Data4Policy

Policy Experimentation Report on Strengthening Climate Resilient Agriculture in Food Systems

2022

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List of abbreviations

APEDA	Agriculture Processed Food and Export Development Authority
API	Application Programming Interface
CCAFS	Climate Change, Agriculture and Food Security
CGIAR	Consultative Group for International Agricultural Research
CRA	Climate Resilient Agriculture
DiCRA	Data in Climate Resilient Agriculture
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IWMP	Integrated Watershed Management Programme
GHG	Green House Gases
LULC	Land Use Land Cover
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
NMEO	National Mission on Edible Oils
NMSA	National Mission on Sustainable Agriculture
PGS	Participatory Guarantee Scheme
PKVY	Paramparagat Krishi Vikas Yojana
PMFBY	Pradhan Mantri Fasal Bima Yojana
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
RAD	Rainfed Area Development
RWBIS	Restructured Weather Based Insurance Scheme
SHC	Soil Health Card
SOC	Soil Organic Carbon
STL	Soil Testing Laboratories
UNDP	United Nations Development Programme
GOT	Government of Telangana

Executive summary

The current food systems sustain majority of the global population and are an important source of livelihood for billions of people worldwide. Climate change threatens the food systems, and its impacts are widespread, complex, and profoundly influenced by socioeconomic conditions. Food systems are also a key contributor to climate change. With the increasing population, coupled with the pressures on land, water, and biodiversity, the effects of changing climate on agriculture have a pronounced impact on developing countries like India. The situation is especially exacerbated for small-holder farmers who are inextricably dependent on agriculture for their livelihoods.

India faces the daunting challenge of protecting the environment, meeting the current food demands of the growing population, and securing the livelihood of smallholder farmers against climatic vulnerabilities. COVID-19 has further disrupted the agriculture–food chain, exposed vulnerabilities of less privileged sections of society, and created a need for building resilience in the agri-food systems. Adoption of potential adaptation and mitigation strategies in the face of changing climate is an essential prerequisite to bolster the agricultural ecosystem and, in this regard, the concept of climate-resilient agriculture gains prominence.

The concept of climate-resilient agriculture and food systems is complex, covering a wide range of actors, and socio-ecological-cultural dimensions. Due to this complexity, there are substantial information gaps across agriculture and food systems. Currently, policymakers are faced with multiple challenges regarding access, availability, and reliability of data on agriculture. The lack of availability of disaggregated, precise, and long-term climatic information of diverse spatial-temporal scales on agriculture parameters is a bottleneck to making informed decisions on climate-resilient agriculture. Policy decision-making requires a shift from perceived or anecdotal evidence to real-time, disaggregated, and contextual data that facilitates relevant local-level actions. Further innovations in data-driven approaches integrating appropriate data of context-specific geographies are vital in achieving precision in agriculture.

To strengthen climate resilience in agriculture, UNDP partnered with the Government of Telangana and the Rockefeller Foundation to jointly initiate the NextGenGov 'Data4Policy' initiative using data-driven approaches and tools. The aim of the Data4Policy initiative is to increase anticipatory capacity, create radical transparency & traceability, and build provenance documentation around agriculture food systems in Telangana. The initiative also ensures the pursuit of sustainable development goals (2,10 and 17). This initiative led to the development of a collaborative digital public good - Data in Climate Resilient Agriculture (DiCRA). DiCRA is guided by the digital public good principles of open access, open software, open code, and open Application Programming Interfaces (APIs) and can be replicated in diverse geographies.

DiCRA integrates open-source satellite-based data on various agricultural parameters and compiles complex information in interactive visual trends and patterns. It incorporates data from open data platforms, non-public domain datasets through data partnerships to provide insights for data-driven decision making in agriculture. DiCRA is also capable of performing Data-Powered Positive Deviance (DPPD) on time series trends of data layers where long-term time series data is available, thus providing insights on long term effects & trends related to climate. DiCRA has the capability to expand analysis to 1 km or 10 km equidistant grids around regions of interest.

Ethnographic evidence of traditional practices combined with data insights from DiCRA on *'what is where, how much is there, how are things changing with space and time'* disaggregated till farm level promotes evidence-based decision-making across the agriculture ecosystem, thus leading to a variety of use cases. Some of the use cases through *mandal-level* data disaggregation are illustrated in the report. The insights from DiCRA on soil health, historic weather patterns, disaster risks, and geo-tagged locations of infrastructural investments can guide policymakers in enabling adaptation strategies, mitigating climatic risks, and optimizing the utilization of resources. DiCRA can further guide key stakeholders to prioritize geographies and investments, learn micro-climatic resilient agricultural practices operating at grassroots levels, and customize the package of practices that diversify food systems. The policy experimentation in Telangana demonstrates DiCRA's applicability to achieve climate resilience in agriculture and food systems.

Identifying the pathways to achieve climate resilience requires systemic transformation across agricultural value chains. CRA pathways are diverse, interlinked and require a combination of strategies coupled with policy action to strengthen measures addressing climatic risks. The pathways covered in this report include strengthened research & development, livelihood diversification practices, strengthening local institutes & introducing risk management tools, and strengthening partnerships. Each of these pathways is backed by relevant case studies of global successful initiatives highlighting sustainable practices to achieve resilience in agriculture and food systems. These pathways provide an opportunity for decision-makers, planners, and practitioners to contribute, through small actionable measures to the achievement of multiple SDGs while working towards ensuring resilience in agriculture and food systems.

The 2022 Policy Experimentation Report showcases the challenges posed by climate change in the agriculture sector and highlights the need for evidence-based data-driven solutions for achieving climate resilience in agriculture. It notes that while technological solutions offer the potential to achieve resilience in agriculture systems, they need to be developed in an inclusive manner and used in ways that do not undermine indigenous and local knowledge or exacerbate inequalities. Further, the report draws on the applicability of digital public goods like DiCRA across diverse geographies zoomed to support informed decision-making for achieving CRA. It further provides multiple pathway solutions for accelerating innovation, reforming policies, increasing financing for sustainable food systems transformation, and building resilience.

Agriculture, food systems, and climate change

Food systems emphasize the complex connectivity and interdependence of activities, actors and institutions across food, ecology, economy, and society required to achieve a sustainable state of food security (IFPRI, 2022). The existing food system (production, transport, processing, packaging, storage, retail, and consumption) sustains the great majority of global population and supports the livelihoods of over a billion people worldwide.

Climate change adversely impacts the food systems by reducing land and soil productivity, biodiversity, crop yield, and supply chain disruptions, etc, rendering a large section of global population vulnerable to food insecurity and poverty (SWINNEN, ARNDT, & VOS, 2022). On the other hand, food systems are estimated to contribute more than a third of the global greenhouse gas (GHG) emissions responsible for climate change, placing food production at the centre of attention as both a contributor to climate change and a critical sector for mounting an adaptive response to climate change.

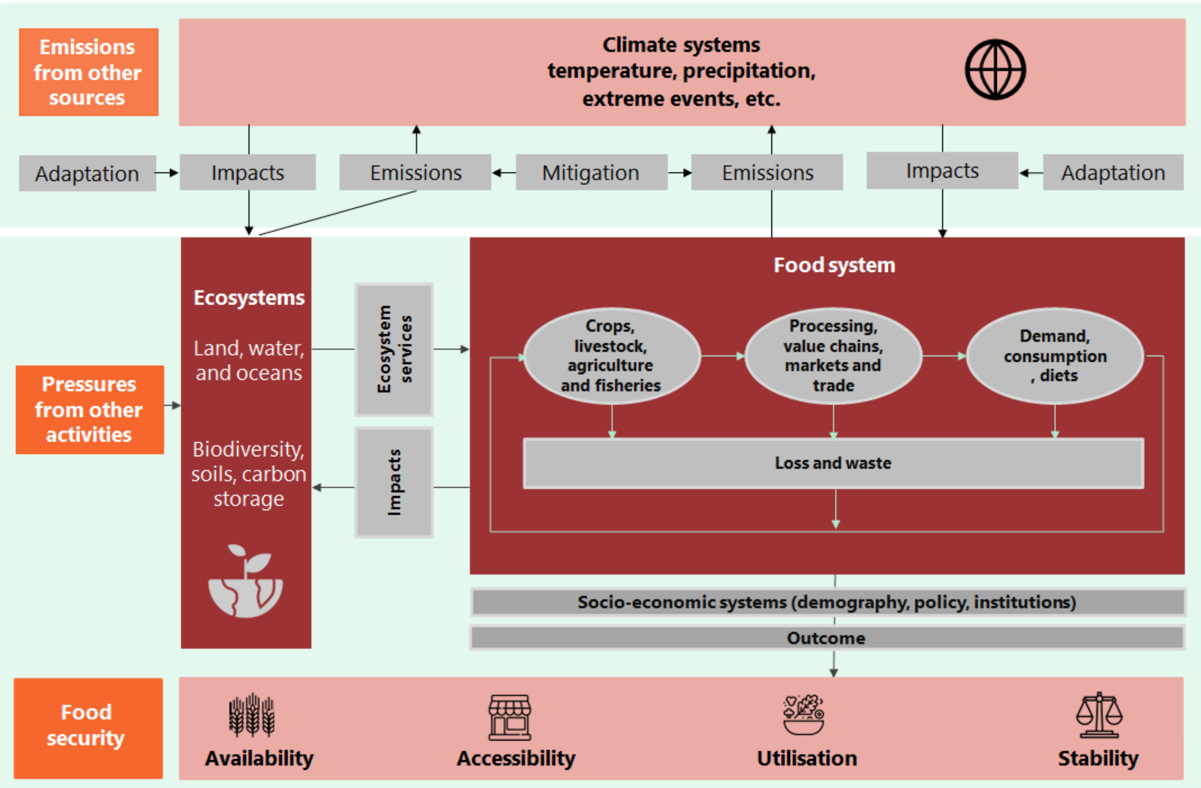


Figure 1: Climate change, agriculture, and food security adapted from IPCC.

The impact of climate change varies by geographies. Agriculture dependent smallholder communities of developing countries like India, are projected to be the most vulnerable to the impacts of extreme climatic events. Agriculture employs almost 2/3rd of the rural households as their principal means of livelihood, 80% of whom are smallholders with less than 2 hectares of farmland. More than a fifth of the smallholders lives below poverty. Productivity loss due to climate change will not only impact food security but also impact livelihoods and real income of farmers. It is estimated that climate change will cause loss of annual farm income by 15%-18% on an average (up to 25% for rainfed areas) in India (Economic Survey, 2017).

With home to 17% of the world population, India has less than 4% of the world's water resources and 2% of land resources available at its disposal. Feeding a population of 1.4 billion with depleting natural resource conditions in agro-ecologically and socioeconomically diverse country like India is a daunting task further aggravated due to climate change. The Covid 19 pandemic has greatly highlighted the massive disruption caused in the food supply chains exposing the vulnerabilities of marginalised communities, smallholders, and the importance of building a resilient food system.

Climate Resilient Agriculture, role of data and key perspectives

Reducing vulnerabilities is key to addressing the net impacts on food security and calls for greater and urgent focus on adaptation mechanisms with aggressive mitigation strategies (FAO, 2015). Climate Resilient Agriculture (CRA), converges the adaptation & mitigation strategies with effective management of biodiversity (land, water, and soil) is an essential pre-requisite for sustainable development in the face of changing climate.

Figure 2: Key definitions of CRA

The concept of climate-resilient agriculture and food systems involves dynamic interactions among different pathways and strategies connecting agriculture related practices with environmental, health, and socioeconomic outcomes under a changing climate (Koo, et al., 2022). Due to this complexity, there are substantial information gaps across agrifood systems, and decision-makers often lack access to timely, reliable, and actionable information for making informed decisions. Developing and adopting technologies that can help bolster countries against food supply shocks and challenges is being recognised widely.

There has been a growing understanding and realisation that policy decision-making requires a shift from perceived or anecdotal evidence to real-time, disaggregated, and contextual data that facilitates relevant local level actions. In this regard, data driven policies & implementation approaches needs to be further catalysed. Currently, the policymakers are faced with multiple challenges regarding access, availability, and reliability of data on agriculture, a few of which are discussed below:

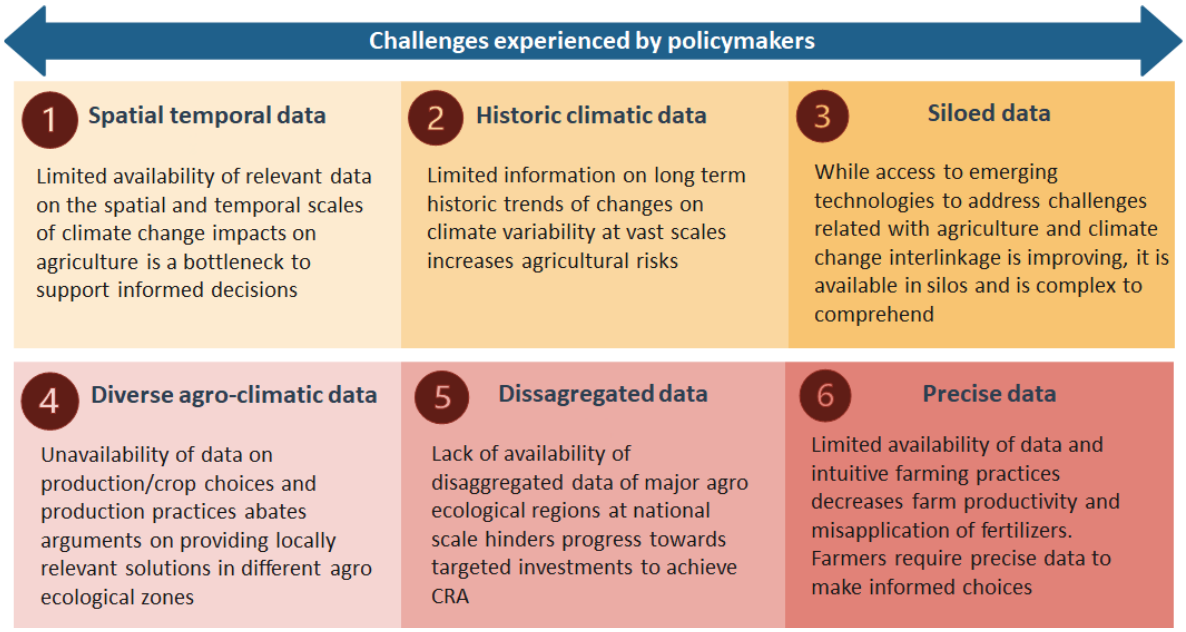


Figure 3: Challenges in data driven approaches to CRA for policymakers

Further innovations in technological digital goods such as open-sourced data platforms which merge diverse data sets on historical climatic trends, crop productivity, soil health, etc. of appropriate context specific geographies are vital in achieving precision in agriculture.

Building evidence of these data driven approaches becomes vital as it may provide emerging insights to support technologies that hold potential to revolutionise the food and agriculture systems. It may further guide the policymakers and key stakeholders in making informed choices in planning, implementing, designing, and evaluating relevant strategies to achieve resilience in agriculture and food systems.

'Data4Policy' initiative

UNDP partnered with the Government of Telangana to jointly initiate the NextGenGov 'Data4Policy' initiative on food systems. The aim of the Data4Policy initiative is to incorporate meso level governance models for future-fit food systems in Telangana using data-driven policymaking tools and approaches to strengthen climate resilience in food systems.

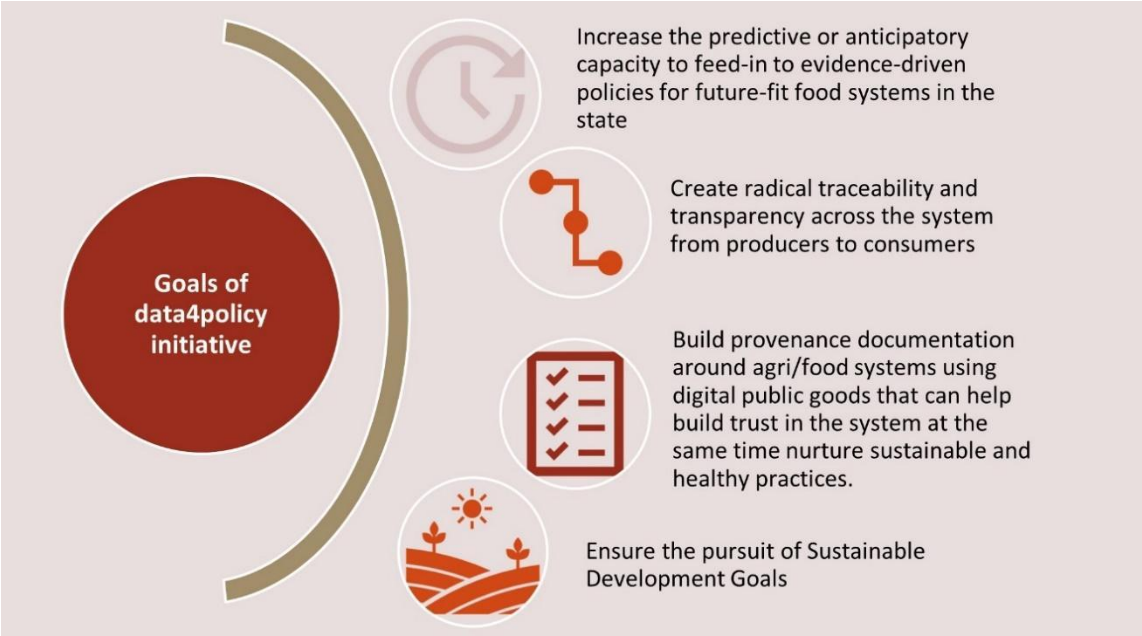


Figure 4: Goals of data4policy initiative

Telangana has emerged as a hub for Agri-tech start-ups and data driven innovations in the country. The state has demonstrated diverse community driven grassroots solutions through implementation of government schemes (Box 1) along with adoption of innovative technologies in agriculture and allied sectors.

Box 1: Schemes Contributing to Climate Resilient Agriculture in Telangana

Agriculture plays an important role in Telangana's economy as over 55% of rural households depend on it as the principal means of livelihood, majority of whom are small holder farmers with less than 2 hectares of land. About 63% of the crops grown are on rainfed farms, making dryland agriculture a prime focus of the government (ICRISAT, 2021). Unfavourable weather conditions such as delayed monsoons, intermittent dry spells, erratic rainfall, and prolonged drought are major concerns of the farmers (NABARD, 2021). To address these challenges Government of Telangana has promoted several schemes with a focus on climate resilience agriculture (Government of Telangana, 2021).

Rainfed area development under National Mission for Sustainable Agriculture (NMSA): For 2021-22, the proposed area to be covered is projected to be around 613 hectares for 10 districts. The estimated cost of central share as per budget estimates was Rs 200 lakh.

Soil health card scheme under NMSA: For 2021-22, hundred thousand (100,000) farmers to be covered across 32 districts as per State Agriculture report in the selected mandals. Rs. 300 lakhs were allocated by the centre as per the Budget Estimates provided by the Government of Telangana.

Paramparagat Krishi Vikas Yojana under NMSA: For 2021-22 GoI has instructed to implement PKVY in aspirational districts i.e., Khammam, Asifabad, Bhupalpally in 5 clusters/districts. The scheme will be implemented in 15 clusters covering 750 acres. The budget estimate by GoT was Rs. 150 lakhs for 15 clusters for 3 years.

National Mission on Edible Oils- Oil Palm: In 2021-22, total area of 45,000 acres is under oil palm cultivation in the districts of Khammam, Kothagudem and Suryapet. The target is to bring over 20 lakh acres under oil palm over 3 years. For 2021-22, Rs. 10 crores were allocated by the state.

Pradhan Mantri Krishi Sinchayee Yojana (PMKSY): From 2014 – 2021, total area of 7.27 lakh acres (5.10 lakh under drip and 2.11 lakh under sprinkler) has been brought under micro-Irrigation with an amount of INR 1,924.96 crore and benefitted 2.7 lakh farmers. For the year 2021-22 total financial budget allocated by the government was Rs. 500 crores.

Rythu Vedika: The Government of Telangana has planned to construct a total of 2601 in the state out of which 2462 will be constructed in rural areas and the remaining 139 in urban areas. For 2021-22 A total of Rs. 3,730.34 lakhs were earmarked in the Budget Estimates under Normal State Plan of Telangana. State Agriculture Action Plan, Telangana, 2021-22

Data in Climate Resilient Agriculture (DiCRA)

Data in Climate Resilient Agriculture (DiCRA) is a collaborative digital public good under the Data4Policy initiative, which provides open access to key geospatial datasets important to climate resilient agriculture. The open data platform managed by the United Nations Development Programme (UNDP) is guided by the digital public good principles of open access, open software, open code, and open Application Programming Interfaces (APIs).

DiCRA has emerged as an easy to scale open-source platform which has attracted 100+ contributors and 1700+ users servicing 100,000+ square kilometre of climate action in a short span of time. The platform has been piloted in Telangana and shown promising results. It is receiving interest for replication in other states and countries.

Data Layers on DiCRA

DiCRA hosts accurate and timely updated information on soil moisture, Soil Organic Carbon (SOC), Normalized Difference Vegetation Index (NDVI), Land Use/ Land Cover (LULC), Leaf Area Index (LAI), Land Surface Temperature (LST), weather data, crop fires, etc.

Key datasets available on DiCRA	
Soil Moisture (SM)	Soil moisture dataset is based on satellite sensors that gives the measurement of the total amount of water, including the water vapour, in an unsaturated soil. It helps to better understand the water cycle and climate, monitor agriculture, and manage water resources.
Soil Organic Carbon (SOC)	SOC dataset is the measurement of the carbon stored in soil organic matter. SOC affects the chemical and physical properties of the soil, such as water infiltration ability, moisture holding capacity, nutrient availability, and the biological activity of microorganisms.
Normalized Difference Vegetation Index (NDVI)	NDVI quantifies vegetation by measuring the difference between near-infrared (that vegetation strongly reflects) and red light (that vegetation absorbs). It is used in the agriculture sector for measuring biomass, precision farming, drought indicating, forecasting fire zones, etc. Lower relative NDVI value and density of vegetation is indicative of stress due to water shortage.
Land Use/ Land Cover (LULC)	The LULC dataset has information available on 9 classes of land cover - water, trees, crops, flooded vegetation, built area, bare ground, snow/ice, clouds, and rangelands. This dataset provides information for conservation planning, food security, and hydrologic modelling, among other things.
Leaf Area Index (LAI)	LAI is defined as half the total area of green elements of the canopy per unit horizontal ground area. LAI dataset is an important indicator of radiation and precipitation interception, energy conversion, and water balance. It is a reliable parameter for plant growth and measures crop growth, and productivity. Measuring LAI plays an important role in measuring the impact of environmental stresses such as drought.
Weather data	Weather data datasets provide information about the cumulative rainfall, minimum & maximum temperature, humidity & wind speed across all 589 weather stations in the state of Telangana.
Fires and Crop fires	Fires dataset provides information on locations of fire events. Crop fires dataset provides information on crop fires due to crop residue burning at mandal and district levels.
Land Surface Temperature (LST)	LST dataset is the measurement of how hot a particular location of the earth would feel to the touch. It is an important reference index used to understand the energy cycles and ecological system balances. LST monitoring provides insights on water stress and drought identification.

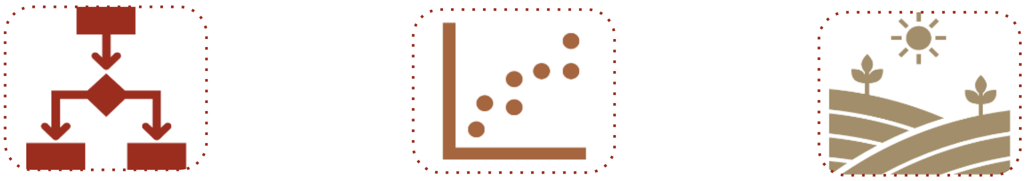
Table 1: Solution architecture of DiCRA: key datasets

Besides the above-mentioned datasets, the platform also hosts datasets such as Particulate Matter 2.5 (PM 2.5), Nitrogen Dioxide (NO_2), Relative Wealth Index, Population, Market Prices, and Warehouse geolocation.

Datasets such as crop productivity, farm boundaries, Air Quality Index (AQI), Digital Elevation Model (DEM), climate exposure, vegetation, extreme weather incidents, disasters, crop type, cold storage, polyhouses, crop extent map, classification of irrigated vs rainfed, crop intensity, length of growing periods, crop type, crop stress, crop diversity, polyhouse detection, and oil palm detection are under development.

Data analytics & insights (DiCRA)

DiCRA has some unique features that aids its wide range of utilities in policy level decisions and action discussed in the next section.



Reliability over a broad spectrum of insights
Incorporates data from open data platforms, non-public domain datasets through data partnerships to provide insights for data-driven decision making in agriculture

Focuses on long term trends and deviances
Historical trends for evidence on effects of climate and performs Data-Powered Positive Deviance (DPPD) on time series trends of data layers where long-term time series data is available

Disaggregated data with local insights
Capability to expand analysis to 1 km or 10 km equidistant grids around regions of interest

Figure 5: Key features of DiCRA

DiCRA assimilates open-source satellite-based data and compiles the complex information in interactive visual trends and patterns. Data insights from DiCRA on *'what is where, how much is there, how are things changing with space and time'* disaggregated till farm level promotes evidence - based decision making across the agriculture ecosystem, thus leading to a variety of use cases. This section illustrates some of the key insights from Telangana that can be derived through DiCRA, and discusses the potential use cases for a wide array of stakeholders in the areas of land & water planning, CRA policy decisions, agri-advisory, disaster risk reduction, etc.

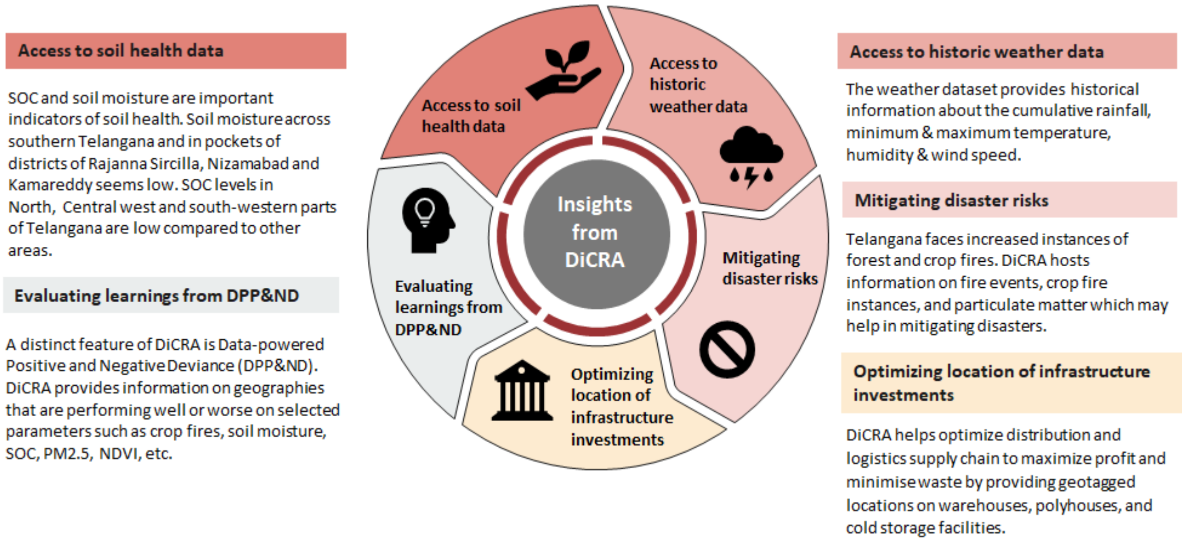


Figure 6: Insights from DiCRA

One of the key capabilities of DiCRA is providing data powered positive and negative deviant areas (figure below). The positive deviance approach seeks to identify outperformers (geographies or farms) that achieved significantly better outcomes than peers despite having similar resources and constraints, and to understand the strategies behind their success so that they can be replicated. Negative deviance aids in the identification of vulnerable populations, allowing for targeted investments. Through these deviances, DiCRA provides insights in identifying the geographies which have improved or deteriorated on parameters of soil moisture, SOC, NDVI, etc. over time (below figure).

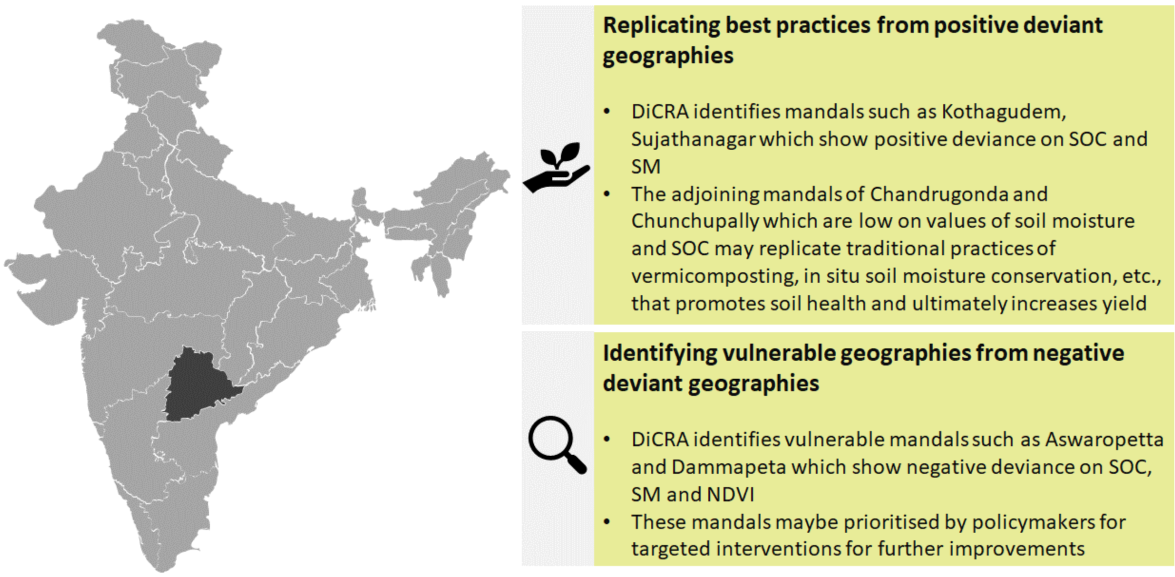


Figure 7: Data powered positive and negative areas

Another capability of DiCRA is provisioning of disaggregated information up to farm level. Data powered positive and negative deviances at mandal level in Bhadradri Kothagudem district on selected parameters is presented as an example (figure below).

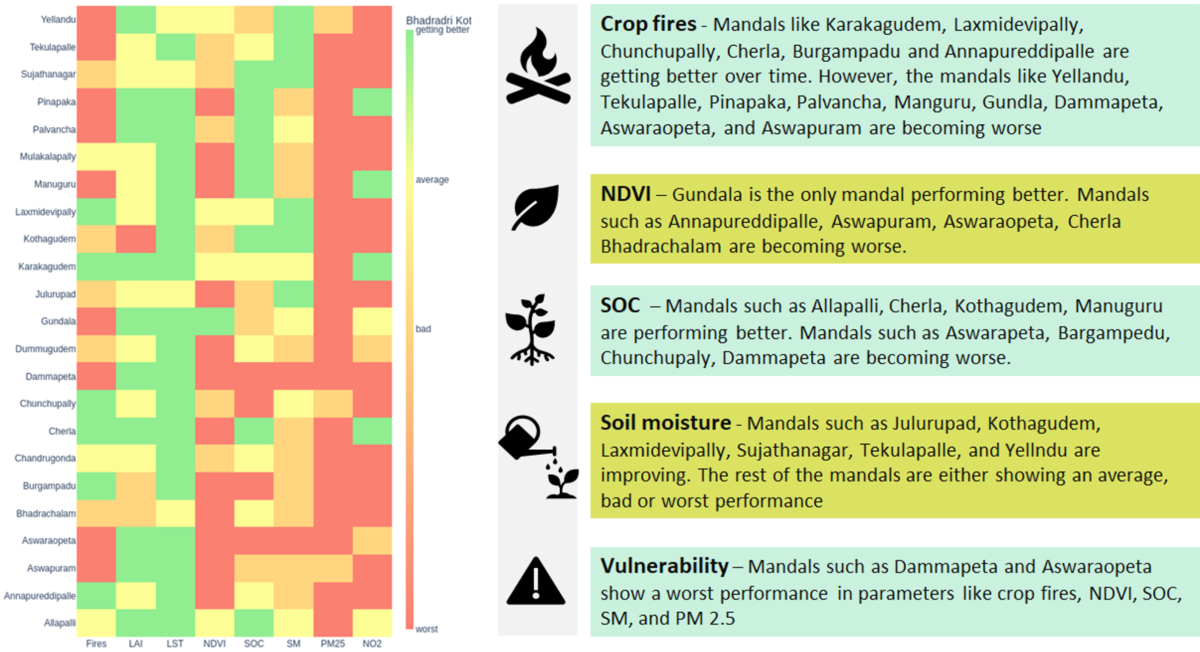


Figure 8: Mandal level insights from DiCRA - Bhadradri Kothagudem district

DiCRA provides reliable insights at Mandal level. For example, Zahirabad mandal in Sangareddy district is characterised by a moderate to high Normalized Difference Vegetation Index (NDVI) value. Through an ethnographic study, it was determined that Zahirabad mandal is practicing integrated farming systems, agro forestry, crop diversification, dry leaf mulching, rainwater harvesting, pitcher irrigation, etc. These practices often contribute to a higher & healthier vegetation in the region and thus a higher NDVI value. Correlating the NDVI values with the interventions focussing on vegetation health/cover of a region can be a determinant for the success and scale of the intervention. Thus, providing the policymakers, a reliable mechanism for Mandal level planning.

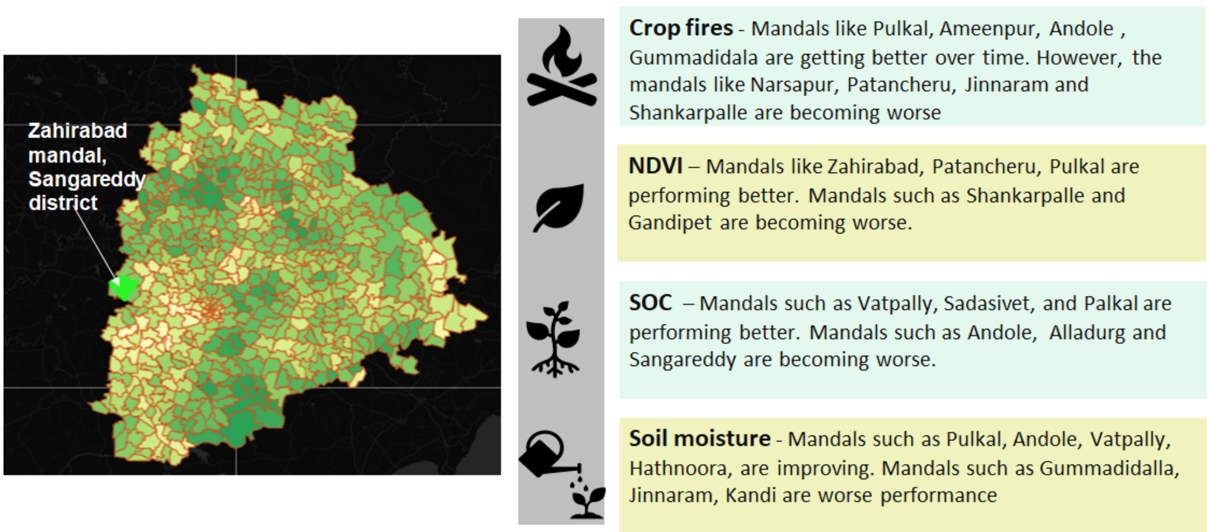


Figure 9: Mandal level insights – Sangareddy district

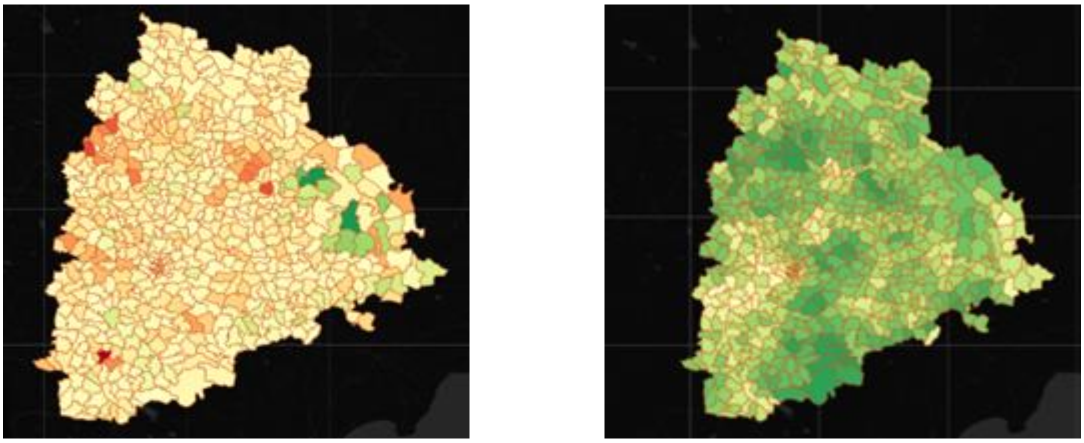


Figure 10: Positive and negative deviant areas (Crop fires and NDVI from left to right)

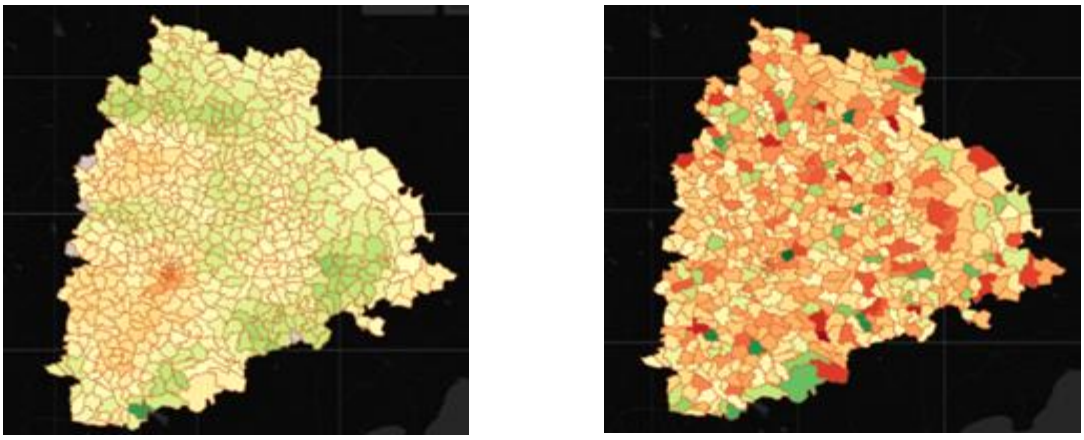


Figure 11: Positive and negative deviant areas (SM, SOC from left to right)

Policy insights and use cases from DiCRA

DiCRA demonstrates the importance of digital public goods in supporting policymakers & other key stakeholders towards climate resilient agriculture and food systems. The evidence from DiCRA demonstrate its immense potential for merging multiple data sets and provide open access, near-real time, relevant information on various facets relevant to policy planning and action. A few possible utilities pertaining to various stakeholder groups in Telangana are discussed here:

STAKEHOLDERS	POLICY PLANNING
Department of agriculture	DiCRA can support the department of agriculture in: ● Identifying geographies (villages, mandal to district) which are low on soil organic carbon , soil moisture from the DiCRA platform and allocate resources to promote practices such as rainwater harvesting, tillage, vermicomposting, in situ soil moisture conservation, etc. ● Leveraging Rythu Vedikas as centres where data driven knowledge related to climatic adversities, market prices, soil health and crop productivity, etc. is translated to farmers. ● Providing customised advisory services to 20,000 villages in Telangana via Rythu Vedika
Ministry of Agriculture	● DiCRA can support the ministry for developing "**Agri stack**" and help in the creation of a digital repository. The digital repository can aid precise

STAKEHOLDERS	POLICY PLANNING
Farmers and Welfare	targeting of subsidies, agriculture extension services and increase the income of farmers. ● Under Agri stack, the government plans to create a unique farmer ID and generate electronic farm records, geo-referenced village maps, real time digital crop survey data, soil profiling, soil health, weather data and ICAR repository data. Information on soil health, weather data, farm data from DiCRA may aid the Ministry of agriculture in effective planning towards digitising agriculture.
Department of Horticulture	● Insights from DiCRA on soil moisture, SOC, land surface temperature, NDVI, weather data (humidity, rainfall, precipitation) may assist the department of horticulture in extending coverage of the **PMKSY scheme** in water stressed areas (mandal to district level). ● The department may gather insights from LULC to identify area under water bodies, crops, and flooded vegetation for the adoption of micro irrigation technology under PMKSY. **Micro Irrigation technology** can be adopted for water guzzling crops like sugarcane, cotton, banana, etc. ● The department may also plan diversification of area from low yielding cereals crops to horticulture crops such as **oil palm** using indicators such as LAI, NDVI, crop type and crop productivity
Agri- businesses and Insurance companies	● Agri input and micronutrient companies may use information on soil health from DiCRA to get information on crop and soil deficiencies and plan appropriate **nutrient packages** to the farmers ● Insurance companies in close association with the department of agriculture may plan to integrate a variety of **insurance products** using information such as weather data, crop productivity, RWI, population and target them to vulnerable groups in times of crop loss due to climatic disasters
NABARD	● NABARD may use insights from DiCRA to **optimise its investments under climate resilient agriculture**. Vulnerable mandals showing negative powered deviance on parameters such as soil moisture, soil organic carbon, NDVI such as Amberpet, Aswapuram, Chilkul, Saidadabad may be targeted and supported for climate resilient credit planning. ● Mandal level insights from DiCRA may help NABARD in undertaking **vulnerability analysis**. The compressed datasets from multiple sources available on DiCRA platform may reduce the time for planning, help access multiple vulnerability parameters and optimise utilisation of resources in different agroecological geographies

STAKEHOLDERS	DESIGNING SUSTAINABLE SOLUTIONS
Department of Agriculture	● The agriculture department may plan **crop residue management system** and allocate funding in mandals/districts which report high incidents of crop fires

STAKEHOLDERS	POLICY PLANNING
	• The department may encourage promotion of in situ crop residue management practice in mandals/districts low in soil moisture, SOC and reporting high crop fire incidents
Department of Horticulture	• Oil palm, a moisture stress-sensitive species, requires an adequate amount of water to maximise productivity. Insights on the soil moisture characteristics through the historic trends of the mandal/district may help the department of horticulture to implement **irrigation schemes** accordingly.

STAKEHOLDERS	EVALUATION AND LEARNING
Department of Irrigation	• LULC can provide insights on presence of water resources in an area (mandal to district level) and trends from 2017 to 2021. LULC, along with soil moisture, rainfall trends, humidity may provide insights to the irrigation department to **estimate/evaluate** the impacts of irrigation schemes on water availability for agriculture.
SAU's/Academic Institutes/Research Institutes/ NITI Aayog	• DiCRA can provide evidence base to various **ethnographic & scientific studies** that may be undertaken by NITI Ayog/SAU's/research institutes on crop type, crop productivity, NDVI, etc. thus providing insights on the efficacy of schemes such as PMKSY and PKVY. The positive deviant mandals such as Waddepally, Utnur, Tekulpalle, Kollapur, Chilkul may be further probed for insights on best practices that positivity affects soil moisture. Good practices such as rainwater harvesting, zero tillage, in-situ soil moisture conservation is a few of the methods that may be replicated in surrounding mandals showing low soil moisture • **NITI Ayog** is currently evaluating agriculture investments to prevent stubble burning in Punjab and Haryana. They may use insights from DiCRA on crop fires, LAI, LST, soil moisture, soil organic carbon, NDVI, PM 2.5, and nitrogen dioxide to **evaluate impact** of these investments on positive and negative deviant villages/ mandals and districts.
World Bank	• DiCRA may assist the World Bank in undertaking **impact evaluation** studies on historic trends of weather data, soil moisture, SOC, etc. Considering the information available is timely and updated, DiCRA may provide transparent and effective data to undertake such research.

Table 2: Illustrative application of DiCRA for key stakeholders

Evidence based learnings using data driven approaches are significant contributors towards sustainable agricultural and food systems. However, pathways to achieve climate resilience requires systemic transformations across the agriculture value chain. Some of the critical pathways are discussed in the next section.

Emerging pathways for Climate Resilient Agriculture

The pathways for climate resilience in agriculture and food systems requires a combination of strategies and policy actions to address climate risks, manage adaptation and mitigation measures, and reduce the intensity of climate impacts (Denton et.all, 2014). Within the context of the policy experimentation on Data for Policy in Telangana, few transformative CRA pathways have been identified which have been experimented in other geographies with similar socio-economic contexts and agro-ecological features. These pathways can be built and strengthened using evidence-based planning and policy development tools including data insights from DiCRA. Each of these pathways have been detailed using use cases from the geographies and contexts these have been experimented highlighting sustainable practices to achieve resilience in agriculture and food systems.

Figure 12: CRA pathways

Enhancing emphasis on research and development for climate resilient agriculture

To move towards policy planning for sustainable food systems, the spatial data may be augmented with contextual social, economic, and environmental analysis. The research options may include undertaking cost benefit analysis (CBA) for calculating subsidies, fertiliser's cost to society, etc.; environmental accounting for greenhouse gas emissions; economic valuation studies; and many more. Moreover, for smallholder farmers, productivity and profitability are correlated with access to reliable data/information. Credible, comprehensive, and understandable research that helps the farmers move beyond intuitive agricultural decisions can aid the profitability meanwhile improving the climate resilience of the agricultural ecosystem.

Investments in productivity-enhancing solutions or practices such as drought tolerant seed varieties, micronutrients for soil health, practices such as intercropping, usage of micro irrigation etc. are essential for overcoming stress on agricultural resources. In India, many drought prone states such as Telangana have adopted Micro Irrigation systems (MIS) to reduce water footprint, and to increase water use efficiency at the farm level under the scheme of Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) – Per drop more crop. PMKSY has been widely adopted in the state through the support of uptake of drip and sprinkler systems. Professor Jayashankar Telangana State Agriculture University (PJTSAU) undertook an impact assessment study on Telangana State Micro Irrigation Project (TSMIP) which indicated in demonstration plots that there was an increase in water savings, energy savings costs, fertiliser use efficiency and reduction in production costs for different fruits, vegetables and commercial field crops when compared to surface irrigation methods (PTJSAU, 2015). On the other hand, investments are also needed to understand the economic viability and impact of various technologies or practices on the livelihoods of local farmer communities.

Wageningen University & Research (WUR) has been spearheading research in the domain of CRA. The findings from research undertaken by WUR as illustrated in the case study presented below imply that investments in Climate Smart Agriculture (CSA) practice have positive returns in short periods (Ng'ang'a Karanja et.al., 2020). Policymakers can identify the CSA practices through similar studies and design instruments to upscale the adoption of CRA practices.

Case study 1 - Investing in climate smart practices in rural Tanzania: Research undertaken by WU

Climate change leads to agricultural losses for small-scale farmers in developing countries. Tanzania is among those developing countries, where climate change will increase the variability in rainfall and the temperatures, thereby causing decline in agricultural production. Tanzanian government aims to mitigate those negative impacts and enhance farmers' adaptive capacities through various initiatives, including the diffusion of CRA practices. **In collaboration with WUR a study was undertaken in 2020 to understand the economic viability of climate resilient practices in rural Tanzania. According to the study, CSA practices such as crop rotation and intercropping of maize with soybean, are profitable for small-scale farmers in Tanzania. The payback period for the investment in these practices, is short-term, about two to seven years.** Moreover, these practices decrease the maintenance costs for the farmers, as farmers must purchase a very small amount of fertilizer to supplement the soil with soybean. Such practices make a very suitable investment option for the small-scale farmers in rural areas with limited financial power.

Advancing climate resilient livelihoods

Climate resilient livelihoods is an approach that strengthens the marginalised groups and degraded ecosystem in building their capacities towards managing and adapting to climate change. It is strongly rooted in the principles of inclusivity, equity, and sustainability. It comprises of various techniques including but not limited to livelihoods diversification, agro-ecology development (also associated with carbon sequestration), sustainable water harvesting, etc.

Diversity of livelihood sources often reduces ecological pressure on the primary livelihood option within the community while making the community less vulnerable to adverse climactic risks. Households with higher rural livelihood diversification in terms of agrobiodiversity (i.e., crop, pasture, and cattle diversity) and diversity of farming activities are less vulnerable to climate change (Tolosa, Cruz - Garcia, Ocampo, Pradhan, & Quientero , 2022). Telangana government has been promoting off farm generation livelihood options for farmers, with livestock enhancement as a major element. Nearly 29 lakh families in Telangana are engaged in livestock sector for their livelihood. Livestock sector is emerging as one of the most potential and income generating off farm - sectors for rural areas in Telangana. Between 2012 to 2019 the livestock population in the state increased from 26.7 million to 32.6 million with 22.09% growth between the years (Socio-Economic Outlook, 2022).

Silvopastoral systems (SPSs) is sustainable alternative to conventional farming/livestock systems. They introduce diversity and good practices that increase the quality of soils and grasslands, improve the productivity of the farming systems, and have the potential to reduce deforestation. Despite these benefits, SPS have not been widely implemented due to technical, financial, and cultural barriers. These include the lack of technical assistance to farmers to adapt the system to specific local conditions, the technical complexity of SPS management and the high initial investment requirements (Chará J.et.al., 2018).

Case study 2: Silva pastoral system for livelihood diversification

SPS are a type of agroforestry where cattle, fodder plants, and trees and shrubs are grown together for animal nutrition and complementary uses such as for timber, and fruit production**. They enhance livestock productivity up to four times in relation to traditional extensive cattle ranching systems. SPS have several benefits such as - increased environmental services, better nutrient cycling, more water infiltration, improved below-ground and above-ground biodiversity.** SPS systems are considered win-win options as they increase livestock productivity, augment incomes, enhance resilience to climate change, harness mitigation benefits by reducing GHG (Pezo, Rioz, Ibrahim, & Gomez, 2019). In Jordan, the revival of silvopastoral land– the Hima through community efforts has allowed the restoration and sustainable use of previously degraded pastures. The Hima governance system allows communities to implement management plans based on short duration grazing and periods of rest to allow for the regeneration of natural pastures. The revival of the Hima system has brought substantial environmental benefits, including groundwater infiltration, and generated off farm income to farmers. Pastoralists can now access better pastures, are willing to pay for water, and respect the Hima system which is being adopted all over the country and is estimated to deliver between JOD 144 and 289 million worth of net benefits to Jordanian society (Haddad et.al., 2022)

Building community capital

Community capital is an amalgamation of various capitals (includes social capital, human capital, natural capital, economic capital, cultural capital, etc.) that create a progressive ecosystem within the community and helps it adapt to the exigencies (such as climate change) without faltering the pursuit of continual growth. These values compound when the community acts as a unit towards a shared goal. Community institutionalisation provides a platform of aligning the community towards a common goal while being appreciative of its unique challenges and opportunities.

Community institutionalisation is a potential CRA pathway that strengthens the actions towards developing & implementing Policies, Platforms, Protocols, and Partnerships. An example of this may be that marginalised woman depending on forest dwelling for Non-Timber-Forest-Produce (NTFP), Minor Forest Produce (MFP), or fuel wood are vulnerable to the climate change affects on their livelihoods and health. Thus, their institutionalisation through Self Help Groups (SHGs) or Farmer Producer Organisations (FPOs) help them cope up against the financial vulnerabilities through collective marketing, hedging, etc. whereas environmental vulnerabilities through sustainable harvesting, ecosystem restoration (replantation), etc. These institutions, if supported with relevant knowledge (data and information) can drive local level innovations and sustainable management of resources. In Telangana special programmes have been designed for training and capacity building of the SHGs and have resulted in socio-economic upliftment of rural women (Narsaiah, 2021). FPOs are also driving the organic farming efforts in the state, providing sustainable livelihoods to thousands of farmers (Singh, 2022)

World Bank aided project PoCRA has promoted institutional innovations through collective action to build resilience of farming communities. The state of Maharashtra in India is home to over 15 million farmers and has over 50% cultivable land, but climate change has impacted the agricultural productivity in several drought prone areas of the state. To mitigate the adverse effects of climate change in these drought prone areas, Maharashtra Project on Climate Resilient Agriculture (PoCRA) supported by the World Bank was launched in 2016 and targeted 15 districts, encompassing 5000 villages.

The significant aspects of the project are focused on leveraging ICTs for planning and monitoring purposes, gender inclusion, and strengthening institutions. The village-level development plan under the project emerges after a comprehensive data-driven microplanning exercise led by the community. The village development plan includes measures for optimal utilization of natural resources, appropriate cropping pattern, adoption of latest technologies, and improved access to markets. Gender inclusion has also been an important focus of the project. These measures build local capacity and achieve the long-term goal of environment and livelihood security (Case study 3).

Case study 3: POCRA

The project aims to drought-proof villages of Maharashtra which are severely affected by agriculture distress and salinity by promoting climate resilient agriculture technologies, investments in creating new assets for increased access to water, diversified cropping system, protected cultivation, and value chain at farm and community level. **A mosaic of restoration and other sustainable land management interventions implemented were co-created by the people and government institutions**. **The landscape transformation has permitted formerly famine-stricken communities to diversify their livelihoods through adoption of climate resilient practices such as integrated nutrient management, integrated pest management, organic farming, seed preparation, applying manure to fields, intercropping and broad bed furrows** (Sambodhi, 2019)**.** The long-term sustainability of the interventions is ensured through the participation and involvement of the community members in the planning process. At the local, the Village Climate Resilient Management Committee (VCRMC) plays a key role in planning, community procurement, monitoring and coordinating project implementation (e.g., watershed plans) and anchoring climate interventions at community level. To that effect, the VCRMC liaises closely with the community institutions associated with the implementation of project activities, e.g., the Water User Associations, Watershed Development Committees, as well as Producer Organizations (incl. Farmer/Common Interest Groups). **The project has taken a gender sensitive approach to prioritize the needs of the women stakeholders in the planning and implementation of project interventions which is being driven through "Krushi Tais" (female mobilizers) at the village level.** The project has introduced transformational changes in the agriculture sector by scaling up the adoption of climate-smart technologies and practices at the farm and micro-watershed level and strengthened resilience against climate change. Increasing the involvement of community-based organizations in the implementation of sustainable land management programmes, with climate change adaptation and co-benefits allows the cost effectiveness of already limited national resources to be brought to scale, in ways that benefit smallholders and protect them from climatic and non-climatic shocks

Climate proofing the agriculture value chain

The climate proofing of the agricultural value chain can be achieved through addressing the:

- ecological risks posed by the value chain on the ecosystem
- financial risks posed the value chain on its participants

Reducing the ecological risks of value chains:
The ecological risks can be addressed through multistakeholder collaborations consciously altering their production choices and practices. Value chains pertaining to cash crops such as oil palm, cashew, cotton, sugarcane, etc. often comes at the cost of trade-offs. The Government of Telangana recently launched the Oil Palm Mission to promote the cultivation of oil palm in the state. The end goal of the Mission is to improve the livelihood of farmers and to bridge the edible oil deficit in the country. Telangana Stands 6th in Oil palm area with 21,382 Ha (53,455 acres). Considering the potentiality for oil palm cultivation in Telangana, the state government is planning to take up 20 lakh acres under oil palm in a mission mode as part of income diversification and has notified 26 districts for oil palm cultivation (Socioeconomic outlook, 2022). While oil palm cultivation diversifies the income of farmers, but causes biodiversity loss, is water intensive, and changes the land use pattern. However, sustainable value chains for these commodities are possible if the production choices and package of practices are rooted in climate-resilient practices. Comprehensive value chain assessments and future-oriented actions toward creating sustainable value chains is a critical CRA pathways. Engaging in multistakeholder collaborations beyond the conventional top-down approaches accelerates the initiatives for climate resilience.

Globally, palm oil is an important source of income for more than 7 million people. In the wake of the global palm oil boom, new plantations were created in several tropical countries, such as Papua New Guinea, Colombia, Nigeria, and Cote d'Ivoire. New palm oil plantations often replaced valuable tropical rainforests, thus robbing many species of their habitats. Slash-and-burn agriculture and the draining of peat swamp forests were releasing large amounts of greenhouse gases such as carbon dioxide and methane. New plantations often also trigger conflicts over land use**.** To limit the destruction of species-rich tropical forests, producers, financial institutions, civil society organisations, industry and trade founded the RoundTable on Sustainable Palm Oil (RSPO) in 2004 (RSPO, 2022).

Coordinated efforts from local to global levels, across all the stakeholders are required to create systems to balance the trade-offs. RSPO engages with all the stakeholders throughout the supply chain of palm oils, including governments and consumers. RSPO highlights how multistakeholder engagement can promote growth of oil palms without compromising the biodiversity, ecology, reduce greenhouse gas emissions and ensure livelihood security.

Case study 4: Conserving ecosystem and sustaining livelihoods through multistakeholder platforms

The Roundtable for Sustainable Palm Oil (RSPO) is a non-profit, multi-stakeholder organisation with an objective to promote the growth and use of sustainable palm oil and palm oil products. The organisation envisions transforming markets to make sustainable palm oil the norm, by convening stakeholders from across its different sectors to set and implement the most ambitious standard for sustainability in the industry. US$4.03 million under the RSPO Smallholder Support Fund (RSSF) has supported 38,597 farmers across 12 countries since 2013, resulting in 71% of current certified independent smallholders. **The aim is to advance production, procurement, finance, and use of sustainable oil products. RSPO engages with all the stakeholders throughout the supply chain,**

including governments and consumers. Moreover, RSPO certified palm oil mills have an average water footprint of 0.005 m^3/ kg, lower than other vegetable oils such as soybean and rapeseed. RSPO certification has significantly reduced the use of restricted pesticides and herbicides for pest or disease control in favour of natural biological methods. RSPO creates a tangible impact on People, Prosperity, and Planet – improves the quality of life of oil palm farmers and their communities, creates a more inclusive and prosperous palm oil industry that embraces sustainability, and enabling systems to better conserve, protect and enhance natural ecosystems and resources.

Reducing the financial risks of farmers:
Insurance is an important tool in managing climate related agriculture risks and if applied in conjunction with other disaster risk measurements and strategies can protect agriculture communities against climate shocks by acting as safety net and buffer shortly after an extreme event**.** Developing enabling policy ecosystem incorporating financial insurance tools against crop losses is important in securing community resilience against climate change and meeting the needs to the next generation farmers.

Climate insurance particularly against crop loss are potentially more cost-effective means of insuring farmers against climate risks in comparison to other forms of insurances (e.g., multi-peril crop insurance). Under it, payments are made based on the crop loss from on-farm inspections. Within this, index-based insurances use models of how climatic extremes have an impact on crop production to determine certain climate triggers that if surpassed could cause substantial crop loss and would support a compensation payment.

Swiss Re has taken several initiatives to generate tangible value across the crop insurance value chain, from improving risk assessment to reducing operational expenses and from developing more tailored insurance solutions (Andriesse, 2021).(case study 5)

Case study 5: Scale-up of climate and disaster risk financing instruments

Swiss Re, in close cooperation with "VanderSat", a provider of global satellite-observed data, products and services, developed an effective climate index insurance tool that protects farmers against the financial losses caused by drought. **Using this tool farmers and insurers receive a daily update of the situation related to soil moisture and are informed on insurance pay-outs. Swiss Re's innovative drought solution is applicable to all rain fed agricultural production and has proven effective in numerous regions and countries in the world.** In Europe, the product is available in over 10 countries. Swiss Re is also developing a weather station covering small number of fields, due to the decreased costs of high-quality weather stations. Such localised data shall allow farmers to avail insurance for a wider range of perils, such as excess rainfall, frost or even hail and pests. To further accommodate growth in this segment, Swiss Re and insurance partners have jointly developed a climate index pricer, to design climate index products for all relevant weather perils based on thousands of real-time weather stations. This pricer provides a great variety of functionality and allows real-time tracking of the climate index payout.

Conclusion

The climate resilient pathways presented in this report offers an opportunity for decision makers, planners and practitioners to contribute, through small and large interventions, to the achievement of multiple SDGs, while working towards ensuring resilience in agriculture food production systems under changing climate. Multiple factors converge in operationalizing the approach in an efficient and effective manner. These factors though cross cutting across the approaches as illustrated in the case studies include, among others, investments in research and development, livelihood diversification, financial climate risk tools, stakeholder participation, and community empowerment.

India is at a crossroads of achieving digital transformation in agriculture sector. A lot of efforts lie in the development of data driven approaches promoting sustainable agriculture practices, ensuring food security and equitable growth. The policy experimentation in Telangana is aimed to augment anticipatory capacity to feed into evidence driven future fit agriculture food systems in policy. Further, the goal is to create radical traceability and transparency across the system by building provenance documentation around food to help build trust in the system and nurture sustainable practices. DiCRA, the world's first digital public good is a result of this policy experimentation.

The insights from DiCRA are critical in generating evidence on microclimatic situation of various agricultural parameters and suite of traditional practices adopted by farmers to promote resilience in agriculture/food systems. Data has become crucial for key stakeholders such as government departments, multilateral agencies, agritech start-ups, CSO's etc. to make informed decisions and tailoring solutions in vulnerable farms to promote adoption of CRA. Beyond the setting of platforms and digital goods, customised knowledge products should be able to reach the last mile. It becomes important to effectively enable systems in place to disseminate information to reach the last mile.

Addressing climate change-related challenges and ensuring food security requires all types of knowledge (formal/non-formal, scientific/ indigenous, women, youth, technological). Transitions to sustainable food systems must take a whole systems approach by taking cognizance of every actor in the value chain of agriculture. The impact of the COVID-19 pandemic highlights the need for flexible adaptation approaches, as in the future, with climate change, weather-related shocks affecting agriculture systems could increase in frequency and intensity, and compounded crises could become more frequent. Best practices, traditional knowledge and science can all contribute to presenting adaptation and resilience-building options.

Finally, scaling up climate resilience in agro-food systems is the need of the hour. Scaling up climate resilience across food systems will enable the ways for sustainable use of natural resources to produce food to deliver a climate-positive future in which people and nature can coexist and thrive. This is important, not only because food systems are affected by climate events, but also because food systems themselves impact the state of the environment and are a driver of climate change. Central to this endeavour are priorities to safeguard nature, sustainably manage existing food production and supply systems, and restore and rehabilitate natural environments. These sustainability efforts will also strengthen resilience to climate shocks to ensure food security.

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United Nations Development Programme (UNDP)
Post Box #3059, 55 Lodhi Estate,
New Delhi – 110003

Thinkthrough Consulting (TTC)
Building no. 30, Third Floor, Basant Lok Community Centre, Vasant Vihar,
New Delhi 110057