefits of CSA promoted by them at the farmer level in terms of resilience (increase in productivity and income) and adaptation to droughts.

Reasons for selecting four stakeholders

There were several agricultural stakeholders who were promoting CSA in Anantapur district, as it is highly vulnerable to climate change risks, e.g. droughts. However, in the present study, it was decided to study the CSA interventions of two public organisations and two NGOs. The major reason was to understand the commonalities and differences in CSA implementation and extension strategies adopted by the public sector and NGOs in promoting CSA interventions. The major advantage of comparing the public sector's CSA priorities with NGOs is that the results will help the policymakers to assess the merits, scope and limitations of public and NGOs in the implementation of CSA and formulate appropriate policy frameworks to foster convergence.

However, there are a good number of alternatives that can also be adopted. For example, the future study may identify a few more stakeholders such as panchayat raj, private sector, Farmer Producers Organisations (FPOs), entrepreneurs and Self Help Groups (SHGs), and this will further help in understanding the CSA priorities of each stakeholder in a particular geographical location. Also, a few research studies may be taken up to compare and contrast the CSA interventions of public and private sectors, private and NGOs, NGOs and FPOs, and SHGs and FPOs.

The present study assesses the seven CSA interventions promoted by the four identified stakeholders in terms of their adaptation to droughts, influence on productivity and income level of farmers. The most important advantage of selecting these three criteria such as productivity, income and adaptation is that they serve as the basis for measuring the impact clearly at the farmer level. However, there is also a possibility of measuring the CSA technologies' potential on the mitigation GHG emissions, water conservation and carbon sequestration. Future studies may include more criteria to holistically study the impact.

METHODOLOGY

Study zone – an overview

India is exposed to various climate variabilities such as warming, droughts, floods, cyclones, heatwaves and cold waves. Among them, drought is causing huge crop and livestock losses. Out of 30 states and nine Union Territories, only 10 states have 50% resilient areas. Out of 634 districts, only 241 districts (38%) were found to be resilient to dry conditions/droughts (Sharma & Goyal 2018).

Background for selecting Anantapur district

A total of 121 districts are considered to be climate-vulnerable in India. Of which, five districts, namely Anantapur, Chittoor, Kurnool, Srikakulam and West Godavari, are located in Andhra Pradesh state. Particularly, Anantapur district is categorised under high/very high vulnerability to climate change due to the frequent occurrence of droughts. For example, almost 51 out of 63 mandals are extremely resource-deprived due to arid conditions. (Mandals are the administrative units in Andhra Pradesh.) Three to four mandals form a taluk. A taluk is an administrative unit for taxation purposes, and it comprises a minimum of four to five mandals and a few taluks from a district. According to the NICRA contingency plan, the district is grouped under the 'scarce rainfall' zone in Andhra Pradesh with an annual rainfall of 560 mm (NICRA n.d.). Anantapur farmers perceived that the occurrence of droughts has increased (both in frequency and intensity), and also decreased in seasonal rainfall, untimely rains, hotter days and nights (Andhra Pradesh 2016; Rao *et al.* 2017). Also, there are many districts in India that are drought-affected. Besides, within Andhra Pradesh state, Chittoor, Kurnool, YSR Kadapa, Prakasham, etc. are drought-affected districts (GoAP 2018). Therefore, future studies may also be taken up in these areas to identify various stakeholders working on CSA, their CSA prioritisation and how they affect the farming community.

District profile

The district has 63 mandals and 952 villages with a population of 4.08 million (2.06 million are male and 2.01 million are female). Almost 72% of its population (2.95 million) are living in rural areas, and the remaining 1.14 million (28.09%) are living in urban areas. It has 0.41 million farmers (20.30% of the total population) and 0.87 million agricultural labourers, i.e. 43.20% of the total population (Census of India 2011).

Agricultural profile

Around 69% of the farmers are smallholders in Anantapur (Andhra Pradesh 2016). Groundnut is continued to be the major crop, while pulses (Bengal gram and red gram), sunflower, sorghum and maize account for a considerable share in the total cultivated crops. The net sown area accounts for 58% of the total geographical area (i.e. out of 19.13 million ha, 11.1 million ha are under agriculture). However, three-fourths (75%) of the net sown area are under rainfed agriculture (Gopinath *et al.* 2013).

Study areas

A total of four villages were selected from the project sites of stakeholders, i.e. one village from each stakeholder. (i) Peravalli, the adopted village of KVK-Reddipalli, (ii) Kalyandurg, the project site of the Department of Agriculture, (iii) Pampanur, project area of Accion Fraterna Ecology Centre and (iv) Kodikonda, project area of Adarsha Rural Development and Training Society (ARDTS; Figure 1).

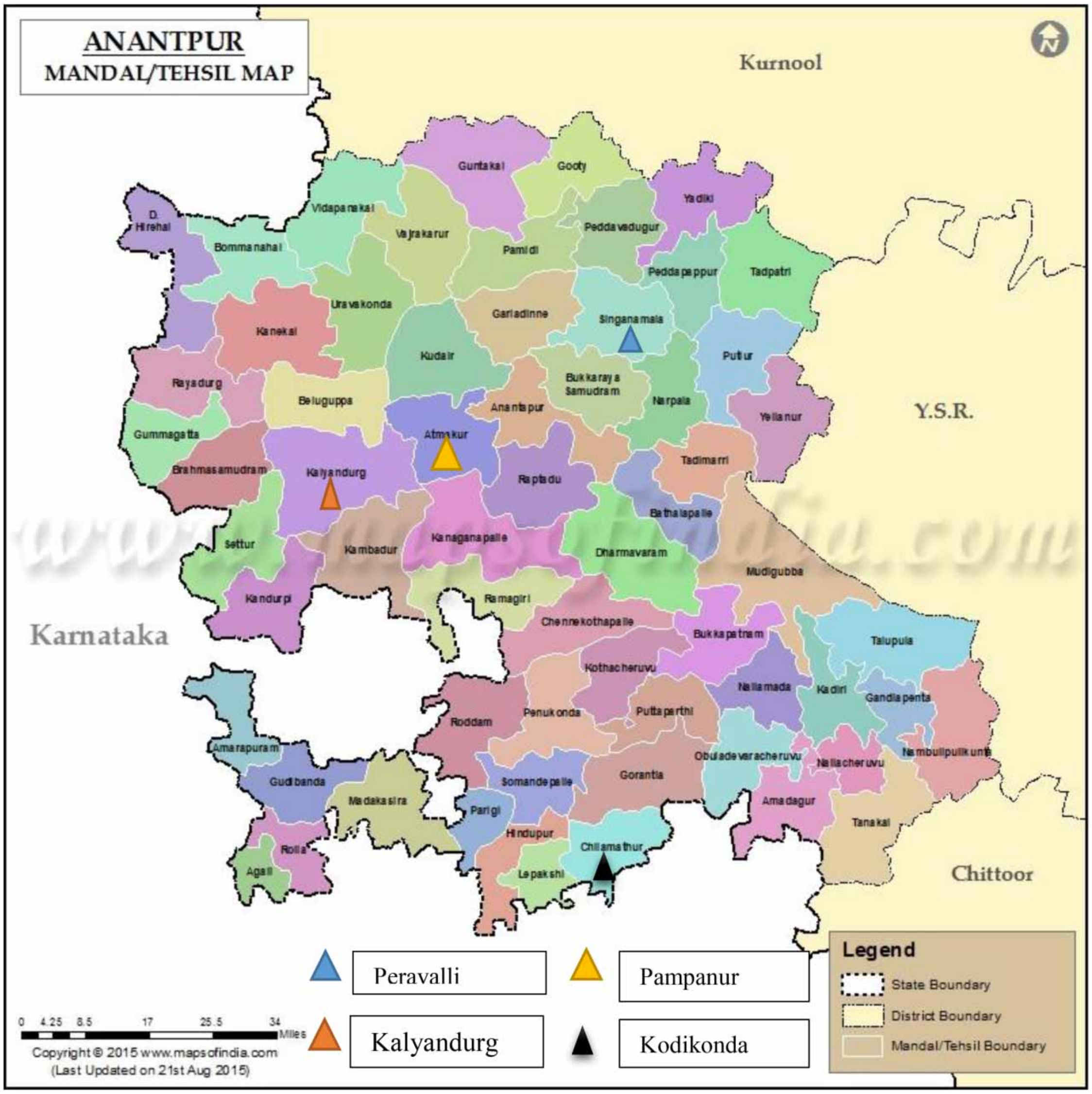

Figure 1 | Study areas. *Source*: Map of India.

Study method

A case study research method was followed to assess and understand the CSA interventions promoted by the four stakeholders: KVK, the Department of Agriculture – public organisations, Accion Fraterna Ecology Centre (AFEC) and ARDTS-NGOs. The major reason for opting for a case study research method was to understand the in-depth information about CSA-related activities of each stakeholder. Furthermore, the case study method is a useful research methodology for interaction and to collect data extensively. Moreover, the research methods such as experimental, non-experimental and non-interactive or analytical were not selected, as the present study did not include any experimentation nor analysis of content that were already published by the identified stakeholders. However, mixed methodologies such as explanatory and exploratory may be adopted as an alternative to the case study method. Both explanatory and exploratory methodologies will help in collecting both quantitative and qualitative data from responders/stakeholders.

Sampling method and sample size

A total of 30 beneficiary farmers were selected purposively from the aforementioned project areas: 8 farmers were selected from Peravalli (Beneficiaries of KVK), 10 farmers from Kalyandurg (Beneficiaries of Department of Agriculture), 7 farmers from Pampanur (Beneficiaries of AFEC) and 5 farmers from Kodikonda (Beneficiaries of ARDTS). These farmers were selected purposively because the identified farmers had adopted the CSA interventions on a larger scale promoted by the stakeholders. Furthermore, they have become innovative farmers for the stakeholders, and the fields of these farmers have now become model CSA farms for neighbouring farmers.

The present study was aimed at understanding the extent of involvement of the four identified stakeholders in the promotion of CSA interventions. Therefore, importance was given to assessing CSA interventions of the stakeholders on a case basis. However, to know the impact of the promoted CSA interventions at the farmer level, a small sample size of beneficiary farmers of the four stakeholders was selected. Also, selecting more beneficiary will provide the same results due to the adoption of similar CSA technologies by the beneficiaries. Hence, the sample size was restricted to 30. Therefore, the sample size of 30 beneficiary farmers was adequate. However, there is a possibility of selecting more project areas/villages with more sample size in future studies. This will provide scope for justifying the impact at a larger level. Moreover, the important advantage of adopting the purposive sampling method was that it helped in selecting the right beneficiary farmers for the study. This has further helped with attaining the desired results. However, the sampling methods such as random sampling may be adopted in a larger area to ascertain the extent to which the number of farmers adopted CSA interventions. Also, both beneficiary and non-beneficiary farmers may be selected to assess the difference between both of them in the adoption of CSA technology, factors that influence adoption, the difference in productivity, resilience capacity and adaptation to droughts.

Collection of secondary data

The secondary data related to CSA interventions of the stakeholders, their project areas, extension approaches, beneficiaries, funding sources and partner organisations were collected from the annual reports and magazines published by the selected stakeholders. The extension approaches refer to methods and strategies adopted by the stakeholders to promote CSA interventions. The most important extension approaches were village-level community institutions, expert to farmer interaction, on-farm demonstrations, ICTs, etc. The project areas are the cluster of villages (one or two villages) wherein the CSA interventions are implemented by the stakeholders. For example, KVK has 3 project sites, Accion Fraterna has 234 project sites, Adarsha has 2 project sites and the Department of Agriculture has more than 50 sites. The collected secondary data were used for the preparation of a semi-structured interview schedule (Tables 1 and 2) to collect the relevant primary data from the stakeholders and beneficiary farmers.

Table 1 | Semi-structured interview schedule used while collecting data from stakeholders

S.No.	Questions	Response
1.	Please enlist major climate change risks observed by your organisation in the Anantapur district	
2.	Major CSA technologies, practices and services promoted by your organisation to overcome the identified climate change risks	
3.	Enlist the villages/areas/project areas while promoting	
4.	What is the priority area of your organisation concerning CSA interventions (technology, practices and services) and why	
5.	Enlist the major CSA technology/practice/service promoted by your organisation and the extent of its adoption	
6.	Please provide details and factors that led to the prioritisation of some CSA technologies/practices/services over other	
7.	Enlist the major extension approach followed by your organisation in promoting CSA technologies/practices/services	
8.	Enlist the major impact at the farmer level in terms of resilience of promoted CSA technology/practice/service to drought, increase in productivity and income	
9.	Is there any convergence or partnership made with other stakeholders to implement CSA technologies/practices/services	
10.	Is there any funding support to your organisation in promoting CSA technologies/practices/services	
11.	If, yes, please provide details of the funding partners and how they influence your CSA prioritisation	
12.	Major challenges faced by your organisation in promoting CSA	
13.	Others if any	

Table 2 | Semi-structured interview schedule used while collecting data from farmers

S.No.	Questions	Response
1.	Enlist the CSA technologies/practices/services adopted by you	
2.	What is your observation of the adopted CSA technology/practice/service to overcome drought or other climate change risks	
3.	What is the difference in income level compared to the previous technology/practice observed by you due to the adoption of the particular CSA technologies/practices/services	
4.	What is the difference in the productivity of crops/soil compared to the previous technology/practice observed by you due to the adoption of the particular CSA technologies/practices/services	
5.	Is the CSA technology available to you?	
6.	If yes, enlist where it is available	
7.	Is the CSA technology affordable to you	
8.	Enlist other factors that led to the adoption of the particular CSA technologies/practices/services	
9.	Major challenges faced by you in promoting CSA technologies/practices/services	
10.	Others if any	

Collection of primary data

The primary data related to CSA technologies, practices and services adopted by farmers as well as their extent of influence on productivity, income and resilience to drought were collected. Also, information such as enabling extension services and factors that influenced the farmers towards the adoption of CSA interventions were collected.

Data collection methods

A total of four focus group discussions were conducted, one with each stakeholder for collecting the major CSA interventions, extension approaches, CSA funding support, partnership, level of convergence, project areas and beneficiary farmers. An in-person interview was also conducted to collect the data from farmers on the extent of adoption of CSA interventions, their impacts on productivity, income and resilience to droughts. During the interview, the data on the above variables were collected using the semi-structured interview schedule consisting of open-ended questions. Also, adopting focus group discussion and in-person interviews has given a relative advantage over other data collection methods. For example, focus group discussion has helped in understanding the different CSA interventions of all four stakeholders in general, and in-person interviews have facilitated understanding of the detailed impact of each CSA intervention at the farmer level. However, there is a possibility of using an ethnographic survey, key informant interview and structured questionnaire for collecting data. These data collection methods will also facilitate arriving at desired results. However, the data collection method like structured questionnaire needs to be standardised before using it for field surveys, as it provides a limited scope for interaction with the respondents. Furthermore, the semi-structured interview schedule was used, since it would help in extrapolating more data from the responders and constructing more questions based on the interaction with the respondents. The conflicting responses of farmers related to the availability of irrigation water, bore wells and extension support services were resolved by triangulating the responses with similar respondents and also with stakeholders.

Analysis of data

There is no particular software used for analysing data. The qualitative data were assessed based on the study objectives and grouped under each cofactor. Also, the quantitative data collected from farmers on increase in productivity, water table and income level were enumerated and elucidated under a relevant cofactor listed in results and discussion.

RESULTS AND DISCUSSION

Several CSA technologies and practices (hereafter CSA technologies and practices will be referred to as CSA interventions) have been promoted by KVK-Reddipalli, Department of Agriculture, Accion Fraterna Ecology Centre and ARDTS. The CSA interventions of these four stakeholders and their impacts on productivity, income and resilience at the farmer level were studied and discussed. Hereafter, Accion Fraterna Ecology Centre will be referred to as Accion and ARDTS as Adarsha.

Also, the results of the study are presented in the CSA intervention or thematic areas of CSA such as seed smart and variety smart rather than stakeholder-wise. For example, in Figure 2, the KVK's CSA interventions were referred to as the promotion of field crops, soil health cards (SHC), watersheds and ICT approaches. However, they were not presented under KVK's interventions, rather their CSA interventions related to CSA and their extension approaches were presented under the specific thematic areas where their CSA interventions suit. This helps in understanding the CSA interventions of all the four stakeholders in a thematic sense and to assess the level of their involvement in terms of promotion and non-promotion of the particular CSA interventions. This will further help in understanding the reasons and factors behind the promotion or non-promotion of a particular CSA intervention by the selected stakeholders.

Seed smart

Seed being the core element in agriculture, its resilience is key to the adaptation. In Laos, improved rice varieties and seed systems emerged as the most promising CSA intervention. Ideally, seeds used by farmers should (i) be a DT rice variety and (ii) have better quality in terms of seed vigour and purity (Wassmann *et al.* 2019). In Nepal, the use of improved seeds was one of the major CSA interventions (Paudel *et al.* 2017). In the present study also, stakeholders were promoting improved seeds as an adaptation measure. For example, KVK at Reddipalli has demonstrated Climate-Smart Seed Management (CSSM) such as seed treatment with *Pseudomonas firmis* under the NICRA project at its adopted village – Peravalli, Singanamala Mandal in Anantapur. The services of students of the Rural Agriculture Work Experience (RAWE) programme – Acharya N. G. Ranga Agricultural University (ANGRAU), Kurnool – were also instrumental in the demonstration. The scientists of KVK and farmers expressed that the groundnut and pulse seeds treated with *P. firmis* have shown a relatively higher adaptive capacity to a prolonged drought up to 15 days, also resistance against root grubs infestation. The beneficiary farmers also perceived that the treatments of seeds of groundnut, red gram and green gram with *P. firmis* have helped reduce the number of fertiliser applications, the number of sprays, cost of inputs and save the number of man-days. To date, around seven farmers have adopted seed treatment and expressed that they were able to save about $20.07–$26.76 per acre. However, the NGOs, Accion and Adarsha did not prioritise the promotion of seed treatment. This is due to KVK-Reddipalli being the implementing partner of the NICRA project of the ICAR, for which it received sufficient funds for both production and promotion of *P. firmis*. Therefore, there is a need for fostering convergence between KVK and NGOs to promote seed treatment at scale by providing knowledge, technical and funding support.

Variety smart

Extension stakeholders across the globe are involved in screening and introducing location-specific varieties to address the risks of climate change and enhance productivity. Both KVK and Accion have been popularising climate-smart varieties (CSV) in

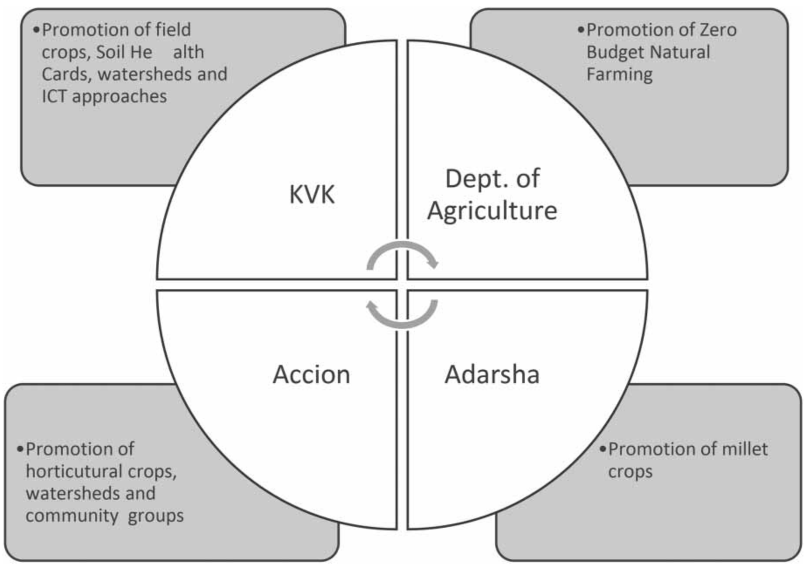

Figure 2 | CSA priority areas of stakeholders in Anantapur.

their project areas. KVK has demonstrated a number of groundnut varieties under the NICRA in Peravalli to enhance the adaptability of farms to droughts. Among them, varieties such as K-6 (drought resistant), K-9 (drought resistant and high oil content (53%)) and Dharani (DT and drought resistant to groundnut leaf spot disease) were significant. The scientists at KVK expressed that both K-6 and K-9 have more tolerance against droughts. Also, K-6 has slightly more potential to withstand even reduced moisture conditions due to delayed monsoon. Dharani yields better with 525 kg/ha than K-6 (478 kg/ha), besides being tolerant against drought and leaf spot disease. Dharani variety is the latest breakthrough in groundnut against the recurring droughts. Farmers who adopted Dharani in Peravalli were able to generate an income of about $87.88 per hectare as against $50.51 per hectare from K-6. KVK has also been promoting DT red gram varieties such as LRG – 41 and PRG – 151 and a DT castor variety PCH-111. The findings showed that the KVK's extension approaches were skewed towards the popularisation of field crop varieties (mostly groundnut varieties). Conversely, the extension approaches of Accion were aimed at the promotion of CSV of horticultural crops, while not neglecting field crops. Accion has promoted the *Benishan* mango variety in its 230 project villages spread around eight mandals (Atmakuru, Kudair, Raptadu, Dharmavaram, Kalyandurgam, Beluguppa, Settur and Kundurpi). The extension functionaries perceived that farmers growing *Benishan* were able to overcome the risks of prolonged droughts and fetch high income. For instance, Mr Kollana (a beneficiary farmer) at Pampanur village (Atmakur Mandal) has adopted mango var. *Benishan* in place of groundnut. He expressed that his half-acre yields about 1,000 kg of mango every season and fetches him about $200.74 at $0.20 per kg. The price would go as high as $0.40 per kg based on market demand. He irrigates his orchard with the help of a pitcher irrigation system (traditional CSA practice). The farm pond (constructed by Accion in his orchard) was his major source of irrigation.

KVK and Accion have different extension approaches in promoting CSV. Accion aims to break the mono-cropping pattern of groundnut by encouraging farmers to integrate horticulture with field crops (groundnut or/and pulses) or shift to horticultural crops. This enables the farmers to minimise the risk of droughts. Meanwhile KVK was promoting field crops due to its programme intervention (NICRA). Yet, both of them have shown greater success in minimising the effects of droughts on agriculture in their project areas, thereby helping farmers to gain remunerative income. The success of both KVK and Accion can be attributed to various factors such as their involvement in the assessment of climate vulnerability, screening the suitable varieties for drought, technical hand-holding and choosing the best-fit extension model for enhancing the adoption rates. Also, both of them have organised rigorous training, capacity-building programmes in their respective adopted villages/project areas to create awareness of CSA interventions. Besides, demonstration units were established in all the project areas by both of them. These have helped them to show the results of improved technology and practices and their impact on crop yield, income and drought resilience directly to farmers in their farm setting. Furthermore, the demonstrated technologies and improved practices had more location specificity, which facilitated speedy adoption by farmers. Also, the regular field visits conducted by the stakeholders helped the farmers to adopt an appropriate PoP and suitable field operations in a timely manner. These extension services enabled the farmers to continue the adoption, helped them understand the latest technologies and minimise the risk of drought. Furthermore, Accion was able to cover more farmers than KVK due to its funding support from Brot für die Welt (Bread for the World, a German-based aid agency) and sufficient manpower at the field level. Accion has about 80 socio-technical organisers in its 230 project villages, whereas KVK has only five to six scientists and is responsible for implementing CSA, besides attending to their regular research and extension activities.

Cropping pattern smart

The cropping pattern needs to be adjusted to suit the changing climate. Up until 2,000, 90% of the farmers in Anantapur had been growing groundnut; however, the farmers were diversifying the crops substantially due to the extension efforts of the public, private sectors and NGOs. The Department of Agriculture and KVK have long been promoting mixed/intercropping and integrated cropping/farming systems to cope with climate change. However, Accion has seen relatively higher success in bringing desirable changes among the farmers in the adoption of climate-smart cropping patterns. The most common cropping pattern promoted by Accion includes groundnut+castor+red gram (7:1), foxtail millet+red gram (7:1), etc. However, its main focus was on the popularisation of horticulture-based cropping patterns, for instance, horticulture+agriculture, i.e. horticultural crops (mango/tamarind/gooseberry/sapota, etc. or vegetables)+annual crops (pulses/millets/groundnut/bajra/jowar/foxtail millet). This cropping pattern was adopted by around 1,520 farm families covering 5,775 acres in 230 Accion project villages.

Mr Vanurappa from Pampanur village (one of the beneficiaries of Accion) has shifted his cropping pattern from groundnut (2 acres total) to horticulture-based intercropping (Mango (1 acre)+1/2 acre of tomato+1/2 acre of chilli). This is mostly because of Accion's incentive arrangements for quality seeds (saplings of mango), digging bore wells and power supply. Besides, he and his family members were involved in the total crop production practices starting from the field preparation to harvesting. Thus, he saves the labour cost of about $133.82 per acre, and also sells the vegetables at farm gate price of $0.40–0.54 per kg locally. Because of these combined CSA interventions, Mr Vanurappa's income level increased to 120–135 USD per acre in a season from 40 USD per acre (which was otherwise his income from groundnut cultivation). Accion was able to popularise and demonstrate high-value horticultural crops at scale largely due to its collaboration with the line departments for supplying power and quality seeds. Similarly, the constant funding support from Brot für die Welt helps Accion to organise climate training and capacity-building programmes regularly.

On the other hand, NGO-Adarsha aimed at popularising millets as climate-smart crops against recurring droughts and increasing temperatures. Some of the millet crops promoted by Adarsha were kora (foxtail millet), samu (little millet), sajja (pearl millet), etc. It was observed from the stakeholder meeting that around 4,000 farmers in Kadiri and Hindupur mandals have switched their cropping patterns from groundnut to millets. Also, millet growers were linked to potential market agents by Adarsha for direct marketing. Thus, the buyback arrangement has helped the farmers to earn about USD 250–270 per acre. However, unlike Accion, there were no major funding supporters for Adarsha. Also, it is an individual-based NGO, aiming to promote millet as a CSA intervention due to its low cost of production, high nutritive value and growing market demand. According to Khatri-Chhetri *et al.* (2019), the stakeholders' preference for low-cost CSA interventions was attributed to the investment capacity, availability of credit and risk aversion behaviour.

The results suggest that Accion and Adarsha being NGOs have the freedom to prioritise their CSA interventions. While for KVK, being the public scientific organisation, its priority areas of CSA were driven by the NICRA project. And therefore, the extension services of KVK aimed at promoting CSA interventions related to food crops/field crops, (mostly groundnut). This apart, the farmers in Anantapur have shown more interest in adopting groundnut-based CSA interventions in the absence of any substantial incentives for 'on and off farm resource augmentation'. It is mostly because 90% of the arable lands are still rainfed in Anantapur. Thus, farmers who were practising rainfed agriculture have rich experience in the cultivation of groundnut. However, the farmers were slowly diversifying their cropping pattern due to the extensive extension services of KVK, the department of agriculture, Accion and Adarsha. The major support services in diversifying crops might be attributed to the creation of watersheds and market linkages (off-farm support), farm ponds and provision of CSV (on-farm support). The farmers were not able to switch their crops from groundnut to horticultural crops if there had been no support services from stakeholders. Therefore, along with extension services, support services are essential to enable farmers to adapt to CSA.

Fertiliser smart

Smart fertilisers and their site-specific application are becoming an efficient CSA intervention with several co-benefits and potential to optimise productivity (Khatri-Chhetri *et al.* 2017; Calabi-Floody *et al.* 2018). The soil testing and the use of SHC can help increase the soil fertility profile, lowering the input cost and enhancing the overall farm production (Patel *et al.* 2017). The findings of the study illustrate that since 2015, KVK has been creating awareness among farmers in Peravalli village about soil test-based application of fertiliser. The scientists of KVK noted that around 60% (39) of the farmers (in Peravalli) have started applying fertilisers based on SHC reports. For instance, farmers like Mr Ramu (Peravalli village), a beneficiary farmer of KVK-NICRA, indicated that without knowing the fact that his field had a huge amount of potassium (K), he was applying a maximum quantity of DAP with the blind belief that it would enhance the productivity. It was only after the knowledge camps organised by KVK on SHC that he understood the nutrient composition of his field. Presently, he applies a specified quantity of urea, DAP and other fertilisers based on the reports of SHC. However, the NGOs-Accion and Adarsha did not promote SHC. The case illustrates that as KVK was the implementing partner of the NICRA project, and it was mandatory for KVK to promote SHC. Whereas NGOs have no such projects, but have different pathways for smart fertiliser. Also, the availability of a soil testing laboratory at KVK with skilled manpower has helped KVK to popularise SHC. Henceforth, there is a wide scope for the government to extend its financial support to the private sector and NGOs to establish soil testing labs, improve the capacity of manpower in soil sampling & analysis and promote SHC at scale.

Similarly, ZBNF introduced by the Government of Andhra Pradesh in 2016 as an alternative to chemical-based and capital intensive agriculture is reported to be an effective CSA intervention and also can increase the income of the farmers (Rajani 2019; Bharucha *et al.* 2020). The Department of Agriculture was mandated to promote ZBNF. The major extension approaches followed by the Department of Agriculture for the promotion of ZBNF were the creation of a cadre of resource pools such as Master Farmers, Cluster Resource Persons and Cluster Activists. These extension functionaries aim at increasing the awareness and knowledge of fellow farmers on ZBNF. The agriculture department has also collaborated with several NGOs (including Accion) to organise Farmer Field Schools to increase the adoption rate and promote ZBNF at scale. Extension workers implementing ZBNF in Kalyandurg village expressed that this CSA intervention has a substantial impact on the adaptation capacity of farm to droughts. Besides this, the beneficiary farmers of ZBNF expressed that there was a substantial increase in soil fertility and crop productivity. This CSA intervention is a typical example of the government intending to promote ZBNF as a sole CSA, while the other areas of CSA interventions receive comparatively less priority. Though ZBNF has the potential to meet all the three pillars of CSA (productivity, resilience and mitigation), the degree of its mitigation and adaptation to climate change varies from farm to farm. Henceforth, the public extension system has to focus on a wide range of CSA interventions by fostering partnerships with NGOs, the private sector, etc. in the implementation of CSA. They can also provide necessary funding support to NGOs, private sectors in organising farmer meetings, training and capacity-building programmes for scaling up ZBNF.

Water smart

Watershed development is an essential yardstick of rural development and natural resource management strategies in many countries (Kerr 2007). In India as well, both public and private sectors have invested in the development of watersheds to address the on-, off- and non-farm water-related problems. This study also reveals that both KVK and Accion have been involved in the creation and renovation of watersheds. KVK has promoted three check dams (the capacity of each check dam is 0.2 million litres) in Peravalli village through the NICRA project for augmenting the water resources to ensure the availability of water for irrigation. Farmers from Peravalli village perceived that even one-fourth of filling during the rainy days has a groundwater recharge potential up to 15–20 inches. This leads to an increase in the water level of 23 bore wells in the village. Farmers further indicated that the check dams have increased the irrigation potential in crops like groundnut and pulses to an extent of two to four times in a cropping season. It was observed that the watersheds constructed by Accion at Muttala, B.M. Palli, Kuder, Battuvanipalli, Garudapuram and Mallipalli have enabled the farmers to diversify their farming systems (e.g. dairy farming, goat and sheep rearing) and enhance non-farm activities such as tailoring, basket weaving, garment making and engine repairs. Both KVK and Accion have a commonality and difference in the promotion of watersheds. The commonality is that both of them have sufficient funding support for constructing watersheds/check dams. KVK has received its funding support from the National Bank for Agriculture and Rural Development (NABARD), while Accion has received funds from multiple sources such as District Water Management Authority (DWMA), the Department of Rural Development and the NABARD. Thus, the fund was found to be the most common factor for both KVK and Accion to establish watersheds in their project areas.

The difference is that Accion has adopted a community approach for the maintenance of these watersheds. It has promoted 18 watershed development committees and seven rainfed cooperative societies. Conversely, KVK has no such organised/formal groups for the maintenance of check dams, yet with little participation from the farming community, it maintains them whenever necessary. However, the watersheds of KVK and Accion were confined to their project areas or adopted villages. Therefore, the government may provide more funding support and incentives to promote watersheds at scale. Also, the other extension service providers may emulate the watershed maintenance committee promoted by Accion for efficient management of watersheds.

However, none of the selected stakeholders uses hydrological prediction modelling techniques to assess the droughts. They mostly rely on India Meteorological Department data for providing alerts to farmers along with contingency plans. However, the stakeholders may utilise the growing importance of hydrological modelling techniques for predicting the recurrent occurrence of drought and better plan their advisory services. Predicting drought can provide useful information which helps to reduce consequences resulting from drought (Shamshirband *et al.* 2020). A Gravity Recovery and Climate Experiment (GRACE)-based modulated water deficit (GRACE-MWD) process for drought monitoring under the modulated annual cycle (MAC) reference frame was used in southwest China. The drought predicting model has achieved a higher ratio of agreement with the standardised precipitation evapotranspiration index at a time scale of 3 months. GRACE-MWD data are less affected by seasonality from land-cover categories, which benefit from the MAC reference frame (Zhao *et al.* 2018). Furthermore, the authors conclude that GRACE-MWD can be used across the globe for better prediction. Also, a study conducted in Iran by Mohamadi *et al.* (2020) on hydrological modelling to predict drought indicated that the hybrid soft computing models gave a more reliable performance compared to the standalone multilayer perceptron, radial basis function neural network, adaptive neuro-fuzzy interface system (ANFIS) and support vector machine models. Furthermore, the

ANFIS-Nomadic People Algorithm model performed well (Mohamadi *et al.* 2020). Furthermore, Malik *et al.* (2020) in their research study on modelling used a new version of the fuzzy logic model, called the co active neuro-fuzzy inference system (CANFIS) for predicting the standardised precipitation index (SPI). In this study, multiple scales of drought information at six meteorological stations located in Uttarakhand state, India, were used. They indicated that the CANFIS model predicted the SPI better than the other models, and prediction results were different for different meteorological stations and proposed that the CANFIS model can build a reliable expert intelligent system for predicting meteorological drought at multi-time scales and decision-making for remedial measures to cope with meteorological drought and can help to maintain sustainable water resources management (Malik *et al.* 2020). Also, Raha & Gayen (2020) in their study simulated the SPI using double exponential (DE) and Holt–Winter (HW) exponential smoothing models for several time steps (e.g. 3, 6, 12, 24 and 48 months) from 1979 to 2014 in meteorological drought for Bankura District. The comparative analysis between the two models indicated that DE was more accurate. The DE model has helped in the identification and monitoring of different drought-related parameters at the same time and the effective identification of drought-prone zones. This model may be used as a more accurate drought forecasting tool for sustainable agricultural production, therefore, to make agriculture water-smart, in addition to the creation of watersheds in vulnerable areas, stakeholders who are implementing CSA in Anantapur need to utilise the drought predication models suitable to their region along with IMD data for better predicting the occurrence of droughts and prepare suitable cropping contingency to minimise the risks of drought on agriculture.

Knowledge smart

Most of the public and private sectors of agricultural value chains have invested in the development of various ICT platforms to provide real-time weather and climate-related information and advisory services relevant to CSA interventions (Lipper *et al.* 2014). The findings of the study also illustrate that among the extension advisory providers, the ICT platform, namely Annapurna Krishi Prasara Seva (AKPS) (AKPS is a mobile-based SMS service platform of the government of Andhra Pradesh), has been extensively used by KVK for disseminating climate-related crop management services/contingency crop planning to its registered farmers in Peravalli. The scientists of KVK expressed that a total of 100 farmers have registered to AKPS to receive weather advisories. The scientists of KVK were involved in the assessment of the changes in weather in Peravalli village through its automatic weather station and developed crop plans with best-fit contingency cropping in the local language (Telugu language – mother tongue of Andhra Pradesh state). These advisories are disseminated to the registered farmers every week. This helps farmers to make a timely decision in agriculture by adopting relevant CSA interventions and enables them to avert the risks such as increase in temperature, delayed rainfall and drought-like conditions. Farmers in Peravalli village expressed that the information on the cultivation of contingency crops such as castor, foxtail millet and Jowar instead of groundnut sent through SMS was adopted by them as a response to the delayed onset of Monsoon in September 2018. This has helped them to effectively avoid the risks of dry spells. Nevertheless, the ICT services were not solely responsible for the adoption of contingency crops and crop advisories by farmers, rather their access to affordable and quality seeds at KVK has enabled farmers to plan and make a timely decision. Therefore, ICT advisories coupled with the availability of CSA interventions at affordable prices have the potential to influence the farmers' decisions towards adaptation and mitigation. FAO states that sharing practices and technologies can be done through increased cooperation among stakeholders; better extension outreach and providing regular technical assistance. To facilitate the stakeholders to share their knowledge on CSA interventions, the role of ICT is a must. In India, most of the farmers accessed the weather-related information through ICTs (Patil *et al.* 2008). Furthermore, information services on the availability of inputs, quality of inputs, and pest and disease management of crops were also used by the farmers through ICTs (Syiem & Raj 2015). The ICTs are emerging as the potential knowledge-sharing platform, and therefore, the ICT services can be leveraged by stakeholders for providing useful climate-related information for farmers to make better decisions in crop planning and management.

Community smart

Local-level community institutions can support the extension services on CSA in India (Sala *et al.* 2016). Community organisations and approaches have increasingly become innovative extension platforms for enhancing the participation of the end-users in the planning and implementation of CSA. Sasya Mitra Group (SMG) promoted by Accion has been one of the successful community models for promoting CSA. Around 800 SMGs are functioning in the district with a membership of 20,000 farmers, i.e. 25 members per SMG. The members are selected from all categories of the farm families, i.e. backward class, scheduled caste, landless agricultural labourers, and small and marginal farmers. SMGs play a major role in the collective decision-making, persuading and mentoring farmers in the adoption of CSA interventions. Also, they share resources such as crop production technologies (seeds) and farm machinery (Ananta Seed Drill, water tankers, etc.) at nominal prices. Also, the profits from hiring charges were saved in a common bank account to use as revolving funds. Hence, SMG has evolved as an effective extension platform in the implementation of CSA and adaptation to climate change. Therefore, the extension stakeholders of CSA may adopt such community models for promoting CSA.

Major learnings from the cases

CSA interventions promoted by KVK, the Department of Agriculture, Accion and Adarsha have a unique way of improving the socioeconomic status of the resource-poor Anantapur farmers, with varying degrees of impact on productivity, income and adaptation to droughts. However, CSA interventions promoted by these stakeholders were confined to their project or adopted areas. Hence, the benefits were not realised by non-beneficiary farmers. Furthermore, the study elucidates that the high adoption rates of CSA interventions by the farmers in the study zones were not just dependent on the availability of various CSA interventions, but on co-factors such as augmented on- and off-farm resources such as ensured water availability (watersheds), incentives for digging bore wells, creation of power supplies, availability of inputs at affordable prices, access to timely extension services and enabling infrastructure (e.g. automated weather station). Henceforth, it is high time that the government fast tracks greater convergence among these extension stakeholders for a wide-scale promotion of CSA interventions. This can help in customising farm-specific CSA interventions with benefits and co-benefits reaching each farmer. The details of stakeholders' wise CSA interventions are mentioned in Table 3.

Table 3 elucidates in a nutshell the important CSA interventions promoted by the selected stakeholders and the benefit of each CSA intervention.

Table 3 | CSA interventions by the stakeholders and their impacts

S.No.	CSA interventions	Stakeholders	Project village	Benefits	By whom the benefits were perceived
1.	Seed smart (treatment of seeds with *P. Firmis*)	KVK	Peravalli	Resistant to drought	Beneficiary farmers and scientists
2.	Varieties smart (K-6, K-9 and Dharani of groundnut)	KVK	Peravalli	Tolerant to drought	Beneficiary farmers and scientists
3.	Horticulture-based cropping pattern (e.g. mango+tomato+chillies)	Accion	Pampanur	Tolerant to drought and high income	Beneficiary farmers and stakeholders
4.	Millet-based cropping pattern	Adarsha	Kodikonda	Tolerant to drought and high nutritive value	Beneficiary farmers and stakeholders
5.	Fertiliser smart (e.g. SHC-based fertiliser application)	KVK	Peravalli	Induce crop to withstand drought	Beneficiary farmers and scientists
6.	Watershed development	KVK and Accion	Peravalli and Pampanur	Induce crop to withstand drought	Beneficiary farmers, non-beneficiary farmers and scientists and officials of Accion
7.	ZBNF	Department of Agriculture	Kalyandurg	Induce crop to withstand drought	Beneficiary farmers and extension personnel of the Department
8.	Knowledge smart (e.g. AKPS)	KVK	Peravalli	Timely contingency crop planning to erratic rainfall, delay in rainfall and droughts	Beneficiary farmers and scientists
9.	Community smart (e.g. SMGs)	Accion	Pampanur	Enhance the adaptive capacity of farmers to droughts	Officers of Accion

This table is based on the interaction with stakeholders and farmers.

Recommendations for the policymakers

The Department of Agriculture may strengthen its collaboration with NGOs in the popularisation of ZBNF at scale and may also finance NGOs for organising demonstrations, field days, field tours, etc.

KVK can be a knowledge partner for NGOs to the dissemination and upscaling of its proven CSA interventions.

There is an imperative need for a CSA policy framework that can help the public extension system (the Department of Agriculture and KVKs) in co-learning the successful CSA interventions and extension models of NGOs. For example, the climate-smart groups (SMGs) promoted by Accion may be emulated by the agriculture department, KVK and other extension service providers.

The climate fund was found to be a critical factor for NGOs to effectively promote CSA interventions. Therefore, the government may provide a portion of public funds to NGOs to invest more in research, agricultural innovations, local techniques and a community approach for large-scale promotion of CSA. The CSR funds may also be mobilised for large-scale promotion of proven CSA interventions.

CONCLUSION

The Department of Agriculture, KVK and NGOs such as Accion and Adarsha were striving towards the promotion of CSA to enable farmers to adapt to droughts in Anantapur district. The findings showed that the extension approaches of the stakeholders such as demonstrations, community groups and Mobile SMS have empowered the farmers to know about various CSA interventions and adapt to the risks of droughts. However, there were marked variations/differences among them in promoting CSA interventions. For example, the extension services of KVK were mostly prioritised towards the popularisation of field crops, and the efforts of the department of agriculture were aimed at promoting ZBNF. Whereas the extension services of Accion have been shifting towards promoting horticulture, integrating high-value crops with field crops, developing watersheds and promoting community-based organisations. Also, the NGO-Adarsha was promoting millets as a CSA intervention by creating backward linkages with potential traders. All these CSA interventions have enabled the farmers to increase the productivity of crops, adapt to the risks of drought and generate income consistently. Henceforth, the variations/differences occur due to stakeholders' mandates, projects, funding options and other support services to CSA. The variation itself is good for farmers until they influence farmers towards their adoption. However, the CSA interventions of NGOs and KVK were implemented at a limited scale due to inadequate convergence, manpower and funding options. Therefore, the government needs to foster convergence among the extension service providers and to support them with more climate funds to achieve a comprehensive, productive, resilient, adaptive and profitable CSA at scale. This will help the stakeholders to widen their CSA priority areas and enlarge the scope of CSA beyond their project areas. The present study focused only on the CSA interventions promoted by two public sectors and two NGOs, and there is a wider scope for identifying more stakeholders, e.g. private sector, FPOs and entrepreneurs, and assessing their extent of involvement in the promotion of CSA and prioritisation. Furthermore, the study collected information only from the beneficiary farmers. Future studies may consider non-beneficiary farmers in the same geographic area to compare and contrast the benefits. Moreover, the same study may be conducted in other drought districts of India, and also future research may be conducted in other climatic risk-affected areas such as flood-prone and heatwave-affected districts to assess the stakeholders' prioritisation and analyse different CSA interventions promoted at farmer levels.

WEBSITES

See https://sustainablefoodlab.org/ available at https://sustainablefoodlab.org/wp-content/uploads/2019/10/Helping-Cocoa-Farmers-to-Achieve-A-Living-Income-and-Adapt-to-Climate-Change-1.pdf.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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